Report

Climate Change Vulnerability Index: A Case Study of District Rahim Yar Khan, Pakistan

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Front cover photo: Severe monsoon flooding in Southern Punjab, Pakistan. (Amjad Jamal/IWMI)
Back cover photo: Relief workers use boats to rescue families stranded in flood-affected villages, providing critical assistance during the emergency response. (Amjad Jamal/IWMI)

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Acronyms and Abbreviations

AA	Anticipatory Action
BISP	Benazir Income Support Program
BWSSA	Built Water Storage in South Asia
CCVI	Climate Change Vulnerability Index
CFE-DM	Center for Excellence in Disaster Management and Humanitarian Assistance
D.G. Khan	Dera Ghazi Khan
DDMA	District Disaster Management Authority
dS/m	deciSiemens per meter
EC	Electrical Conductivity
EPD	Environmental Protection Department
EWS	Early Warning System
FAO	Food and Agriculture Organization
FCAs	Fragile and Conflict Affected Settings
FLWSs	Food, Land, and Water Systems
GoP	Government of Pakistan
HEC	Higher Education Commission
IDMC-GRID	Internal Displacement Monitoring Center-Global Report on Internal Displacement
IDPs	Internally Displaced Persons
IPCC	Intergovernmental Panel on Climate Change
IWMI	International Water Management Institute
KFUEIT	Khwaja Fareed University of Engineering and Information Technology
km^2	Square Kilometre
MENA	Middle East and North Africa
MHVRA	Multi-Hazard Vulnerability and Risk Assessment
mm	Millimetre
MoF	Ministry of Finance
MoPD&SI	Minister of Planning, Development, and Special Initiatives
NbS	Nature-Based Solutions
NDMA	National Disaster Management Authority
NGOs	Non-Governmental Organizations
NSER-BISP	National Socio-Economic Registry, Benazir Income Support Program
P&DD	Planning & Development Department
PBS	Pakistan Bureau of Statistics
PDMA	Provincial Disaster Management Authority
PMD	Pakistan Meteorological Department
PWDs	People with Disabilities
UN DESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Program
UNDRR	United Nations Office for Disaster Risk Reduction
UNHCR	United Nations High Commissioner for Refugees
UNISDR	United Nations International Strategy for Disaster Reduction
WB	World Bank
WEF	World Economic Forum
WEFE	Water, Energy, Food, and Environment

Executive Summary

Purpose and Context

Globally, human well-being is increasingly threatened by the dual pressures of natural and man-induced hazards. The increasing frequency and intensity of climate-induced disasters underscore the urgent need for comprehensive strategies to mitigate their impacts on vulnerable populations. These disasters, driven by rising global temperatures and shifting weather patterns, disproportionately affect countries with limited resources and adaptive capacity. In developing countries like Pakistan, these challenges are pronounced due to the country's heavy reliance on agriculture, high poverty rates, and rapid population growth. Punjab province and more specifically Rahim Yar Khan district, exemplifies these vulnerabilities being highly susceptible to climate-induced disasters such as riverine floods, extreme heatwaves, waterborne diseases, and locust infestations. These recurring events disrupt livelihoods, exacerbate socio-economic disparities, and challenge the adaptive capacity of both host communities and internally displaced persons (IDPs). In this context, an assessment was undertaken in response to the growing need for localized climate vulnerability intelligence to support government, humanitarian actors, and development partners in strengthening anticipatory action, resilience planning, and evidence-based investments in fragile settings.

Method and Data

The research report presents a Climate Change Vulnerability Index (CCVI) developed for district Rahim Yar Khan by providing a comprehensive evaluation of the district's climate-related vulnerabilities across its four tehsils: Khanpur, Liaquatpur, Rahim Yar Khan, and Sadiq Abad. The CCVI is a composite index that measures vulnerability by integrating three critical dimensions: exposure, sensitivity, and adaptive capacity. Exposure assesses the district's likelihood of facing climate extremes such as rising temperatures, excessive rainfall, and deteriorating water quality and quantity. Sensitivity examines the district's socio-economic conditions including food, water, and land security; health status; and climate-induced migration. Adaptive capacity evaluates the district's ability to cope with and recover from climate impacts considering factors such as literacy rates, employment levels, and the possession of valuable assets. The multidimensional approach allows CCVI to offer policymakers actionable insights from a unique case study of district Rahim Yar Khan enabling the development of adaptive strategies and targeted interventions that address both immediate and long-term challenges posed by climate change.

The uniqueness of this district lies in its socio-economic and environmental context thereby making it a representative region for climate vulnerabilities in Punjab. With 65% of its population reliant on agriculture, it faces severe economic challenges driven by extreme weather events. Moreover, the 2022 floods displaced people, turning into critical refuge for climate migrants from neighboring flood-stricken areas. This dual role as both an affected and host community places immense stress on the district's infrastructure, resources, and population. Additionally, its geographic location at the intersection of the Punjab, Sindh, and Balochistan provinces exposes it to cross-provincial climate impacts, further intensifying its vulnerability. Since the district is characterized by high poverty levels with a significant proportion of its population reliant on subsistence agriculture, limited access to healthcare further compounds these socio-economic challenges thereby creating a vicious cycle of vulnerability and poverty.

The CCVI results over the study period (2019-2023) reveal that vulnerability fluctuated across tehsils due to varying exposure levels, socio-economic sensitivities, and adaptive capacities. In rural areas, tehsil Khanpur exhibited a noticeable reduction in vulnerability at certain times, driven by improved water management practices and targeted interventions. However, its vulnerability rebounded during extreme weather events. Tehsil Liaquatpur's vulnerability trends showed progress in managing agricultural risks, but persistent water quality issues and health sensitivities limited further improvement. Tehsil Sadiq Abad's rural areas demonstrated resilience through community-driven initiatives and sustainable water management practice thereby reducing vulnerability over time. However, tehsil Rahim Yar Khan's rural areas faced increasing challenges with rising vulnerability attributed to limited adaptive measures, growing population pressures, and intensified exposure to climate extremes.

This report, therefore, serves a dual purpose. First, it introduces a scalable CCVI methodology that can be applied across districts to identify climate vulnerability hotspots. Second, it demonstrates the tool's use through a detailed case analysis of district Rahim Yar Khan to enable stakeholders in visualizing evolving vulnerability patterns and design informed adaptation strategies.

Key Findings

In urban areas, the CCVI analysis highlights stark disparities: tehsil Rahim Yar Khan's urban side has experienced significant increases in vulnerability over the years, primarily due to rapid urbanization, inadequate infrastructure, and the growing burden of waterborne diseases such as hepatitis. This contrasted with tehsil Sadiq Abad, where a reducing vulnerability. Tehsils Khanpur and Liaquatpur's urban areas showed fluctuating vulnerability trends, with progress often undermined by recurring climate shocks and insufficient adaptive capacity.

Additionally, the CCVI's integration of gender-disaggregated and age-specific data provides critical insights into the disproportionate impacts of climate change on vulnerable populations. For example, women and children in rural areas faced adverse effects from food insecurity and limited access to clean water further exacerbating health vulnerabilities. Similarly, the elderly population in urban areas experienced compounded risks due to inadequate healthcare infrastructure and exposure to extreme heatwaves. These findings underscore the importance of tailored interventions that address the specific needs of different demographic groups. The analysis highlighted critical challenges faced by district Rahim Yar Khan. Frequent exposure to floods, heatwaves, and waterborne diseases continued to disrupt livelihoods and exacerbate vulnerabilities. Limited access to clean water, with nearly 30% of the population relying on unsafe sources and inadequate health services further strained the district's capacity to adapt. Meanwhile, inconsistent progress in improving employment and infrastructure highlighted the need for sustained efforts to build resilience. These vulnerabilities are not equally distributed, as some areas face compounding challenges due to socio-economic and environmental factors thereby requiring targeted and localized interventions.

Implications

Addressing these challenges requires a multi-faceted approach and IWMI can play a pivotal role in supporting these interventions. In the short term, priority should be given to establishing emergency response teams equipped to handle local risks and to improving water and sanitation systems to mitigate the rise in waterborne diseases such as hepatitis. IWMI can provide technical expertise and data-driven tools and advance remote sensing analyses to identify high-risk areas and design effective water management strategies. Another such crucial short-term intervention is mapping vulnerable areas using Geographic Information Systems (GIS) and remote sensing tools to guide efficient resource allocation and disaster preparedness.

The medium-term strategies should focus on promoting nature-based solutions (NbS) such as rainwater harvesting and groundwater recharge to enhance water security and agricultural resilience. IWMI's research and experience in implementing NbS can guide the development of scalable rainwater-harvesting and aquifer-recharge projects. At the same time, its collaboration with academic institutions can foster knowledge sharing and capacity building. Additionally, developing crop zoning strategies tailored to local climate conditions can help farmers adapt to changing weather patterns and improve food security.

The long-term goals should include building a comprehensive disaster management framework that integrates risk mitigation strategies and developing climate-resilient infrastructure to protect critical assets and communities. IWMI's ability to incorporate scientific research into policy frameworks can support the development of climate-resilient infrastructure and ensure evidence-based decision-making. Inter-provincial collaboration will be essential to ensure coordinated disaster responses and equitable resource sharing. By acting as a bridge between research, policy, and implementation, IWMI can not only enable district Rahim Yar Khan, but also other districts, to transform their climate vulnerabilities into opportunities for sustainable growth and resilience, with the support of the government, private sector, development partners, civil society, and academia in Pakistan.

Introduction

The World Economic Forum's Global Risks Report (2024) identifies extreme weather events as the most severe global risks highlighting their dual impact: directly threatening infrastructure, economies, and vulnerable regions, while simultaneously driving significant human mobility (WEF 2024). These extreme events are increasingly linked to long-term climate change and heightened climate variability which together amplify the frequency, intensity, and spatial reach of hazards. Over the years, the increasing frequency and severity of such events, compounded by both natural and anthropogenic factors, have intensified their impacts on populations worldwide. Annals of history attest to mobility - migration - as one of the longstanding and recurrent human responses to climatic stressors driven by diverse social, economic, environmental, or political factors. These events disrupt livelihoods, deplete resources, and destabilize communities, forcing many to seek refuge elsewhere.

Table 1. Types of Hazards.

Type	Impact	Example
Man-Induced Hazards	Slow-Onset Hazards	Droughts, famines, environmental degradation, deforestation, and pest invasion
	Epidemics	Respiratory infections, cholera, measles, dysentery, and malaria
	Industrial / Technological Hazards	Pollution, the extraction of hazardous waste, and fires
	Complex Emergencies	Conflict, violence, human rights violations, and war
Natural Hazards	Sudden Impact Hazards	Floods, earthquakes, storms, volcanic eruptions, landslides, and tsunamis

Source: International Alert (2015).

Table 1 presents a classification approach that divides man-made hazards into industrial, technological, and complex emergencies each of which has the potential to exacerbate the adverse impacts of natural disasters (International Alert 2015). In this report, a hazard is defined as a potentially damaging physical event, phenomenon, or human-induced process that may cause loss of life, injury, socio-economic disruption, or environmental degradation (UNDRR 2017; IPCC 2014). Hazards may be natural, anthropogenic, or a combination of both and can exacerbate existing vulnerabilities when interacting with exposure and limited adaptive capacity. Additionally, categorization of natural hazards is predicated upon their distinct characteristics which encompass geophysical, meteorological, hydrological, climatological, biological and extraterrestrial phenomena (IPCC 2014).

As the global population continues to grow, more people are becoming susceptible to the risks posed by extreme weather events thereby leading to an anticipated escalation in temporary human migration and internal displacement. This evolving dynamic underscore the critical need for enhanced adaptation and resilience measures that address not only the immediate impacts of such events, but also their broader socio-economic and environmental implications.

This study aims to develop and apply a Climate Change Vulnerability Index (CCVI) to provide a spatially differentiated and district-level assessment of climate-induced vulnerabilities affecting both host communities and climate-induced migrants in Pakistan. Responding to the absence of updated sub-national vulnerability assessments since the Multi-Hazard Vulnerability and Risk Assessment (MHVRA 2017), the research focuses on district Rahim Yar Khan due to its high exposure to climate hazards and its dual role as both an affected district and a major host of climate migrants during the 2022 floods. By integrating socio-economic, demographic, and climate indicators across rural and urban tehsils, the CCVI is designed to support anticipatory action, targeted resilience planning, and evidence-based decision-making. The study further demonstrates how vulnerability analytics can be operationalized through digital tools including an interactive web-based dashboard to strengthen proactive disaster risk management and climate resilience planning.

While climate change vulnerability is often assessed through environmental and socio-economic indicators, human mobility represents one of its most visible and consequential outcomes. Climate-induced migration not only reflects underlying exposure and limited adaptive capacity, but also increases pressures on host communities, public services, food systems, water resources, and labor markets. In districts such as Rahim Yar Khan, which simultaneously experience direct climate impacts and in-migration from flood-affected regions, vulnerability must therefore be understood as a dynamic process shaped by both environmental stress and population movement. For this reason, migration is discussed not as a standalone phenomenon, but as an integral component of the vulnerability framework underpinning CCVI.

Global Migration and Internal Displacement due to Disasters

Globally, the growing frequency and intensity of climatic stressors have been empirically correlated with the occurrence of natural disasters including but not limited to floods, rainfall, seismic activities, and mass movements (Ahmad and Afzal 2020). As shown in Figure 1, there has been a notable surge in the frequency of catastrophic events (387 in total) categorized by type during 2022 in contrast to the annual average (370 in total) recorded between 2002 and 2021 (EM-DAT 2022). Strikingly, floods, known for their tendency to induce social risk, economic losses, and human casualties, have been regarded as the pre-eminent global natural disaster precipitating widespread displacement and associated vulnerabilities (Hoq et al. 2021).

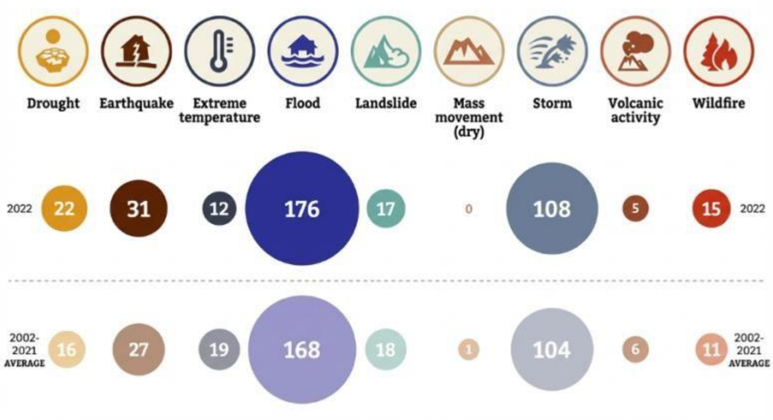


Figure 1. Occurrence of Disasters by Type – 2022.
Source: EM-DAT (2022).

These natural disasters have significantly contributed to a rise in the global number of internally displaced persons (IDPs) which reached 71.1 million in 2022; a 20% increase compared to the worldwide average in 2021 (IDMC-GRID 2023). Forced migration, a critical and pervasive global phenomenon, also experienced a marked surge during the same period, with five countries including Pakistan, the Philippines, China, India, and Nigeria reporting high figures. Pakistan accounted for 8.17 million forced migrations, followed by the Philippines with 5.45 million, China with 3.63 million, India with 2.51 million, and Nigeria with 2.44 million. Collectively, these numbers represent approximately 32.6 million forced migrations thereby reflecting a substantial 41% increase compared to the average annual figures over the preceding decade (IDMC-GRID 2023). These findings underscore the escalating impact of extreme weather events on human mobility thereby emphasizing the urgent need for adaptive strategies to mitigate displacement and its associated challenges.

In addition to displacement caused by natural calamities, conflict and violence have also been significant drivers of forced migration. Episodes of displacement resulting from international armed conflicts, non-international armed conflicts, communal violence, crime-related violence, and civilian-state violence have escalated sharply in recent years. For instance, Ukraine reported approximately 16.87 million displaced individuals in 2022 followed by the Democratic Republic of the Congo with 4.00 million, Ethiopia with 2.03 million, Myanmar with 1.01 million, and Somalia with 621,000 migrations. Alarmingly, these figures represent a threefold increase over the annual average recorded over the past decade (UN DESA 2023). Together with displacement due to natural disasters, these conflict-induced crises highlight the multifaceted and compounding challenges of forced migration necessitating a comprehensive approach to address both environmental and conflict-related drivers of displacement.

Regional Migration and Internal Displacement due to Disasters - Case of South Asia

Reflecting global trends, South Asia has experienced a significant increase in internal displacement with paralleling patterns observed in the Middle East and North Africa (MENA) and Sub-Saharan Africa regions (IDMC-GRID 2025). In 2022, the region accounted for 12.6 million displaced individuals thereby representing approximately 21% of the global displaced population. Of these, 12.5 million cases were attributed to natural hazards, while 35,000 were attributed to conflict and violence (IDMC-GRID 2023). South Asia contributed 12% (8.8 million) to the global IDP population in 2022 with internal displacement driven by a dual burden of natural disasters and conflict. The natural events led to the displacement of 3.3 million individuals, while conflicts and violence forced 5.5 million people to abandon their homes. Within South Asia, Pakistan emerged as the most affected with 8.17 million displacements due to natural calamities and 680 incidents linked to conflict and violent deaths. India followed with 2.51 million disaster-induced displacements and 1,000 incidents of conflict-related violence. Bangladesh recorded 1.52 million cases of disaster-induced migration and 560 incidents of conflict-related deaths. Afghanistan experienced 220,000 disaster-related displacements alongside a notable 32,000 conflict-related deaths. Nepal, despite comparatively lower displacement figures, still reported 93,000 cases of disaster-induced migration highlighting the region's vulnerability to environmental risks (IDMC-GRID 2023).

A deep dive into the country level in the realm of internal displacement, Pakistan emerged as the frontrunner by experiencing a staggering 8.8 million people migrating due to various natural calamities, which was accompanied by 680 incidents of conflicts and violent deaths (IDMC-GRID 2023). India followed suit, with 2.5 million cases of internal migration attributed to disasters, along with 1,000 instances of conflicts and violent deaths. Bangladesh witnessed 1.5 million occurrences of internal migration because of the catastrophe, accompanied by 560 incidents of conflicts and violent deaths. Afghanistan, on the other hand, saw 0.2 million instances of internal migration due to disasters, coupled with a substantial 32,000 incidents of conflicts and violent deaths. Lastly, Nepal experienced 93,000 internal migration cases, creating serious vulnerabilities to disasters (IDMC-GRID 2023).

These figures highlight the compounded challenges South Asia faces in addressing internal displacement driven by both natural and human-induced factors. The regional impact further underscores the urgency of developing integrated, context-specific solutions to mitigate the dual drivers of displacement and to enhance resilience among vulnerable populations.

Disaster, Migration, and Vulnerability Nexus

Since the phenomenon of migration is intricate and multifaceted, it is shaped by a myriad of interconnected factors, leading to associated vulnerabilities, in which individuals possess a pre-eminent disposition to encounter adverse consequences attributable to their susceptibility to diverse manifestations of risk. These include environmental changes, downturns in economic cycles, threats to security, financial breakdown, and natural calamities (Van Hear et al. 2012; De Ruiter and Van Loon 2022). The dynamics amongst these determinants are manifested within the context of hazard, where individuals' vulnerability to calamities is influenced by fundamental political, economic, and social mechanisms (UNHCR 2017).

Moreover, interactions between humans and the ecosystem also led to a surge in vulnerability to disasters. Such occurrences disrupt community operations and exceed their capacity to cope with massive human, material, and economic disruptions (Shah et al. 2020). Moreover, humanitarian crises have the potential to undermine progress in development efforts due to the improper management of displaced individuals, while exerting strain on temporal, spatial, household, community, and state dimensions (UNDDR 2018). This phenomenon is further attributed to the impact of migration on existing equilibrium and stress-absorption capabilities of host communities. Resultantly, a new community manifests within the socio-cultural milieu, characterized by a unique equilibrium state that is compromised in its ability to endure and recover from potential calamities.

A multitude of literature on vulnerability within the framework of climate change has established its inability to constitute a viable approach for mitigating the multifaceted complexities arising from climate change and its variability across socio-economic dynamics (Climate-ADAPT 2022).

Figure 2 illustrates the interconnected pathways through which climate change and climate variability influence environmental and socio-economic systems, shape vulnerability through exposure, sensitivity, and adaptive capacity, and ultimately inform migration decisions, including displacement, adaptation in place, or voluntary mobility.

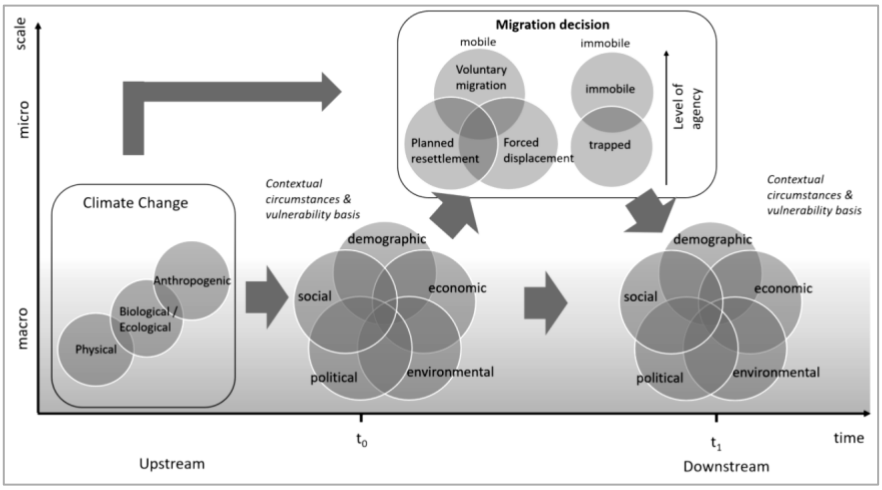


Figure 2. Climate Change pathways shaping Vulnerability and Migration Decisions.
Source: Rebacca et al. (2020).

Thus, as illustrated in Figure 2, vulnerability to climate change encompasses the extent to which a system becomes prone to detrimental effects and uncertainties associated with climate change and climate variability, mediated through exposure, sensitivity, and adaptive capacity (IPCC 2014). Henceforth, consequences stemming from climate change and disasters engender substantial devastation to communities, human casualties, agricultural and non-agricultural loss, and infrastructure corrosion with numerous detrimental effects on the sustenance of countless individuals (Raikes et al. 2021).

Within the realm of climate change research, *vulnerability is frequently framed as an intrinsic predisposition of individuals and communities to the consequences of climate change, considering their degree of exposure and adaptive capacity* (Bera and Singh 2021). Within this framework, sensitivity refers to the extent to which socio-economic conditions such as reliance on climate-sensitive livelihoods, food and water insecurity, health status, and demographic characteristics that amplify the impacts of climate stressors once exposure occurs. In the realm of economic studies, the concept of vulnerability is commonly examined through the lens of financial risk and inherent susceptibility to economic shocks that can disrupt individuals' means of subsistence (Salgado Baptista et al. 2022). Thus, in its entirety, the varied conceptualizations and applications of vulnerability underscore its multifaceted character and paramount importance for comprehending social and environmental phenomena.

Vulnerabilities and Challenges related to Food Security during Disasters

Among the various sub-processes of climate-induced migration risks, food insecurity is identified as the most significant factor impacting host communities (Cernea 1995). Climate-induced disasters exert considerable pressure on agricultural productivity, disrupt livelihoods, and frequently exacerbate the socio-economic vulnerability of marginalized populations (Ortiz-Bobea et al. 2021). Additionally, the supplementary fluctuations in water supply, coupled with concurrent demand escalation, place an additional burden on the agricultural sector.

Such calamities can lead to food crises, which can be exacerbated by a ratchet effect that hinders recovery when coupled with conflict. This issue is significant due to its implications for both the physical and economic accessibility to essential sustenance, encompassing the availability and means of obtaining food resources (Belianska et al. 2022).

Consequently, food security demonstrates a robust correlation with climate change and its ensuing ramifications for food systems (Choithani 2019). Moreover, it is imperative to acknowledge that climate-induced disasters can push specific sectors of the population especially those engaged in agriculture, into a state of profound destitution (Thiede and Gray 2020). The ramifications of flood-related calamities are critical due to a lack of adequate means to obtain sustenance, limitations on their use, and diminished ability to procure food (Pingali et al. 2019). Communities are faced with a multitude of consequential outcomes arising from floods including decreased agricultural output, reduced employment prospects, reduced economic capacity, intensified health challenges, increased risks of impoverishment, heightened susceptibility to food insecurity, and concerns about hunger (Tellman et al. 2021). Thus, the goal of ensuring food security necessitates the simultaneous preservation of economically viable well-being and the establishment of an enduring and ecologically sound provision of sustenance, as is universally recognized as an inherent entitlement of the global populace (FAO 2018; Frelat et al. 2016).

Vulnerabilities and Challenges Related to Water Security During Disaster

The phenomenon of rapid urbanization, coupled with population growth, socio-economic transformation, and climate change, has led to unprecedented pressure on water resource systems. Consequently, these factors have led to substantial changes in the physical environment over time (Mishra et al. 2021). Therefore, developing countries worldwide are experiencing an escalating water-stress issue, in fragile and conflict-affected settings (FCASs) (Salgado Baptista et al. 2022). Besides, the scarcity of secure water access is increasingly becoming an imminent predicament for individuals thereby engendering substandard health conditions, undermining sustainable means of subsistence, and inflicting unwarranted distress on the impoverished demographics at large (Blaikie et al. 2003). During disasters, these pressures translate directly into reduced access to safe water for both displaced populations and host communities.

On the one hand, sub-standard water quality, rendering water unsuitable for various applications, entails a multitude of adverse health and environmental ramifications while exacerbating the scarcity of available water resources. On the other hand, insufficient precipitation induces significant changes in water resources and agricultural systems with potential ramifications of considerable magnitude contingent on the resilience of local communities and populations (WB 2022).

Thus, the exacerbation of tensions over competing water use is attributable to the divergence between human water consumption and the requisite environmental flow. The disruption of water distribution services during natural calamities further compels IDPs to seek alternative water sources independently and to resort to precarious options that may pose significant risks to their well-being (Lin et al. 2020). Henceforth, the imperative of reinstating water service functionality cannot be overstated in the context of water-secure communities. This process assumes a pivotal role in facilitating the restoration of various activities within a community that has suffered adverse consequences because of a natural calamity.

Vulnerabilities and Challenges Related to Land Use and Resettlements During Disasters

The IDPs exhibit a preference for seeking security within the host communities. However, in the event of disaster, such displaced individuals and host communities encounter numerous challenges in their efforts to cope with their respective circumstances. The absence of land ownership among IDPs poses significant challenges in the context of a disaster thereby creating various social challenges for displaced individuals (Shah 2020). These challenges impede community involvement and render both communities susceptible to adversity. Therefore, it is imperative to ensure that individuals who have been involuntarily displaced receive equitable and impartial assistance and entitlements devoid of any form of prejudice or discrimination.

During disasters, the intricate interplay between community resilience and natural calamities is highlighted by the challenges and vulnerabilities associated with food security, land use, and water security. Agricultural productivity, livelihoods, and socio-economic stability are disrupted by food insecurity that is exacerbated by climate-induced disasters. Alongside this, the fragility of water resources is exacerbated in developing countries and fragile contexts, by water scarcity and degradation, which are influenced by rapid urbanization, population growth, and climate change. Additionally, the integration and reintegration of displaced populations into host communities are impeded by land-use challenges and resettlement issues. These interconnected challenges and vulnerabilities underscore the need for a nationwide analysis to comprehensively understand the multifaceted impacts of climate change and disasters on food security, water availability, land use, and displacement dynamics. IWMI-Pakistan leads research aimed at understanding and addressing challenges arising from climate-induced migration and displacement across migrant, displaced, and receiving communities with a focus on identifying shared risks affecting food, land, and water systems (FLWSs). This work also examines how communities respond to increasing stress on these systems and develops evidence-based policy recommendations that support proactive disaster risk management, environmental protection, and climate adaptation. Through its engagement in Pakistan, IWMI’s research offers valuable insights into the vulnerabilities faced by communities, especially in regions where climate-induced disasters intensify socio-economic fragility. A broader, systems-level perspective helps inform targeted strategies to build resilience, ensure sustainable resource use, and address the long-term implications of climate change across all levels of society.

Climate Change and Associated Vulnerabilities in Pakistan

Pakistan, a country with a burgeoning population estimated at 241.49 million, ranks 5th globally in population (PBS 2023). In response to the exponential population growth, an unstructured process of urbanization has rendered the country susceptible to a range of risks thereby exerting a profound impact on economic progress. The proliferation of natural hazards is due to the country's elevated heterogeneity in geological composition and varied meteorological patterns across the Indus Basin which encompasses a substantial portion exceeding 60 percent of the total land area and the absence of a multi-hazard early warning system (EWS) (UNDRR 2023). Figure 3 illustrates the prevalence of individuals residing in a socio-economically disadvantaged country that lacks access to a comprehensive multi-hazard EWS to lessen the negative consequences of climate-induced vulnerabilities.

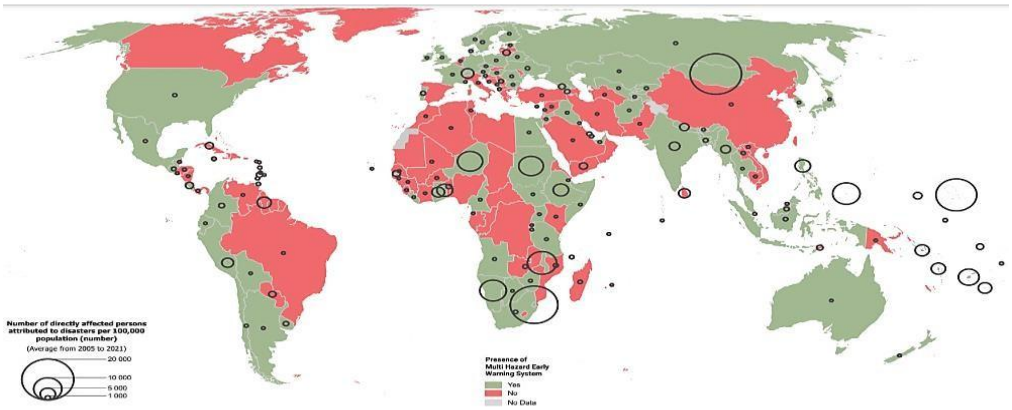


Figure 3. Countries with/without Access to Multi-Hazard Early Warning Systems.
Source: UNDRR (2023).

Thus, the country's geographical expanse, together with inadequate investment in resilience-building, as measured by EWS coverage, exhibits a distinctive juxtaposition marked by pronounced disparities, with substantial fluctuations in temperature across seasons and space. Similarly, ADB reported that Pakistan is in the bottom third of performing countries in dealing with climate hazards and water security (Asian Water Development Outlook 2020) among 56 countries in the Asia-Pacific region. Pakistan has a multifarious landscape and a dynamic climate characterized by elevated temperatures and aridity with recent years witnessing fluctuations in climatic conditions (WB 2023). Such observed fluctuations have had profound ramifications for the intricate interplay between socio-economic systems and the multifaceted trajectory of human development (Figure 4).

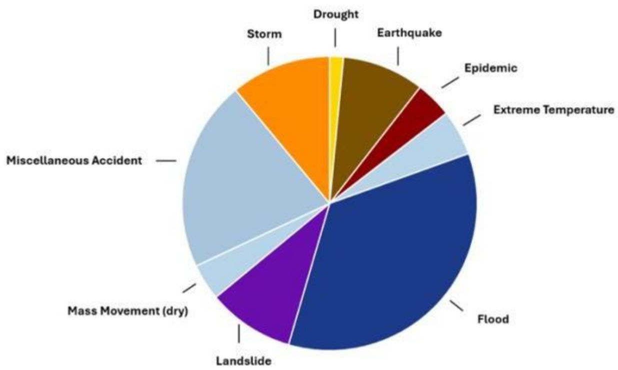


Figure 4. Average Annual Natural Hazard Occurrences between 1980–2020.
Source: WB (2023).

According to research findings by the National Disaster Management Authority (NDMA-2021), most catastrophic events in Pakistan originated primarily from meteorological changes with around 76 percent of the overall count attributed to hazards associated with weather phenomena. Additionally, tectonic activity along the boundaries of the Indian and Eurasian plates has caused substantial seismic instability in the country (Manzoor et al. 2022). As a result, recurrent flooding episodes occur in the Indus River basin during the monsoon, while summer heat waves cause floods thereby altering the snow-fed characteristics of rivers. Moreover, earthquakes occur annually and may recur at a triennial rate. With prolonged precipitation deficiency, geological events such as mass movements of soil and rock, atmospheric disturbances such as strong winds and rotating air masses, hydrological incidents such as the release of water from glacial reservoirs, gravitational snowslides, and technological system malfunctions are associated risks. Furthermore, unpredictable rainfall patterns, expansion of the monsoonal precipitation regime, and glacier melting accelerate the occurrence of consecutive flooding events in river systems thereby encompassing both downstream and upstream reaches (Ahmad and Afzal 2020).

Over the years, the country has encountered exceedingly elevated levels of disaster risk including but not limited to floods, droughts, erratic weather behaviors, famines, locust attacks, earthquakes, and epidemics thereby positioning itself amongst the top ten most vulnerable countries globally affected by climatic abnormalities also bearing a significant burden in terms of global death toll for 2022 (MoF 2023; EM-DAT 2022; German Watch 2021) (Figure 5). However, it is imperative to acknowledge that, over the period 1980 to 2020, only two drought events in Pakistan have persisted for more than 2 years (EM-DAT 2023).

Europe	Heat Wave	16,305	Nigeria	Flood	603
Uganda	Drought	2,465	South Africa	Flood	544
India	Flood	2,035	Philippines	Tropical Storm 'Megi'	346
Pakistan	Flood	1,739	Indonesia	Earthquake	334
Afghanistan	Earthquake	1,036	Brazil	Flood	272

Figure 5. Top Ten Countries with Highest Death Toll due to Disasters (2022).
Source: EM-DAT (2022).

Study Rationale and Objectives

Since the Multi-Hazard Vulnerability and Risk Assessment (MHVRA) was last updated by NMDA in 2017, there is a gap in the literature on climate-induced vulnerabilities for both migrants and host communities in Pakistan. In response to a call for comprehensive research to address vulnerabilities faced by host communities and climate migrants, Pakistan has been selected as a case study due to its climate vulnerability and the growing phenomenon of climate-induced migration. The report has been developed with the overarching purpose of providing an evidence-based spatially differentiated understanding of climate vulnerability in district Rahim Yar Khan. By integrating socio-economic, demographic, and climate indicators into CCVI, the report aims to support policymakers, planners, and development partners in designing context-specific, proactive interventions that reduce risk, safeguard livelihoods, and strengthen adaptive capacity across rural and urban landscapes. The CCVI serves as both an analytical framework and a practical decision-support tool that can be replicated in other districts to inform targeted climate resilience planning in Pakistan.

Based on the extent of poverty and deprivation, climate hazards including riverine floods in the Indus River, drought, locust attack in the desert, dust storms, epidemics, waterborne diseases coupled with limited research due to remote location at the junction of Sindh, Punjab, and Balochistan provinces, a specific district chosen for the in-depth case study is Rahim Yar Khan . Moreover, the district became a crucial refuge accommodating many climate migrants from neighboring flood-stricken districts in Punjab, Sindh, and Balochistan during the 2022 devastating floods which caused widespread displacement across Pakistan. This influx intensified existing challenges with the district struggling to support both local and displaced populations amidst damaged infrastructure and limited resources. Henceforth, it obliges itself to a dual role, serving as a community affected by calamitous events and as a host community for adjacent regions.

This poses a significant threat to approximately 50 percent of the overall population due to potential flooding and faces the risk of epidemics (25 percent of the population at risk) and earthquakes (5 percent of the population at risk) (NDMA 2017). Apart from environmental hazards and restricted access to resources, economic and social factors also play a role. The district's population is predominantly agrarian with agriculture serving as their primary source of income. Nevertheless, farmers have faced significant challenges maintaining their livelihoods due to an increasing number of extreme weather events and the consequences of climate change resulting in a vicious cycle of poverty and vulnerability that is difficult to break. More challenges faced by host communities and IDPs in the Rahim Yar Khan district are highlighted in the CCVI analysis conducted between 2019 and 2023.

However, the technical report highlights critical reasons for examining why climate-induced vulnerabilities were reduced during the period in district Rahim Yar Khan and what strategies can be adopted in the future to make disaster risk response proactive rather than reactive. Based on the technical report, a Microsoft Power BI dashboard was prepared visualizing the district's socio-economic and climatic profiles, as well as the CCVI developed for district Rahim Yar Khan. This dashboard has now been extended into a comprehensive web-based module (Figure 6).

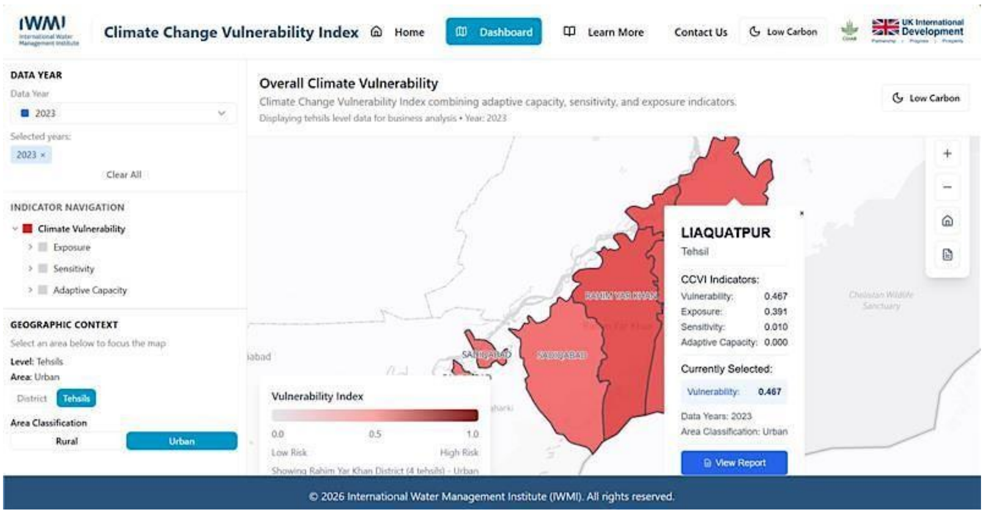


Figure 6. User Interface of Web-Based Module on Climate Change Vulnerability Index (CCVI).
Source: IWMI-Pakistan.

This analysis builds upon IWMI's broader portfolio of work on climate resilience, migration, and vulnerability assessment in Pakistan and the wider South Asian region. Notably, it extends insights presented in IWMI's 2024 research reports including 'Navigating Climate Change, Disasters and Displacement in Pakistan' and 'Digital Ecosystems and Migration Responses to Climate Extremes' by deepening the district-level lens and expanding the methodological framework through tehsil-disaggregated CCVI modelling (Khalid et al. 2024; Waqar et al. 2024). These studies collectively form a coherent evidence base that strengthens the institutional positioning of this report and reinforces IWMI's leadership in climate-fragility research. It emphasizes the need for better disaster preparedness and response mechanisms including the role of digital ecosystems, social media, and early warning systems in building community resilience. However, there are challenges such as limited access to technology, gender digital divide, and inadequate government support for displaced populations.

Research Design

Study Area

Rahim Yar Khan, a district located in the southern region of Punjab in Pakistan covers an area of 11,880 square kilometre (km^2) and homes to a substantial population of 5.56 million individuals (male: 2.89 million, female: 2.67 million, transgender: 551) with an average household size of 6.7 and population density/km^2 of 468.41 (PBS, 2023). This district lies in the vicinity of Rajanpur and Dera Ghazi Khan (D.G. Khan) districts in Punjab and is near Kashmore and Ghotki in Sindh. It is administratively organized into four tehsils: Liaquatpur, Khanpur, Sadiq Abad, and Rahim Yar Khan (Figure 7).

The PBS (2023) report on socio-economic indicators for Punjab at the district level indicates that district Rahim Yar Khan is categorized as a low socio-economic status district. This classification is primarily due to the district's unfavorable conditions across social, cultural, and economic dimensions (PBS 2023). Moreover, the climatic conditions exhibit frequent fluctuations with an intense summer season featuring high temperatures ranging from 27.4°C to 43.4°C and a relatively temperate winter season (PMD 2023).

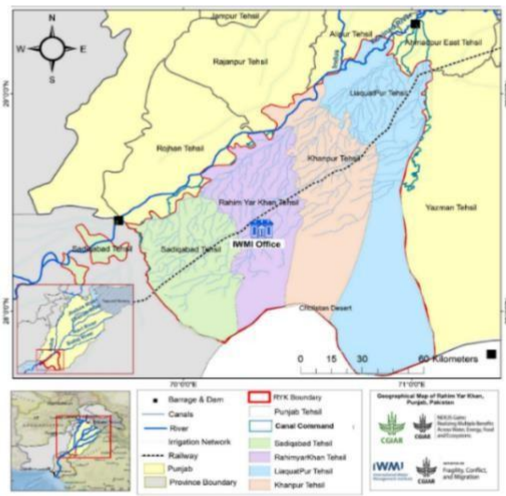


Figure 7. Administrative Map of District Rahim Yar Khan.
Source: IWMI-Pakistan.

Over the years, the district has experienced unpredictable precipitation patterns and recurrent floods resulting in unfortunate casualties and infrastructure damage (PBS 2023; PDMA 2022). It has become a practice that during the monsoon season, a series of inundations occurs on the Indus River resulting in substantial inundation of thousands of square kilometers across all four tehsils within the district. This causes individuals to rely on external entities for necessities such as food, water, and shelter (NDMA 2017). Simultaneously, it is imperative to acknowledge that individuals' vulnerability was further exacerbated by impediments encountered in seeking healthcare services, educational opportunities, employment prospects, and economic engagement within the affected areas where they have been displaced.

Data Management Approach

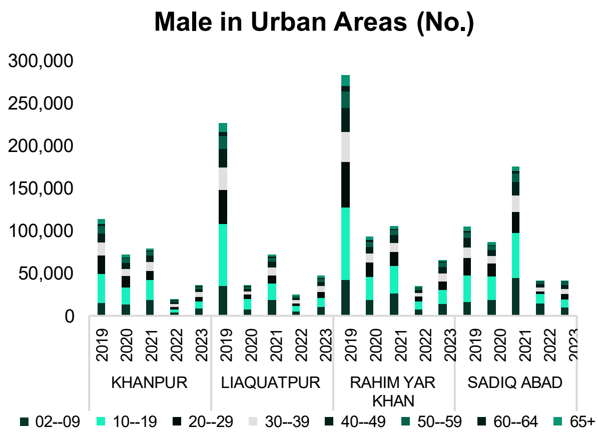
Following a detailed socio-demographic profile of district Rahim Yar Khan, the CCVI is computed for the district using data from the National Socio-Economic Registry, Benazir Income Support Program (NSER-BISP), Government of Pakistan (GoP) between 2019 and 2023. This data captures poor households in Pakistan and is the output of the first national door-to-door poverty survey conducted by NSER-BISP. The CCVI is estimated as the sum of four tehsil indices using gender-disaggregated and age-specific data at both the urban and rural levels. A value of 1.0 indicates that the district/tehsil is highly vulnerable to climate change, whereas a value of 0.0 means that it is less vulnerable. Variables used for analysis and detailed methodology of CCVI are listed in Annexure A and B respectively.

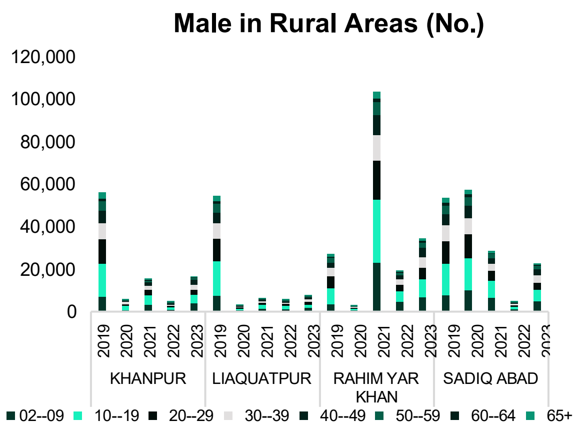
Results and Qualitative Insights

Socio-Demographic Profile of District Rahim Yar Khan

The population data for the tehsils of Khanpur, Liaquatpur, Rahim Yar Khan, and Sadiq Abad from 2019 to 2023 demonstrate distinct trends in rural and urban areas and across age categories. Khanpur and Liaquatpur tehsils exhibit consistent growth among younger age groups (2-10 years) in rural areas, indicative of a predominantly young demographic base with high birth rates. In contrast, the urban population of younger and middle-aged groups in these tehsils exhibits a fluctuating trend. This is evident in tehsil Khanpur's urban areas where the population aged 10-29 slightly decreases potentially because of migration to other regions in search of better opportunities. The elderly population (65+) is on the rise in Liaquatpur and Sadiq Abad tehsils suggesting that these communities have benefited from improved healthcare access and longer life expectancies.

In both rural and urban areas, Rahim Yar Khan and Sadiq Abad tehsils show more significant population growth across most age categories from 2021 onwards. The increase in the number of working-age adults (30-59) and the elderly in rural areas of these tehsils suggests that migration rates have decreased and that economic stability has improved through employment opportunities that encourage residents to remain. Similar growth trends in working-age groups, particularly men, are observed in urban populations, in tehsil Rahim Yar Khan thereby suggesting a consistent demand for labor and urbanization. In general, these trends highlight the contrast between the rural stability of young people and the urban fluctuations that may result from potential migration, indicative of the broader socio-economic dynamics in these regions (Figure 8).





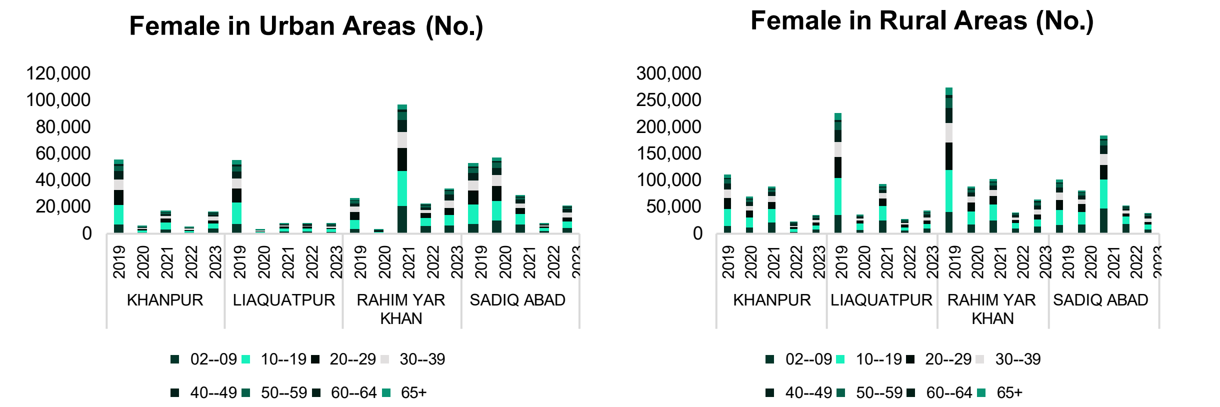


Figure 8. Gender and Tehsil-Wise Population Distribution in District Rahim Yar Khan (2019–2023).
Source: Estimated using NSER-BISP, GoP.

Data from 2019 to 2023 for district Rahim Yar Khan indicates that the number of households with employed members varies significantly across four tehsils and between rural and urban areas. Tehsil Khanpur's rural employment peaked in 2019 with 34,717 households employing members followed by a decline to 15,418 households employing members by 2023. In contrast, tehsil Khanpur's urban employment declined from 16,916 in 2019 to 7,053 in 2023.

Figure 9 further shows that rural employment in tehsil Liaquatpur decreased from 67,053 in 2019 to 20,105 in 2023, while urban employment remained stable. Tehsil Rahim Yar Khan showed a more pronounced increase in urban jobs from 9,375 in 2019 to 11,965 in 2023 suggesting a potential urbanization trend. Moreover, rural employment in tehsil Sadiq Abad fluctuated, but ultimately reached 14,187 households in 2023. Conversely, urban employment increased substantially suggesting that the urban job market is resilient.

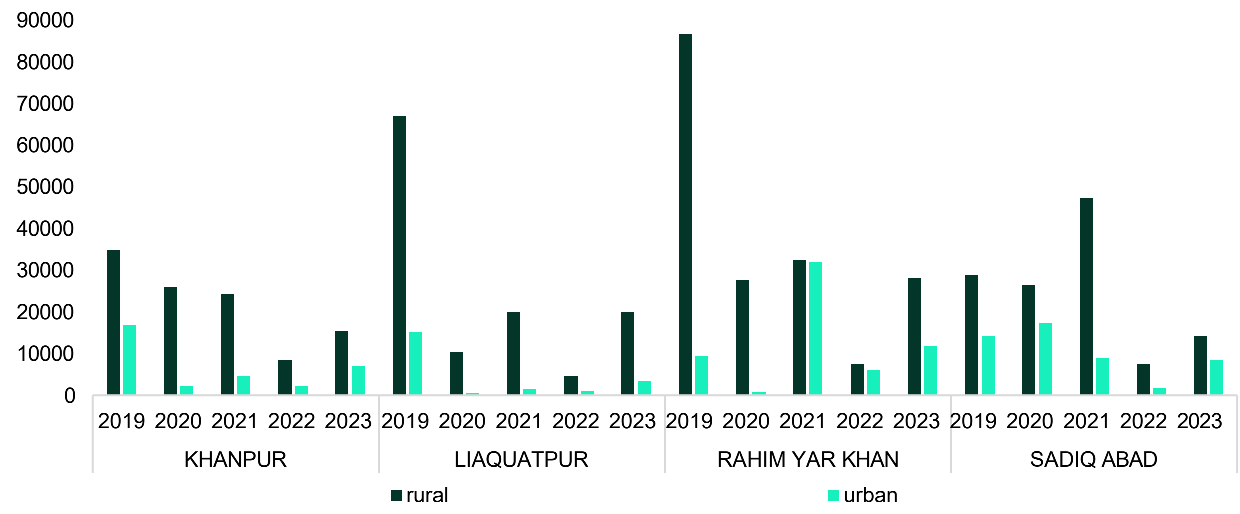


Figure 9. Tehsil-wise Number of Households with Employed Members.
Source: Estimated using NSER-BISP, GoP.

This suggests evolving employment dynamics in the district with rural areas generally experiencing declines and urban regions exhibiting varying levels of resilience underscoring the need for targeted employment strategies. A decrease in employment levels is attributed to the impact of floods on agriculture and other livelihoods, as well as to temporary migration due to climate change. The economic pressures are attributed to inadequate industrial development, decreased agricultural output, or limited employment opportunities. Additionally, factors such as migration within district Rahim Yar Khan especially from rural to urban areas, agricultural decline, and varied rural economic activities may also contribute to fluctuations in employment levels.

From 2019 to 2023, 56,000 individuals were forced to migrate outside of district Rahim Yar Khan, primarily from rural areas. Temporary migration from rural areas in tehsils Khanpur and Rahim Yar Khan is also a significant phenomenon. Migration rates in rural areas were consistently higher in 2019, when rural migration reached 8,105.

Nevertheless, rural migration declined consistently from 2020 onwards, while urban migration experienced a transient surge in 2021 and 2022, driven by increased urbanization, economic opportunities in urban centers, and the impact of the 2022 floods (Figure 10).

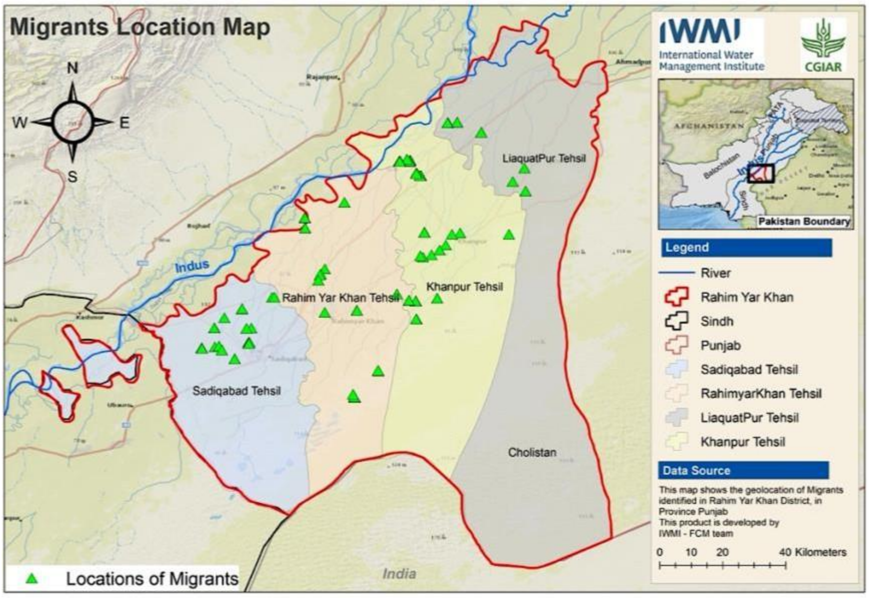
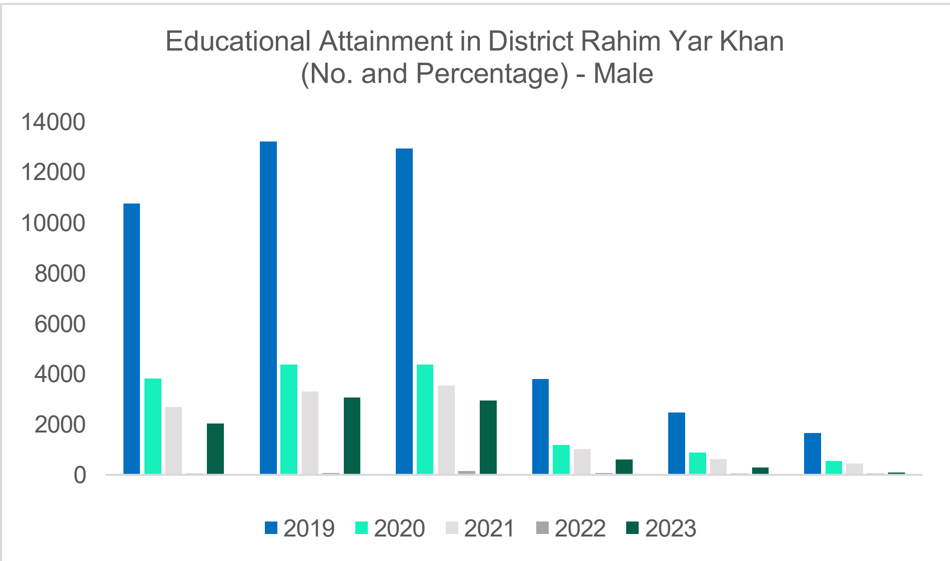


Figure 10. Migrants' Location Map for District Rahim Yar Khan (2024).
Source: IWMI-Pakistan.

Concerning education statistics, higher education attainment in rural areas decreased from 2019 to 2023, suggesting potential economic or systemic issues affecting completion and access. Rural communities face educational difficulties, limited employment opportunities, and reduced earning potential thereby perpetuating poverty cycles and limiting economic development. Moreover, the skills divide widens at intermediate and upper levels, further impacting local economies. It has been observed that female educational attainment is generally lower than that of males potentially affecting economic independence and employment opportunities thereby exacerbating socio-economic disparities (Figure 11).



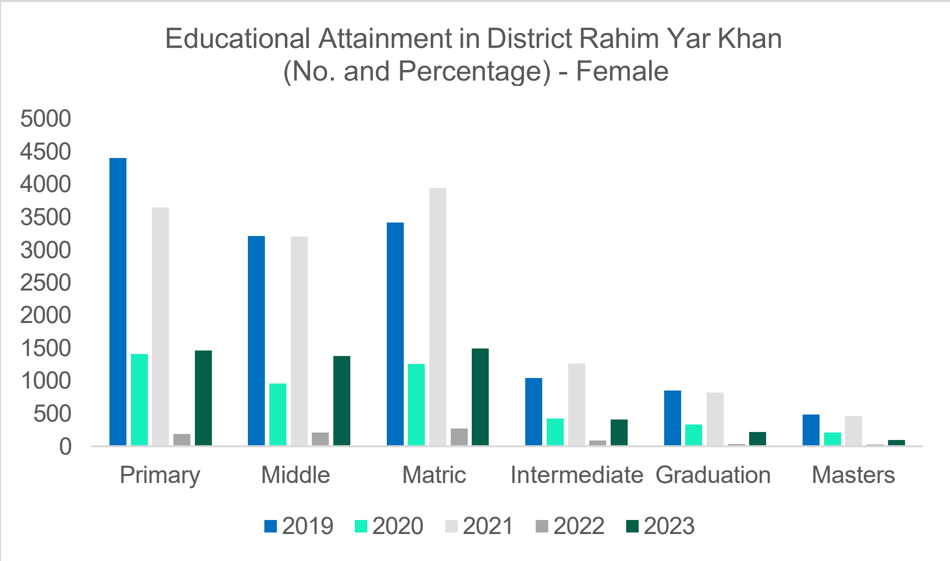
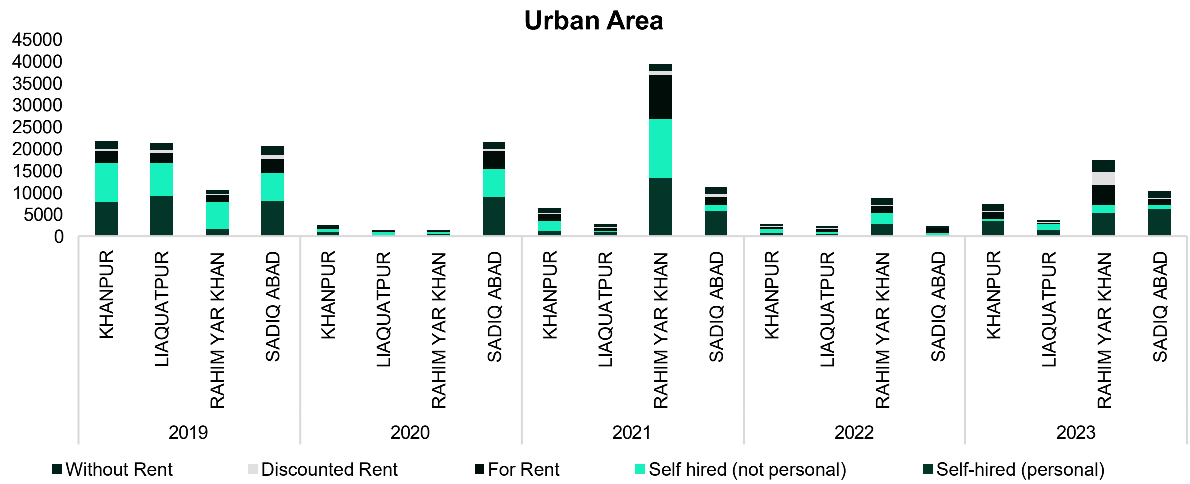


Figure 11. Educational Attainment in District Rahim Yar Khan (No. and Percentage).
Source: Estimated using NSER-BISP, GoP.

The data further provides insights into housing trends in the urban side of district Rahim Yar Khan across different modes of house acquisition from 2019 to 2023. The self-hired (personal) category which likely represents homes owned or occupied by individuals for personal use, showed mixed trends across the tehsils. It peaked in 2021 (13,356) but declined sharply to 5,453 by 2023 suggesting a potential shift away from homeownership or a reduction in the number of newly built homes. Similarly, self-hired (not personal) housing, indicative of homes shared or rented by others, also showed a steep decline from 13,518 in 2021 to 1,638 in 2023 thereby reflecting a shrinking reliance on such arrangements. On the other hand, rented houses 'for rent' steadily increased in tehsil Rahim Yar Khan, where it rose from 1,711 in 2019 to 4,706 in 2023 thereby signaling a growing demand for rental housing. Discounted rental housing saw a more modest increase with a notable rise in Rahim Yar Khan tehsil (2,940 in 2023) suggesting affordability as a driving factor in housing choices.

Informal housing arrangements, as reflected in the 'without rent' category, experienced consistent growth across all tehsils especially in Rahim Yar Khan, where the numbers rose from 974 in 2019 to 2,680 in 2023. This shift indicated a rise in shared housing or family living arrangements thereby reflecting broader economic pressures or cultural trends. Overall, the district's urban area shows a clear transition from self-owned and self-hired housing to rental and informal arrangements, driven by affordability and changing socio-economic dynamics. Households that rely on rented or discounted rental houses are typically more economically exposed, as they are more vulnerable to fluctuations in income or rent (Figure 12).



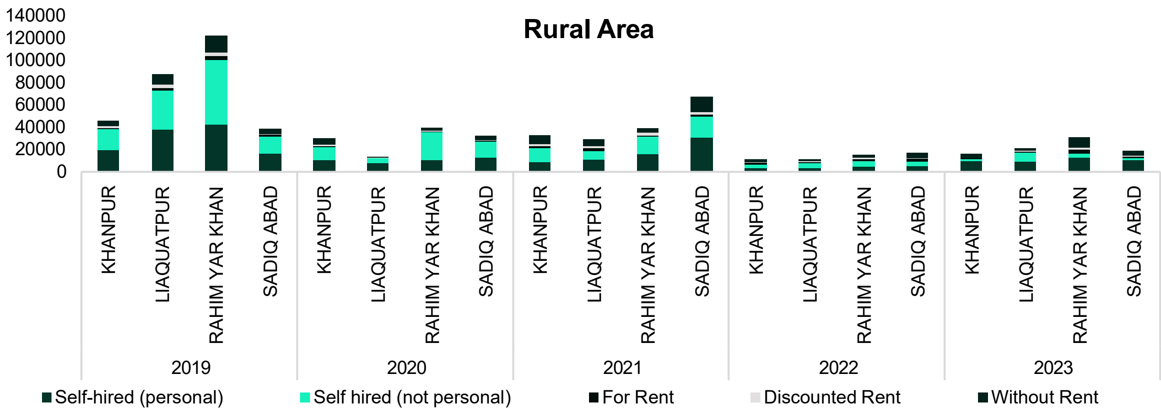


Figure 12. Households possessing different Types of Houses in District Rahim Yar Khan (No.)
Source: Estimated using NSER-BISP, GoP.

Additionally, urban areas exhibit a comparatively higher adoption of modern flush systems, whereas rural areas rely more on basic sanitation systems. Tehsil Sadiq Abad has the highest access to flush tanks, sewerage systems, and overall sanitation infrastructure reflecting relatively better services than in other urban centers. Tehsil Rahim Yar Khan leads in sewerage system connectivity, with a sharp increase in 2021, while Khanpur and Liaquatpur tehsils lag especially in modern systems such as flush tanks and sewerage connections. Additionally, the 'No Support' category, while lower than in rural areas, remains concerning, especially in the Khanpur and Liaquatpur tehsils. Trends over the years reveal fluctuations, with some regions improving in specific categories, such as sewerage connectivity, while others such as tehsil Khanpur show inconsistent progress. These findings underscore the need for consistent and targeted investments in urban sanitation systems to address existing gaps (Figure 13).

On the other hand, rural areas across all tehsils exhibit greater dependence on basic sanitation facilities such as hole-and-pit toilets despite advancements in sanitation thereby leading to increased vulnerability due to the risk of environmental contamination and health issues. Tehsil Rahim Yar Khan demonstrates the highest overall access to sanitation facilities including flush tanks and sewerage systems, but also shows a significant reliance on open drains and pits. Liaquatpur and Khanpur tehsils exhibit limited progress with heavy dependence on open drains, pits, and 'No Support, the latter being high in Liaquatpur thereby indicating widespread lack of access to any sanitation infrastructure. Tehsil Sadiq Abad shows moderate progress but still reflects substantial gaps, especially in advanced systems such as sewerage connections. The high proportion of 'No Support' across all areas underscores the urgent need for targeted interventions to improve rural sanitation in these regions.

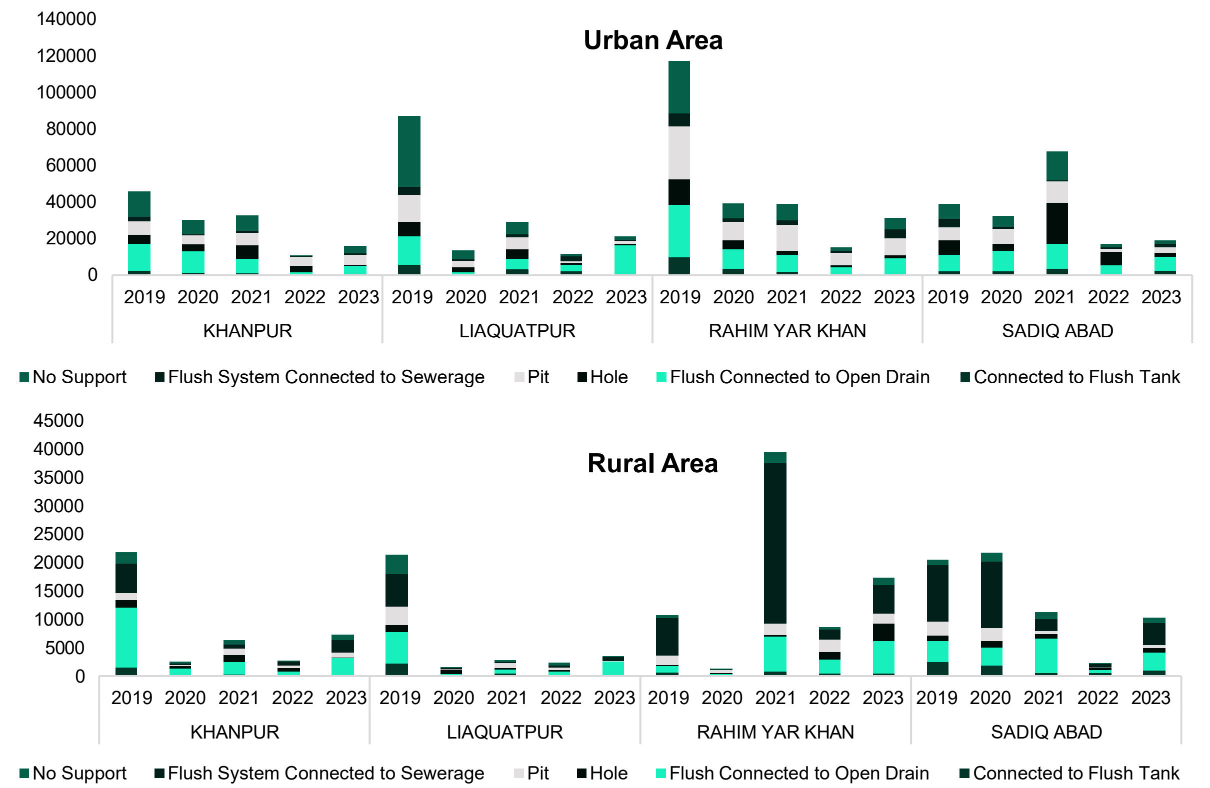
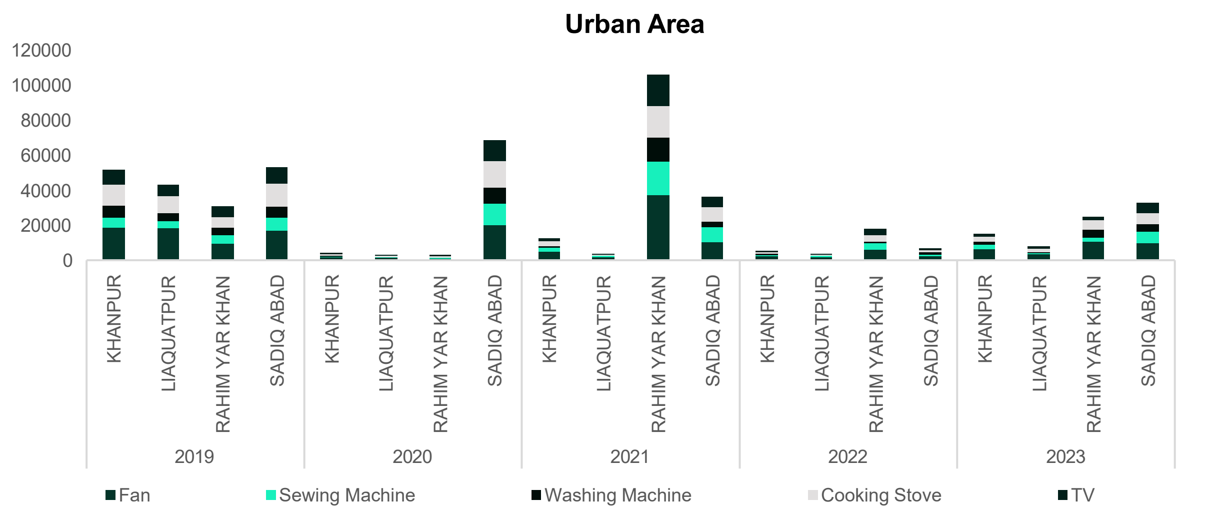


Figure 13. Households using Different Types of Sanitation Facilities (No.)
Source: Estimated using NSER-BISP, GoP.

Significant changes in the availability of essential household items across both rural and urban areas are evident in the data. In general, rural households in tehsils Rahim Yar Khan and Liaquatpur show a substantial decrease in the possession of items suggesting potential economic challenges (Figure 14). Overall, there is a notable fluctuation in the ownership trends of fans, sewing machines, washing machines, cooking stoves, and TVs across 2019 to 2023 in district Rahim Yar Khan. Specifically, tehsil Rahim Yar Khan consistently dominated in owning fans (37,422 in 2021) and cooking stoves (18,179 in 2021) thereby reflecting higher urban household affluence. Tehsil Sadiq Abad also demonstrated relatively high ownership levels with substantial figures for sewing machines (6,733 in 2023) and TVs (5,870 in 2023). Khanpur and Liaquatpur tehsils show lower overall ownership than the others with Liaquatpur recording the weakest figures across most categories by 2023 including washing machines (513). The data suggest that urban households in Rahim Yar Khan and Sadiq Abad tehsils have better access to and ownership of household appliances than those in the smaller urban centers of Khanpur and Liaquatpur. However, the declining ownership trends from 2019 to 2023 across several categories indicate potential economic challenges or shifting household priorities in these urban areas.



Rural Area

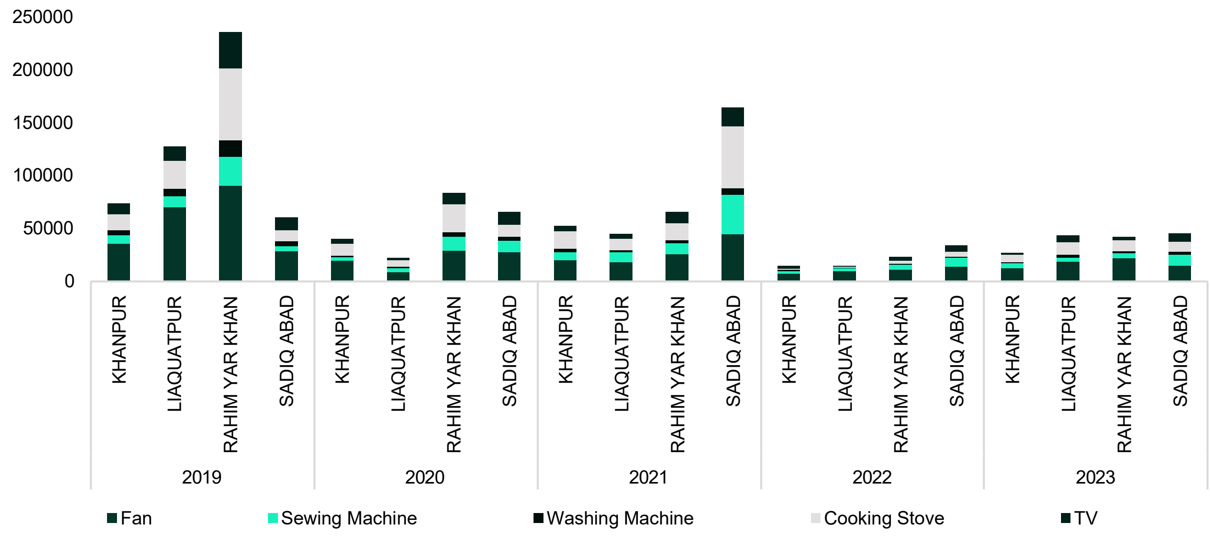


Figure 14. Households possessing Valuable Assets (No.)
Source: Estimated using NSER-BISP, GoP.

The data on household livestock ownership in district Rahim Yar Khan from 2019 to 2023 indicates a substantial decrease in rural and urban ownership across all tehsils thereby underscoring challenges in the agricultural and economic sectors. The farm sector in tehsil Rahim Yar Khan had the highest livestock ownership at 40,629 in 2019, but this number decreased to 2,432 by 2023, representing a significant 94 percent decline. Similarly, tehsil Khanpur's rural agricultural livestock ownership dropped from 10,637 in 2019 to 1,506 in 2023, while its urban livestock ownership decreased from 2,099 in 2019 to 286 in 2023 thereby indicating a trend toward urbanization and potential livelihood changes (Figure 15).

On the other hand, urban areas exhibit even more drastic reductions. Notably, the impact of economic pressures on traditional agricultural practices was underscored by the decline in the rural area of the tehsil Sadiq Abad from 9,967 in 2019 to 2,674 in 2023, despite urban livestock ownership remaining minimal. In general, the significant decline in livestock ownership over the years suggests a potential crisis in rural agriculture which may be driven by economic hardship, land degradation, or changing market dynamics.

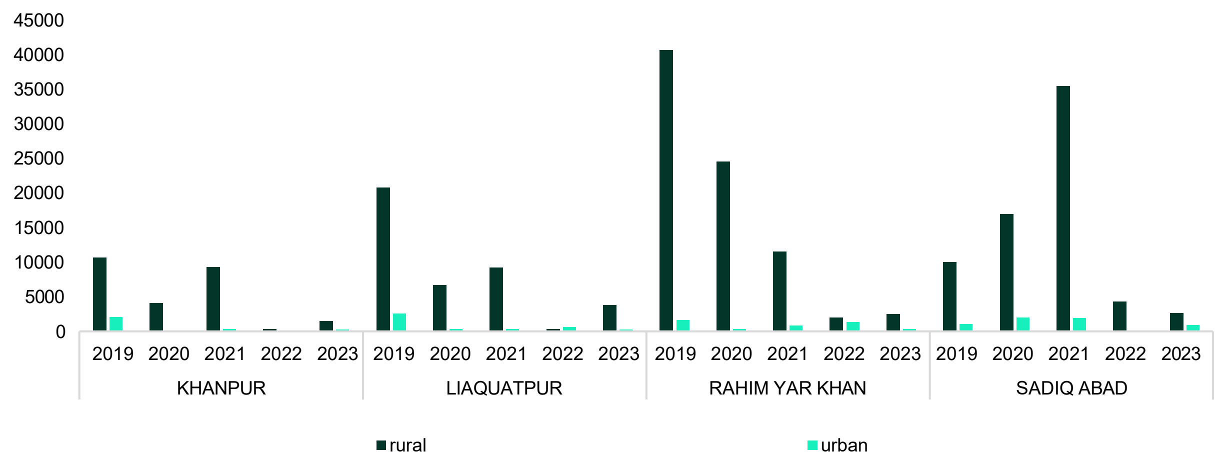
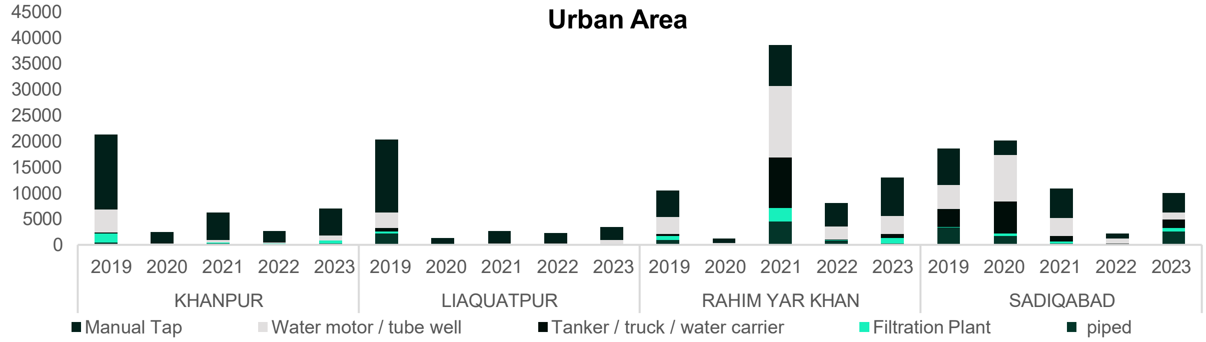


Figure 15. Tehsil-wise Number of Households possessing Livestock.
Source: Estimated using NSER-BISP, GoP.

Data on domestic drinking water supplies in four tehsils of district Rahim Yar Khan from 2019 to 2023 demonstrates substantial changes in water accessibility and dependence on a variety of sources. The use of traditional sources such as rivers and reservoirs has significantly decreased in rural areas, while reliance on piped water and manual water taps has increased. The reliance on manual water taps decreased considerably, while the number of piped water sources increased in tehsil Sadiq Abad (Figure 16).



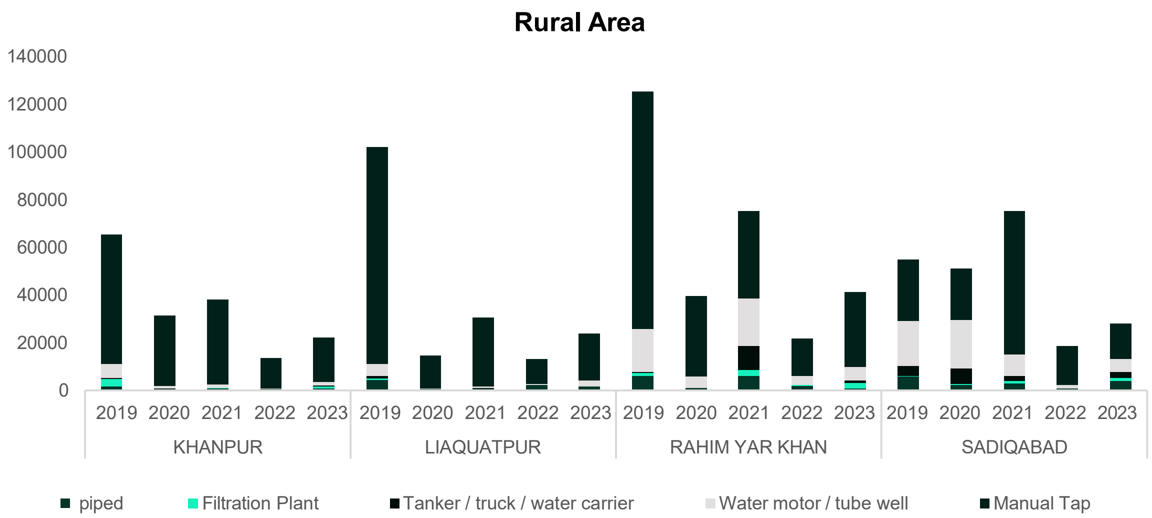
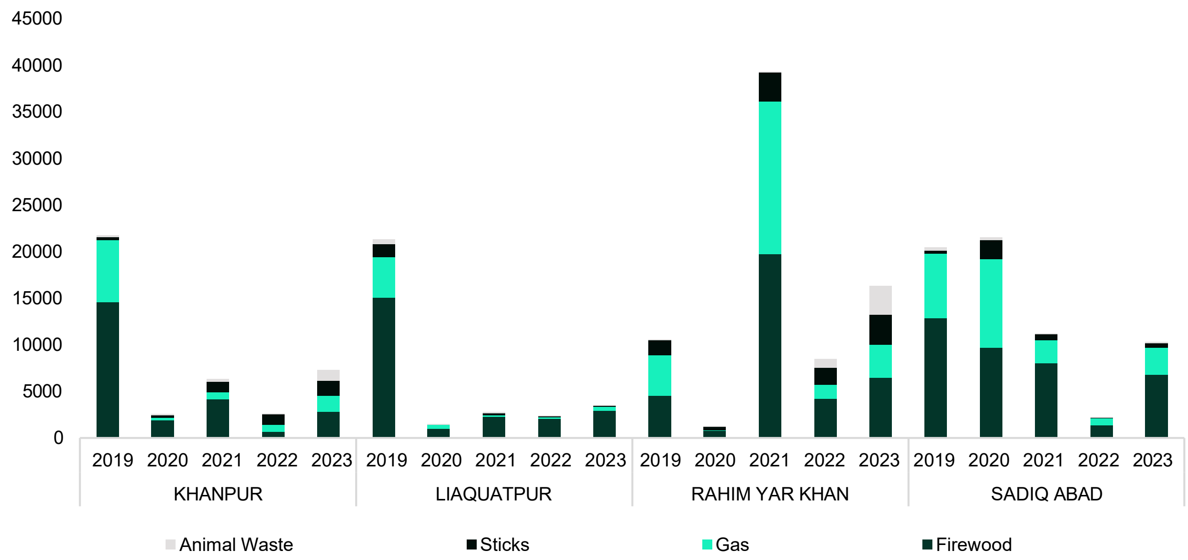


Figure 16. Number of Households using different Sources of Water for Drinking.
Source: Estimated using NSER-BISP, GoP.

However, the low number of filtration plants in both urban and rural areas suggests a need for improved water purification facilities, as reliance on them appears limited. Although numerous households continue to depend on less reliable sources in rural areas, the general trend suggests a transition to more reliable water supply systems. This emphasizes persistent obstacles in guaranteeing consistent availability of safe drinking water which is a necessity for the health and welfare of the public.

Additionally, tehsil Khanpur shows a gradual decline in firewood consumption from 2019 to 2023, while gas consumption has increased significantly indicating a transition to greener energy sources. In tehsil Liaquatpur, the trend is comparable with a substantial decrease in the use of firewood and an increase in the adoption of gas even though traditional fuels continue to account for a significant share (Figure 17).

Urban Area



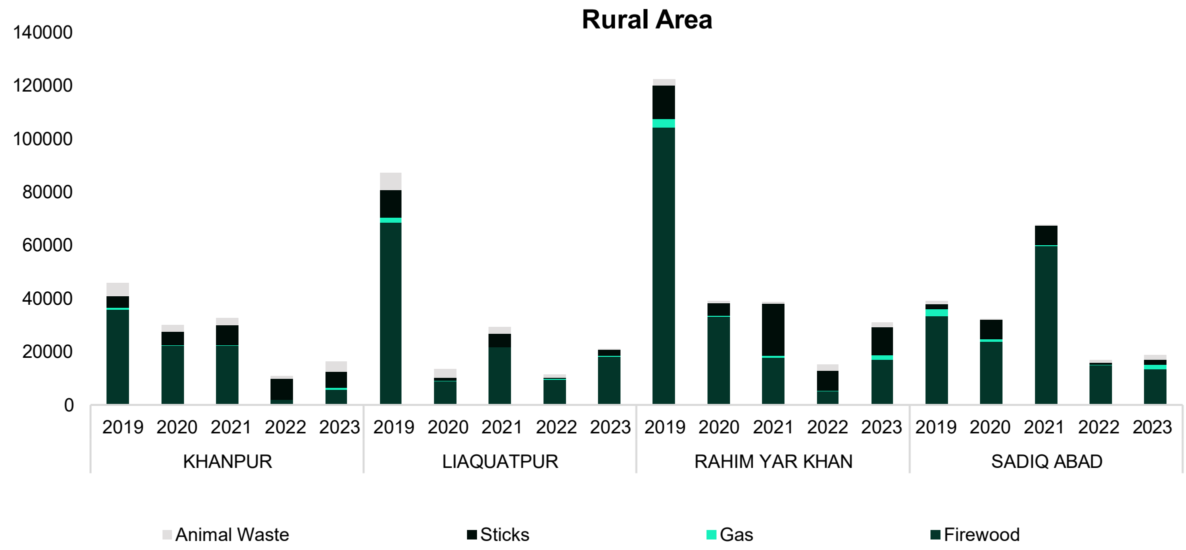


Figure 17. Number of Households using Different Sources for Burning during Cooking.
Source: Estimated using NSER-BISP, GoP.

Among the tehsils, Rahim Yar Khan has the highest reliance on firewood. However, it has also demonstrated an encouraging increase in gas utilization over the years indicating an evolving energy landscape. This pattern is mirrored in tehsil Sadiq Abad which has experienced a significant decrease in firewood and an increase in gas consumption despite continuing to rely heavily on traditional fuels. In general, the incremental transition toward cleaner cooking fuels is evident across all tehsils; however, firewood remains the predominant source underscoring the persistent obstacles to achieving widespread access to modern energy sources.

In the case of health statistics, chronic illness is more prevalent in rural areas than urban areas causing financial strain and reduced productivity due to medical expenses and limited access to healthcare services. Rural areas also have a higher number of households with persons with disabilities (PWDs) due to limited healthcare availability. However, the decline in the number of households with PWDs is due to improvements in reporting mechanisms enhanced healthcare services, and data collection methods. Urban areas have seen a reduction in infant mortality rates indicating improved access to healthcare facilities and sanitation. In contrast, rural areas have high infant mortality rates, with the most severe case in tehsil Rahim Yar Khan (Figure 18).

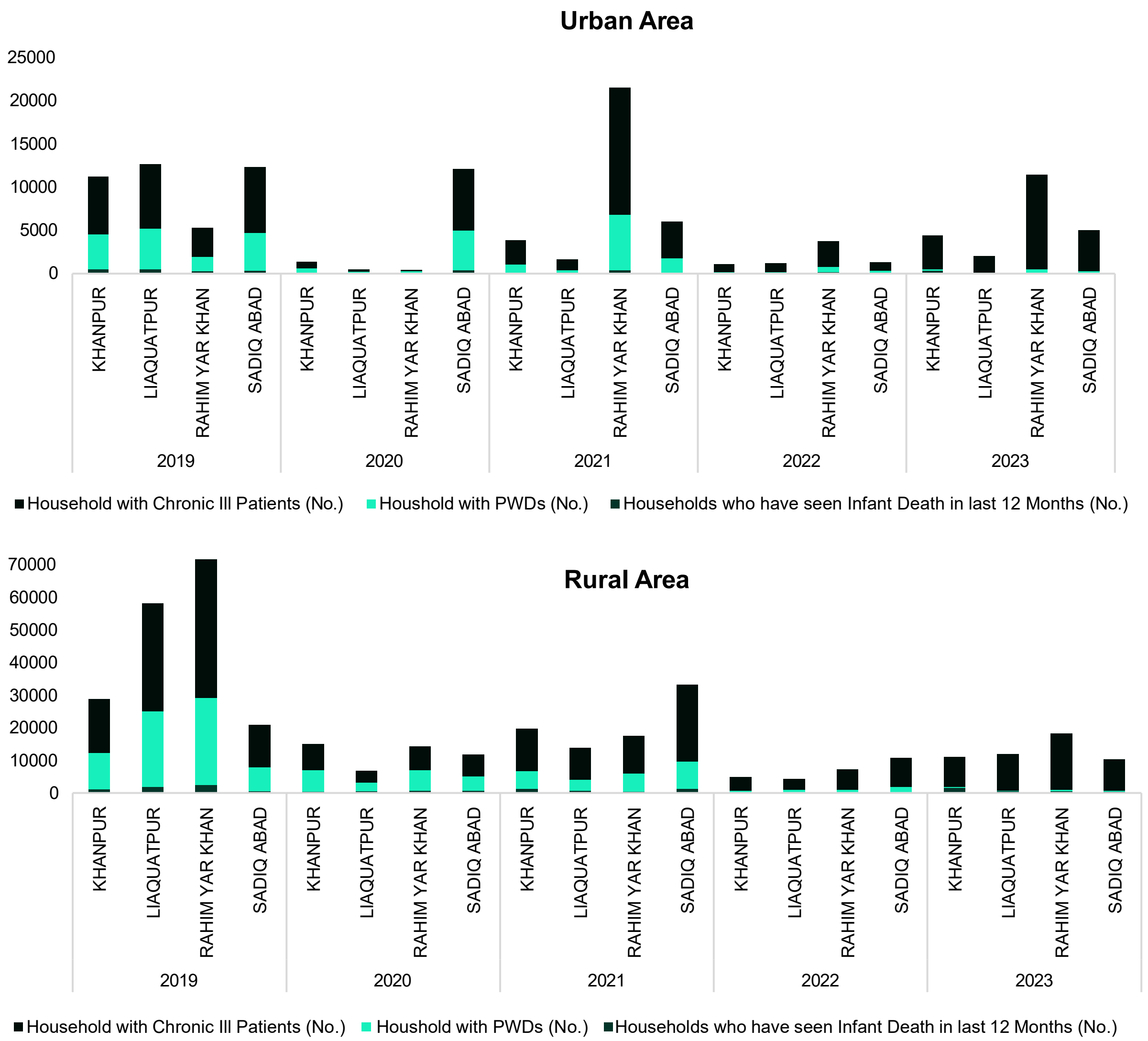


Figure 18. Households with Chronic Ill Patients, PWDs, and Infant Death Episodes in the Last 12 Months (No.)

Source: Estimated using NSER-BISP, GoP.

Conclusively, the complex interplay of challenges and opportunities is revealed in the district's socio-demographic profile. In rural areas, there is a pressing need for economic revitalization and enhanced social services, as evidenced by significant declines in the young population and employment, alongside an increasing elderly population. The socio-economic disparities are further rooted in a decrease in educational attainment among females. Although urban areas exhibit some resilience and modest employment growth, they are not immune to economic pressures, as evidenced by declining ownership of essential household items. Persistent vulnerabilities rural populations face is exacerbated by inadequate sanitation facilities, reliance on traditional energy sources, and limited access to quality healthcare. Therefore, it is essential to address these multifaceted challenges through sustainable development initiatives and targeted policies to promote economic stability and community well-being in the district.

Climate Profile of District Rahim Yar Khan

Unique climatic patterns influence agricultural practices and daily life in the Rahim Yar Khan district. The administrative center, tehsil Rahim Yar Khan, has a typical semi-arid climate with hot summers and moderate winters. A substantial seasonal variation is evident in monthly average temperatures: approximately 14.5°C in January, rising significantly to 32.1°C in May, before reaching 34°C in June. In contrast, months of December through February are characterized by minimal temperature fluctuations. Temperature in tehsil Sadiq Abad is comparable; however, it is slightly elevated during the prime summer months due to its geographical location (Figure 19). This tehsil also exhibits exceptional rainfall patterns with precipitation occurring during the monsoon season which is crucial for local agriculture. Tehsil Khanpur, located in the northern part of the district, experiences lower temperatures and variable precipitation. This is primarily due to its elevation which often reduces summer heat. In contrast, tehsil Liaquatpur experiences temperatures that closely align with the district average, but it may also be affected by climatic factors due to its diverse topography.

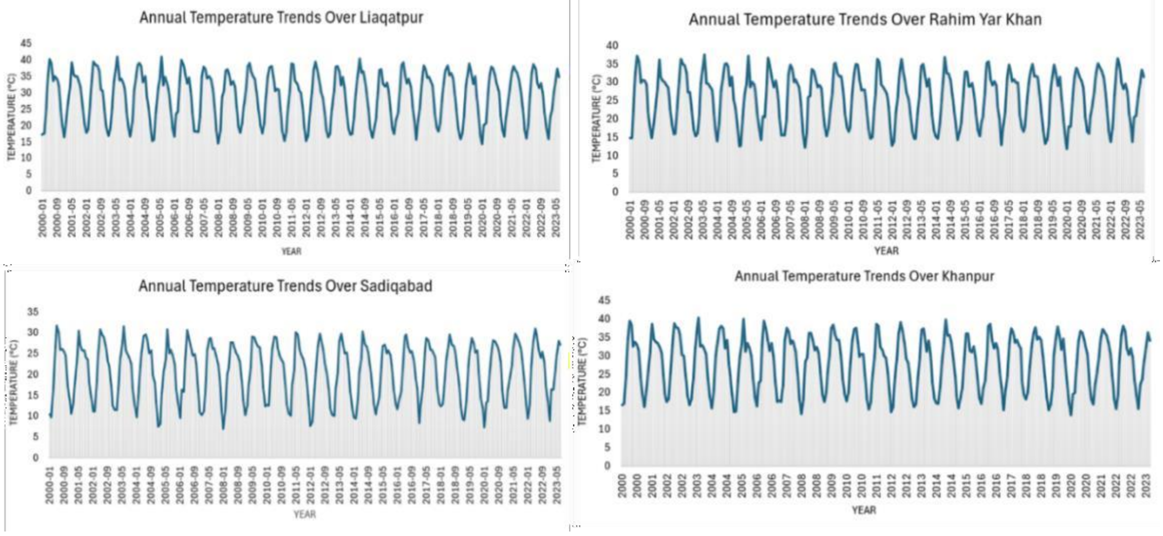


Figure 19. Annual Average Temperature Trends by Tehsil (Celsius).
Source: ERA5-Land Reanalysis.

Exceptional monsoon activity is the primary cause of substantial variability in total annual rainfall which ranges from a mere 45.2 millimeters (mm) in 2023 to an extraordinary 761.8 mm in 2022, as evidenced by the precipitation data. This rainfall plays a crucial role in agricultural productivity, economic stability, and vulnerability in district Rahim Yar Khan. On one hand, heavy rain has led to floods, soil erosion, and crop damage thereby affecting livelihoods and displacing communities. On the other hand, extended drought and flood periods have also reduced water availability for irrigation thereby affecting agricultural productivity.

Tehsil Khanpur, reliant on rain-fed agriculture, is susceptible to droughts or floods. Tehsil Sadiq Abad, although better at managing fluctuating precipitation is still vulnerable to floods and extreme temperatures. High temperatures and variable rainfall significantly influence tehsil Rahim Yar Khan's agricultural productivity and livelihoods. In contrast, tehsil Liaquatpur faces potential water scarcity due to lower precipitation levels than in other tehsils (Figure 20).

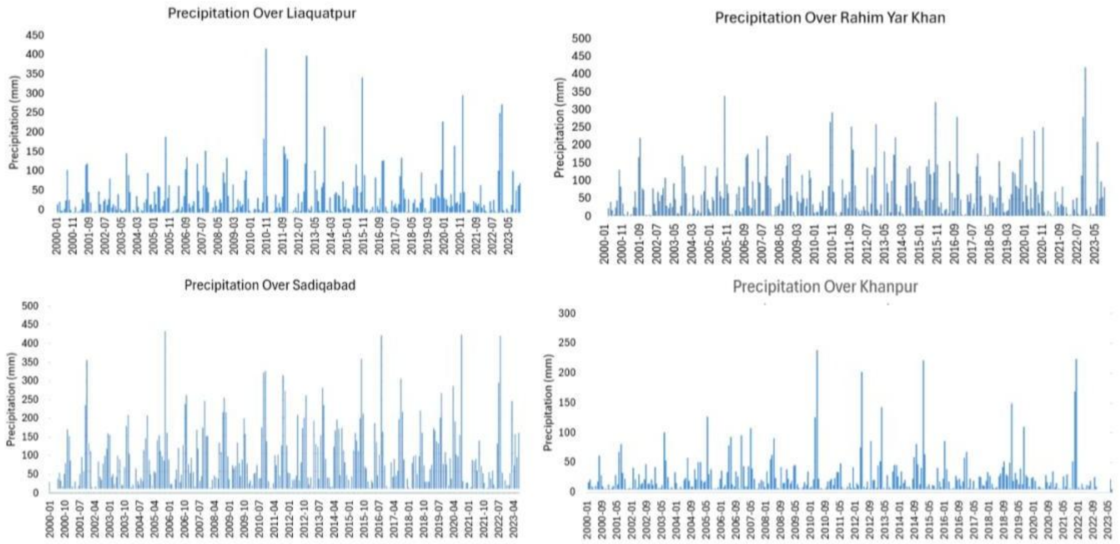


Figure 20. Annual Average Precipitation Trends by Tehsil (mm).
Source: ERA5-Land Reanalysis.

From 1981 to 2015, district Rahim Yar Khan received an average annual rainfall of 125 mm. It has experienced significant rainfall variations in recent years. In 2022, during Pakistan's extreme monsoon season, Punjab recorded 70% above-average rainfall likely bringing over 200 mm to district Rahim Yar Khan. In 2023, Punjab's rainfall was

30% above average (503.3 mm) with district Rahim Yar Khan recording notable spikes in May (27.3 mm) and higher-than-normal rain in July. However, August was drier (-58%), as reported by the Pakistan Meteorological Department (PMD).

Additionally, the 2022 monsoon season was notably severe across all tehsils resulting in widespread flooding. This underscores the necessity of improved agricultural adaptation strategies and water management. Moreover, local farmers and policymakers must understand these tehsil-specific climatic trends to develop effective agrarian plans, water conservation measures, and infrastructure improvements that mitigate the effects of climate variability and support sustainable development across the district.

Moreover, Figure 21 shows the groundwater quality situation in district Rahim Yar Khan at various tehsil levels from 2019 to 2023 highlighting that the southern side of the district, along the railway line, is grappling with groundwater quality degradation. The electrical conductivity (EC) values exceed 3.5 dS/m, with a significant contribution from district Rahim Yar Khan. The central and eastern parts of district Rahim Yar Khan showed relatively good groundwater quality (EC < 1.5 dS/m). However, some areas had patches of moderate to high salinity (EC > 3 dS/m). From 2022 to 2023, there was a gradual improvement in certain areas, but hotspots of high salinity (>3 dS/m) persisted in the south and southeast, whereas the water quality remained poor near Cholistan.

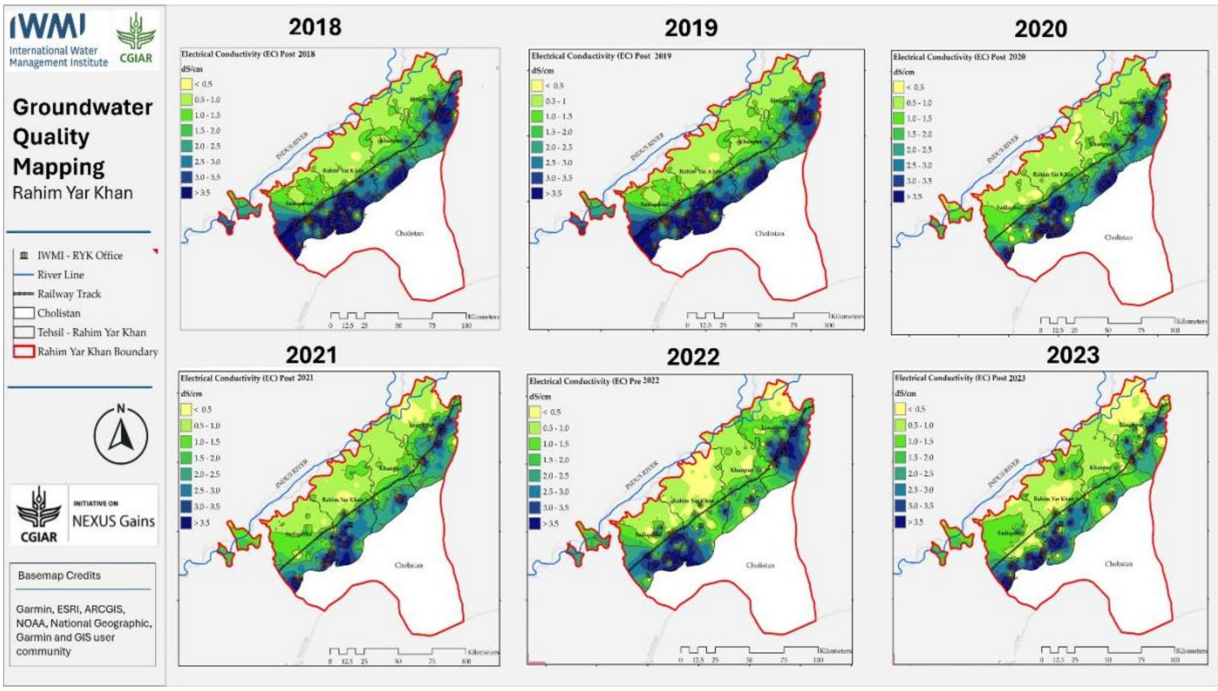


Figure 21. Tehsil-wise Water Quality Parameters in District Rahim Yar Khan.
Source: IWMI-Pakistan.

Figure 22 shows the groundwater level situation in district Rahim Yar Khan at various tehsil levels from 2016 to 2019. The tehsils Rahim Yar Khan and Sadiq Abad are experiencing groundwater depletion rates that have changed over the past few years, with declines exceeding 10 meters below the water table. In contrast, the tehsils Khanpur and Liaquatpur are reaching water table depths of 1.5 to 6.0 meters.

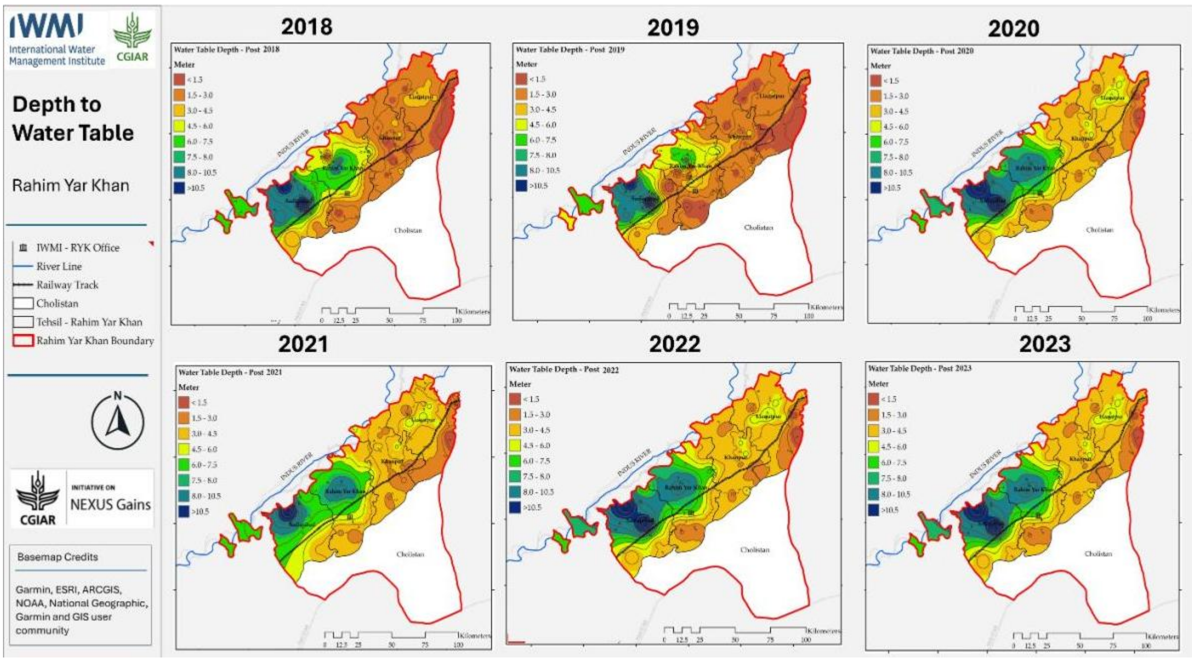


Figure 22. Tehsil-wise Groundwater Level Condition in District Rahim Yar Khan.
Source: IWMI-Pakistan.

To gauge the impact of the climatic conditions on the socio-economic landscape of the district, while comprehending vulnerability of the district's population and ecosystems, CCVI for the period 2019 - 2023 will be an essential tool in highlighting concerning trends such as substantial decreases in employment, educational attainment, and livestock ownership in rural tehsils. Moreover, impacts of unpredictable precipitation and rising temperatures pose a threat to agricultural productivity and livelihoods. Thus, CCVI offers a comprehensive evaluation of vulnerability across four tehsils by analyzing gender-disaggregated and age-specific data and will assist policymakers in developing adaptive strategies and targeted interventions to address the urgent challenges posed by climate change.

Climate Change Vulnerability Index (CCVI) for District Rahim Yar Khan

Drawing on the Intergovernmental Panel on Climate Change (IPCC) definition of vulnerability as:

> *'The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.' (IPCC Report, 2001)*

The climate change vulnerability analysis of the district Rahim Yar Khan is undertaken based on three factors:

- Exposure to temperature (min/max), excessive rainfall, and water quality and quantity
- Sensitivity as determined by FLWSs, health status, and climate-induced migration
- Adaptive Capacity as determined by literacy status, employment status, and possession of valuable assets

A detailed description of the methodology used to calculate the CCVI is given in the Annexure B.

Results and Discussion

The CCVI for district Rahim Yar Khan shows substantial socio-economic vulnerabilities across its four tehsils. The urgent necessity for targeted interventions is underscored by this comprehensive analysis which emphasizes the interplay between exposure, sensitivity, adaptive capacity, and overall vulnerability.

The results for tehsil-wise CCVI in district Rahim Yar Khan reveal varying vulnerability trends across the tehsils, reflecting diverse urban responses to climate-related risks. Tehsil Liaquatpur experienced fluctuating vulnerability peaking in 2020 (0.53) before declining to 0.46 in 2023 thereby indicating some progress in mitigation efforts. Tehsil Sadiq Abad consistently showed lower vulnerability with a significant decline from 0.48 in 2022 to 0.34 in 2023 suggesting notable improvements in resilience. Tehsil Khanpur had its highest vulnerability in 2020 (0.57), but exhibited an inconsistent trend thereby ending with a moderate index of 0.51 in 2023, hinting at partial, but unstable adaptation measures (Figure 23). Tehsil Rahim Yar Khan faced the highest vulnerability in the district with a sharp increase from 0.47 in 2022 to 0.57 in 2023, reflecting a rising susceptibility to climate risks despite previous reductions. These trends highlight the uneven distribution of vulnerability across urban tehsils influenced by differences in adaptive capacities, urban planning, and climate exposure.

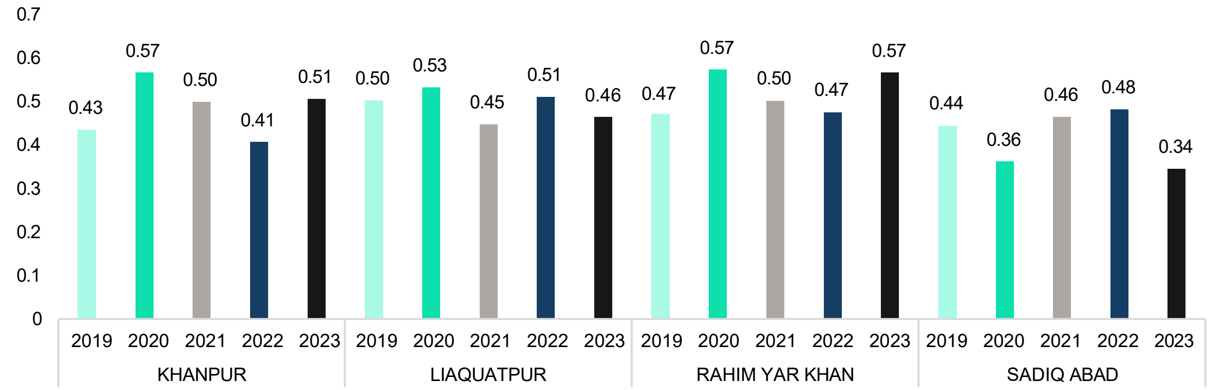


Figure 23. Tehsil-wise Climate Change Vulnerability Index in Urban Areas of District Rahim Yar Khan.
Source: Estimated using NSER-BISP, GoP.

The CCVI in rural areas of district Rahim Yar Khan reveals varying levels of vulnerability, with some tehsils showing significant fluctuations over time. Tehsil Liaquatpur's vulnerability peaked in 2021 (0.51), but sharply declined to its lowest in 2023 (0.40) thereby reflecting a potential improvement in adaptive measures and reduced exposure to climate risks. Tehsil Sadiq Abad, however, exhibited increasing vulnerability up to 2022 (0.54) followed by a slight reduction in 2023 (0.42), suggesting ongoing, but possibly uneven mitigation efforts. Tehsil Khanpur demonstrated a significant drop in vulnerability in 2022 (0.32) but rebounded in 2023 (0.49) thereby highlighting instability in resilience-building strategies. In contrast, tehsil Rahim Yar Khan saw its lowest index in 2021 (0.26), but experienced a sharp increase to the highest level in 2023 (0.54) indicating rising susceptibility to climate-related risks. These trends underline varying trajectories of climate change vulnerability across tehsils reflecting differences in adaptive capacities, environmental stressors, and socio-economic responses in the district's rural areas (Figure 24).

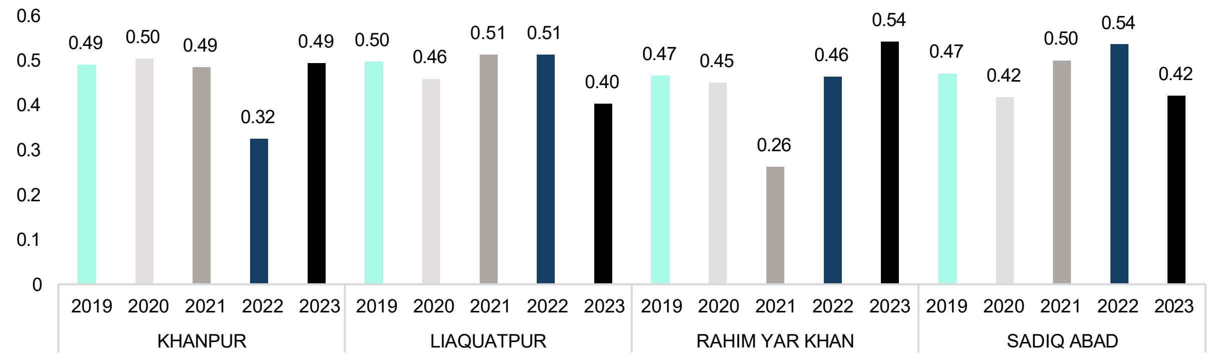


Figure 24. Tehsil-wise Climate Change Vulnerability Index in Rural Areas of District Rahim Yar Khan.
Source: Estimated using NSER-BISP, GoP.

Climate change has resulted in significant socio-economic distress across all tehsils, as evidenced by rainfall patterns, extreme temperatures, and weather events. Vulnerabilities are exacerbated in rural areas by reduced livestock ownership. Communities are acutely susceptible to climatic variability due to their substantial dependence on traditional agriculture. In conclusion, the CCVI analysis for district Rahim Yar Khan reveals a critical landscape of vulnerability influenced by climate-induced changes and socio-economic factors. It will be imperative to address these vulnerabilities by implementing customized strategies, enhancing adaptive capacity, and improving infrastructure to foster sustainable development and resilience in the district. Data underscores the need for interventions that prioritize economic recovery, educational enhancement, and health care accessibility in rural regions that are more susceptible to these issues.

The spatio-temporal distribution of the CCVI for urban and rural areas in district Rahim Yar Khan is presented in Figure 23, highlighting the areas most at risk and prioritizing adaptation measures accordingly. The CCVI for urban tehsils in district Rahim Yar Khan from 2019 to 2023 shows substantial variation due to changes in exposure, sensitivity, and adaptive capacity. In tehsil Khanpur, vulnerability fluctuated at 0.43 in 2019, then reached a peak of 0.57 in 2020 due to limited adaptive capacity and concluded at 0.51 in 2023 as sensitivity increased. Tehsil

Liaquatpur exhibits greater instability with a peak of 0.53 in 2020 driven by inadequate adaptive capacity, followed by fluctuations between 0.45 and 0.51 in subsequent years. The highest vulnerability (0.57) was observed in tehsil Rahim Yar Khan in both 2020 and 2023 attributed to increased sensitivity and lower adaptive capacity. However, there was a slight decrease in vulnerability in 2021 and 2022 due to higher adaptive capacity. The overall vulnerability of Tehsil Sadiq Abad was lower with a significant reduction in 2020 to 0.36 driven by enhanced adaptive capacity, and further to 0.34 in 2023 thereby demonstrating resilience in the face of fluctuations in exposure and sensitivity (Figure 25).

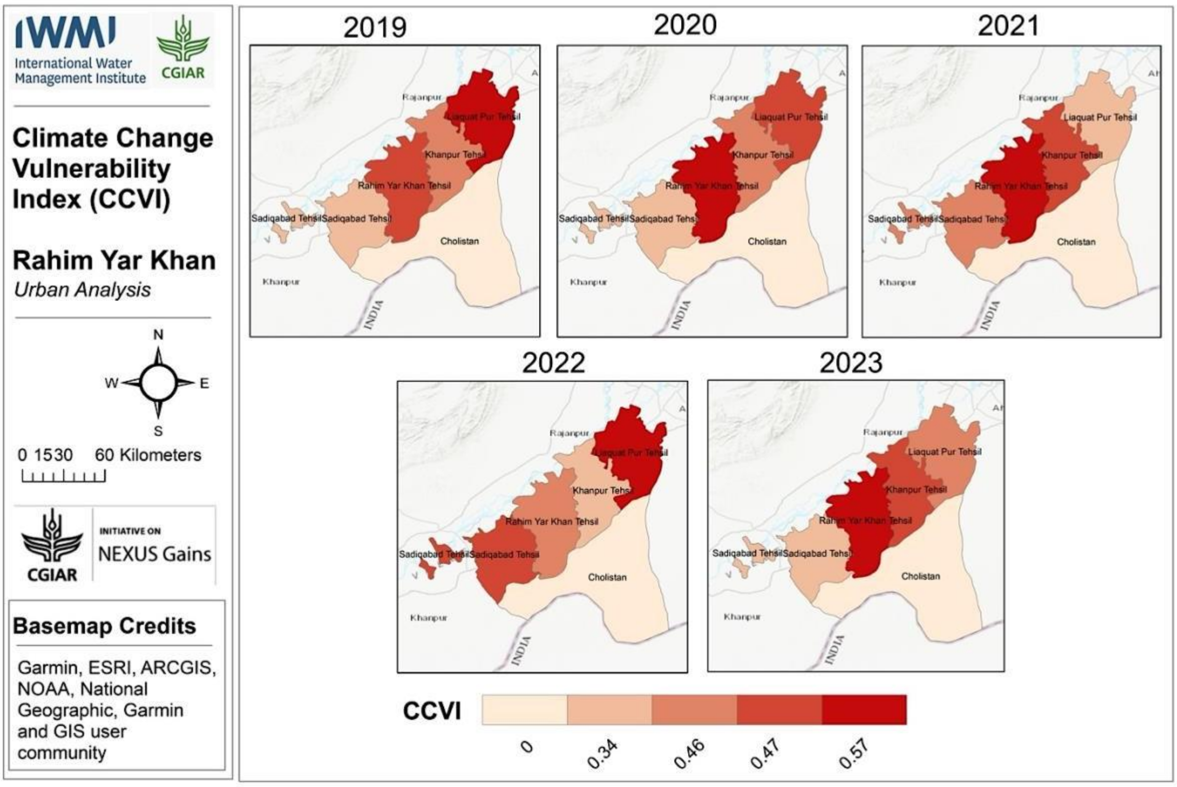


Figure 25. Spatio-temporal Distribution of Climate Change Vulnerability Index (CCVI) for District Rahim Yar Khan – Urban Analysis.
Source: Estimated using NSER-BISP, GoP.

The climate change vulnerability data for rural tehsils in Rahim Yar Khan district from 2019 to 2023 shows significant disparities in exposure, sensitivity, and adaptive capacity, as shown in Figure 24. The vulnerability index in tehsil Khanpur remained relatively stable at approximately 0.49 over the years, except in 2022 when it decreased to 0.32 due to a substantial decrease in sensitivity and an increase in adaptive capacity. Tehsil Liaquatpur exhibited a higher volatility with a sudden reduction in sensitivity in 2020 and a low adaptive capacity in subsequent years. This resulted in a relatively high vulnerability index (0.51) from 2020 to 2022 which decreased to 0.40 in 2023 due to improved adaptive capacity. In 2021, tehsil Rahim Yar Khan demonstrated a low vulnerability score of 0.26, reflecting its enhanced adaptive capacity. However, this value increased to 0.54 by 2023 as sensitivity increased. Tehsil Sadiq Abad exhibited fluctuating vulnerability, beginning at 0.47 in 2019, declining to 0.42 in 2020, reaching a peak of 0.54 in 2022, and subsequently decreasing to 0.42 in 2023 as sensitivity and adaptive capacity improved. The overarching trends underscore unique problems: some demonstrate enhanced adaptive capacity, while others remain highly susceptible to climate risks (Figure 26).

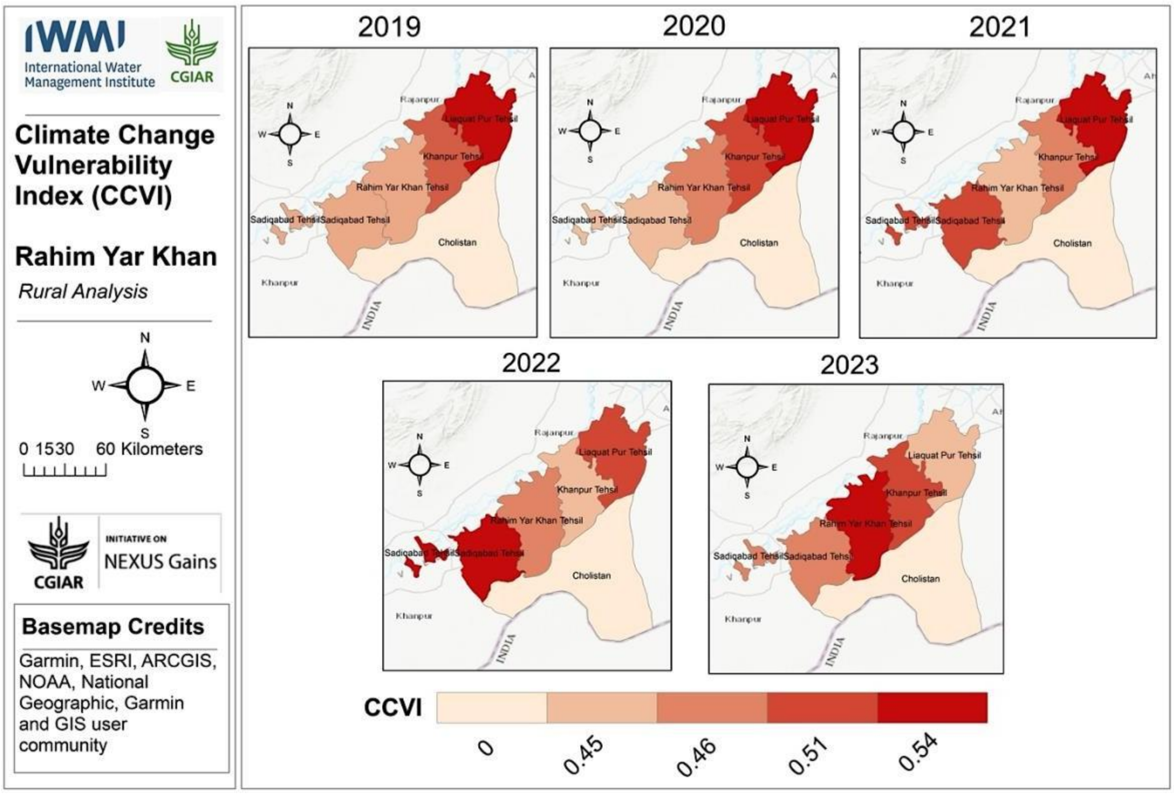


Figure 26. Spatio-temporal Distribution of Climate Change Vulnerability Index (CCVI) for District Rahim Yar Khan - Rural Analysis.

Source: Estimated using NSER-BISP, GoP.

Conclusively, moderate fluctuations in the vulnerability index of district Rahim Yar Khan from 2019 to 2023 suggest the persistence of existing climate-related hazards. In 2019, the district's overall index was 0.47 which increased marginally to 0.48 in 2020 due to increased exposure and sensitivity to climate events. This increase was followed by a decline to 0.46 in 2021 likely due to reduced exposure and enhanced adaptive capacity.

Table 2. Climate Change Vulnerability Index (CCVI) for District Rahim Yar Khan, Punjab, Pakistan.

Year	Value of Climate Change Vulnerability Index for District Rahim Yar Khan
2019	0.47
2020	0.48
2021	0.44
2022	0.46
2023	0.47

Source: Estimated using NSER-BISP, GoP.

In 2022, the overall CCVI for the district increased to 0.46, and in 2023 to 0.47 indicating ongoing challenges. These fluctuations suggest that despite progress in reducing climate change vulnerability, the district remains exposed to significant risks thereby necessitating efforts in resilience-building and adaptation.

These spatial variations in climate vulnerability are closely intertwined with the district's migration and fragility dynamics discussed earlier in the report. Tehsils exhibiting high sensitivity and low adaptive capacity are not only more exposed to climate hazards, but are also more likely to experience distress migration, population displacement, and pressure on host communities. Recurrent climate shocks coupled with limited livelihood options and weak service delivery intensify fragility by eroding household coping capacities and increasing dependence on external assistance. Conversely, tehsils demonstrating relatively lower vulnerability and stronger adaptive capacity reflect contexts where resilience-building measures can reduce forced migration, stabilize livelihoods, and strengthen the absorptive capacity of host communities. By explicitly linking climate vulnerability patterns with migration pressures and institutional fragility, the CCVI provides an integrated evidence base to inform targeted interventions that address the root causes of climate-induced displacement while enhancing resilience across both migrant-origin and host areas. The results further highlight spatial variations in vulnerability that directly inform the proposed short-, medium-, and long-term recommendations. Areas exhibiting high sensitivity and low adaptive capacity require urgent service delivery improvements, enhanced early warning mechanisms, and stronger institutional coordination. Conversely, tehsils showing resilience trends present opportunities for scaling successful community-based initiatives and strengthening nature-based solutions. By grounding recommendations in vulnerability evidence, this report ensures that proposed actions directly correspond to the district's evolving needs and risk patterns. The following short-, medium-, and long-term interventions are proposed to reduce the adverse effects of future climatic events and enhance resilience by understanding the district's unique vulnerabilities.

Short-term Interventions

- Effective disaster management necessitates the immediate establishment of an Emergency Response Team with the District Disaster Management Authority (DDMA) trained in local risk factors and emergency protocols. The Environmental Protection Department (EPD) and DDMA should also conduct risk assessments to identify the most vulnerable populations and areas. IWMI can support by mapping vulnerable populations and regions using advanced tools such as GIS and remote sensing, and by offering training to Emergency Response Teams on water-related risk factors and emergency protocols to enhance disaster preparedness and response.
- IWMI can collaborate with health professionals and the public health department by sharing findings from its extensive water quality analysis (over 1,000 collected samples) including contaminant levels in groundwater. This can inform strategies to mitigate waterborne diseases, such as hepatitis, especially in the context of climate-induced migration, while encouraging data sharing and stakeholder engagement to integrate health-related insights into decision-making.
- The most critical aspect of the catastrophe cycle is understanding the event, i.e., to grasp risks and understand the nature of dangers. Communities require transportation and evacuation equipment, while marshy regions necessitate specialized vehicles and observation radars. Kits, boats, hand pumps, and drones can be delivered to each district with financial and professional assistance before any climatic event.
- IWMI can also support by strengthening and upscaling data management systems to ensure easy access to critical data for farmers and stakeholders. Additionally, it can provide capacity-building workshops for government departments on data-driven decision-making and anticipatory action using advanced tools such as remote sensing and water accounting.
- The Education Department and local non-governmental organizations (NGOs) can initiate educational campaigns that concentrate on disaster preparedness in schools and communities, as it is crucial for increasing public awareness. IWMI can support by developing and providing tailored educational materials and tools on water-related disaster risks and preparedness thereby leveraging its expertise in climate resilience. Collaborating with the Education Department and local NGOs, IWMI can assist in designing school- and community-based awareness campaigns that incorporate data insights and case studies to enhance public understanding and promote proactive disaster management.
- The Telecommunication Authority is responsible for the establishment of a dependable communication system for notifications which will improve response capabilities.
- DDMA should prioritize compilation of an inventory of local resources and emergency supplies to ensure that it is prepared for any imminent disasters.

Medium-term Interventions

- Training programs for local volunteers can be implemented by DDMA and local NGOs and should be maintained as an ongoing activity to enhance community resilience.
- Through geospatial analysis, IWMI can assess water supply and sewerage systems to optimize water access points to reduce collection time and help the government in implementing sustainable solutions like solar-powered water systems and decentralized wastewater treatment for efficient resource management.
- Given the significant number of people involved in agriculture, it is necessary to implement crop zoning to help farmers optimize their farming practices, improve productivity, and develop resistance against natural obstacles.
- IWMI can also support by leveraging its expertise from the FCDO WRAP Project and the US Department of State's Built Water Storage in South Asia (BWSSA) Project to map and enhance water storage potential in district Rahim Yar Khan. This includes exploring NbS such as rainwater harvesting and groundwater recharge alongside supporting ongoing watercourse lining efforts to ensure sustainable freshwater use in agriculture.
- Implementation of EWS for a variety of disasters including droughts and floods, by PMD. The warning system offers interfaces that cater to both experts and the public for effective drought and flood monitoring.

The interface includes key indicators such as precipitation, vegetation conditions, soil moisture status, and biomass growth and by integrating spatial patterns of rainfall, soil moisture, and vegetation health anomalies, the system identifies areas at risk of agricultural drought, regions where vegetation has already been impacted, and zones undergoing recovery to normal conditions.

- It is imperative to develop comprehensive urban and rural development plans in collaboration with experienced municipal planners and disaster administrators.
- Academic institutions should participate in community-based research, data compilation, and practical actions to lessen the adverse effects of climate catastrophes and associated vulnerabilities.
- Engagement with district-specific irrigation and agriculture departments to advance climate-smart agricultural methods and integrated water management systems thereby guaranteeing sufficient water resources for both human and livestock in the district. There is also a need to adopt an integrated approach and collaborate among various government departments to generate and share evidence-based information to ensure a proactive disaster risk response, while replicating successful models like Rescue 1122 Emergency Service in other cities across the country.

Long-term Interventions

- There is a need for the establishment of a comprehensive catastrophe management framework essential for the long-term sustainability of resilience in district Rahim Yar Khan. The provincial government and the DDMA should collaborate to develop this framework that integrates resilience and risk mitigation strategies.
- The provincial government and DDMA should establish agreements with neighboring districts and provinces to facilitate coordinated disaster responses via regional collaboration.
- The Planning & Development Department (P&DD) in Punjab should allocate funding and resources to these initiatives, as investing in climate-resilient infrastructure is also necessary.
- The Higher Education Commission (HEC) and local universities can spearhead these initiatives to establish research programs to further enhance local capabilities by promoting research and development in disaster risk reduction strategies.

Challenges and Limitations

While the CCVI provides valuable insights into spatial and temporal vulnerability patterns across the district, several methodological and data-related limitations should be acknowledged. First, the analysis relies predominantly on NSER-BISP data which while comprehensive for socio-economic variables may not fully capture rapid on-ground climate impacts in real time. Second, spatial resolution constraints restrict the ability to map micro-level disparities within tehsils. However, these limitations do not detract from the robustness of findings, but highlight areas for future refinement and deeper integration with complementary data sources.

Conclusion

This study applied a tehsil-disaggregated Climate Change Vulnerability Index (CCVI) to district Rahim Yar Khan to generate a nuanced, evidence-based understanding of how climate change, socio-economic conditions, and institutional capacity interact to shape vulnerability across rural and urban contexts. By integrating exposure, sensitivity, and adaptive capacity dimensions using gender- and age-disaggregated data, the CCVI provides a robust analytical framework for identifying spatial and temporal patterns of vulnerability that are directly relevant to both host communities and climate-induced migrants.

The findings demonstrate that climate vulnerability in district Rahim Yar Khan is neither static nor uniform. Instead, it fluctuates across tehsils and over time in response to climatic shocks, livelihood dynamics, demographic pressures, and uneven access to services. Tehsils exhibiting high sensitivity driven by dependence on climate-sensitive livelihoods, declining livestock assets, food and water insecurity, and health burdens combined with low adaptive capacity are consistently more vulnerable to climate extremes. These same areas are also more prone to distress migration, livelihood erosion, and increased pressure on host communities, reinforcing the disaster-migration-vulnerability nexus highlighted in the literature review. Conversely, tehsils that demonstrate improvements in adaptive capacity, institutional coordination, and community-based practices show relatively lower vulnerability and greater resilience, reducing the likelihood of forced mobility and enhancing absorptive capacity.

Importantly, the results underline that climate-induced vulnerability is closely intertwined with fragility dynamics. Recurrent climate shocks, when coupled with poverty, weak service delivery, and limited institutional reach erode household coping mechanisms and intensify dependence on external assistance. In such contexts, migration emerges not only as a response to climatic stress but also as a manifestation of structural vulnerability. The CCVI therefore serves as a critical tool for linking climate risk analysis with migration planning, disaster risk reduction, and resilience-building efforts thereby enabling policymakers to move beyond reactive responses toward anticipatory and preventive action.

By grounding recommendations in empirical vulnerability patterns, this study moves beyond generic policy prescriptions. Instead, it proposes differentiated short-, medium-, and long-term interventions that correspond to the district's evolving risk profile. Short-term measures prioritize immediate service delivery, early warning, and emergency preparedness in highly vulnerable tehsils. Medium-term interventions emphasize nature-based solutions, livelihood diversification, and institutional strengthening to reduce sensitivity and enhance adaptive capacity. Long-term strategies focus on climate-resilient infrastructure, integrated water and land management, and the embedding of vulnerability analytics into planning and budgeting processes. This phased approach ensures that policy responses are sequenced, realistic, and aligned with both development and humanitarian objectives.

Beyond district-level relevance, the CCVI methodology demonstrated in this report is scalable and replicable across Pakistan. Its integration with a web-based digital module further enhances its utility as a decision-support system thereby enabling planners and development partners to visualize vulnerability trends, prioritize investments, and monitor progress over time. In doing so, the study contributes to IWMI's broader regional research agenda on climate resilience, migration, and fragility in South Asia reinforcing the value of spatially explicit and data-driven approaches for addressing complex climate risks.

In conclusion, this report underscores that reducing climate vulnerability requires addressing not only exposure to hazards, but also the underlying socio-economic and institutional drivers of sensitivity and adaptive capacity. By explicitly linking climate vulnerability with migration and fragility dynamics, the CCVI provides an integrated evidence base to support proactive, inclusive, and resilience-oriented policy action both in district Rahim Yar Khan and in other climate-stressed and fragile geographies across Pakistan.

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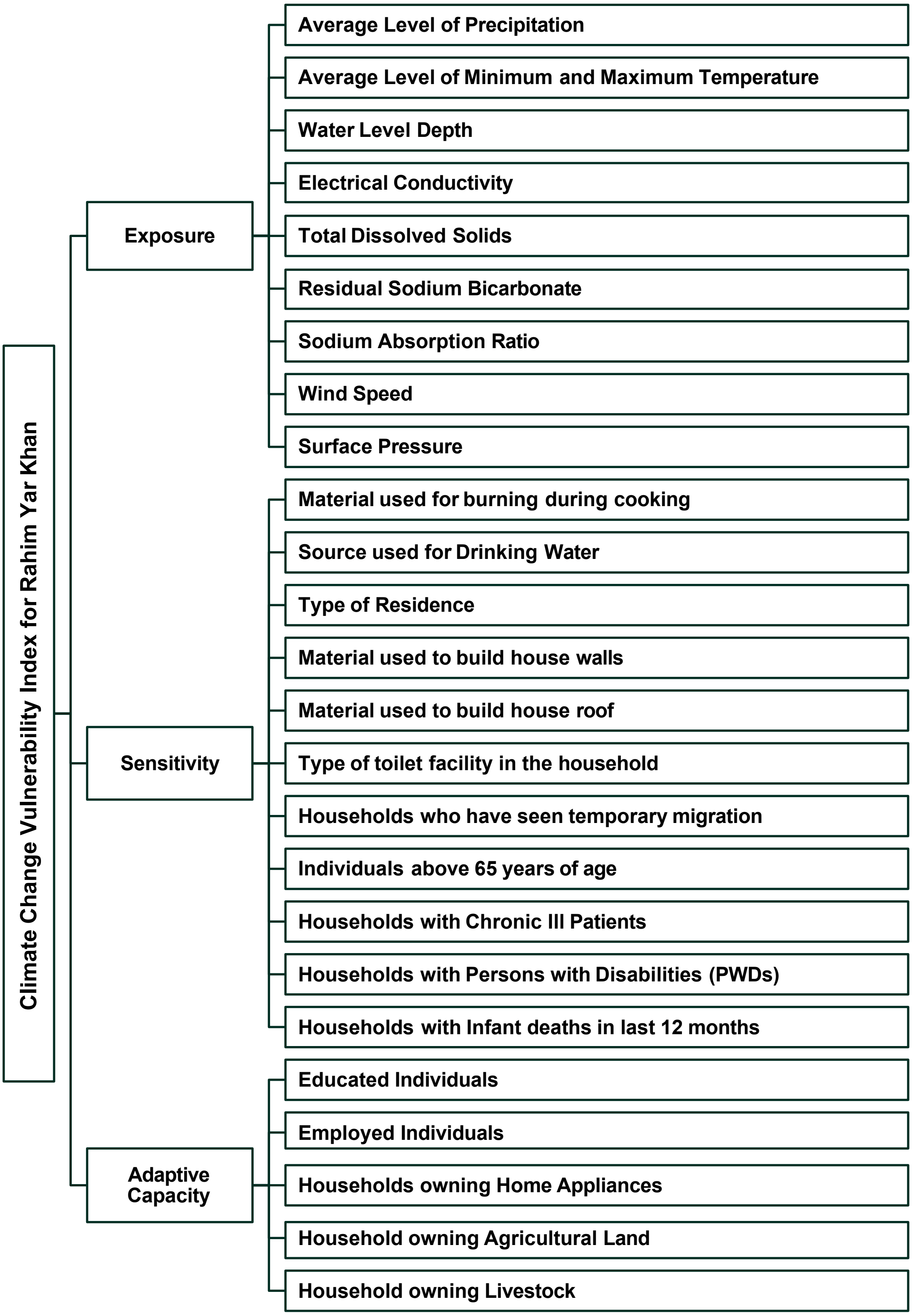
Annexures

Annexure A. List of Variables



Source: Extracted from NSER-BISP, GoP.

Annexure B. Methodology

This study applies CCVI to assess district-level vulnerability by integrating climatic and socio-economic indicators across rural and urban tehsils. It adopts a composite framework grounded in IPCC vulnerability concept that is operationalized through three dimensions including exposure, sensitivity, and adaptive capacity. Instead of relying on single indicators, CCVI captures multidimensional vulnerability thereby allowing for spatial comparison and identification of climate hotspots that support targeted adaptation planning. Following Brookes (2003) explanation of vulnerability, the calculation of CCVI for district Rahim Yar Khan involves measurement of exposure, sensitivity, and adaptive capacity of the district as follows.

i. **Exposure** (E_{it}) is the level of exposure in the district i during year t and calculated as follows.

$$E_{it} = \frac{[SDR_{it} + SDMaxT_{it} + SDMinT_{it} + RangeT_{it} + SDWS_{it} + SDSP_{it} + EC_{it} + TDS_{it} + RSC_{it} + SAR_{it}]}{10}$$

Where;

- SDR_{it} is the standard deviation of average precipitation in district i during year t
- $SDMaxT_{it}$ is the standard deviation of the average maximum temperature in district i during year t
- $SDMinT_{it}$ is the standard deviation of the average minimum temperature in district i during year t
- $RangeT_{it}$ is the range between the maximum and minimum temperature in district i during year t
- $SDWS_{it}$ is the standard deviation of wind speed in district i during year t
- $SDSP_{it}$ is the standard deviation of surface pressure in district i during year t
- EC_{it} is the electrical conductivity for groundwater in district i during year t
- TDS_{it} is the total dissolved solids in groundwater in district i during year t
- RSC_{it} is the residual sodium carbonate in groundwater in district i during year t
- SAR_{it} is the sodium absorption ratio in groundwater in district i during year t

ii. **Sensitivity** (S_{it}) is the level of sensitivity in the district i during year t and calculated as follows.

$$S_{it} = \frac{[S_{1it}+S_{2it}+S_{3it}+S_{4it}+S_{5it}+S_{6it}+S_{7it}+S_{8it}+S_{9it}+S_{10it}+S_{11it}]}{11}$$

Where;

- S_{1it} is the number of households using different materials for burning during cooking in district i during year t
- S_{2it} is the number of households using different sources for drinking water in district i during year t
- S_{3it} is the number of households in the district own the type of residence i during year t
- S_{4it} is the type of material used to build house walls in district i during year t
- S_{5it} is the type of material used to build a house roof in district i during year t
- S_{6it} is the number of individuals above 65 years of age (male, female, and transgenders) in district i during year t
- S_{7it} is the number of households with chronic ill patients in district i during year t
- S_{8it} is the number of households with PWDs in district i during year t
- S_{9it} is the number of households with infant deaths (in the last 12 months) in district i during year t
- S_{10it} is the number of households that have seen temporary migration in district i during year t
- S_{11it} is the number of households in district use the type of toilet facility i during year t

iii. **Adaptive Capacity** (AC_{it}) is the level of adaptive capacity in the district i during year t and calculated as follows.

$$AC_{it} = \frac{AC_{1it} \pm AC_{2it} \pm AC_{3it} \pm AC_{4it} \pm AC_{5it}}{5}$$

Where;

- AC_{1it} is the number of educated individuals (male and female) in district i during year t
- AC_{2it} is the number of employed individuals in district i during year t
- AC_{3it} is the number of households owning home appliances in district i during year t
- AC_{4it} is the number of households owning agricultural land in district i during year t
- AC_{5it} is the number of households owning livestock in district i during year t

By taking an unweighted average of the corresponding variables, all are normalized through the linear transformation method.

$$\text{Normalized } X_{it} = \frac{[X_{it} - MinX_{it}]}{[MaxX_{it} - MinX_{it}]}$$

The Climate Change Vulnerability Index ($CCVI_{it}$) in district i during year t will be calculated as follows.

$$CCVI_{it} = \frac{E_{it} + S_{it} + (1 - AC_{it})}{3}$$

CCVI values range from 0 to 1 where higher values indicate greater vulnerability. Indicators were normalized and aggregated under their respective dimensions before computing composite scores for each tehsil and rural–urban category. Gender-disaggregated and age-specific NSER-BISP data (2019-2023) were used to ensure socially differentiated vulnerability assessment. Detailed variable descriptions and computation steps are provided in Annexure A.

CCVI was selected because it integrates climatic hazards with socio-economic conditions thereby enabling assessment of both physical exposure and household-level resilience. Unlike single-sector indices, CCVI captures interactions between food, land, water, health, livelihoods, and demographic characteristics hence making it suitable for fragile and climate-affected contexts such as Rahim Yar Khan. This multidimensional structure allows policymakers to identify not only where vulnerability is highest, but also which underlying drivers including exposure, sensitivity, or limited adaptive capacity require priority intervention.

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