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Bridging Tradition and Adaptation: The Role of Indigenous Knowledge in Enhancing Water Resilience amidst Climate Change in District Karak, Pakistan.

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Abstract

The main objective of this research study is to assess the association of indigenous knowledge 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 (indigenous knowledge) 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. Climate change resilient water management exhibited a highly significance association with the knowledge of the local wild plant that determines the suitability of land for cultivation (P=0.007), the knowledge of the local wild animals and insects (P=0.000), traditional knowledge to predict weather pattern, rainfall and dry spells (P=0.030), and traditional knowledge to conserve water in soil after irrigation (P=0.004). Documenting functional indigenous knowledge, development of targeted educational programs on climate change resilient agricultural practices, ensuring active participation of all farmers in community meetings, and investing in existing water storage and innovative irrigation infrastructure, were some of the policy recommendations in light of study findings.

Keywords: Irrigation water, climate resilience, indigenous knowledge

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 (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;). 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. It is feared that climate change will put South Asia's water governance and management institutions to a great test, even though it is only a secondary factor in the creation and growth of water disputes (Kloos *et al*., 2013; & Price, 2016).

Population of Khyber Pakhtunkhwa Province, according to the 1998 census, was 17.7 million which has now escalated to 39.6 million by the year 2022. This increase in population has direct Impact on the water sector, which has to cater the increased domestic, industrial and agricultural demands. The water quality is deteriorating because of the increased municipal, industrial, and agricultural waste, mostly dumped into water courses and natural streams. Moreover, due to population growth and climatic changes the per capita water accessibility has declined from 5000 cubic meters in 1947, to around 1000 cubic meters, and is expected to additionally diminish to 800 cubic meters per capita in 2025. The situation is further worsened for dry and arid districts of the province like District Karak (shah *et al*. 2023). In this situation of water scarcity, climate change, population growth, urbanization, and pollution, there is high need for sustainable and adaptive management of water resources. Such strategies involves implementing strategies and practices that ensure the availability and quality of water resources for both present and future generations. Resilient water management solutions, such as water-saving technologies, up gradation of water storage and distribution systems, are required to manage water resources (Zhou *et al*., 2021). Socio-cultural practices can significantly affect climate change resilient water management. Traditional socio-cultural practices, such as indigenous knowledge, socioeconomic structure of the community, water management technology, and water governance standards, have affected water resources management. These methods have improved the adaptability of water systems in many parts of the world.

Indigenous knowledge refers to the knowledge, abilities, and customs that local groups have gained over many years as a result of their interactions with the environment. This information is frequently derived from observations and personal experience, and it is tailored to the local environment by taking into account the particularities of the local environment, culture, and socioeconomic circumstances. Indigenous knowledge is essential to understand how people perceive climate change and how they adopt to these changes. Indigenous peoples have long coexisted peacefully with nature, and their understanding of regional ecosystems and climatic patterns is very beneficial for managing with the effects of climate change. Construction of sophisticated system of canals and terraces to cultivate crops in a harsh and unpredictable climate are some of these adoptive strategies. Traditional knowledge is used to manage water resources, such as building and maintaining canals and irrigation systems, and developing terraced fields. In this way the issues of altered rainfall patterns and more frequent droughts are managed through customary practices developed through centuries (Adger *et al*., 2013).

Research studies acknowledge the importance of indigenous knowledge for coping with and adapting to climate change. Indigenous knowledge can offer valuable understanding of local ecosystems, weather patterns, and innovative techniques for water management. By incorporating this knowledge into formal water management plans, more efficient and sustainable strategies for climate change resilience can be developed. This highlights the need for collaboration between traditional knowledge and modern scientific approaches (Berkes *et al*. 2018). In light of the above background, this research study is designed to assess the association of indigenous knowledge with climate change resilient irrigation water management.

Review of Literature

This literature review explores the existing research on adaptive socio-cultural practices in water management that can withstand the impact of climate change. The chapter is divided into six sections. Section 2.1 to 2.2 describes the literature review related to role of indigenous knowledge, with respect to climate change resilient water management.

Indigenous knowledge

An ethnographic case study in Iran on utilizing indigenous knowledge for resilient water management to climate change (Ghorbani *et al.*, 2021) looked at water management practices in the Iranian province of Jiroft County. The research study talked about how indigenous knowledge of local water administration might be applied to resource governance in dry locations all over the world. Through qualitative research, the connections between a community's social structure, indigenous knowledge, water management techniques, and legal regulations in the context of anthropogenic climate change were investigated. The study discovered that historically reliant communal roles created a Social Agreement for the Supply of Water. Cultural norms produced interconnected hierarchies of water ownership, profit-sharing, and social responsibility; when combined, these hierarchies produce a fair system of role-sharing, social benefit distribution, socio-ecological resilience, and adaptive ability in the face of drought brought on by climate change. They determine that hierarchical land ownership-based water distribution is designed through collective participatory approaches; it is possible to create a model of spontaneous common pool resource management that promotes community drought resistance. The system is referred to as "lowest-profit agricultural water users, bilateral compensating mutual support". Using the lessons obtained from this spontaneous adaptive management instance, the authors offer suggestions for altering other centralized, outdated infrastructure and legal methods to water management.

Ajani *et al.* (2013) looked into how farmers from African nations are adjusting to the effects of climate change by using indigenous knowledge. The researchers reported that these farmers devised and put into practice the use of substantial adaption techniques to which enabled them to lessen their sensitivity to climatic fluctuation and change throughout time. But this information is rarely taken into account when developing and implementing modern mitigation and adaptation measures. According to the study, it is crucial to include indigenous knowledge into climate change policy in order to create sustainable, cost-efficient, and effective adaption plans.

Nyong *et al.* (2007) investigated the importance of local expertise in mitigating and adapting to climate change. Previous international attempts to combat global warming focused on mitigation with the aim of reducing and stabilizing atmospheric greenhouse gas (GHG) concentrations. Due to the slow pace in achieving this, adaptation was seen as a potential alternative to reduce sensitivity to the projected negative impacts of global warming. It is becoming more and more obvious that mitigation and adaptation are necessary, together rather than separately. The latest calls, as a result of this mitigating strategy, now include flexibility. However, the African Sahel is not a wholly new concept when it comes to incorporating mitigation and adaptation into worries about climate change. The region is noted for its severe and ongoing droughts, which have been documented for generations. use of extensive mitigation and adaptation strategy which surpass what future climate change models have projected, the local populations in this region have been able to decrease their vulnerability to past climate variability and change. However, the development and application of contemporary mitigation and adaptation measures hardly ever take this knowledge into account. Incorporating indigenous knowledge lighting can help with the development of sustainable climate change mitigation and adaptation measures that are rich in local content and planned in partnership with local people.

Climate change resilient water management

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.

Pittock (2011) investigated the Disputes and connections between Water management that is sustainable and national climate change policy. Even in the absence of climate change, the freshwater ecosystems and the resources they offer for people are under a great deal of stress due to increasing water demand and declining water quality. 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.

Materials and Methods

Study universe

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, Toor Mirch and Kabir Kallay of tehsil Karak constitute specific study area.

Sample size and sampling

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-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

$$nh\left(\frac{Nh}{N}\right) * n \qquad \text{(Equation-1)}$$

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-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

Data collection

The data was collected using an interview schedule covering all the study variables given in the conceptual framework of the study (Table-2). The conceptual framework of the study comprises of one independent variable (indigenous knowledge) and one dependent variable (climate change resilient water management). Likert scale was used for measurement of study variables.

Table-2 Conceptual framework

Independent variables	Dependents variables
Indigenous knowledge	Climate change resilient water management

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.

$$\text{percentage of data class} = \frac{\text{f}}{\text{N}} * 100 \qquad \text{Equation-2}$$

Where f = frequency of data class
N= number of observations

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).

$$\chi^2 = \sum \frac{(O-E)^2}{E} \qquad \text{Equation-3}$$

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)

Results and Discussions

This chapter comprises of three sections. Section 4.1 is about the uni-variare results of the independent and the dependent variables. Association results of the independent and dependent variables is given in section 4.2.

Perception of respondents regarding indigenous knowledge

Human-environment interaction is an important source of practical knowledge and abilities for human. Such knowledge, termed as indigenous knowledge, is gained through centuries of observations and personal experiences, and is inculcated into local culture. Most of the developmental philosophies and interventions are based on indigenous knowledge which provide deeper insight into local environment, culture, and socioeconomic circumstances. Awareness of indigenous knowledge is also essential to understand how people perceive climate change and how they adopt to these changes. Results on indigenous knowledge of the respondents is given in table 3. Results show that 87.1% of the respondents agreed that they had the knowledge of the local wild plant that determined the suitability of land for cultivation, 83.9% stated that they had the knowledge of local wild animals and insects that lived in their area, and 77.5% of respondents informed that The knowledge of local plants and animals was transmitted to them from their forefathers. Farmers has a close and direct interaction with nature. Their interaction with wild plants, animals and insects is a major source of their farming experience and making relevant decisions. Thus, farmers judge the state of their farms' fertility by closely inspecting indicator plant species. Similarly, some animals and insects are indicative of crop health or happening of diseases. Better understanding of these indicative wild plants and animal species is helpful in making right and timely decisions for crop management. Most of such knowledge, however, is conventional and learnt from forefathers. Other research studies also suggest that close relationship between farmers and their environment is useful source of their indigenous knowledge, having both cultural and historical relevance, that affect their agricultural practices. Elders play a crucial role in protecting and sharing important insights that is passed down through the generations. Some of the sustainable practices are firmly ingrained in the local context. It is imperative to acknowledge and value such indigenous knowledge systems (Fernandez-Gimenez, 2000; & Ghorbani *et al.*, 2021).

Moreover, predicting weather patterns, rainfall, and dry spells is something that a vast majority of people (95.7%) say they could do using conventional knowledge, a significant portion (71.5%) of respondents asserted that they possess traditional knowledge to reduce water loss during irrigation, while a majority (61.5%) claimed possessing knowledge to limit water loss during irrigation, and over half of the respondents (57.6%) claim to have traditional knowledge on how to save water in the soil. In dry areas devoid of irrigation system, irrigation water is a scarce commodity. Farmers in such remote areas face problems in planning agricultural activities relevant to their fields. Indigenous conventional knowledge of rainfall patterns, dry spells and weather conditions helps in predicting water availability for crop planning. Moreover, traditional knowledge of efficient irrigation practices and subsequent water retention in the soil reduces water losses and ensure its availability to growing cops. Recognizing climatic conditions based on indigenous wisdom is quite important for agricultural planning and sustainable water management practices, which is vital for regions facing water scarcity. This implies a knowledge of the interactions between soil and water, which is crucial for sustainable agriculture. The integration of traditional knowledge with scientific methodologies can lead to creating resilient and adaptive agricultural systems (Toledo & Barrera-Bassols, 2008).

Table 3 Frequency distribution and percentage proportion of respondent based on indigenous knowledge, frequencies are given in parenthesis

Statement	Agree	Disagree	Total
You have the knowledge of the local wild plant that determines the suitability of land for cultivation.	263(87.1)	39(12.9)	302(100)
You have the knowledge of the local wild animals and insects.	253(83.9)	49(16.2)	302(100)
The knowledge of local plants and animals is transmitted to you from your fore father.	234(77.5)	68(22.5)	302(100)
You have traditional knowledge to predict weather pattern, rainfall and dry.	289(95.7)	13(4.3)	302(100)
You have traditional knowledge to reduce water lose during irrigation.	216(71.5)	86(28.5)	302(100)
You have traditional knowledge to reduce water lose during irrigation.	185(61.5)	109(36.1)	302(100)
You have traditional knowledge to conserve water in soil after irrigation.	174(57.6)	80(26.5)	302(100)

Farmers vulnerable to adverse climatic conditions and water shortage are compelled to meticulously observe and learn from climatic patterns to adopt to adverse conditions and plan their cropping patterns accordingly. Such adaptation includes efficient on farm and off farm water conservation.

Association between Indigenous Knowledge and Climate Change Resilient Water Management

Practical knowledge and abilities gained by human beings through human-environment interaction provides basis for making rational choices and decisions that are helpful in coping with odd situations. Such knowledge is helpful in better perceiving and adopting to changes in natural events due to human induced climatic changes. Results on association of indigenous knowledge with climate change resilient water management is given in table 4.11 and explained below.

Results show that climate change resilient water management exhibited a significant association with having the knowledge of the local wild plant that determines the suitability of land for cultivation (P=0.007), moreover, a highly significant (P=0.000) association was found between climate change resilient water management and having the knowledge of the local wild animals and insects, furthermore, knowledge of local plants and animals is transmitted from fore father had a significant association with climate change resilient water management (P=0.036). People who are aware of how local wild plants affect the appropriateness of a piece of land typically see a link between their knowledge and highly climate change resilient water management practices. This pre-existing ecological information could have an impact on how people view and handle water. Furthermore, those who agree that knowledge has been passed down from their ancestors are more likely to see a link between their traditional knowledge and extreme climate change. This perspective aligns with broader arguments on the necessity of adopting multiple knowledge systems for sustainable development (Toledo & Barrera-Bassols, 2008). Adaptive management may become more culturally relevant and community-responsive by acknowledging and using traditional knowledge, which is frequently firmly ingrained in the local context and molded by prolonged interactions with the environment. The need of maintaining and incorporating traditional wisdom, which frequently conveys insights into sustainable practices accumulated across generations (Berkes et al., 2000; Toledo & Barrera-Bassols, 2008).

Results further show that having traditional knowledge to predict weather pattern, rainfall and dry spells had a significant association with climate change resilient water management (P=0.030). Moreover, the association of climate change resilient water management was significant with having traditional knowledge to conserve water in soil after irrigation (P=0.004). People who have traditional knowledge about water conservation in the soil after irrigation follow highly climate change resilient water management. The value of conventional understandings of soil moisture dynamics after irrigation is useful in water conservation and rational water use. An important source of information for maximizing irrigation techniques in the face of shifting climate patterns is historical knowledge in this area, which may have been derived from investigations of regional soil properties and water retention capabilities (Berkes et al., 2000; Moller et al., 2004).

However, the association of climate change resilient water management was non-significant with having traditional knowledge to reduce water lose during irrigation (P=0.360).

To summarize above results, indigenous knowledge is generated through exposure to natural and social environment. Such knowledge is helpful in determining the most appropriate practices for efficient on farm water management. The indigenous knowledge is transmitted from generations and accumulated with additional experiences for efficient climate change resilient water management. Specific aspects of indigenous knowledge, such as knowledge of local wild plants, animals, transmission from forefathers, and weather prediction, are significantly associated with perceptions of high climate change resilient water management. This highlights the importance of recognizing and integrating indigenous knowledge into community-based water management strategies.

Table 4.11 Association between Indigenous Knowledge and Climate Change Resilient Water Management

Indigenous knowledge	Perception	Climate Change Resilient Water Management		Total	Chi-square (P-value)
		High climate change resilient water management	Low climate change resilient water management		
You have the knowledge of the local wild plant that determines the suitability of land for cultivation.	Agree	114(43.3)	149(56.7)	263(100)	X^2=7.354 (P=0.007)
	Disagree	8(20.5)	31(79.5)	39(100.0)	
You have the knowledge of the local wild animals and insects.	Agree	114(45.1)	139(54.9)	253(100.0)	X^2=14.075 (P=0.000)
	Disagree	8(16.3)	41(83.7)	49(100.0)	
The knowledge of local plants and animals is transmitted to you from your fore father.	Agree	102(43.6)	132(56.4)	234(100. 0)	X^2=4.399 (P=0.036)
	Disagree	20(29.4)	48(70.6)	68(100.0)	
You have traditional knowledge to predict weather pattern, rainfall and dry.	Agree	113(39.1)	176(60.9)	289(100.0)	X^2=4.691 (p=0.030)
	Disagree	9(69.2)	4(30.8)	13(100.0)	
You have traditional knowledge to reduce water lose during irrigation.	Agree	84(48.3)	90(51.7)	185(100. 0)	X^2=2.041 (p=0.360)
	Disagree	26(32.5)	54(67.5)	109(100. 0)	

You have traditional knowledge to concern water in soil after irrigation.	Agree	84(48.3)	90(51.7)	174(100.0)	X^2=11.284 (P=0.004)
	Disagree	26(32.5)	54(67.5)	80(100.0)	

Frequencies are given in parenthesis

Conclusions and Recommendations

Indigenous knowledge accumulated and transmitted from generations plays a crucial role in agricultural decision-making, weather prediction, and sustainable practices. The integration of traditional wisdom with scientific methodologies is seen as enhancing resilience in agricultural systems, especially with reference to climate change resilient irrigation water management. This also highlights the importance of recognizing and integrating indigenous knowledge into community-based water management strategies.

The study recommended documenting the indigenous knowledge and practices functional in resilient and sustainable farming practice in arid zones along with emphasizing the importance of intergenerational knowledge transfer, particularly in areas such as weather prediction, ecological balance, and sustainable agriculture.

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