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Echoes of Survival: Climate Change Impact & Typologies of Adaptation among Vulnerable Communities toward Climate-Induced Food Insecurity in Pakistan

Mohsin Khan [1,2*] , ***Yanxia Zhang*** [3], ***Shahbaz Khan*** [4,5]

[1] *College of Humanities and Development Studies, China Agricultural University, Beijing 100193, China*
[2] *School of Public Policy & Urban Affairs, Northeastern University, Boston, MA 02119, USA*
[3] *College of Humanities and Development Studies, China Agricultural University, Beijing 100193, China*
[4] *Colorado Water Center, Colorado State University, Fort Collins, CO 80523, USA.*
[5] *Central Great Plains Research Station, USDA-Agricultural Research Service, Akron, CO 80720, USA*

ABSTRACT

Climate change exacerbates severe and differential impacts across diverse classes and genders, influencing their livelihoods, food insecurity vulnerabilities, and adaptation measures. Through an intersectional and social justice approach integrated with grounded theory, we documented field observation with individual narratives and amplified voices from a wide range of individuals, including internally displaced people, women, smallholders, landless tenants, daily wage laborers and community leaders in fragile districts of Bannu and D I Khan in Pakistan. We found a growing impact of climate on these households' food security including socio-psychological stress and stigmas. In addition to formulating an interpretive framework, our results highlight the significant role of socio-religious, cultural, gendered, behavioral, environmental, and institutional factors in shaping individuals' climate-induced food security vulnerabilities, and their ability to adapt to climate extremes. These individuals employed several mitigation strategies to cope with food insecurity, including diversification of non-farming livelihoods, in-

*CORRESPONDING AUTHOR:
Mohsin Khan, College of Humanities and Development Studies, China Agriculture University, Beijing 100193, China; School of Public Policy & Urban Affairs, Northeastern University, Boston, MA 02119, USA; Email: mohsin_aup@yahoo.com

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creased reliance on social and communal networks and informal credit markets. The study emphasizes on considering the interplay between socio-economic classes, religion, social networks, and gender dynamics in relation to adaptive strategies to foster sustainable food systems and further suggests that existing policies and adaptation programs should benefit from incorporating community and individual narratives to tackle climate extremes.
Keywords: Climate Change; Food Insecurity; Social Justice Approach; Adaptation Strategies; Social Networks; Sustainable Food Systems; Gender Dynamics

1. Introduction

Frequent and intense extreme weather events like droughts, floods, and heatwaves are posing significant challenges for both human populations and ecosystems, particularly in the agriculture sector [1]. Projections suggest that climate change not only affect global food production but also reduces food nutritional quality by the mid-21st century, with South Asia hosting the highest proportion of food-insecure populations [2–7]. Consequently, food shortages and price inflations disproportionately impact the most vulnerable populations worldwide [8, 9]. For instance, in 2019, an estimated 113 million people were affected by food insecurity due to climate change, with the most vulnerable populations residing in low-income countries and those relying on agriculture for their livelihoods [10]. These populations are often situated in regions already experiencing the effects of climate change, such as drought-prone areas and those at risk of sea-level rise [4, 9].

Pakistan, alike other developing nations in South Asia, prominently ranks as the 8th most vulnerable country globally due to the adverse impacts of climate change [11]. The agricultural sector, upon which over 70% of Pakistan's population depends, continues to face significant threats due to escalating climate-induced hazards. Events such as droughts and the devastating floods of 2010 and 2022, have resulted in widespread crop failures, and infrastructure destruction, and left millions of people without food [12, 13]. Additionally, these disasters have led to the displacement of millions of people and the inundation of agricultural land, exacerbating food insecurity crises [14, 15]. However, the greater and more detrimental effects of these climate extremes are felt among marginalized groups such as the poor, women, children, internally displaced persons, smallholders, and residents of unstable and conflict-ridden areas [14–16].

Scholars and practitioners have raised critical questions about the "differentiated impact" of climate change. The differential impacts of climate change refer to the disproportionate burden faced by certain groups due to the interplay of socio-economic, gendered, and power dynamics, compounded by systemic inequities [17, 18]. These impacts are evident in diverse livelihood challenges, food insecurity, vulnerabilities, and adaptive capacities, especially among marginalized communities [17–20]. and requires a more comprehensive understanding of food security and its relation with climate change's impact on these diverse households and communities. Moreover, understanding food security involves examining various dimensions like access, availability, affordability, utilization, stability, sustainability, and resilience [19–22]. These dimensions are interconnected with socio-cultural, behavioural, environmental, and institutional factors, influencing individuals' and communities' food security status and playing a significant role in adapting to climate extremes [23]. For instance, food accessibility, referring to the ability to obtain adequate and nutritious food, encompasses factors such as access to markets and transportation infrastructure, as well as social, gender and cultural barriers [19, 21, 24]. Availability focuses on ensuring an adequate food supply, while affordability is crucial for individuals and households to purchase food at reasonable prices, and often relies on income and other capabilities of individuals [19]. Additionally, stability and sustainability, a crucial aspect of food security and sustainable food systems, ensure that food production, distribution, and consumption practices are environmentally sustainable [25, 26], amidst external shocks and emphasize long-term practices i.e.—building resilience crop varieties, improving seedling preparation, storage and nu-

tritional knowledge (e.g. capacitating farmers and communities), and access to health services, ensuring optimal utilization of food resources [19, 20, 27, 28].

Despite significant quantitative evidence on the dimensions and determinants of food security, there remains a critical gap in documenting the lived experiences and adaptation strategies of those directly affected by climate change [29]. This lack of qualitative insight limits our understanding of how intersectional factors—such as gender, class, and socio-economics—shape vulnerabilities and adaptive capacities [30–32]. Furthermore, the exploration of drivers and implementation of adaptation measures, including farm-level, off-farm, and household strategies, remains insufficient, despite their importance in mitigating food insecurity and fostering resilience to climate impacts. Existing literature on social justice theory and climate adaptation further indicates that qualitative research methods are necessary for gathering adaptation strategies from local communities, which may not be evident through traditional data sources like census, surveys, or economic data [17, 18, 27, 30–35]. Moreover, there is a limited exploration into the extent to which distinct communities have implemented or identified the key factors influencing these adaptive measures [29, 36–42]. To address this research gap and examine different typologies of adaptation e.g., farm-level measures, such as establishing climate-resilient crop varieties [43–46], and off-farm strategies and household-level mitigation strategies, such as access to credits or information [47], investments in education, income, building social networks, and physical resilience measures like nature-based solutions and irrigation infrastructure [48–54], is essential for anticipating the full impacts of climate change on food security, human livelihoods, and for planning appropriate adaptive measures [55].

Specifically, there is limited understanding of how intersectional factors, such as gender, socio-economic status, and cultural practices, influence adaptation strategies, and how social justice can be integrated into these strategies. Such an approach provides insights into adaptation measures, drivers, and contextual factors, including people's behaviours and attitudes, while addressing vulnerabilities and differential capacities to cope with climate change-induced food insecurity. We specifically addressed three research questions:

1. How can integrating intersectional and social justice perspectives enhance our understanding of climate-induced food insecurity and various intersecting factors influencing individual or household food security and adaptation in the context of climate change?
2. How do these various drivers and factors interact with broader socio-cultural, religious, political and institutional factors?
3. How do these individuals or groups, particularly in resource-poor or marginalized communities, implement different adaptation strategies to manage food security in the context of climate change?

Thus, considering the importance of the unequal and differential impact of climate change, the interplay between these factors and individual characteristics, and analyzing lived experiences of participants, we developed an interpretive framework, to contribute to the development of theory-driven research on climate change adaptation and food security, and its role in the resilience and vulnerabilities of communities facing environmental challenges. We employed an intersectional and social justice approach integrated with grounded theory and examine the intersectionalities of socio-economic classes and gender with food security and climate change and also investigated typologies of communities' adaptation to climate change and food insecurity crises in a fragile region of Pakistan.

By documenting individual narratives and amplifying voices from a diverse range of participants including community leaders, non-profit workers, and vulnerable individuals such as internally displaced people, women, smallholders, landless tenants, and daily wage labourers, we examined the impact of climate change and identified different adaptation strategies among them. This inclusive methodology is crucial as it provides a comprehensive understanding of adaptation strategies directly from the perspectives of those being affected, providing meaningful insights. Additionally, our study emphasizes the importance of future research and conceptual framework development in the field of climate change adaptation research, emphasizing the need to consider socio-

cultural and economic classes, religion and gender dynamics, and their relations to various adaptative strategies to foster sustainable food systems, resilience and address the escalating threats of climate disasters.

Furthermore, our findings underscore key issues that have broader geographical relevance such as gender, and socio-economical and ecological classes, have several implications for climate change in Pakistan and Asian societies, due to stronger patriarchal norms and deeper inequalities, which often limit these individual's abilities to respond to and cope with external shocks like Climate Change. Given the expected exacerbation of ecological degradation and increasing food insecurity in Pakistan, there is an urgent need for comprehensive and critical analyses to inform policymakers. By shedding light on the complex ways in which climate change affects vulnerable groups within local communities, our study suggests that existing policy and adaptation programs can benefit from utilizing such community (In this study, the term 'community' refers to a group of individuals who share common geographical, cultural, or social characteristics. However, it is important to note that communities are not homogenous; they are socially differentiated, often along lines such as gender, socioeconomic status, ethnicity, and other factors. This differentiation, as evidenced in the empirical material of this article, significantly shapes the ways in which individuals experience and respond to climate change impacts, including food insecurity. Acknowledging these differences is critical in understanding the varying vulnerabilities and adaptive capacities within communities) insights.The subsequent sections are structured into four parts, where the second section delves into the literature regarding the (differential) impact of climate change on health, and food insecurity, and examines various adaptive measures, and complex interplay of various dimensions of food-climate change, forming a conceptual framework. Following this section, we provided a detailed methodology, as well as the results and discussion in the fourth section. The final chapter summarizes the key findings, offers policy recommendations, and addresses the limitations of the current research study, as well as proposed future research directions.

2. Climate Change Impact—Drivers and Adaptation Measures

It is well documented that extreme weather events, exacerbated by climate change, pose significant risks to natural ecosystems, agriculture, and human societies [56]. Although agriculture plays a significant role in contributing to climate change, it remains highly vulnerable to its impacts [4, 10, 57, 58]. Various agro-environmental and climatic factors influence farm productivity, with extreme events like floods, wildfires, and droughts presenting significant challenges. Given agriculture's pivotal role in many economies, especially in developing countries, its susceptibility to climate change has profound implications for food security and household well-being. This dependence on agriculture further exacerbates global vulnerability, jeopardizing farmers' and communities' livelihoods and contributing to poverty.

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Climate change may not only exacerbate environmental challenges but also profoundly impact food security and human health. Studies indicate increased psychological disorders, mortality, and morbidity associated with extreme weather events and vector-borne diseases [61–65]. The World Health Organization (WHO) predicts a substantial rise in climate-related deaths by 2030–2050, primarily attributed to extreme weather events the expansion of vector-borne diseases [61, 63], and the deterioration of food quality and access [4, 66]. In ad-

dition, the global spread of diseases like malaria and dengue fever is closely linked to climate change, as rising temperatures create favorable conditions for disease-carrying vectors [64, 65]. Furthermore, the psychological impact extends beyond immediate health concerns, with communities exposed to climatic disasters experiencing lasting psychological impacts, including post-traumatic stress disorder and chronic psychological dysfunction [67].

These events exacerbate differential impacts within communities, particularly among vulnerable groups such as women, children, internally displaced people, and refugees who are exposed to extreme climatic events like floods, cyclones, heatwaves, wildfires, sea-level rise, and other forms of environmental degradation [14, 15, 18, 23, 68–70]. Consequently, these events contribute to elevated levels of food insecurity and other vulnerabilities in these communities. Thus, implications of climate change on livelihoods, particularly regarding food insecurity, poverty, and social power relations, result in diverse patterns of change that magnify various dimensions of the food system, and the differential impacts across various classes and genders, affecting livelihood opportunities, vulnerabilities, hardships, and survival [17–20]. This further underscores the necessity of understanding not only the relationship between food security, its dimensions, and climate change impacts but also the importance of conceptualizing adaptability to these climate-related vulnerabilities at both individual and broader societal and ecological levels [18, 71]. Acknowledging the crucial engagement of these communities and local dynamics, facilitating climate justice narratives and adaptive measures towards food insecurity is important to consider [7].

However, another significant question is what are adaptive strategies and how effective they are to cope with these complex challenges. Traditionally in terms of Climate Change and food security, these adaptation strategies can be broadly categorized into two main approaches: 1) the ex-ante measures, which are proactive actions taken in anticipation of climate events, and 2) ex-post responses—considered usually as "reactive" measures implemented after the occurrence of natural calamities. Ex-ante adaptations often involve diversification strategies aimed at leveraging the diverse impacts of climate events on different crops, farming, and household-related activities. For instance, in drought-prone areas, farmers may diversify their farm plots' locations to exploit variations in rainfall, cultivate a variety of crops with different climate sensitivities, or engage in non-farm activities less vulnerable to climate fluctuations [7, 43–46, 56, 60, 72]. Additionally, maintaining flexibility in input decisions until weather uncertainties diminish and investing in crop insurance are common ex-ante strategies [43–46]. On the other hand, ex-post adaptations focus on mitigating crop or welfare losses after climate events have occurred. These measures may include utilizing cash reserves or grain stores, accessing formal or informal loans or credit markets, selling tangible household assets including poultry or livestock, or migrating to regions less affected by climate extremes (ibid). Farmers may also adjust management practices during the growing season, such as replanting with faster-maturing crop varieties or resorting to irrigation in case of insufficient rainfall [43, 44].

However, not all individuals, e.g. farmers in such cases possess the ability or have access to implement these strategies, particularly in impoverished regions where access to education, agricultural extension services, social safety nets, and financial markets, is limited. This is especially true in conflict-ridden areas like Pakistan, where trust in government institutions, particularly those related to agriculture and extension services, is low [73, 74]. Consequently, the poorest households, women or daily wagers often struggle to shield their consumption from climate-related shocks [17, 18, 23]. In Asia and Pakistan, where structural inequalities and power dynamics within "Islamic patriarchy" manifest across various levels, lack of ownership or inheritance of land rights, and other resources have further escalated the vulnerability of women and reduced their abilities to cope and adapt to these climate variations. Similarly, migrated, and displaced individuals from their homes due to conflict or natural disasters, also lack the resources and infrastructure necessary to meet their basic needs e.g., food [75–77]. Such male-outmigration leaves behind women and children, creating households that are dependent on women to support their families alone, fur-

ther elevating their risks to climatic vulnerabilities [17]. The disruption of social networks due to displacement and the inability to implement effective ex-ant or ex-post approaches leaves vulnerable individuals to prolonged food insecurity and adverse health and economic outcomes, particularly affecting women, and children [77–79].

Certain adaptive strategies aim to mitigate immediate risks, but they may inadvertently worsen food security over time. For instance, ex-ante strategies can help reduce catastrophic losses but might lead to lower yields and income during favourable years by opting for less risky yet lower-yielding crops. Similarly, ex-post measures like selling assets in distress, relying on crop insurance, or receiving food aid might offer short-term relief but could compromise future productivity, and reliance on scarce food assistance from host communities, government, or other institutions. These trade-offs highlight the intricate challenges farmers or these vulnerable individuals or communities often face in balancing short-term survival with long-term livelihood sustainability. Moreover, while such coping mechanisms may address specific aspects of food or climate-induced crises, they can also have profound psychological and social impacts on households and families. For instance, feelings of helplessness, desperation, and anxiety about future disasters or crises, coupled with ongoing struggles for survival, can further exacerbate marginalization [17, 77, 79, 80].

Considering the multifaceted challenges posed by climate change, we proposed a novel conceptual framework (**Figure 1**) that comprehensively illustrates intricate and interconnected relationships between the impact of climate change on households' food security, human health, and the role of socio-religious, cultural, gendered, behavioral, environmental, political, policy and, institutional factors shaping food security vulnerabilities and adaptation interventions (e.g. ex and post-ant and ex-post strategies). Through analyzing drivers or influencing factors which includes individual and contextual factors that shape household food security and climate change adaptation measures. This framework underscores the complex, non-linear dynamics of climate change adaptation, emphasizing that strategies are not uniform but are influenced by an array of individual, socio-religious, economic, cultural, gendered, environmental, political and institutional factors. At the core of the framework are the individual-level drivers of adaptation, including actions like asset liquidation, access to credit, social support networks, social capital and information. These drivers or factors interact with broader socio-cultural, administrative, political and institutional forces—such as gender norms, religious practices, environmental conditions, and policy structures—that either support or hinder adaptive capacities. For example, in many agrarian societies, gender norms often limit women's access to resources and decision-making power, directly affecting household adaptation potential [14, 15, 18, 23, 68–70]. Religious practices may either facilitate or restrict certain agricultural behaviors, influencing the extent to which communities can adopt climate-resilient practices [50, 81].

Furthermore, the framework highlights the critical role of environmental factors, such as geographical location and agro-ecological shifts, which exacerbate the vulnerabilities of marginalized groups and also impact farm productivity. For instance, rural and agrarian households heavily dependent on natural resources face disproportionate risks from climate change impacts, including biodiversity loss, soil degradation, and water scarcity. These households, particularly in low-income settings, may have limited access to adaptive resources, leaving them more vulnerable to food insecurity. Food security outcomes, represented by the dimensions of access, affordability, utilization, and stability, are contingent upon how effectively households can navigate these drivers and contextual factors. Ex-ant or short-term adaptations, such as crop diversification, accessing loans, or mixing agricultural practices (e.g., intercropping or utilizing indigenous knowledge), may provide immediate relief from climate-induced shocks. However, if not supported by robust institutional mechanisms (e.g., insurance schemes or access to climate-resilient infrastructure), such practices may lead to unsustainable dependencies or increased long-term vulnerability and impact sustainablity of the food systems. On the other hand, long-term adaptations or ex-post measures focus on mitigating crop or welfare losses after climate events have occurred. Such as ecosystem restoration, agroforestry, and the adoption of climate-resilient cultivars

and livestock, have more significant potential for sustainable food security but are highly resource-dependent. Sustainable agricultural practices (e.g., integrated pest and water management) require technical knowledge, capacity-building, and policy support—all of which are often limited to marginalized or resource-poor regions. Without institutional backing, these long-term strategies may remain inaccessible to those most in need [43, 44].

The framework also integrates the concept of social capital, highlighting the importance of social or communal networks and collective action in reinforcing adaptive capacities. For example, households in regions with strong social cohesion may be more resilient, as they can rely on informal networks for knowledge-sharing, resources, or financial support during times of crisis [50].

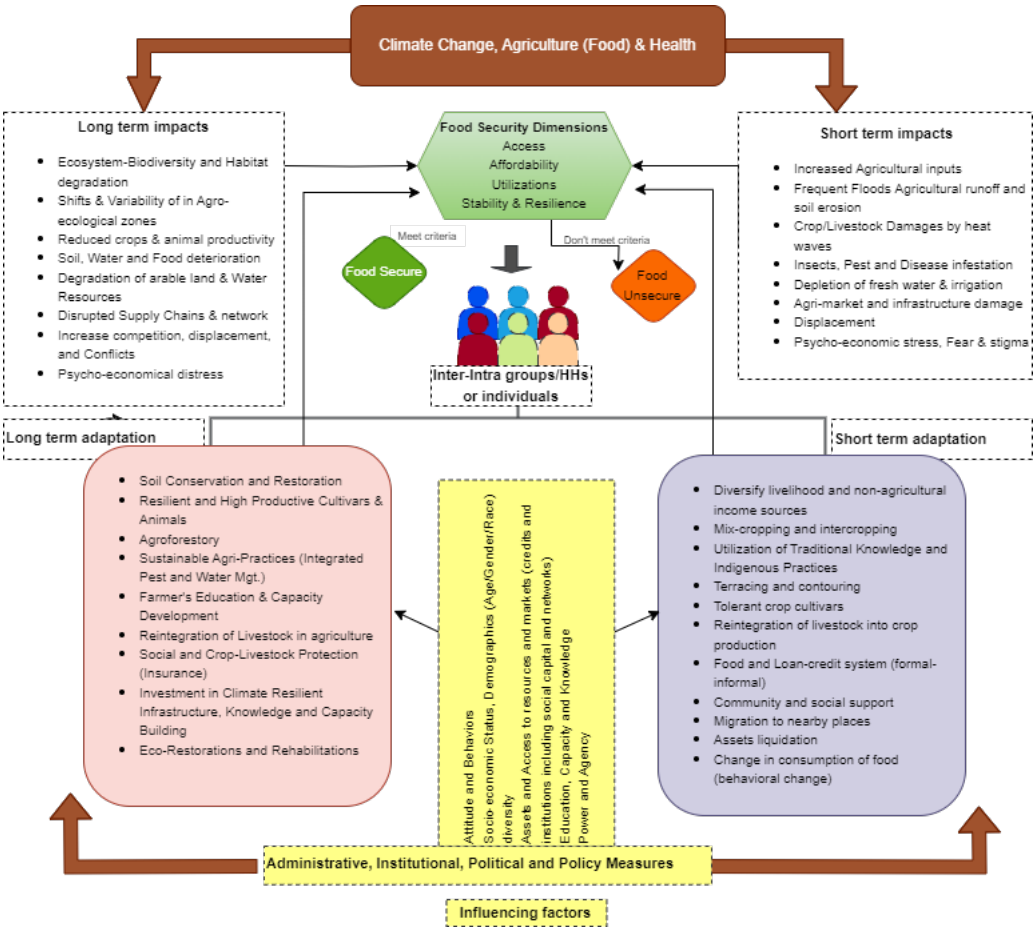

Figure 1. Conceptual framework (Authors, 2024).

At a broader level, the framework emphasizes the significance of administrative, institutional, political, and policy measures in mediating food security outcomes. The role of institutions—whether governmental, religious, or local—cannot be understated, as they shape access to critical resources, influence behavioral adaptation, and determine the level of support available for households facing food insecurity. Inclusive governance structures, financial support mechanisms, and capacity-building initiatives are key components of effective adaptation strategies. Policy interventions, such as investment in climate-resilient infrastructure, crop and livestock insurance mechanisms, and farmers/community capacity building, are crucial in enhancing long-term adaptation. However, weak governance, corruption, or inequitable policy implementation can undermine these efforts, especially for vulnerable groups. This highlights the need for targeted, context-specific interventions that address the unique vulnerabilities of different social groups, such as women, low-income households, and

racial or ethnic minorities.

Ultimately, the effectiveness of adaptation strategies is contingent upon the understanding and acknowledging significant interplay of these drivers, contextual factors, and measures. The framework offers a novel lens through which we understood the intersections of socio-religious, cultural, gendered, and institutional factors through qualitative analysis from the field. By prioritizing the most vulnerable populations, adaptation strategies can be designed to not only mitigate the immediate impacts of climate change on food security but also foster long-term resilience. This ensures more equitable outcomes across different socio-economic and cultural groups, particularly for those who are disproportionately affected by climate change.

Through the lens of intersectional, and grounded theory, emphasizing the iterative process of theory-building that emerges from empirical data in this research study, the analysis of the lived experiences of participants illustrates a complex interaction between environmental stressors, class, gender, religious and cultural beliefs, and adaptive responses (**Figure 1**). Through this interpretive framework, we contribute to the development of theory-driven research on climate change adaptation and food security, and its role in the resilience and vulnerabilities of communities facing environmental challenges.

3. Methods

This study employs an intersectional and social justice approach integrated with grounded theory. By considering the narratives of vulnerable communities regarding the differential climate change impact, its adaptation and addressing food insecurity, we focused on two districts affected by climate and conflict namely Dera Ismail (DI) Khan and Bannu, located in the province of Khyber Pakhtunkhwa, Pakistan.

Intersectionality framework explores how various social-economic identities—such as gender, class, ethnicity, race, economic status and others—intersect to influence individuals' experiences, vulnerabilities, and social positions [14, 15, 17, 18, 20, 23, 31, 32, 68–70, 82] and assist us in understanding how multiple socio-cultural, economic, and religious factors collectively shape vulnerability to climate-induced food insecurity. Social justice theory on other hand, allowed us to examine differential impact posed by structural inequalities—such as disparities in policy implementation, social network, informational and institutional support, and resource distribution—exacerbating food security [30, 32, 82, 83]. Addressing these structural inequalities may help in mitigating the impact of climate disasters on food security and promote more inclusive and effective adaptation strategies [30–32, 50, 84]. Grounded theory, a qualitative research methodology, enables the formation of concepts through the analysis of interview or focus group data, providing valuable insights into participants' "lived experiences" [85, 86]. Lived experience, in this context, refers to participants' subjective accounts, and everyday realities and personal narratives of individuals facing climate-induced challenges [87, 88].

We employed an iterative process involving constant comparisons to identify patterns and variations in participants' responses [37, 89]. Similarities and differences within the data are explored, leading to the grouping of concepts into themes, further categorized into core categories [71, 85, 89]. Responses obtained from personal stories, field observations, and focus group discussions were organized into themes and analyzed in an Excel spreadsheet. Additionally, agricultural, and other adaptation methods or conditions of these individuals or communities were directly observed, contributing to the development of interventions to tackle the food insecurity crises in the food-insecure region of the Khyber Pakhtunkhwa province in Pakistan.

3.1. Study Design and Context of Research

Study Area, Participant's Selection, and Procedures for Research

The research commenced with the careful selection of study areas and participants. D I Khan and Bannu districts, located in the southern region of the Khyber Pakhtunkhwa province in Pakistan, were chosen due to their susceptibility to climate variability and a history of frequent disasters [73]. Characterized by low human development indices, social infrastructure and fragile en-

vironmental conditions compounded by prolonged conflict and internal displacement, these districts provided a suitable context for our study. Villages prone to natural disasters were identified based on district reports from sources like the National Disaster Management Authority and Provincial Disaster Management Authority[90]. Utilizing snowball sampling, participants were selected according to predefined criteria, including gender, age (>18 years), residency in the area for the past two years, and experience with climate-related disasters, targeting individuals from low socio-economic and cultural class or backgrounds[17, 71, 91, 92], ensuring a diverse representation, including daily wage laborers, landless tenants, women, youth, smallholders, and internally displaced people (IDPs) from both rural and urban areas. Additionally, two in-depth interviews with four district and local leadership aided in identifying patterns of adaptative measures based on their specific experiences and knowledge in the area.

Visits to major IDP camps, villages and households in Bannu and D I Khan provided further insights into the ground realities. In total, 27 individuals were interviewed and recruited in the focus groups' session and were not provided with any incentives for their involvement in the 60–90-minute sessions each for interview and 2 FGDs (one in each district), which were conducted in local Hujras (a social gathering place in Pashtun culture), mosques, and schools. Data were collected using careful facilitation during FGDs ensured an inclusive environment, allowing participants to share freely while maintaining confidentiality and sensitivity to power dynamics. To ensure participant's safety, comfort and openness, focus groups were conducted in local settings (Hujra, Mosques or schools) that were familiar to them. Similarly, to minimize bias, facilitators were trained to encourage a range of responses and to be aware of their own positionality in relation to the study context. Ethical considerations were paramount, with attention given to ensuring participants felt safe sharing their experiences. Therefore, study procedures were reviewed and approved by the respective Institutional Review committee at the university prior to conducting interviews and focus group discussions.

The grounded theory guided the iterative research process, beginning with key questions aimed at understanding the impact of climate change, and the adaptive measures taken by vulnerable communities to address food insecurity amidst climate disasters. Focus groups, led by facilitators following a structured moderator guide, were conducted, with detailed notes taken throughout the discussions. Subsequently, the focus group sessions were transcribed from local languages such as Puhstoo and Saraiki into English. Following the principles of grounded theory, facilitators engaged in discussions after each session to identify emerging ideas and concepts, which were incorporated into subsequent focus group sessions. The details of the participants for the focus group discussion/interviewee are listed in **Table A1**.

3.2. Data Analysis, Validity and Triangulation

After conducting the initial interviews and focus group discussions, facilitators noted consistent themes across both groups, suggesting that theoretical saturation had been reached. Consequently, no additional focus groups were deemed necessary. Afterwards, data analysis was carried out using the main technique of coding, as prescribed by Glaser & Strauss[85], a widely accepted method among qualitative researchers[92]. This coding process involves three steps (**Table A2**): open coding, axial coding, and selective coding. Open coding entails the classification and abstract labelling of words and phrases in interview data, with researchers matching preliminary codes to the interview data. The goal of axial coding is to identify and develop connections between primary categories and subcategories. Forming the basis of the fundamental theory, selective coding entails assigning categories to the primary category. The triangulation method, which takes into account various data types, researchers, ideas, and methodologies, was used to guarantee the validity of the data. To perform this validation procedure, data from multiple sources, including research participants, investigations, summaries from researchers, and note-based audit trails, were triangulated[85, 92, 93]. Triangulation further ensures robustness in the interpretation of the data, since this rigorous validation approach increased the

findings' credibility and trustworthiness.

After transcription, the transcripts and field notes underwent a thorough review to align codes with themes that identified various strategies for intervention development. The final themes were determined through consensus. Each co-author then meticulously reviewed the transcripts, carefully assessing each quotation to ensure alignment with themes representing different types of interventions for individuals living in food-insecure, climate-fragile areas. Subsequent discussions focused on how individuals conveyed their experiences through narratives, offering valuable insights. Quotes and stories from participants were extracted to illustrate the diverse interventions discussed. A detailed methodological illustration is provided in **Figure 2**. Data analysis was conducted using MS Excel/spreadsheet.

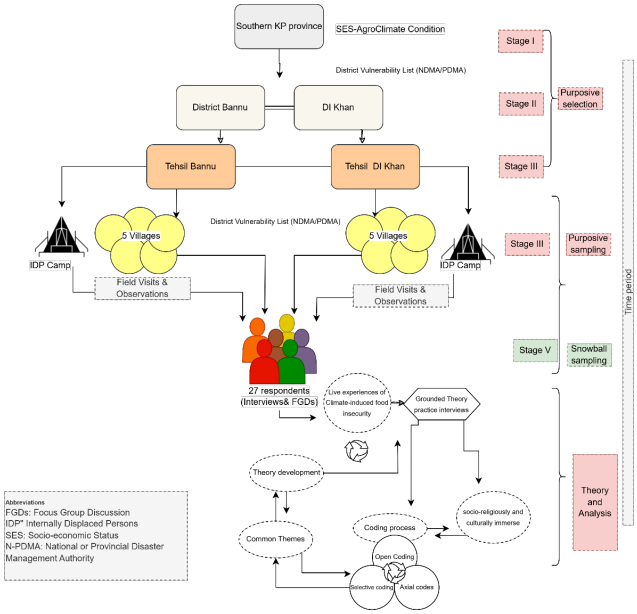

Figure 2. Methodological illustration of the study (Authors).

4. Results and Discussions

Based on our conceptual framework, we established 59 open and respective axial codes, and their link to the construct 8 primary themes (**Table A1**), to understand the impact of climate-induced food insecurity, and typologies of various adaptation measures, and how these impacts and measures vary among these vulnerable individuals. However, one important theme that emerged during listening to the narratives was individual perception and behaviour surrounding climate change and food insecurity.

4.1. Intersectionality of Socio-Cultural and Religious Beliefs Influencing Climate-Change and Food Insecurity

> *"Indeed, in the creation of the heavens and the earth, and the alternation of the night and the day, and the [great] ships which sail through the sea with that which benefits people, and what Allah has sent down from the heavens of rain, giving life thereby to the earth after its lifelessness and dispersing therein every [kind of] moving creature, and [His] directing of the winds and the clouds controlled between the heaven and the earth are signs for a people who use reason."* (Surah Al-Baqarah 2:164)

Perceptions of climate disasters are profoundly ingrained in the religious, cultural, and social fabric of the places under study, influencing people's reactions and adaptive measures. Religious beliefs, for instance, offer a lens through which individuals interpret and navigate environmental challenges. Reflecting on the recent deluge of floods that swept through their village in D I Khan district, one elder religious leader (age 55) remarked solemnly, *"These floods are a reminder of Allah's power and mercy. We must endure these trials with patience and faith, for Allah tests those whom He loves."*

He further cited verses from the Quran

> *"Corruption has appeared throughout the land and sea by [reason of] what the hands of people have earned so He may let them taste part of [the consequence of] what they have done that perhaps they will return [to righteousness]* (Surah Ar-Rum 30:41)

Similarly, another older male (55) from a Bannu "*Despite all the economic challenges I face, I remain hopeful to Allah that he will help me and one day my children will achieve good status. Because he (Allah) will never let us down.*" This strong expression of faith not only under-

scores the resilience ingrained in the community's belief system but also influences individuals' coping mechanisms and outlook in the face of adversity. Such as another participant told us:

"As a devout believer in Allah, I firmly believe that Allah is the only provider of all sustenance, including food. I am also a firm believer in the idea that having many children can bring blessings, and that they will bring their food with them, as it is Allah who provides for us all." - Religious leader (male, 40, Bannu). These religious beliefs are reinforced by the century old-cultural practices playing a pivotal role in shaping individual's perceptions and how they affect the vulnerability to food insecurity, reflecting not only dietary customs but also communal values of sharing and solidarity i.e.

"We only eat meat when there is a guest in our home," a young participant said during the conversation. Adding to his remarks, labour (age 35 from Bannu), he further demonstrated *"Thanks for being Muslim, as my family only eats during Eid-Ul-Adha and tries to store it for the next few days"*. He laughed while expressing his pain. It is pertinent to note that Eid-ul-Adha is one of the biggest Muslim feasts on the Zul-Hajj where those Muslims who can afford animals, slaughter them in the name of Allah (God) and distribute meat among relatives and poor families. This festival is meant to support poor families, particularly considering the food requirements of deserving people.

Interestingly, most of these vulnerable families in these areas tend to have more family members, as they continue to produce more children and practice polygamy (while we did not explicitly ask about it, yet as a resident of this community, we acknowledge this fact and trend and observed it even in our families). One reason that we found was a strong religious belief may further explain having more family members and not taking food insecurity as a serious matter. Such as a small farmer (male, age 40) from Bannu who was our gatekeeper and "Molvi"—an influential religious person expressed his distress on the issue of family size and food insecurity as follows:

> *"As a devout believer in Allah, I firmly believe that Allah is the only provider of all sustenance, including food. I am also a firm believer in the idea that having many children can bring blessings, and that they will bring their food with them, as it is Allah who provides for us all."*

Similarly, literature shows that one cause of food insecurity contrary to climate change, is larger family sizes [5, 25]. The emergence of the family size, as reflected in the code *"We have so many kids so we always have less food to eat"*, suggests that larger families may struggle more with food insecurity, as they require more resources to sustain themselves. This finding also corresponds to serval quantitative studies where households with higher family sizes have been significantly associated with a higher probability of being food insecure [5, 25, 50, 94].

A couple of other interrelated factors that were brought up during discussion were persistent land fragmentation due to inheritance which further depends on family size in these areas. During our focus group discussion, a local farmer shared his concern about the decreasing productivity of his farmland due to the fragmentation caused by inheritance. He stated, "*My father had 10 acres of land, and it was divided among my six brothers and sisters after his death. Now I have three children, and after my death, my land will be divided among them, which will further decrease the productivity of the land.*"

Since this province has the highest family size, due to cultural norms, and tradition of being together as a joint family (nuclear family), people often experience food insecurity. Such as an old landless tenant (age 35) in a focus group in Bannu discussion said *"It is our culture to live together, we eat together, we laugh together, and we will die together even if we are hungry".* He further said, *"My children, and grandchildren, and even their children live together"*.

On the contrary, women and young participants disagree with these prevailing trends and notions. Such as a young man working for a local Community-based organization in Bannu disagreed with that old man, and said: "*Yes, that's why your grandchildren are always running after Alums and charity food*". "…and *since that condition would have been much better by adjusting the income and resource in a single family rather than nuclear family, where one person earns, and rest of the big family rely on*

that single income".

Therefore, family size, and religious and cultural practices, which further can affect land distribution or parcelization (dividing land equally among all children) can cause the reduction of agricultural or farmland productivity amidst climate change [50, 94]. As more and more land is divided among the children of each generation, the size of the farmland is decreasing, and it becomes difficult to cultivate, hence substantially affecting their source of livelihood. However, this problem is not limited to this particular area, as the fragmentation of farmland due to inheritance is a common issue in many other parts of the world [8, 94] and substantially impacts the food security of households.

Likewise, intra-household power dynamics, gender segregation, and the absence of guardianship and parents can further increase food insecurity among family members. A widow of age 30 (Bannu), her voice trembling with emotion, shared her struggles in navigating the treacherous terrain of patriarchy and gender inequality [95]. *"As a woman, I faced countless obstacles on the path to prosperity,"* she confided, her words echoing with the resonance of shared experience.

Similarly, a young female age 29 from Bannu explained; "*My parents died when we were three years old and were living with my aunt, who used to abuse me and treat me as a slave. We never eat better food, and she always gives meat and fruits to her kids. We even once decided to run away from home, but my grandmother stopped me. Throughout these days, we never knew what to do. But we survived somehow as we grew".*

Another woman (age 30+, DI Khan) shared her experience that *"most of the time when we have guests, the men first eat, and once they are done, we all woman eat that leftover food." and "...sometimes we even don't have that leftover and sleep without food*". In both cases, the absence of guardianship or parental figures to ensure equitable distribution of food and protection from mistreatment has led to increased vulnerability and food insecurity.

"My father and brother didn't give me my right of land as I am a woman "expressed by a woman in an IDP camp further illustrated the complex interplay of social and cultural factors that can exacerbate food insecurity in certain communities when it comes to gender and land rights. In the tribal and Pashtun cultures of Khyber Pakhtunkhwa, gender segregation and discrimination against women are deeply rooted [96]. As a result, women are often denied their basic rights, including access to land, education, and employment opportunities.

Most of the women who shared their experiences where their guardians or father or elder brother "*refused to give her rightful share of land because she is a woman"*. This gender-based discrimination can lead to a lack of resources and financial independence, making it difficult for women to provide for themselves and their families [95]— Consequently, denied their right to land ownership, freedom, and agency in achieving well-being and are deprived of the capability to make choices and pursue their goals, ultimately limiting their opportunities and potential to improve their lives [95, 96].

The patriarchal structure entrenched within these communities, compounded by the absence of guardianship and parental figures, perpetuates unequal resource distribution and heightens vulnerability among women and marginalized groups. Additionally, varying perceptions of climate change which are influenced by complex socio-cultural and religious beliefs further exacerbate these disparities. Women and marginalized groups often bear the burden of climate-related challenges, such as irregular weather patterns and environmental degradation, which disrupt agricultural livelihoods and exacerbate food insecurity [17, 18]. Consequently, perceptions of food insecurity in these areas further varied and confronted the deep-rooted cultural and social norms that fuel inequality and discrimination [86], while also considering the differential impacts of climate change on different individuals. Moreover, recognising and addressing the intersecting dynamics of gender, socio-economic class, cultural identity, and underlying power dynamics, promoting agency, and challenging entrenched social norms, can foster more equitable access to resources can alleviate food insecurity and fight against climatic extremes within households and communities.

Inadequacy and Failure of Economic, Social, and Policy Systems in the Face of Climate Disasters

The problem of food insecurity is a result of market failure with roots in economic, social, and policy systems rather than being a result of a shortage of food produced or distributed [96, 97]. Rocha [97] explains the core issue lies in the unequal distribution of income and power in society, which limits access to food for marginalized populations. Market-based approaches, she argues, often prioritize profits over human welfare and fail to address the systemic inequalities underlying food insecurity. Instead, Rocha advocates for government policies that recognize food security as a fundamental human right, promote equitable access to food, and tackle the root causes of poverty and inequality. Similarly, Hussain and Akram [98] highlighted the part that Pakistan's food insecurity plays in being sustained by policy failures. They identify the main causes of the issue as being insufficient social safety nets, poor governance, and low investment in agriculture and rural development. Our focus group discussions, where participants expressed their concerns about institutional and economic issues and restricted access to necessary resources made worse by climatic disasters, mirrored these policy failures.

For example, a thirty-plus-year-old male labourer from Bannu conveyed his concern by saying, *"How can we think of fruits and meat when we don't have enough money to buy staple food?*" Likewise, a widow who provides the family's only source of income bemoaned, saying, *"The pension the government gave me after my husband died is just peanuts. Fruits are rarely within our budget; all we can afford to buy is bread and beans to get by".* These testimonials shed light on the economic hardships that vulnerable populations endure, hardships made worse by climate-related natural disasters including floods, droughts, and harsh weather.

Further codes and themes like "No price control mechanism," "Rise in unemployment," and "Poor control of district authority" further underscore the themes of economic inadequacy and policy failure. Especially in the wake of climate disasters, these codes highlight the structural shortcomings of the institutional and economic systems in meeting the demands of disadvantaged people. The absence of price control measures increased jobless rates, and poor governance—all of which worsen food insecurity and prolong poverty cycles in the face of environmental crises—were mentioned as sources of frustration by the participants.

During our discussions, an old community worker criticized the prevalence of the black market, stating, "There is an open black market, and every time the government raises the price of petrol, merchant stores raise the prices." Another participant expressed outrage over political corruption, stating, "How about that filthy politician… (name omitted) whose son is engaging in smuggling flour to Afghanistan… When we are dying of hunger and have no work, the government and these people engage in profit-making… there is no control or authority to stop them from this dirty greedy business."

In addition, the restricted or limited food access that people of all genders and socioeconomic classes report, such as "*We only eat once a day*," reflects larger structural discriminations that lead to ongoing food insecurity that is made worse by natural disasters. Inadequate investment in agriculture, weak governance, and discriminatory practices further exacerbate the problem, leaving vulnerable populations struggling to meet their basic needs in the aftermath of environmental shocks. The researcher [74, 96] also discovered that rural populations in Pakistan were dissatisfied with these institutional sources, especially in the areas of agriculture and extension, which could exacerbate their worries. Thus, addressing food insecurity requires not only immediate relief efforts but also systemic reforms that address the root causes of poverty and inequality, ensuring equitable access to food and resources for all, especially in the face of climate-induced disasters [15, 50, 74, 96].

4.2. Lives vs Livelihood—Impact of Climate Change

Despite religious and cultural belief systems, our thematic analysis related to environmental stress and hazards also demonstrated that individuals across different socio-economic classes and genders feel the impact of natural disasters and climate variability on food security [17, 18]. For instance, codes such as "Flooding in villages," "low land fertility," "pest attack on crops," and

"frequent or persistent Drought" underscored the challenges faced by these vulnerable individuals in maintaining food availability. One male participant, who was thirty years old, expressed regret over the loss of their livelihood during a focus group discussion in Dera Ismail Khan. He said, *"We only had one cow, which got killed during last year's flooding in our village... we used to sell the milk and were able to maintain my subsistence life."* All we have left is debt and destitution right now. This story illustrates the terrible effects that climate-related disasters have on household incomes.

In the same district, a 38-year-old smallholder farmer voiced concerns regarding their land's decreasing productivity, saying, *"I have been cultivating this land for several years, but now it is not as productive as it used to be. The fertility of the soil has diminished, and I have not been able to revive it. I find it challenging to raise enough crops because of this to support my family and make a life. I've experimented with several fertilizers and methods, but nothing appears to be effective. Concerning the future of my farm and the food security of my family, I am worried".* This idea clarifies the various difficulties that farmers encounter, such as degraded soil and the incapacity to provide for their families basic food needs, particularly for middle-aged male smallholder farmers.

Similarly, the code "Low precipitation" further emphasized the effects of environmental threats on livestock and grain productivity. Although the climate variability in the districts is similar, the villages in Dera Ismail Khan are more vulnerable to flooding because of their proximity and lack of resilient infrastructure.

However, Bannu participants talked about their experience with drought, saying, *"My chickpea crops used to give me enough money to buy seeds and pay for my son's tuition. This contrasted with other participants. We have had less rain this year than we did last, and irrigation water has been scarce since then. My hands and pockets are empty, and my property is bare as a result"*. The negative effects of climate fluctuation on agricultural output, household income, and standard of living are highlighted in this account.

We were able to see directly the catastrophic effects of climate change, which were evident in both the ongoing drought and the disastrous floods, during our field trips to several villages in Bannu and D I Khan. For example, we saw the desolation of dried-up Date orchards when we visited Tukhuba Kalan in Bannu, the lead author's hometown. Speaking with local farmers, we found a generalized worry as they related stories of crops failing and revenues dropping because of irrigation water scarcity owing to prolonged drought. Given their livelihood dependency on these farms and rainfed agriculture, we witnessed the repercussions of climate change on agriculture and local economies.

During our field visits to IDP camps and villages in Bannu, we also saw the effects of climate change in action. These marginalized communities, including daily wage workers and internally displaced persons (IDPs), were living and working in extreme heat and had limited access to drinking water or cooling facilities, which made them more susceptible to heat-related illnesses and dehydration. A thirty-five-year-old lady who works as a daily wage labourer in the agriculture sector spoke about her issues resulting from climate change during a focus group discussion in an IDP camp near Bannu.

"My daily wage worker livelihood depends on my ability to find employment every day," she recalled. "*But with more regular catastrophic weather events like droughts and floods, finding a steady job has become harder. Agricultural operations are halted during droughts, thus there are no work options for me in the fields. In addition, floods destroy infrastructure, which makes it harder for me to travel to nearby towns in search of work and interferes with transportation. Because of this uncertainty, my family is finding it difficult to meet even the most basic needs, including food and housing, which has further driven us into poverty"*, she expressed further her concerns.

In Bannu's IDP camps, we saw similar terrible living circumstances for displaced families. Precarious conditions were evident in these IDP camps, which were exacerbated by the extreme heat, restricted access to clean water, and inadequate sanitary facilities. Families struggled to cope with the appalling conditions, and children were especially vulnerable to malaria and cholera due to a lack of basic sanitation and clean water.

These observations along with the personal stories and narration further revealed the multiplied difficulties

that vulnerable people experience, as socio-economic vulnerabilities already present are made worse by climate change. Climate change-induced harsh and irregular weather patterns pose serious challenges to the livelihood stability of daily wage workers, such as the women in our study, who depend on their paychecks for family support. Cycles of poverty and marginalization are further sustained by the difficulty of getting stable employment as a result of climate-related disruptions [12, 14, 16], emphasizing the pressing need for focused initiatives to help these at-risk groups mitigate the effects of climate change on their lives and means of subsistence and help them adapt to them.

Our examination and accounts emphasize the complex interplay among socio-economic and environmental strains, climate variability, and food insecurity [17, 18, 27] within the villages under investigation. The participant accounts illustrated how climate-related events have a domino impact on household livelihoods. Aside from reduced agricultural output and animal losses, households often struggle with debt and unstable finances. For example, the participant who lost their cow to flooding described how the loss caused them to become impoverished and in debt in addition to taking away their source of income. This demonstrates how the effects of climate change are interrelated, increasing pre-existing vulnerabilities and sustaining poverty cycles [96]. The stories also highlighted the ongoing difficulties they faced, including their battle with diminishing harvests and unstable livelihoods. In addition to jeopardizing household food security, the failure to generate a sufficient income from farming or other sources of revenue restricts access to healthcare and education, which exacerbates poverty and vulnerability.

Moreover, the varying degrees to which districts are exposed to climate hazards highlight the significance of taking local context into account while constructing resilience. Bannu and Dera Ismail Khan, for example, are subject to varying temperatures; the former is particularly vulnerable to flooding because of its geography and poor infrastructure. Our results are consistent with previous studies on food insecurity, which have identified low income, unemployment, and climate-related factors as major drivers of food insecurity [99, 100]. The difference in exposure emphasizes the necessity of focused interventions that target vulnerabilities and improve community-level adaptability. Furthermore, the stories illustrate the psychological toll that food poverty brought on by climate change takes on families. Many people's and families' mental health is severely impacted by the uncertainty of future harvests and the ongoing battle to make ends meet. When households deal with the effects of climate change, anxiety, stress, and a sense of powerlessness are common sensations that exacerbate already-existing social and economic problems [40, 76–79, 101, 102].

The Consequence of Food Insecurity: Social Stigma, Fear and Shame

Likewise, besides cultural and institutional barriers and social changes, gender segregation and disparity, and poor infrastructures in villages and cities can all contribute to food insecurity by limiting access to resources and opportunities. These also include the feeling of guilt and shame in asking for help as one community female worker shared her experiences as "*most of the time in this tribal culture, people don't ask for help when they are hungry or have no food in their houses" and "Allah is the sole breadwinner who is responsible to feed us"* truly represent deep religious values shaping their attitude and practices.

There is guilt and social pressure that keeps them suffering from such a condition. They think that if they expose their poverty, and lack of food in the house, the community and especially their relatives will make fun of them. Some "families do not let their children play with others as those children can find their poverty status". And "these parents do not want their kids to be exposed to social pressure or stigma because other children may tell them about what they ate at home, making them feel bad". This relates to the findings of Bernal et al. [103] who suggest individuals' social and psychological status contributes to the development of feelings of humiliation and inferiority, which in turn exacerbates the problem of food insecurity.

Another woman (age 26+) expresses her grief of poverty and hunger and relates it with food insecurity "*We used to boil just water when there is no food at home, and then I and my labor husband pretend that we are cook-*

ing food" …. she cried when she said "*…and our kids sleep without food as we lie to them that we are cooking for them*", which imply that they are so lacking in food that they are forced to pretend they have something to eat, even though they don't. This highlights the shame and stigma associated with food insecurity, as families may feel the need to hide the fact that they are struggling to put food on the table, particularly for their children.

The experiences of poverty, hunger, and food insecurity can lead to significant psychological pressure and mental health issues. In the case of the woman mentioned the pressure of not being able to provide food for her children, and the need to lie to them about having food, is likely to cause immense emotional distress. Living in a constant state of food insecurity, where the ability to provide necessities is compromised, can also lead to anxiety, depression, and other mental health problems [19, 101]. Leung et al. [101] further revealed that long-term experiences such as psychological pressure can also lead to chronic stress, which is known to increase the risk of a variety of physical and mental health problems including obesity and hypertension (ibid).

Considering this stigma, we further inquire whether being an internally displaced person also affects their ability to seek help for food. Several IDPs shared their painful experiences such as one female IDP (age 28+ from Bannu) saying "*We were treated like an animal when we went to get my IDP card for food ration in the Camp. The male was given priority and we are not able to ask anyone due to fear and shame*" … "*We were even harassed by the district manager who scolded us often*".

Similarly, a daily wager, who lost his livelihood due to the pandemic, shared his experience of shame and fear in seeking help for food. He said that the way he was handled at the local government office when he went to apply for food aid made him feel dehumanized and ashamed. "I felt like the way the officials looked at me was judging me," he added. I felt like a pauper because of them, and I was embarrassed to ask for assistance." Even when someone is struggling to support themselves and their family, this stigma and sense of shame can keep them from getting the help they need, which can lead to serious mental health problems. For instance, during the COVID-19 pandemic, a global problem that has had a substantial influence on food security, researchers like Fang et al. [102] looked into the relationship between food insecurity and mental health. Their research claimed that food insecurity was associated with poor mental health outcomes, including depression, anxiety, and stress, during the pandemic. The findings suggest that food insecurity is a significant stressor that can have negative effects on mental health, particularly during times of crisis such as the COVID-19 pandemic. This research supports the idea that the experience of food insecurity can lead to psychological distress and mental health problems, as discussed in our focus group discussion.

4.3. Typologies of Adaptations—How Communities Cope with *Climate Change and Food Insecurity?*

And [Yusuf (Joseph)] said, 'You will sow for seven consecutive years; and what you harvest leave in its spikes, except a little from which you will eat. Then will come after that seven difficult [years] which will consume what you saved for them, except a little from which you will store. Then will come after that a year in which the people will be given rain and in which they will press [olives and grapes].'
[Quran, Surah Yusuf 12:47]

In our qualitative exploration of coping mechanisms toward climate change and food security crises, our participants gave detailed typologies of adaptations. These strategies, deeply intertwined with the religious, socio-economic and religious and cultural fabric and also influenced by an individual's experiences and socio-economic status, show resilience in facing environmental stressors and food insecurity (**Figure 3**).

4.3.1. Tawakul (Faith) on Allah: Fatalism in Climate Adaptation & Food Insecurity

In our study focused on understanding adaptive behaviours towards climate change-induced food insecurity, we found a significant attitudinal adaptation influenced by religious beliefs. Participants, particularly local religious leaders such as Imams of the Masjid (Mosque), expressed the belief that all climate disasters are predetermined by Allah. This perspective fosters a sense of

"*fatalism"*, wherein individuals perceive environmental challenges as divine will, shaping their response to adversity.

Drawing from Islamic teachings emphasizing submission to Allah's will and patience during hardship, participants exhibited strong faith by showing how they accepted and perseverance to the divine will of *Allah*. One participant succinctly expressed this attitude, stating, "*Allah is the sole breadwinner who is responsible for feeding us.*" Likewise, reflecting on the recent deluge of floods that swept through their village, one elder remarked solemnly, *"These floods are a reminder of Allah's power and mercy. We must endure these trials with patience and faith, for Allah tests those whom He loves." He further cited verses from the Quran*

> *"Corruption has appeared throughout the land and sea by [reason of] what the hands of people have earned so He may let them taste part of [the consequence of] what they have done that perhaps they will return [to righteousness]* (Surah Ar-Rum 30:41)

We know that Quranic verses highlight the concept of "*Inna ma'al usri yusra*" (Verily, with hardship comes ease) [Quran 94:6] and "*Fa inna ma'al usri yusra*" (For indeed, with hardship [will be] ease) [Quran 94:5], followed by stories of prophet Yusuf (A.S.) on how to adapt and mitigate natural calamities, further reinforce this attitude, and adaptive behaviors, providing spiritual guidance and encouragement in times of need and strengthen community resilience. Such a testament further shows how religious values can shape attitudes and adaptation towards environmental stressors and food insecurity. Integrating religious beliefs into adaptation strategies can enhance the adaptive capacity of tribal and Pashtun communities, fostering a holistic approach to climate resilience rooted in faith, culture, and tradition.

4.3.2. Liquidations: Selling Productive Assets

In our discussions, the theme of selling productive assets and belongings as a means of survival echoed with profound resonance. Giving up priceless belongings was a heartbreaking last resort for many people facing the harsh reality of food shortages and environmental hardship. A widow who was internally displaced (over 30) and living in the D I Khan IDP camp had a particularly upsetting incident when she said, *"Our life had been challenging enough... but when a bomb blast took away my husband, the struggle to survive became even more daunting." My single significant asset, the jewellery my late husband purchased me, was sold to provide food for my children because I had no other means of support. I was also restricted from working due to stringent religious and cultural codes of conduct"*.

Her description of the difficult decisions faced by people put in the furnace of misfortune is spot on. Giving up treasured objects that are filled with sentiment and memories is a sign of the extent people will go to to protect the welfare of those they care about when things go tough. Aside from this moving account, several people in different research groups shared comparable experiences.

A landless tenant who now become a daily wager (age 40 from Bannu), shared his plight, recounting how he was compelled to sell his farming tools to put food on the table for his family. *"I had no choice but to sell my farming tools. It was hard, but I had to do it to survive,"* he lamented, underscoring the harsh realities faced by vulnerable groups. Likewise, a young mother who is now volunteering as a community mobilizer for a local non-profit community organization spoke of selling her family heirlooms to afford necessities for her children. *"It was heartbreaking to part with our family heirlooms, but we had no other option. My children's needs came first,"* she reflected, her voice heavy with resignation.

These diverse accounts shed light on the multifaceted nature of asset liquidation as a coping mechanism [28, 29, 44, 85]. While it may provide temporary relief in times of acute need, it also extorts a heavy toll on individuals and families, affecting their sense of security and stability. In the face of such adversity, it becomes imperative to explore sustainable solutions that alleviate the need for such drastic measures and foster resilience within communities.

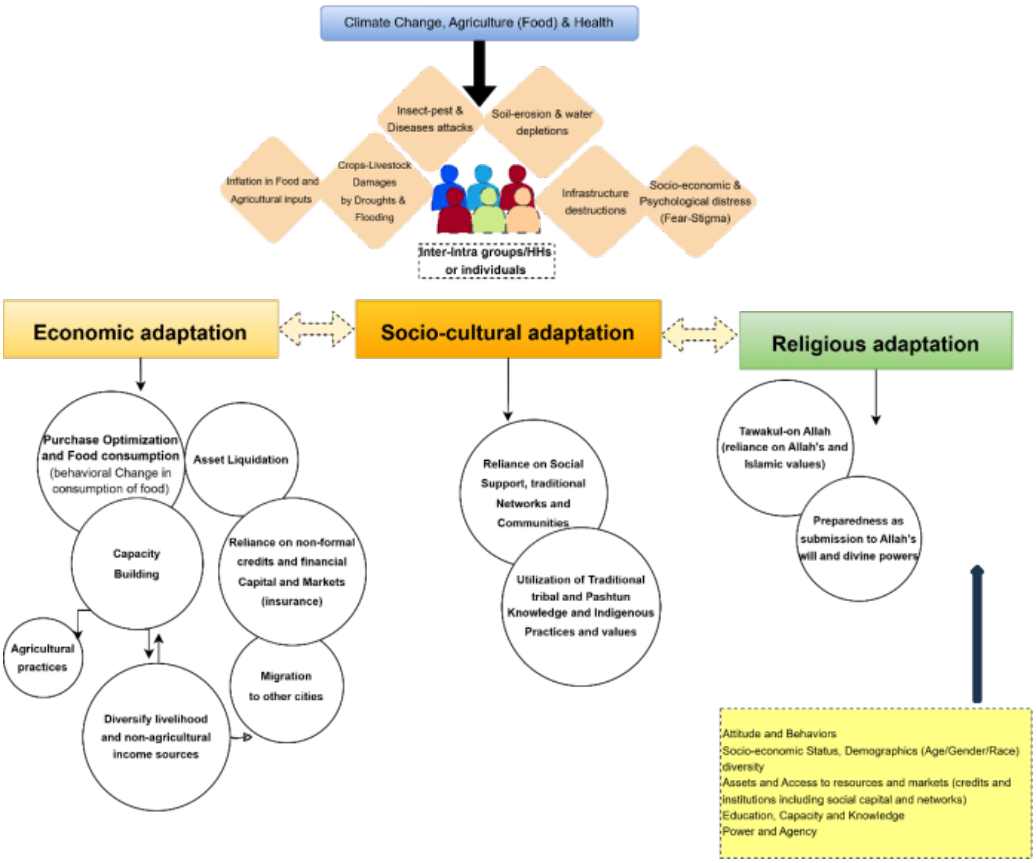

Figure 3. Typologies of Adaptative Measures among participants (Authors)—*Relative size and place show how important it was (# of time it was described in interviews or FGDs or personal observations and coding).*

4.3.3. Affordability-Based Purchase Optimization

During our discussions, individuals shared tactics for making the best food choices possible, motivated by the competing demands of price and environmental sustainability. These stories illuminated the complex dance between budgetary limitations and the imminent threat of disruptions in the food supply chain brought on by climate change. Such as a middle-aged woman of four children from Bannu commented on this careful balancing act, saying, *"I buy food when it gets cheaper." "I no longer purchase fruits"*. This brief statement highlights the practical strategy many have used to navigate the maze of economic uncertainty. When faced with the harsh reality of having little money, people are forced to make thoughtful decisions and frequently give up nutritional variety in favour of less expensive options. As we dug deeper into this theme, we came across tales that vividly depicted the costs associated with pursuing nourishment.

A middle-aged father related his family's experience of struggling to make ends meet while food prices continued to rise. "*We had to make significant food cuts in the past, but we used to enjoy a variety of meals. Luxuries like meat and fruits are beyond our means*," he bemoaned, a hint of resignation in his voice. His account is a moving reminder of the severe compromises that disadvantaged households must make in the fight against food insecurity.

Another young mother who served in a community organization from DI Khan shared the same feelings when she described how her family had to give up once-loved staple foods. "*The era of extravagant dinners is long gone. We now just eat basic food because anything more would be financially unfeasible for us*," she said, regretfully. The stark reality that many people experience as they struggle with the never-ending onslaught of environmental disruption and economic suffering is captured in her words. These personal narratives and stories highlight the hard fact that getting healthy food has

become a difficult and obstacle-filled journey for many people. People must negotiate a world of uncertainty and scarcity as economic inequities increase and climate change wreaks havoc on agricultural productivity. Examining comprehensive solutions that tackle the underlying causes of food insecurity and build community resilience is crucial when faced with such obstacles.

4.3.4. Community Cooperation, Food Assistance, And Social Support

"In our darkest hour, it was the kindness of strangers that sustained us. Their generosity was a beacon of hope in our time of need," (A female, aged 30 from D I Khan IDP Camp).

Despite difficult conditions, inspirational tales of fortitude and solidarity gleamed, deeply entwined with the shared experience. During the session, participants told moving stories of selflessness and unwavering support that sustained them during trying times. These tales give insight into the significant role that social cohesiveness and group efforts play in building fortitude and resilience. In a moving account of the strength of intergroup solidarity, a male internally displaced person (IDP) said, *"One neighbour gave his Hujra where we stayed for more than 6 months and continued to bring food for my kids.*" His words reverberate over the ages, attesting to the resilient ties of kindred and camaraderie that withstand the hardships of relocation and impoverishment. Such acts of kindness and hospitality are representative of the deeply ingrained sense of community solidarity that penetrates the social fabric of the Pushtun culture.

As the collective mentality that characterizes Pushtun culture demonstrates, the feeling of camaraderie truly reaches far beyond the boundaries of individual homes. A grandmother spoke with a voice full of quiet determination as she discussed her thoughts on the innate links to one's family that keep communities strong during difficult times. With a tone full of ancient knowledge, she said, *"In our tribal culture, we stand together as one*."

As such scholars called it a social capital which is the collective strength of the community that serves as a bulwark against the ravages of adversity[44] and can help to mitigate hunger and deprivation during such difficult times. The enduring human spirit and the transforming potential of group action are powerfully evoked by these tales. Friendship and solidarity are the threads that shine through the furnace of misfortune, providing comfort and food to those in need.

Migration to other cities

ستا د نیستی پیغور ییراکړ
مینه ملاتړ هچې بل وطن تهڅونه
O' my love, they are laughing at your poverty,
Let's get ready to go to another land!

Migrating to other cities has been one adaptive measure to tackle climate-induced food insecurity and loss of livelihood. After a devasting flood, recovering can be a difficult task that is full of uncertainty and misery. Ali found himself in a precarious situation following the disastrous floods that decimated his little town in D I Khan in 2010. Having lost both his house and means of support to the ruthless waves, he had to make the difficult choice to either rebuild in the unpredictably changing weather or go elsewhere for safety. Choosing the latter, Ali set out toward Rawalpindi, dragging the broken pieces of his history with him. *"Migration was more than just seeking safety for me," Ali thought to himself. "It served as evidence of my steadfast resolve. I persisted despite the difficulties because I thought that by making these sacrifices, a better life would become possible."* Ali saw migration as a symbol of his unwavering energy and resolve, rather than just a way out of hardship. Even though he was heartbroken to be apart from his family, he held onto the hope of a steady job and a new beginning. Now, while working nonstop in Rawalpindi, Ali's hands are building a new future out of the wreckage of his old one. Even if there may be many obstacles in his path, he doesn't waver in his conviction that a better tomorrow is possible with resiliency and persistence. We found similar stories and experiences from IDP camps, who fled their hometown owing to fragile conditions, and consistent fear, and for the sake of their families, and

a better future.

4.3.5. Capacity Building and Enhancement of Livelihood

Stories of overcoming adversity and adjusting to new circumstances come to light, offering encouragement and empowerment. People talked about how they had learned and developed, emphasizing the positive impact that education and skill acquisition can have during difficult circumstances. One farmer, who had seen the unpredictable nature of life, recounted his incredible journey of metamorphosis. His voice reeking of suffering, he said, *"I struggled to make ends meet." "But one day, I heard about a training program in sustainable agriculture... It was a beacon of hope amidst the darkness, offering me the tools and knowledge to cultivate a brighter future."* His remarks highlight the transforming impact of education and skill development in boosting adaptive ability and fostering sustainable livelihoods in the face of environmental uncertainty. They also connect with the unwavering spirit of resilience. Participants also discussed how capacity-building programs had a significant impact on how their lives were shaped.

A young entrepreneur discussed her journey of self-discovery, her eyes beaming with newly discovered confidence. "*The training program gave me the abilities and information I needed to launch my own company,"* she grinned. *"It helped me a lot, like a miracle, empowering me to chart my own course amidst the turbulent seas of uncertainty."* Her experience serves as a perfect example of the revolutionary power of capacity-building programs in opening up fresh doors to resilience and prosperity [74].

4.3.6. Access to Financial Capital and Markets

Access to financial resources and market opportunities emerged as lifelines in the fight against food insecurity and vulnerabilities caused by climate change in the crucible of economic precarity and environmental disruption. To provide paths to economic empowerment and resilience, participants emphasized the critical role that civil society groups and community-based initiatives play in promoting access to financial capital and market linkages.

A middle-aged male participant from DI Khan spoke about the transforming impact of financial support and communal solidarity, his voice filled with appreciation. "*We were able to overcome economic and environmental challenges thanks to the financial support we received from relatives and our connections with CSOs,"* he said respectfully. "It was a lifeline in our darkest hour, offering us a glimmer of hope amidst the storm." In addition to demonstrating the catalytic role that community support plays in promoting communal well-being and prosperity, his testimony sheds light on the symbiotic relationship that exists between resilience-building initiatives and economic empowerment.

Through an analysis of these coping strategies in the context of food insecurity brought on by climate change, our research identifies distinct patterns influenced by socioeconomic position and gender. distinct social strata give rise to distinct coping mechanisms, which are a reflection of unequal access to resources and opportunities. For instance, due to their limited resources and lack of employment possibilities, people from low-income socioeconomic backgrounds—such as widowed internally displaced women—often resort to asset liquidation as a last choice to survive, giving up priceless possessions.

Contrarily, middle-class households appear to prioritize affordability and buy optimization, presumably by consciously changing their food selections to cut expenses while maintaining a certain level of nutritious diversity. In these traditional tribal communities, people of all socioeconomic classes demonstrated how they use their informal financial and social capital to gain access to strong support systems and market connections, strengthening their resistance to food insecurity and climate change (Pashtun Society). However, women are more likely than men to encounter cultural norms and socioeconomic inequalities, which have a big influence on coping mechanisms. This intersectionality makes it clear that targeted interventions are needed to address the complex problems that people from different genders and socioeconomic backgrounds face. These interventions should support inclusive resilience-building programs that are tailored to meet a variety of community needs.

Many scholars[12, 17, 27, 60, 69, 77, 79, 103] also argue that focusing on adapting to climate variability is crucial for addressing climate change effectively, as it is a more immediate and tangible threat that farming and non-farming communities or individuals, and governments are more likely to comprehend and respond to[60, 69, 98]. Building knowledge and institutional capacity to cope with variability can pave the way for longer-term adaptations that safeguard livelihoods while ensuring resilience in the face of climate change. Central to this effort is also ensuring meaningful engagement with these diverse communities, and incorporating intersectional considerations such as gender, socio-cultural class, and religious perspectives to make these interventions more equitable and contextually relevant[12, 17, 18, 23, 27, 38, 42, 53, 56].

Consequently, as our results suggest, to apprehend the effectiveness of adaptation strategies, it is essential to consider the varying socio-economic, religious, class, gender, and local environmental context within which these adaptive strategies operate and should also consider how vulnerabilities vary across countries, regions, and social groups[17, 18]. Finally, institutional policies also play a crucial role in facilitating adaptation efforts, particularly through effective mechanisms such as agricultural systems, or access to formal credit and the dissemination of climate information through extension services[3, 46, 51, 74, 95, 97]. These interventions provide the necessary resources and support systems to enable farm households to implement effective adaptation measures.

Our study found a complex interplay between institutional, sociocultural religion and economy and the impact of climate change on food insecurity and found varying adaptation strategies within these distinct vulnerable communities. The effectiveness of climate change adaptation strategies hinges on recognizing the complex interplay of socio-religious, cultural, gendered, economic, and institutional factors that shape food security vulnerabilities. Our framework provides a novel lens to analyze these interconnected influences through qualitative field insights, revealing how both proactive (ex-ante) and reactive (ex-post) adaptation strategies are context-specific. Through our analysis and narrative inquiry, we examined the multifaceted challenges faced by these diverse individuals, grappling with environmental stressors. Our findings underscore the profound and differential impact of climate-induced disasters on livelihoods, food availability, and psychological well-being, consequently revealing the complex interplay of socio-economic, cultural, and gendered factors that shape vulnerability to food insecurity. Religious and cultural beliefs emerge as powerful determinants of perception and response to climate change and food insecurity, shaping individuals' adaptive strategies and coping mechanisms. The fusion of religious teachings with cultural practices imbues communities with resilience and fortitude, yet also presents barriers to seeking external assistance and addressing underlying vulnerabilities. Gender disparities, land distribution dynamics, and intra-household power dynamics further exacerbate food insecurity, highlighting the need for gender-sensitive and culturally appropriate interventions. Moreover, our study explains the inadequacy of existing economic, social, and policy systems in mitigating the impact of climate disasters on food security. Market failures, governance challenges, and policy shortcomings perpetuate cycles of poverty and inequality, amplifying the vulnerabilities of marginalized populations. The testimonies of individuals struggling to access nutritious food amidst economic hardship and environmental upheaval underscore the urgent need for systemic reforms that prioritize equity, social justice, and human rights. Nevertheless, amidst adversity, tales of resilience, solidarity, and adaptive capacity emerge as beacons of hope. Asset liquidation, purchase optimization strategies, and social support networks offer temporary relief and sustenance to vulnerable populations, underscoring the resourcefulness and ingenuity of communities facing adversity. Furthermore, capacity-building initiatives, access to financial capital, and market linkages empower individuals to navigate the complexities of climate change and build sustainable livelihoods.

Our study and framework underscore the necessity for interventions designed to address the specific needs of marginalized groups effectively and specific in nature considering the complexity of the nature of the challenge, the interplay between institutional, so-

ciocultural religion and economy and the impact of climate change, on food insecurity, and varying adaptation strategies within these distinct vulnerable communities. To enhance the effectiveness of climate adaptation efforts, it is important to integrate local knowledge systems and community-led strategies into broader policy frameworks. This approach not only respects local contexts but also ensures that adaptation measures are grounded in the lived experiences of those most affected. For instance, policies should integrate local knowledge and practices, recognizing how gender and social norms, religious and cultural beliefs shape food security, climate change perceptions, and access to resources and decision-making processes. Interventions tailored to these local contexts will ensure they are both practical and impactful, addressing both immediate needs and long-term sustainability.

Similarly, hearing community voice requires genuine participation. This involves actively involving those most affected by climate change and food insecurity in the decision-making process, and respecting these indigenous knowledge, practices, and experiences. Building partnerships with local leaders, grassroots organizations, and community representatives is essential for co-creating solutions that are relevant and effective. Meaningful engagement should include inclusive dialogues, representation of marginalized groups, and integration of their perspectives into policy and practice.

Likewise, comprehensive reforms are needed to address market failures, governance challenges, and policy shortcomings. Innovations in climate and socio-economic policy should focus on promoting equity and social justice, acknowledging differential impact and intersectional approaches, enhancing access to resources, and supporting marginalized populations and individuals (i.e. women, IDPs and others), Gender-sensitive adaptation strategies should be prioritized to address the unique vulnerabilities of women in climate-vulnerable communities. This requires targeted interventions that enhance women's access to resources, decision-making power, and adaptive capacities. This could also involve revising policies to improve agricultural and other market access, implementing robust social safety nets, and strengthening local networks, and capacities for disaster preparedness and response. Such as building the capacity of vulnerable groups is essential for fostering resilience. This includes providing access to financial capital, education, and training that empower individuals to navigate and adapt to climate challenges. Support for local entrepreneurship, improved market linkages, and skill development programs can significantly enhance adaptive capacity and sustainability.

Therefore, advancing towards sustainable and resilient food systems and effective climate adaptation requires a nuanced approach that acknowledges and addresses the intersecting factors of vulnerability. By focusing on specific, community-driven interventions, fostering genuine stakeholder engagement, and pursuing systemic reforms, we can better tackle the complexities of climate-induced food insecurity. This comprehensive strategy will contribute to a more resilient, equitable, and sustainable future for all.

4.3.7. Limitations and Future Research Directions

By amplifying the voices of those most affected by environmental stressors and identifying typologies of climate adaptation aimed at reducing food security crises, our study significantly contributes to the expanding literature on climate change adaptation and food security. We provide nuanced insights into the lived experiences of vulnerable communities, enriching our understanding of the complex dynamics at play. However, we acknowledge several limitations inherent in our study. While our sample size is adequate for in-depth qualitative analysis, its scope may limit the generalizability of our findings to broader populations. Conducting additional studies with larger and more diverse samples could help validate and extend our insights to different contexts. Moreover, the subjective nature of qualitative research introduces the potential for bias in data collection and analysis. Rigorous validation and scrutiny of findings are essential to ensure the credibility and reliability of our results. Additionally, our study captures a snapshot of climate impacts and adaptation strategies within a specific timeframe. Therefore, there is a need for more in-depth ethnographic and longitudinal research to track evolving vulnerabilities and resilience efforts over time.

Author Contributions

Conceptualization, data collection, analysis and interpretation and original manuscript writing and addressing reviewers/editorial comments, M.K.; supervision and study design, Y.Z.; Final manuscript preparation, M.K., editing of manuscript S.K. All authors reviewed and approved the final version of the manuscript for publication.

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Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the "Institutional Review Board (or Ethics Committee) of China Agricultural University (protocol code 10019 and date of approval 2022-05-16)" for studies involving humans.

Informed Consent Statement

Oral consent has been obtained from the participants to publish this paper.

Data Availability Statement

All data used in the study are available from the author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

Appendix A

Table A1. Participant's details.

S. No	Districts	Name	Employment	Age	Education Level	Venues for Interviews and FGDs
1)	DI Khan	Not disclosed	Mosque Leader	35	primary	Mosque and Hujras (local community centers), Office or and Residence of individuals
2)	Bannu	Not disclosed	Mosque Leader	40	middle	
3)	Bannu	Not disclosed	IDP	23	primary	
4)	Bannu	Not disclosed	Small farmer	43	primary	
5)	Bannu	Not disclosed	Landless Tenant	35	No education	
6)	Bannu	Not disclosed	Daily wage	40	primary	
7)	Bannu	Not disclosed	Daily wage	28	primary	
8)	Bannu	Not disclosed	Daily wage	26	No education	
9)	Bannu	Not disclosed	Daily wage	28	No education	
10)	Bannu	Not disclosed	Daily wage	35	No education	
11)	Bannu	Not disclosed	Local Government	29	Graduate	
12)	Bannu	Not disclosed	CBO	45	Higher Secondary	
13)	Bannu	Not disclosed	House wife	33	primary	
14)	Bannu	Not disclosed	Lady health worker	35	middle	
15)	Bannu	Not disclosed	House wife	28	No education	
16)	DI Khan	Not disclosed	IDP	33	No education	
17)	DI Khan	Not disclosed	IDP	26	No education	
18)	DI Khan	Not disclosed	Small farmer	33	No education	
19)	DI Khan	Not disclosed	Landless Tenant	31	No education	
20)	DI Khan	Not disclosed	Daily wage	29	No education	
21)	DI Khan	Not disclosed	Daily wage	45	No education	
22)	DI Khan	Not disclosed	Daily wage	40	primary	
23)	DI Khan	Not disclosed	Daily wage	35	middle	
24)	DI Khan	Not disclosed	Daily wage	35	No education	
25)	DI Khan	Not disclosed	NGO/CBO worker	29	Graduate	
26)	DI Khan	Not disclosed	NGO worker	40	Graduate	
27)	DI Khan	Not disclosed	House wife	35	Graduate	

Table A2. Selective codes and themes regarding food (in) security challenges amidst Climate stress in the study area.

S. No.	Open Codes	Axial Codes	Themes
1.	We don't know about food security	No knowledge of food security	Perception of food security, safety, and diet disparity
2.	Allah is the sole provider of all food and sustenance…	Religious beliefs shaping attitude towards food insecurity	
3.	Our kids sleep hungry	Stressful situation	
4.	We cannot beg for food or money	Shame and guilt	
5.	We don't have money	Financial instability/lack of money	
6.	We have so many kids, so we always have less food to eat	Family size	
7.	We eat whatever we get	lack of options/choices in food consumption and concerns over food safety	
8.	Our food is not good as compared to my neighbors		
9.	Cannot afford seed	No price control mechanism	Lack of institutions and policy measures
10.	No awareness of diet and food	lack of knowledge	
11.	Smugglers are free to do whatever they want	Increasing cost of agriculture inputs	
12.	Cannot afford food	Poor control of district authority	
13.	Urea and DAP cost is high	Rise in unemployment	
14.	Prices are uncontrolled	Inefficacy of subsidies	
15.	We only eat once a day	Limited access to food	
16.	No jobs for us	Poor infrastructures in villages and cities	
17.	War in Waziristan/Terror attacks	No financial support from government	
18.	We have less pension than my needs	Financial instability	
19.	We only eat cereals	Political instability	
20.	No health units	No regulation of flour mills and smuggling across boarders	
21.	Flour goes to Afghanistan	Low price of our crops	Improper or lack of economic system
22.	We don't get what we want to sell	Death of livestock	
23.	Middleman gets all shares	Significant and seasonal changes of price	
24.	Bank charge too much fee for buying seeds	Job insecurity	
25.	There is no life for poor labor	No food markets	
26.	Where can I find cheap food for my kids?	Improper roads	
27.	Did you see road while coming to our village?	More distance from market	
28.	I don't have car to travel	No food markets Improper roads More distance from market Suicide attacks	
29.	How to work when everyday there is bomb-blast	Life in stressful situation	War and Conflict in the region
30.	There is no security I will be back alive		
31.	I saw my son being killed in attack		
32.	Every moon soon we see more rain and loss of crops	Flooding in villages	Environmental-Economic stress and other hazards
33.	We need water for crops and animals	Drought	
34.	We used to have more goats now we don't	Low precipitation	
35.	My only cow died…	Fertility of livestock reduce	
36.	Land is infertile now	Land fertility or soil fertility lost	
37.	My child died due to heat in IDP camp	IDP Camp's fragility	
38.	My crop was lost due to pest attack	Pest attack	
39.	Lock down in covid19 took my job	Loss of job due to Pandemic	
40.	First, we all eat at one time	Change of eating in family Poor eating habits Land Inheritance and family disputes	Cultural barriers, social and demographic changes
41.	…I have five children, and after my death, my land will be divided among them	Land parcelization (due to inheritance)	

Table A2. *Cont.*

S. No.	Open Codes	Axial Codes	Themes
42.	My father and brother didn't give me my right of land as I am woman	Gender segregations and disparity	
43.	How can I feed a family of 16 people?	Higher Dependency ratio due to large family size	
44.	My aunt kept me as slave and didn't give me food after death of my parents	Poor cooperation among NGOs and government	
45.	District administration don't allow us to talk to local people	No systematic diet plans	
46.	My mother cook food and decide on food	Allocation of food in home	
47.	I eat better food than my siblings (sister)		
48.	I feel weak during work	Weakness in body	
49.	I can't focus during farming	Mental stress	Impact of food insecurity
50.	I feel guilt to ask for help…I don't allow my kids to play with other	Shame and stigma	
51.	I eat sometime but give food to my kids	Better food for kids or skip meal	
52.	My son must eat even if I don't eat	Sacrifice for kids	
53.	My wife eats better	Respect for family value and woman	
54.	I sold my wife jewelry…sold my bike	Selling assets for food	
55.	My mother is heart patient, we try to give her better food		
56.	I get loan from uncle	Financial support from relatives	Mitigation and adaptation strategy
57.	I one participated in training that improve my skills in organic farming	Training and livelihood improvement	
58.	I buy food when it gets cheaper. I don't buy fruits these days	Eating cheap food/staple crops only	
59.	Neighbors helped after I migrated. Host community was very cooperative	Social support from host community or groups	

Source: Author's field notes, observations, and FGDs excerpts (2022).

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