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FROM THEORY TO PRACTICE: IMPLEMENTING WATER MANAGEMENT TECHNOLOGY FOR CLIMATE RESILIENCE: A CASE STUDY IN KARAK DISTRICT

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ABSTRACT
The main objective of this research study is to assess the association of water management technology in climate change resilient water management. The research is carried out in three union council of district Karak i.e., village councils (VCs) Sabar Abad , Toor march and kabir kally. Out of the total population of 1324 framers a sample size of 302 framers was proportionally allocated to each VC and selected through random sampling technique. Data was collected through interview schedule. The conceptual framework of the study consisted of one independent variable (water management technology) and one is dependent variable (climate change resilient water management). The variables were measured on three levels Likert Scale. Chi-square test was applied at the bi-variate level to ascertain the association among these study variables. Association between climate change resilient water management with water management technology show that climate change resilient water management exhibited a highly significance association with constructing tank/ponds to store irrigation water (P=0.001), tanks and ponds constructed for water storage are reliable Constructing tanks and ponds can help in capturing and storing rainwater or runoff, which can then be used for irrigation during dry spells or periods of water scarcity induced by climate change. In especially in areas susceptible to climate extremes and fluctuation, the infrastructure used for storing water must be reliable in order to guarantee a steady supply of water for irrigation (P=0.002), and store and treat house hold waste water for irrigation purpose reusing and recycling treated wastewater for agricultural use can reduce the demand on freshwater resources, particularly in regions where water shortage is a result of climate change (P=0.003). These results highlight the value of making infrastructural investments for water distribution and storage, along with incorporating creative solutions like reusing home wastewater. The study emphasizes how local perspectives and expertise influence adaptive water management plans.
Keywords: Water management technology, climate resilience, resilient water management.

1. INTRODUCTION
Agricultural has always been at the heart of human existence providing food fiber and other essential resource for our survival. However, environmental changes have a serious negative impact on agricultural production practices, crop yields, water resources, and the overall sustainability of agricultural system (Arunanondchai et al., 2018). All agricultural crops require persistent supply of sufficient water for satisfactory agricultural production. According to scientists, the climatic changes have profound effect on the water cycle. It is causing water stress in form of drought and

floods in many regions of the world. In most of the arid regions of the world the quantity and quality of water for household and irrigation purposes is declining. Considering these difficulties, managing water resources effectively requires resilient water management strategies. The use of water-saving devices is one of the essential elements of resilient water management. According to a report by the Asian Development Bank, infrastructure investments in water storage might increase resilience to the climate change effects, such as floods and droughts (Price, 2016).

Despite of the heavy reliance on agriculture, some of the world regions, like South Asia, are likely to face significant social, political, and economic difficulties in irrigation water management. Inabilities and unwillingness to adopt agricultural technologies at institutional and community levels are the important reasons of poor irrigation water use efficiency in the region (World Bank, 2018; Fischer et al., 2007 and Grübler et al., 2007). Consequently, most of the South Asia's nations struggle with significant water management issues, and they also have underdeveloped institutions and trans-boundary water management practices. With over 2.5 billion people dependent on agriculture for their livelihoods, agricultural drought impacts are particularly acute in Pakistan, especially during the past 20 years. The droughts have impacted approximately 1.43 billion people, while only accounting for 5% of the documented disasters. Thus, population growth, climatic changes and inappropriate farming practices negatively affect water availability and utilization at farm level. In this scenario, the water stress for irrigation purposes is unavoidable.

1.1 Climate change resilient water management

Resilient water management is increasingly recognized as essential for ensuring sustainable access to clean water, particularly in the face of growing challenges like climate change, population growth, and urbanization. It encompasses strategies and practices aimed at enhancing the ability of water systems to withstand and recover from shocks and stresses while meeting the needs of present and future generations.

One critical approach to resilient water management involves the implementation of Integrated Water Resources Management (IWRM) principles. IWRM emphasizes the coordinated development and management of water, land, and related resources to optimize economic and social welfare while preserving ecosystems. This approach recognizes the interconnectedness of water systems and the importance of considering multiple stakeholders' needs and interests. For instance, in a study by Biswas and Tortajada (2016), the authors argue that IWRM frameworks can facilitate adaptive management strategies that enhance resilience to water-related challenges.

Nature-based solutions (NBS) are another key component of resilient water management. NBS leverage natural processes to address water management challenges effectively and sustainably. For example, restoring wetlands and forests can help regulate water flows, improve water quality, and mitigate the impacts of floods and droughts. The World Bank emphasizes the importance of NBS in water management, citing examples from around the world where nature-based approaches have been successfully implemented to enhance resilience (World Bank, 2020).Investing in resilient infrastructure is also crucial for effective water management. This includes upgrading water treatment plants, improving stormwater management systems, and designing urban infrastructure to withstand extreme weather events. Resilient infrastructure can help reduce vulnerability to climate-related risks and ensure the reliability and safety of water supply systems (World Economic Forum, 2018).

Furthermore, stakeholder engagement and participatory decision-making processes are essential for building resilience in water management. By involving local communities, indigenous groups, and other stakeholders in planning and decision-making, water management strategies can better reflect diverse perspectives and priorities. This participatory approach can foster ownership and support for water management initiatives, leading to more sustainable outcomes (Global Water Partnership, 2018). Resilient water management requires a comprehensive and integrated approach that combines IWRM principles, nature-based solutions, resilient infrastructure, stakeholder engagement, and effective governance. By adopting such strategies, communities can enhance their resilience to water-related challenges and ensure the sustainable management of water resources for future generations.

Muller (2007) investigated how to manage water resources as a measure of urban resilience to climate change. Floods, outages in the water and electricity grid, and subsequent economic collapse into "failed cities" are only a few of the weather-related threats that human settlements face as a result of global warming and related climate changes. It is also necessary to take action to assist underprivileged urban areas in adapting so that they can be more robust to potential change, even though up to this point, concentration has been more on mitigation than adaptation. Water management will be significantly impacted by climate change, which may present an opportunity to start planned adaptation strategies. The cost of adaptation urban water sector in sub-Saharan Africa is projected to be between 10 and 20% of the region's existing foreign aid. In accordance with the "polluter pays" idea, this report recommends that additional cash be made accessible and should go Rather than ring-fenced climate funding, use government budgets. The Paris Declaration on Aid Effectiveness from 2005 represented contemporary trends in international development assistance, and this would guarantee that "climate proofing" is accepted as normal.

In the water industry, Ludwig et al. (2014) investigated integrated water resource management and climate change adaptation. In order to better optimize water consumption among various water-demanding sectors, integrated water resources management (IWRM) was launched in the 1980s. Water systems have, however, become increasingly complex since they were first developed as a result of changes in the global water cycle brought on by climate change. Research and decision-making on adaptation have been sparked by the realization that water supplies and flood threats will be significantly impacted by climate change. This essay examines the key parallels and divergences between IWRM and climate change adaptation. The primary distinction between the two is IWRM's emphasis on present-day and historical challenges as opposed to adaptation's (long-term) future focus. The significant uncertainty in estimates for the future are one of the key issues with implementing climate change adaptation. Due to these significant uncertainties, two totally distinct adaptation strategies have been devised. A top-down strategy built on large-scale biophysical impact evaluations that emphasize quantifying and reducing uncertainty through the use of a wide range of scenarios and several climate and effect models. The propagation of uncertainty across the modelling chain is the approach's fundamental flaw. The bottom-up strategy, on the other hand, essentially ignores uncertainty. By creating resilient water systems, it focuses on lowering vulnerabilities, frequently at a local level. However, integrating either of these strategies into water management is inappropriate. The bottom-up strategy places an excessive emphasis on socioeconomic vulnerability and insufficient attention on creating (technological) remedies. The top-down method frequently causes an "explosion" of ambiguity, which makes decision-making more difficult. A more promising direction of adaptation would be a risk based approach. A method that starts with creating adaption strategies based on present and potential threats should be further developed and tested in future study. In order to create effective adaption measures and tactics, these techniques should then be evaluated utilizing a variety of future scenarios.

2. Literature Review

Sustainable water management and national climate change policy were investigated by Pittock (2011). Even without climate change, increasing water demands and declining water quality place enormous strain on freshwater ecosystems and the human resources they provide. These effects will be made worse by the impending start of climate change, putting even more strain on already overburdened resources and areas. Numerous Governmental efforts to combat climate change have developed, focusing on energy sector structural transformation and expanding carbon sinks. The majority of public discussion of water issues to far have centered on how hydrology is directly impacted by climate change. However, there is growing evidence that climate change policies alone could have considerable additional, detrimental effects on freshwater resources and ecosystems, possibly leading to maladaptation.

Making comprehensive, coordinated policy is necessary to prevent this maladaptation. The following comparisons are made between the Australia, Brazil, China, the European Union (EU), India, Mexico, South Africa, Tanzania, and the

United Kingdom each have national climate change policy. In order to find more opportunities for theoretical investigation and testing, it is important to (i) pinpoint areas where there are detrimental study regions where institutions and mechanisms exist to maximize integration among climate, water, and biodiversity policies, (ii) examine trade-offs between climate change policies and freshwater resources, and (iii) present a much-needed overview from a variety of countries. Governments face additional difficulties in creating integrated policies that provide a variety of advantages because of the conflicts and synergies between climate, energy, water, and environmental policy. Senior political leader involvement, improved accountability and enforcement mechanisms, multi-agency processes, and cyclical policy creation are success factors for better policy development that have been found in this study and synthesis.

2.1 Water management technologies

Water harvesting and storage systems are a crucial for climate change adaptation. Efficient use of water management technologies is determinant in the success of climate change adaptation. Some of the traditional technologies collect and store rainwater to lessen reliance on groundwater and surface water supplies, which may be at risk of contamination or drought due to extreme weather occurrences. In order to solve water scarcity brought on by climate change, numerous countries of the world have successfully installed rainwater harvesting and storage systems (Rahman et al., 2019). Another critical technology for climate-resilient water management is wastewater treatment and reuse. Reusing treated wastewater can lessen the need for freshwater resources by being utilized for irrigation, industrial activities, and in some circumstances even drinking water (Asano et al., 2007).

Srivastav et al. (2021) conducted research on climate-resilient approaches for agricultural and water resource sustainability. While stronger climate change models and a new family of hydrological tools are being established, the water management industry's traditional engineering risk and dependability solutions can also be employed to successfully address current climatic uncertainties. Under climatic uncertainty, a new approach to designing and implementing water resources infrastructure is encouraged. It is based on a development of the concept of "robust decision making," along with modern analytical techniques and methods. Along with other anomalies including decrease in agricultural output, food security, an increase in sea level, the melting of glaciers and a loss of biodiversity, warming of the earth is regarded as the primary harmful result of climate change.

Due to climatic anomalies, lower agricultural Production and declining water quality have both been seen throughout time. Crop production is extremely climate-sensitive. Average rainfall and temperature trends throughout the long run, seasonal climate fluctuations, shocks at different growth stages, and extreme weather events all have an impact on it. Since the 1960s, the percentage of areas impacted by drought, as measured by the Index of the Palmer Drought Severity, has increased around the world in the areas planted with the primary wheat, soya bean, sorghum, barley and maize crops, between roughly 5 and 10% and 15 and 25%. As these nations are more susceptible to temperature increases, the United States will have losses in wheat production of 5.5 to 4.4% per degree Celsius, India would experience losses of 9.1 to 5.4%, and Russia will experience losses of 7.8 to 6.3% per degree Celsius.

By increasing storage capacity (or rainwater storage), implementing fair policies for water supply and distribution, maintaining the health of rivers, and managing watersheds, water management can decrease the negative effects of climate change on the availability of water resources. Similar to this, developing crops resistant to climate change, managing irrigation water, adopting a Using climate-smart farming techniques and promoting indigenous knowledge increase agricultural productivity and hence maintain food security. Technical assistance can give farmers the climate parameter scientific assessments they need for managing sustainable agriculture. These technologies might involve the use of software, practices for controlling nutrients and water, tools for measuring temperatures, and examinations of the soil's health, among other things. A multifaceted approach by the stakeholders (farmers, local society, academia, scientists, policy makers, NGOs, etc.) may provide better outcomes in reducing the risks of climate change on agriculture and water resources, as outlined in this research.

Iglesias and Garrote (2015) Adaptation tactics for managing agricultural water in Europe, in countries where water shortage is already an issue, climate change is predicted to increase the risks while also opening up new opportunities in some cases. Understanding the hazards and adaptation solutions put forth so far can help with efforts to create adaptation strategies for agricultural water management. This knowledge could help establish priorities for modifying water resources for irrigation. Over 168 incredibly important articles that have appeared in the preceding 15 years were examined. The authors characterized the main risks across European areas and assess adaptation options. In order to create concrete adaptation plans and address specific area difficulties, the authors characterized the effort and value of a number of agronomic and policy interventions using this large database.

The authors are confident that technical development will influence some adaptation options in the coming decades. However, the choices for adaptation take into account existing technological views rather than speculating on a future technological shift. Increasing adaptive capacity and responding to fluctuating water demands are the most effective courses of action, but implementing those plans can be challenging. practice calls for a reformulation of current water policy, proper training for farmers, and workable financial tools. By reducing the sector's vulnerability to climate change, these findings are intended to support stakeholders as they take on the adaptation challenge. Pahl-Wostl's (2007) focused on examining transitions to adaptive Managing water resources in the face of climatic and global change. As a result of climate change and global warming, there are more uncertainties, as well as the rapidly shifting socioeconomic boundary conditions present significant problems for water management. More attention is needed to comprehend and navigate the transition from the current management regimes to more adaptable regimes that consider the environmental, technological, economic, institutional, and cultural components of river basins. This proposes a paradigm shift in water management from an approach based on control and prediction to one based on learning. "Manage your learning by managing it" could be used to describe the shift towards adaptive management. Such adjustment attempts to improve river basins' ability for adaptation at various scales. The report addresses significant obstacles to understanding a change in methods for managing water for research and use. Process dynamics in transition and a conceptual framework for classifying water management regimes are introduced. The European project “Ne Water” is described as one strategy for creating new scientific techniques and useful instruments for the implementation of participatory evaluation and adaptive water management.

3. Materials and Methods

The study was carried out in District Karak, one of the dry districts of southern Khyber Pakhtunkhwa with predominant rain fed agriculture. District Karak comprises of 4 tehsils out of which tehsil Karak is purposively selected due to high number of registered farmers to the agriculture extension department and availability of canal irrigation, tube well irrigation and rain fed irrigation systems simultaneously. Union councils Sabir Abad, Toormirch and Kabir Kallay of tehsil Karak constitute specific study area. As per the available record of the agriculture extension department, the total registered famers in the three selected union councils (Sabir Abad, Toormirch and Kabir Kallay) are 1324 (Table 3.1) the required sample size for a population of 1324 is 302 (Sekaran, 2010). The required sample size is proportionally allocated to each union council using proportional allocation equation (Bowley, 1926) as given below

$$nh\left(\frac{Nh}{N}\right) * n$$

(Equation-1)

Where nh = required sample size for a specific UC
Nh = Population of corresponding UC
N = Total population
n = total sample size

Proportional allocation of respondents to each UC is given in (Table-1)

Table 3.1 Proportional allocation of respondents to each union council

S.No	Name of Union Council	Number of Registered Farmer	Sample Size
1	Sabir Abad	461	105
2	Toor Mirch	441	101
3	Kabir Kallay	422	96
	Total	1324	302

The data was collected using an interview schedule covering all the study variables given in the conceptual framework of the study (Table 3.2). The conceptual framework of the study comprises of one independent variable (Water management technology) and one dependent variable (climate change resilient water management). Likert scale was used for measurement of study variables.

Table 3.2 Conceptual framework

Independent variables	Dependents variables
Water management technology	Climate change resilient water management

3.3 Uni-variate analysis

The uni-variate analysis comprises of frequency count and percentage calculation of demographic, Independent and dependent variables. The percentage count was measured using equation-2.

$$\text{Percentage of data class} = \frac{f}{N} * 100$$

Equation-2

Where f = frequency of data class

N= number of observation

3.4 Bi-variate analysis

To test the association between the dependent and independent variables, bi-variate analysis procedure was applied. Chi-square test was used to ascertain the association between the study variables. The values of chi-square were calculated by using equation-3 (Tai, 1978).

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Equation-3

X2 = chi square

O = observed frequencies in i row and j column

E = Expected frequencies regarding i row and j column

r = Number of rows

e= Number of columns

Df = (r-1) (c-1)

4. Results and Discussions

4.1 Uni-variate

4.1.1 Perception of respondent regarding water management technology

On the face of climatic changes, water scarcity and stress are the major problems faced by the farming communities. The scientists, therefore, innovate technologies to address the issue of water availability in such stressed situations. There, however, are gaps in innovating water management technologies and its actual adoption by the farmers. Perception of respondents on water management technologies is given in table 4.1.1.

Most respondents (82.8%) concur that they gather enough irrigation water to irrigate their farmland, therefore, only 27.8% constructed tank/ponds to store irrigation water and 26.5% stated that the tanks and ponds constructed for water storage were reliable. Despite of stressful condition of water availability the people managed to gather/arrange sufficient water for their irrigation purposes. Nearly one fourth of farmers were innovative enough to construct water ponds or tanks to store and irrigation water in it satisfactorily. There are opportunities for on-farm water storage, however, poverty and unawareness are two important factors obstructing adoption of these technologies and infrastructure. Consequently, farmers are constrained to squeeze their farming practices according to available water. Brouwer et al. (2018) also stated that promoting the implementation of water storage infrastructure has the potential to augment water accessibility in lean times and bolster farming capacity, however, poverty, unawareness and unreliability obstruct construction of these water storage structures. In order to boost acceptance and adoptive better trust in on-farm water storage facilities, it may be necessary to address these issues, through awareness campaigns and government support in construction and maintenance initiatives or infrastructural upgradation of water storages for irrigation purposes (Burchhardt, 2011).

Furthermore, 26.8% respondents used cemented water channels for irrigation, while the majority (73.2%) does not. In addition, a small percentage (7.3%) of respondents use drip irrigation or sprinkle irrigation, while the majority (92.7%) does not. Furthermore, 59.6% respondents said that they stored wastewater from their homes for use in irrigation. These results indicate variations in the adoption of modern irrigation infrastructure. Cementing water channels and drip irrigation are efficient water conservation innovative practices. However, it bears high initial cost, mostly intolerable for poor farmers. There is a possible gap in the adoption of irrigation methods that are more water-efficient and effective. It, however, is encouraging that farmers are utilizing available waste water from household for irrigation purposes. Not all farmers have adopted contemporary irrigation infrastructure; providing an opportunity to inform and encourage farmers to use contemporary irrigation techniques, which can increase crop yields and water efficiency (Perry & Steduto, 2010). There is a propensity for recycling and using domestic water for farming purposes. This gives an opportunity to further encourage and increase the use of treated domestic wastewater, contributing to water conservation and efficient agricultural water usage.

Table 4.1.1 Frequency distribution and percentage proportion of respondent based on water management technology

Statement	Agree	Disagree	Uncertain	Total
You collect sufficient irrigation water to irrigate your agriculture land.	250(82.8)	52(17.2)	0(0)	302(100)
You have constructed tank/ponds to store irrigation water.	84(27.8)	218(72.2)	0(0)	302(100)
Tanks and ponds constructed for water storage are reliable.	80(26.5)	222(73.5)	0(0)	302(100)
You use cement water channels to irrigate you fields.	81(26.8)	221(73.2)	0(0)	302(100)
You use drip irrigation/ sprinkle irrigation at your farm.	22(7.3)	280(92.7)	0(0)	302(100)
You store and treat house hold waste water for irrigation purpose.	180(59.6)	106(35.1)	0(0)	302(100)

4.2.1 Perception of respondent regarding climate change resilient water management

The world is facing various challenges, including climate change, population growth, urbanization, and pollution. On the face of these challenges the climate change Resilient water management is the sustainable and adaptive management of water resources. It involves implementing strategies and practices that ensure the availability and quality water resources in sufficient quantity for both present and future generations. Adoption of water-saving technologies, up gradation of water storage and distribution systems are some important strategies for resilient water management. Perception of the respondents on climate change resilient water management is given in table 4.2.1 and explained below.

Majority of 66.6% respondents agreed that water storage practices helped to overcome water shortage due to climate change, 48.7% stated that culturally promoted practices like ponds/dams ensure regular water supply for irrigation, however 60.3% disagreed that water losses in irrigation channels are reduced due to cemetery these channels. This implies an understanding of the value of storage as a resilience approach in the face of changing climatic conditions. However, there are differing views about how well culturally propagated practices like dams and ponds achieve consistent water supplies for irrigation. Similarly, there were divergent views on the effectiveness of certain infrastructure practices in mitigating water losses. This diversity of views may stem from varying local experiences, maintenance practices, and the overall effectiveness of channel infrastructure in preventing water seepage and evaporation. The data indicates a considerable recognition within the community regarding the significance of storage as a resilience strategy. This acknowledgment resonates with the broader research emphasizing the role of water storage as a critical adaptation mechanism in limiting the implications of climate change on water availability (Bates et al., 2008; Hurd et al., 2013). The effectiveness of cementing irrigation channels may depend on factors such as soil type, climate conditions, and the quality of construction (Burt et al., 2000).

Furthermore, 85.1% respondents disagreed that Irrigation water ponds were used for multiple purpose like fisheries and poultry farming, 82.1% disagreed that on farm water losses are controlled by applying drip irrigation, and 61.3% disagreed that mulching is applied to reduce water lose through evaporation. This implies a limited perception of the multi-functional use of irrigation water ponds. It's evident that drip irrigation is not widely adopted as a water-saving strategy. In addition, there are possible voids in the water-saving mulching strategies' uptake. Drip irrigation is recognized as an efficient way for water use in agriculture, as it provides water directly to the plant roots, minimizing losses through evaporation and runoff (Sadras & Rodriguez, 2007). Mulching is the process of applying organic or inorganic materials to the soil's surface in order to prevent weed development, preserve moisture, and lessen evaporation. Combination of drip irrigation and mulching saves substantial amount of irrigation water (Stewart et al., 2001).

Table 4.2.1 Frequency distribution and percentage proportion of respondent based on climate change resilient water management

Statement	Agree	Disagree	Uncertain	Total
Water storage practices help overcome water shortage due to climate change.	201(66.6)	101(33.4)	0(0)	302(100)
Culturally promoted practices like ponds/dams ensure regular water supply for irrigation.	147(48.7)	153(50.7)	2(.07)	302(100.0)
Water losses in irrigation channels are reduced due to cemetery these channels.	118(39.1)	182(60.3)	2(.7)	3029100.0)
Irrigation water ponds are used for multiple purpose like fisheries and poultry farming.	44(14.6)	257(85.1)	1(.3)	302)100.0)
On farm water losses are controlled by applying drip irrigation.	52(17.2)	248(82.1)	2(.7)	302(100.0)
Mulching is applied to reduce water lose through evaporation.	95(31.5)	185(61.3)	22(7.3)	302(100.0)

Frequencies are given in parenthesis

4.3 Bi-variate Results

4.3.1 Association between water management technologies and climate change resilient water management

Irrigation water management technologies are developed by scientists and diffused by extension agents and farmers for efficient water management without compromising crop yield. Such technologies range from damming irrigation water in earthen ponds, storing it in cemented structures or tanks and using advanced irrigation technologies like drip irrigation, sprinkle irrigation etc. adoption of these technologies vary among farmers depending on their socioeconomic statuses and access to such technologies. Perception of the respondents on irrigation water management technologies and its association with climate change resilient water management is given in Table 4.3.1.

Results in Table 4.3.1 show that climate change resilient water management show a significant association with constructing tank/ponds to store irrigation water (P=0.001), and tanks and ponds constructed for water storage are reliable (P=0.002). The result implies that investing in the construction of tanks/ponds for water storage may contribute positively to climate change resilience in water management. It suggests that individuals who adopt this practice are more likely to perceive their water management as resilient to the challenges posed by climate change. Moreover, those who find tanks/ponds reliable are more likely to perceive higher climate change resilient water management. A study by Colding and Folke (2001) emphasizes the importance of local knowledge and perceptions in natural resource management. The authors argue that local perceptions of the reliability and effectiveness of ecological resources can significantly influence community resilience. The farmers learn from their environment and adjust their behavior to tap the environmental resources effectively and use them during lean times.

Moreover, cementing water channels to irrigate fields exhibited significant association with climate change resilient water management (P=0.003). Similarly, storing and treating house hold waste water for irrigation purpose had a significant association with climate change resilient water management (P=0.003). The utilization of cement water channels, as indicated in this study, is often associated with improved water infrastructure that can withstand the challenges posed by a changing climate. Previous research has shown that well-constructed and durable water channels contribute to the overall resilience of water systems, especially in regions prone to extreme weather events and disruptions (Jones et al., 2018). The durability and reliability of cement water channels make them a viable component of climate-resilient water management strategies. Moreover, those farmers who store and treat household wastewater are more likely to perceive higher climate change resilient water management (Rahman et al., 2020). Moreover, Garrido et al. (2018) investigated the efficiency of different irrigation technologies in the face of climate variability. Their research acknowledged the complexity of factors influencing climate-resilient water management, including technology adoption. Arnell et al. (2016) conducted a comprehensive study on water management practices and their implications for climate resilience, emphasizing the need for adaptive strategies. While their work highlighted the overall importance of efficient irrigation methods, it is crucial to recognize the context-specific nature of these relationships. The present study, in line with Arnell et al.'s findings, suggests that preference for water storage and cementing channels is a decisive factor in shaping perceptions of climate change resilience.

On the other hand, non-significant association was found between climate change resilient water management and collecting sufficient irrigation water to irrigate agriculture land (P=0.998), and using drip irrigation/ sprinkle irrigation at farm (P=0.340).

Farmers is arid zones face high water shortage. They adopt crude and refined technologies to overcome the problem of water shortage. Collecting and storing water in water ponds and tank help them in storing irrigation water for lean time. Some household integrate household and irrigation water use by using household waste water for irrigation purpose to solve the problem of water scarcity. Moreover, the problem of water loss due to seepage is controlled by cementing water channels that ensue resilient irrigation water management.

Table 4.3.1 Association between Water Management Technology and climate change resilient water management

Water management technology	**Perception**	**Climate change resilient water management**		**Total**	**Chi-square (p-value)**
		High Climate change resilient water management	**Low Climate change resilient water management**		
You collect sufficient irrigation water to	Agree	101(40.4)	149(59.6)	250(100.0)	$X^{2=}$.000 (P=0.998)

irrigate your agriculture land.	Disagree	21(40.4)	31(59.6)	52(100.0)	
You have constructed tank/ponds to store irrigation water.	Agree	47(56.0)	37(44.0)	84(100.0)	X^2=11.694 (p=0.001)
	Disagree	75(34.4)	143(65.6)	218(100.0)	
Tanks and ponds constructed for water storage are reliable.	Agree	44(55.0)	36(45.0)	80(100.0)	X^2=9.638 **(p=0.002)**
	Disagree	78(35.1)	144(64.9)	222(100.0)	
You use cement water channels to irrigate you fields.	Agree	44(54.3)	37(45.7)	81(100.0)	X^2=8.912 **(p=.003)**
	Disagree	78(35.3)	143(64.7)	221(100.0)	
You use drip irrigation/ sprinkle irrigation at your farm.	Agree	11(50.0)	11(50.0)	22(100.0)	X^2=.909 (p=0.340)
	Disagree	111(39.6)	169(60.4)	280(100.0)	
You store and treat house hold waste water for irrigation purpose.	Agree	76(42.2)	104(57.8)	180(100.0)	X^2=11.489 (p=0.003)
	Disagree	46(43.4)	60(56.6)	106(100.0)	

5.1 Conclusions and Recommendations

Confidence in gathering enough irrigation water is high, but concerns exist about the reliability of existing water storage infrastructure. Certain practices, such as constructing tanks/ponds and using cement water channels, are significantly associated with higher perceptions of climate change resilient water management. The study identifies areas for improvement in the adoption of modern irrigation infrastructure and water-saving strategies like drip irrigation and mulching.

Address concerns about inclusivity and effectiveness in community meetings. Implement measures to enhance the representation of diverse voices, ensuring that all community members, especially marginalized groups, have a platform for expressing their concerns in water-related decisions. Develop strategies to overcome challenges in achieving collective action on water-related initiatives. Foster a sense of shared responsibility and community ownership in water management projects, emphasizing the benefits of collaboration and cooperation. Invest in improving the reliability of existing water storage infrastructure. Implement awareness campaigns and financial incentives to encourage the adoption of modern irrigation infrastructure and water-saving technologies, such as drip irrigation and mulching.

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