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Gender vulnerability and climate adaptation in high mountain regions: evidence from remote valleys in Gilgit-Baltistan

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ABSTRACT

This study explores the effects of climate change on vulnerable populations in Gilgit-Baltistan with a particular focus on gender inequality and adaptation measures. Using a mixed research method, this study explores how climate events, especially glacial lake outburst floods (GLOFs), altered precipitation patterns, and increased temperature disproportionally impact women in the remote regions. Data were collected through household surveys and interviews with the local communities in Darkut and Sosat valleys in Ghizer district of Gilgit-Baltistan. Results of the study show that despite men and women experiencing livelihood disruption, women undergo added difficulty considering prevailing socio-cultural norms, curtailed accessibility to resources, and limited mobility. This analysis underlines the utmost importance of gender-sensitive adaptation policies and grassroots level resilience plans. It also highlights the need to bridge Indigenous knowledge and scientific approaches for a local increase in adaptive capacity.

1. Introduction

Human-induced climate change is the result of more than a century of net greenhouse gas emissions driven by land use practices, energy consumption, and their transformations, as well as prevailing patterns of production and consumption (IPCC 2023). Its consequences are becoming increasingly costly, with the global economic toll of disasters mounting over recent decades. The direct costs of disaster averaged USD 70–80 billion per annum between 1970 and 2000, but this amount surged to USD 180–200 billion per year between 2001 and 2020, indicating an escalating financial burden (UNDRR 2025). Climate change not only threatens local ecosystems but also endangers livelihoods, infrastructure, and broader development prospects. In this context, adaptation has become a central pillar of climate resilience strategy. Effective adaptation includes strengthening infrastructure to withstand climatic extremes, promoting climate-resilient agriculture, improving water resource management, and implementing early warning systems (IPCC 2007). Achieving this, however, requires more than technical intervention, as it demands the integration of scientific knowledge, coherent policy development, and the active participation of local communities. Central to these efforts is the understanding of vulnerability, which the International Panel on Climate Change (IPCC) defines as a function of exposure, sensitivity, and adaptive capacity (IPCC, 2007).

Recent literature highlights the importance of the gendered dimensions of climate vulnerability. Li, Yu, and Lee (2025) argue that climate vulnerability significantly increases gender inequality in terms of food, health, and habitat, with impacts exacerbated in counties with existing gender

gaps. Likewise, Anjum and Aziz show that women in low- and middle-income countries face heightened health vulnerabilities, including maternal, neonatal, and mental health risks, alongside increased caregiving burdens. Madhuri (2025) and Adeola, Evans, and Ngare (2024) further highlight how limited access to resources, entrenched gender norms, and weak integration of gender concerns into climate policy reduce women's adaptive capacities. Ali et al. (2025) provide evidence that while men and women farmers possess similar awareness of climate change, women face distinct constraints in adaptation response. Aslam et al. (2022) and Shah, Rana, and Ali (2023) reveal that while communities recognise GLOFs and floods as a major threat, socioeconomic variables such as gender, education, and past experiences shape adaptation responses. Urbanisation further exacerbates vulnerability as rapid growth and weak governance strain resources and heighten exposure to hazards (Shah et al. 2025; Shah and Rana 2023). At the community level, Khalid et al. (2021) stress the importance of integrating gender into multi-dimensional vulnerability assessments, while Waseem and Rana (2025) identify structural and institutional barriers to effective adaptation.

The Gilgit-Baltistan (GB) region, situated within the Hindu Kush-Karakoram-Himalaya (HKH) range, exemplifies these challenges. GB is experiencing one of the fastest warming trends in Asia, with rising temperatures with the passing time (Ali et al. 2024). This warming has accelerated glacial melt, resulting in the formation of hundreds of unstable glacial lakes. Gilgit-Baltistan hosts around 3000 glacial lakes, 33 of which are classified as highly prone to glacial lake outburst floods (GLOFs) (Yahya et al. 2024). Records show an increasing recurrence of GLOF events, with at least 179 incidents reported in the Karakoram region between 1533 and 2020 (Bazai et al. 2021; Singh et al. 2023; Veh, Korup, and Walz 2020). The socio-economic impacts of these hazards are far-reaching, undermining agriculture, water security, health, and infrastructure. Yet, their effects are not evenly distributed, as women in mountain regions are particularly vulnerable due to entrenched socio-cultural norms, economic exclusion, limited access to education and resources, and marginal roles in decision-making processes (Gioli et al. 2014; Gurung 2012). Valleys such as Darkut and Sosat in the Ghizer district illustrate the multi-dimensional vulnerabilities of GB's mountain communities. Darkut Valley, located 167 km from Gilgit, is surrounded by glaciated peaks and has a high exposure to GLOFs, as evidenced by the devastating 2010 flood that caused extensive losses to housing, farmland, and infrastructure (Ali, Akhtar, and Hussain 2023). Similarly, Sosat Valley, 105 km from Gilgit, has experienced repeated flash floods and landslides in 1994, 2005, and 2012, triggered by glacial melt and ice collapses (Aslam et al. 2023; Haider et al. 2024). These hazards have led to food insecurity, biodiversity loss, and economic instability, making both valleys highly climate-sensitive and socially marginalised.

In the remote mountains of Gilgit-Baltistan, women's disproportionate exposure to climate change impacts, compounded by socio-cultural barriers to empowerment, necessitates an inclusive and gender-sensitive approach to resilience planning. However, the current literature is largely concentrated in urban regions and other areas where women have comparatively better access to education, health, decision making and other facilities. Thus, the gendered aspects of climate vulnerability and adaptation in remote high mountain regions remain unexplored in both empirical research and policy discourse. Furthermore, existing literature also highlights the importance of integrating Indigenous knowledge with scientific insights and ensuring women's participation in adaptation strategies (Khan, Ahmad Rana, and Nawaz 2020; Markkanen and Anger-Kraavi 2019). However, limited empirical research exists for the Ghizer district, particularly in valleys highly exposed to GLOFs and flash floods. Moreover, few attempts have been made to quantify gender-specific vulnerabilities through composite frameworks such as the Gender Vulnerability Index (GVI). This study addresses this gap by identifying gender-specific risks and vulnerabilities associated with climate change and GLOFs in the mountain communities of Gilgit-Baltistan, examining differences in exposure, sensitivity, and adaptive capacity between men and women, and proposing a gender-responsive and sustainable policy framework to strengthen local resilience and ensure equitable adaptation outcomes.

2. Methodology

Darkut and Susat are the most vulnerable valleys situated in the Ghizer District of Gilgit-Baltistan. Both valleys are extremely susceptible to the impact of climate change, with rising temperatures making the frequency and magnitude of glacial lake outburst floods (GLOFs) and other natural hazards more likely. The terrain's rough mountainous nature and its distinct socioeconomic compositions provide it with an ideal site to investigate gendered vulnerabilities to climate disasters. A mixed-research approach was employed that draws upon quantitative and qualitative information for an in-depth assessment of gendered-vulnerability to climate change. Data on knowledge, attitudes, and practices (KAP) were collected through the household survey, and information was collected through key informant interviews (KIIs) with the stakeholders. This two-fold approach allowed the inclusion of numerical data and contextual information, allowing for the exploration of gender-specific vulnerabilities, adaptations, and how social structures are steering climate adaptation in the study area (Figure 1).

A stratified sampling method was utilised to provide an appropriate representation of both valleys. Each valley represented a stratum, and homes were randomly picked within each stratum to fill out the survey. The sample size was ascertained according to Cochran's (1977) sample size formula:

$$n = \frac{N}{(1 + N(e))^2} \tag{1}$$

where n is the sample size, N is the population size, and e is the precision level desired. With a total population of 220 households in the study area, a 95 per cent confidence level, and a 5 per cent margin of error, the minimum required sample size was calculated as 141 households. To increase reliability and account for potential non-responses, we collected data from a total of 160 households

The household survey utilised a semi-structured questionnaire, framed with the input of subject experts, and a comprehensive review of literature. The questionnaire was divided into two parts: one related to demographic characteristics of households (e.g. household size, land ownership, sources of income, workforce composition, and dependency ratios) and the other regarding issues
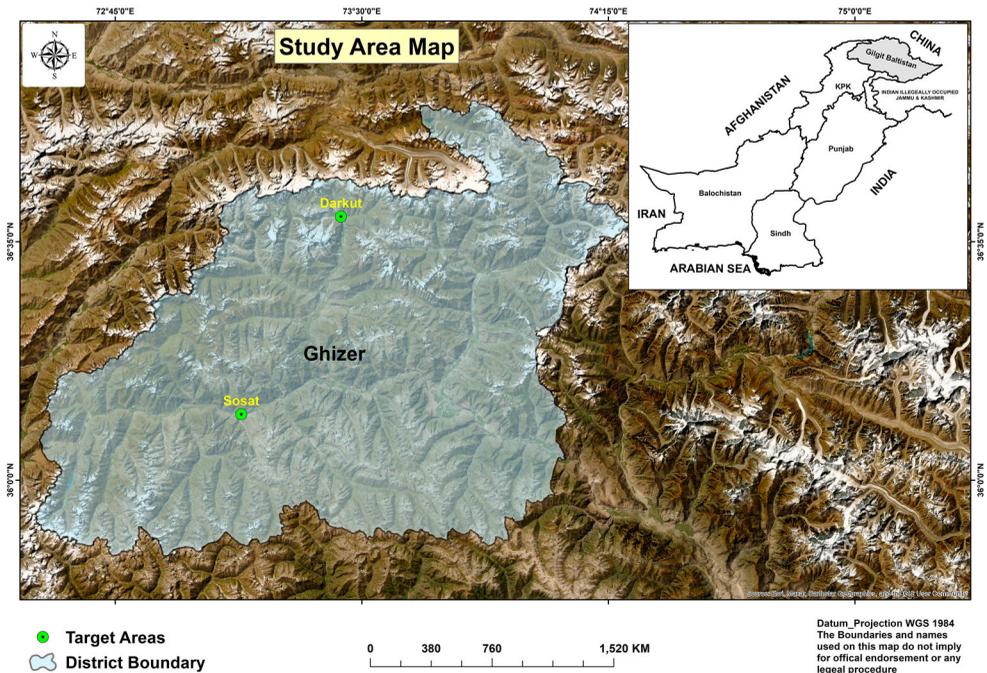

Figure 1. Map of study area (District Ghizer).

of gender vulnerability and coping capacity. This framework permitted both demographic background and an understanding of individual vulnerabilities and the availability of resources for men and women within households. To obtain qualitative information on gender-based adaptation measures and adaptive capacity, purposive sampling was adopted for the selection of participants for KIIs. Informants comprised policymakers, government officials at the local level, community leaders, and subject-matter experts who were well aware of the climate effects and gender relationships in the area.

2.1. Gender Vulnerability Index (GVI)

The research modified the Gender Vulnerability Index (GVI) framework to evaluate gender-specific vulnerability, borrowing from Scoones' (1998) sustainable livelihoods approach, which takes into account social, financial, physical, human, and natural capital as important factors. The GVI, borrowing from Basiru et al.'s (2022) approach, incorporates eight elements essential to gender vulnerability: human resource capacity, climate-related disasters, livelihood strategies, social networks, health, food and nutrition, water security, and access to technology. These factors are compiled into three dimensions of vulnerability – exposure, sensitivity, and adaptive capacity – using the IPCC model of vulnerability assessment.

The construction of the GVI entailed normalising every subcomponent on a 0–1 scale, with 0 indicating low vulnerability and 1 indicating high vulnerability. Standardisation was done utilising the following formula:

$$\text{Index}_{Sg} = \frac{(S_g - S_{\min})}{(S_{\max} - S_{\min})} \tag{2}$$

Here, Smin and Smax are the minimum and maximum of each subcomponent, respectively, and Sg represents each gender group's subcomponent score. After standardisation, sub-components were averaged through Equation (3) to obtain the value of every major component:

$$M_g = \frac{\sum_{i=1}^{8} \text{index } Sg}{n} \tag{3}$$

Here, Mg is one of the eight main components – "gender (g), human resource capacity (HRC), disaster due to climate change (NDC), livelihood strategies (LS), social network (SN), health (HE), food and nutrition (FN), water (WA), and technologies (TS)" – the index refers to the subcomponents, indexed by i, which make up each main component, and n refers to the number of subcomponents in each main component. The gender aspect of GVI was calculated by taking the average of the values resulting from the calculation of each of the eight major components for the gender, as shown in equation (4):

$$GVI_G = \frac{\sum_{i=1}^{8} WMiMGi}{\sum_{i=1}^{8} WMi} \tag{4}$$

which can also be explained as:

$$GVI_g = \frac{W_{HRC}HRC_G + W_{NDC}NDC_G + W_{LS}LS_G + W_{HE}HE_G + W_{SN}SN_G + W_{FN}FN_G + W_{WA}WA_G + W_{TS}TS_G}{W_{SDP} + W_{NDC} + W_{LS} + W_{HE} + W_{SN} + W_{FN} + W_{WA} + W_{TS}} \tag{5}$$

GVIg, "the Gender Vulnerability Index for gender g", refers to the weighted average of the eight main components. The weights of every primary component, WMi, are determined by the equal contribution of the subcomponents to the overall GVI. In this research, the GVI is measured on a 0 (least vulnerable) to 1 (most vulnerable) scale. The Gender Vulnerability Index (GVI) consists of eight main components: "human resource capability, climate change-induced disasters, livelihood

strategies, social networks, health, food and nutrition, water, and technology". Each dimension includes several indicators or subcomponents (Table 2). The GVI dimensions and indicators are designed after a brief literature study on the topic. Adaptive capacity was measured using the demographic attribute of gender, the diversity of livelihood options being used, and the resilience of social networks. Finally, sensitivity is measured by examining how a gender's food, water, and health security are faring at the moment. All indicators for the Gender Vulnerability Index (GVI) were converted into standardised indices using a 0–1 min – max normalisation. In this process, the minimum observed value for each indicator was set to 0 and the maximum to 1, with all other values rescaled proportionally. This allowed comparability across indicators of different units (e.g. years of education, household size, access to water). A score close to 0 indicates low vulnerability, whereas values closer to 1 indicate high vulnerability (Table 2).

3. Results and discussion

3.1. Socioeconomic and demographic profile

Table 1 presents the demographic and socioeconomic profile of 160 Darkut (123) and Sosat (37) respondents from District Ghizer. The region is predominantly men-headed households (126), with 34 women-headed households. Most respondents belong to the older age groups (36–55 and 56+), and almost all are married. Unemployment (47 respondents) is extremely high, followed by housewives and private jobholders. Education levels are quite low, with 63 respondents not being educated and only some with bachelor's and master's degrees. Table 1 further shows that 48.1 per cent of households have a low dependency[1] ratio, indicating a favourable balance between working-age members and dependents. However, 43.75 per cent face a high dependency

Table 1. Descriptive statistics.

Respondent profile	Darkut (*N*)	Sosat (*N*)	Total
Total households	180	40	220
Sample size	123	37	160
Man household head	103	23	126
Woman household head	20	14	34
Age: Below 18	0	0	0
Age: 19–35	9	10	19
Age: 36–55	47	14	61
Age (56 and older)	67	13	80
Marital status: married	123	34	157
Marital status: unmarried	0	3	3
Marital status: others	0	0	0
Occupation (government job)	9	9	18
Occupation: private job	21	7	28
Occupation: unemployed	42	5	47
Occupation: housewife	20	13	33
Army retired	22	1	23
Occupation: business	9	2	11
Education level (uneducated)	47	16	63
Education: primary	7	2	9
Education: middle	14	5	19
Education: high	38	7	45
Education: intermediate	11	4	15
Education: bachelor	6	1	7
Education: master	0	2	2
Household size less than 5 (small H size)	18	13	31
6–10 (medium household size)	76	20	96
11 and above (large household size)	29	4	33
Dependency ratio			
Less than 50 per cent (low dependence)	64	13	77
50–75 per cent (moderate)	18	10	28
Above 75 per cent (high dependence)	56	14	70

Table 2. Indexed sub-component, major components.

Major dimensions	Sub-components	Sub-components indices Men	Sub-components indices Women	Major component indices Men	Major component indices Women	Two Sample t-test T-value	Two Sample t-test p-value
Human resource capacity	Dependency ratio	0.51	0.46	0.24	0.39	4.8	0.00
	Age of household	0.39	0.46				
	Education level of household	0.13	0.35				
	Household size	0.02	0.31				
Disaster	Gender experienced climate change extreme events	0.37	0.59	0.45	0.56	3.18	0.00
	Gender received any warning about climate-related disaster	0.27	0.29				
	Gender died or injured by any climate-related hazards	0.02	0.05				
	Livestock of gender died or injured in disaster	0.9	0.91				
	Gender migrated temporarily due to climate change extreme events	0	0				
	Gender experienced erratic rainfall patterns in the last 10 years	0	0				
	Level of temperature increases over last 10 years	0	0				
	Disaster destroyed farmland or properties of household	0.89	0.97				
Livelihood strategies	Total land available for frits/agriculture or forest	0.44	0.31	0.23	0.37	3.8	0.00
	Households depend on agriculture as a main source of income	0.59	0.79				
	Members of the household family go to the city or foreign country for work	0.13	0.11				
	Gender raise animals	0	0				
	Gender grow crops	0.07	0.09				
Health	Time takes to get health facilities	0.38	0.47	0.09	0.14	2.53	0.04
	Household family with chronic illness	0.52	0.58				
	The household family has been sick for the past 3 weeks	0.03	0.05				
	Gender died in family due to climate-related disaster	0.007	0.03				
Social network	Household received help by relatives or friends in the past month	0.89	0.61	0.5	0.54	2.4	0.05
	Household helped family of friends in the past month	0.92	0.79				
	Household borrowed money from relatives in past month	0.32	0.76				
	Household lent any money to friends of relatives in the past month	0.37	0.49				
	Household or family members go to community leaders for help	0.55	0.61				
	Gender belongs to NGOs or affiliated body	0.26	0.29				
Food and nutrition	Gender having sufficient food throughout a year	0.67	0.73	0.1	0.18	3.02	0.00
	Gender having adequate food for the whole year	0.24	0.11				
	Gender-collect non-timber forest plants for consumption	0.38	0.58				
	Crops that households harvest to eat during different times of the year	0.38	0.42				
	Gender suffered from any nutritional deficiency	0.63	0.67				
	Gender use firewood as a source of energy for cooking	0.2	0.26				
	Time is taken to spend on fuel wood collection from the forest	0.35	0.35				
Water	Households having constant water supply for irrigation	0.85	0.67	0.24	0.28	2.0	0.05
	Gender heard about any conflict over water in the community	0	0				

Table 2. Continued.

Major dimensions	Sub-components	Sub-components indices		Major component indices		Two Sample t-test	
		Men	Women	Men	Women	T-value	p-value
	Household access to safe or clean water for drinking	0.76	0.78				
	Households collect water from	0.32	0.33				
	Time taken to get water resources for a household	0.37	0.39				
Technology	Household access to cell phone	0.99	0.26	0.4	0.75	3.41	0.00
	Household access to the internet	0.49	0.68				
	Households use inorganic fertilisers for crop production	0.03	0.02				
	Households use animal traction in agricultural production	0.63	0.76				
	Households receive any weather projection	0.36	0.39				

burden, suggesting economic pressure due to a larger proportion of non-working members. Only 17.5 per cent fall into the moderate range, highlighting a community with contrasting household dependency structures. Dependency ratio is the ratio of dependents – people younger than 15 or older than 64 – to the working-age population – those aged 15-64.

Table 1 further shows that most people (50 per cent) fall in the age category of 56 years and older, followed by 38 per cent aged between 36 and 55. The least populated age group (19–35) is only 12 per cent. Marital status-wise, the vast majority of the respondents were married (157 people), with only a few (3 people) classified as unmarried. Employment data indicate that 46 respondents were involved in regular employment within the government and private sectors. In contrast, a great majority of the population included unemployed persons (47), housewives (33), and retired military personnel (23). More than 11 respondents indicated being self-employed in business ventures, as presented in Table 1. Educational statistics from Table 1 indicate that most of the respondents (63) are uneducated, with progressively fewer people with increasing levels of education. High school education is the most prevalent among the educated classes (45), and only 2 people have achieved a master's degree. This portrays significant education inequalities and poor access to higher education in the study region. Table 1 also demonstrates the prevalence of dependency ratios within three groups: low, moderate, and high. The sample population has a majority (77) in the low dependency group, followed by 70 with high dependency, and only 28 with moderate dependency. Darkut has a higher density in both the low and high dependency groups, while Sosat has a more even distribution. In total, low dependency households overwhelm the sample population.

The Gender Vulnerability Index (GVI) outcomes in Darkut and Sosat valleys indicate significant differences between men and women in major vulnerability dimensions, with GVI scores between 0.09 and 0.75 (Table 2). Women have higher overall vulnerability in human resource capacity (0.39 compared to 0.24), mainly because of lower education, larger household sizes, and older household age profiles. In disaster, women suffer more, with increased vulnerability indices in farm damage, climate-related injury, and animal loss. Livelihood strategies also emphasise women's reliance on small agricultural land and income streams, particularly in crop production (0.79 compared to 0.59 for men). Women also have greater health-related vulnerabilities, as signalled by greater travel time to health facilities, higher incidence of illness, and a higher percentage of climate-related family deaths.

Social networks-wise, men exhibit more robust immediate support systems, whereas women depend on borrowing and community networks. Nutritional and food security issues are more pronounced in women, who experience reduced food adequacy and increased nutritional deficiencies with better year-round access to food. While both sexes report similar problems with water collection, men have access to more dependable irrigation water. Notably, women show comparatively

Table 3. Major components, indexes, and the Gender Vulnerability Index.

Major dimensions	Computed index		
	Man	Woman	Total
Human resource capacity	0.24	0.39	0.63
Disasters due to climate change	0.45	0.56	1.01
Livelihood strategies	0.23	0.37	0.6
Health	0.09	0.14	0.23
Social network	0.5	0.54	1.14
Food and nutrition	0.1	0.18	0.28
Water	0.24	0.28	0.52
Technologies	0.4	0.75	1.15
GVI	0.28	0.40	0.34

improved access to some technologies, such as the internet and farm equipment, even though men possess virtually universal access to mobile phones. In general, these results highlight substantial gender-based differences in vulnerability and adaptive capacity when faced with climate change.

3.2. Major components, indexes, and the Gender Vulnerability Index

Table 3 displays the calculated indices of man and woman vulnerability to climate change in terms of several dimensions in Darkut and Sosat. Results show women to be more vulnerable than men in terms of human resource capability (0.39 vs. 0.24), exposure to climate-related disasters (0.56 vs. 0.45), livelihood strategies (0.37 vs. 0.23), health (0.14 vs. 0.09), social network (0.54 vs. 0.50), food security (0.18 vs. 0.10), access to water (0.28 vs. 0.24), and technology (0.75 vs. 0.40). The cumulative Gender Vulnerability Index (GVI) also further supports higher total vulnerability for women (0.40) over men (0.28). These results demonstrate women's reduced ability to cope with and adjust to climate change, highlighting the importance of gender-sensitive resilience enhancement interventions.

Figure 2 is the gender vulnerability radar diagram that shows the computed indices for the key components of the Gender Vulnerability Index (GVI) and the composite GVI for women and men. The figure clearly shows that women are more vulnerable in all the key dimensions, such as human resource capacity, climate-related disasters, livelihood strategies, health, social networks, food and
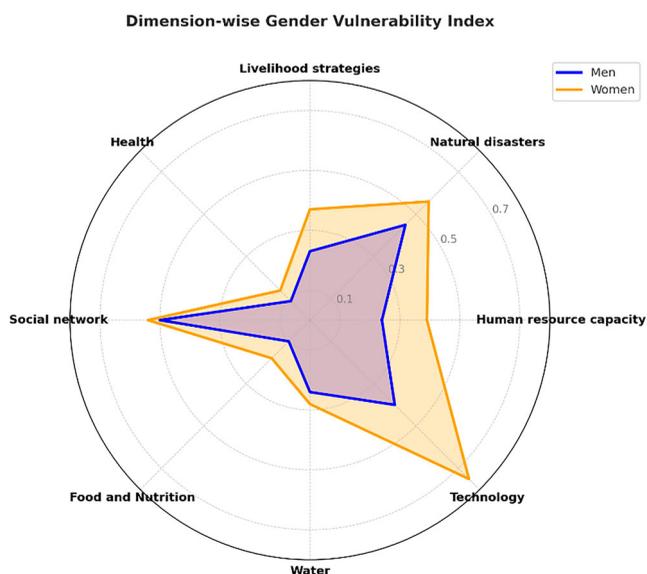
**Figure 2.** Spider diagram for 8 major components of GVI.
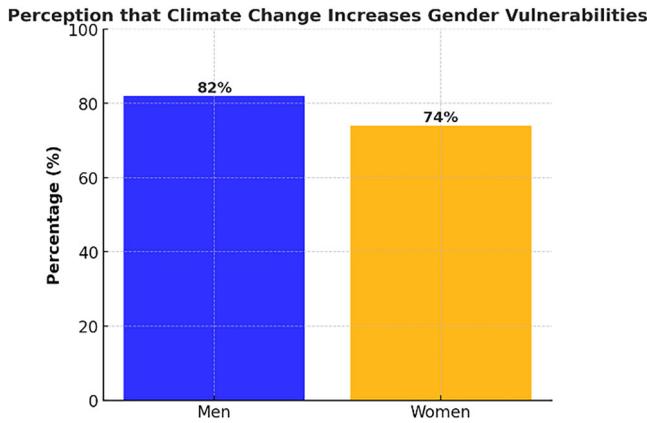
Figure 3. Climate change increasing gender vulnerabilities.

nutrition, access to water, and technology. These results are in agreement with the data depicted in Tables 2 and 3, which reassert the higher vulnerability of women to climate change effects.

3.3. Perception and adaptation to climate change (PACH)

The gender-disaggregated analysis of climate change perceptions and adaptation responses (Figures 3–7) highlights notable differences between men and women in the study area. A higher proportion of men (82 per cent) than women (74 per cent) recognised that climate change is increasing gender vulnerabilities (Figure 3), and men (80 per cent) also reported being "very concerned" about its impacts on livelihood sources compared to 74 per cent of women (Figure 4). In terms of adaptive actions, 72 per cent of men indicated that their communities had taken steps to adjust livelihood practices, whereas slightly fewer women (68 per cent) reported such initiatives (Figure 5).
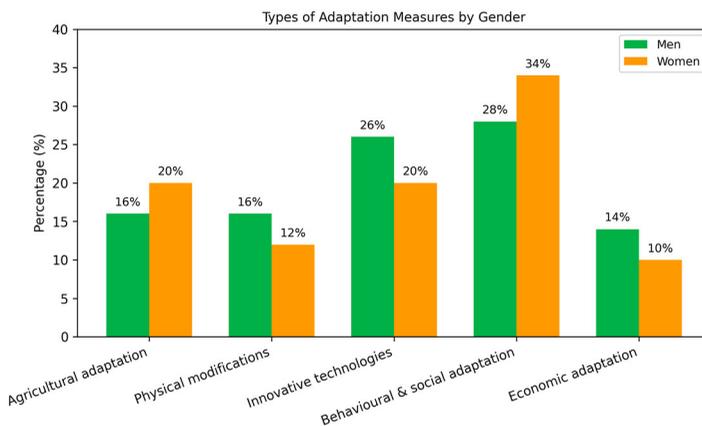
The types of adaptation measures further reveal gendered priorities: men emphasised innovative technologies (26 per cent) and physical modifications (16 per cent), while women leaned more towards behavioural and social adaptation (34 per cent) and agricultural adjustments (20 per cent) (Figure 6). Regarding support needs, women expressed stronger demand for financial assistance (44 per cent) and education and awareness programs (22 per cent), while men highlighted infrastructure development (18 per cent) and technical assistance (14 per cent) (Figure 7).
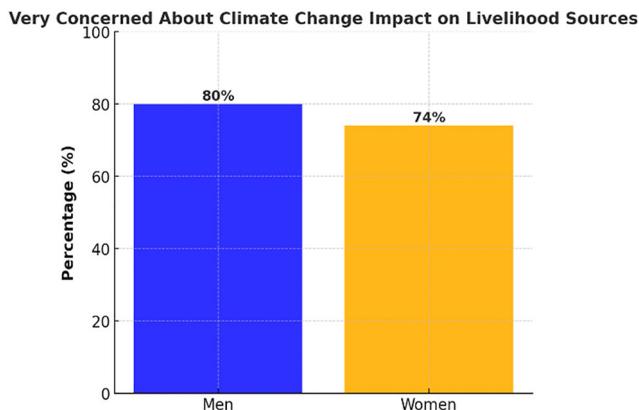
Figure 4. Concerned for the impact of climate change on livelihood sources.
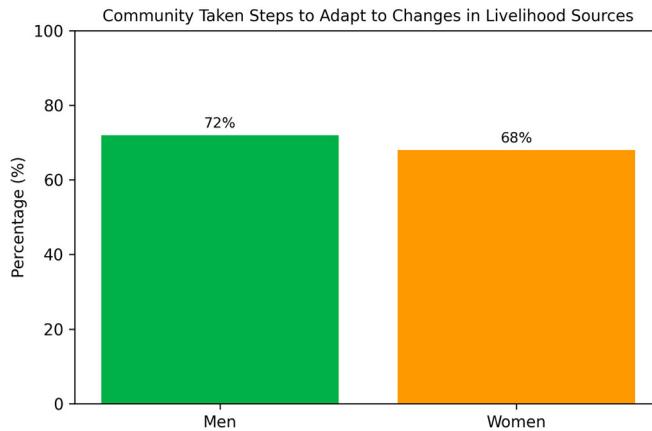
Figure 5. Community taken steps to adapt to changes in livelihood sources.

Figure 6. Types of adaptation measures climate change effects on livelihood sources.

4. Discussion

Results of this study show that women experience greater exposure to climate disasters, with higher reported losses in farmland, property, and household resources. Women are also more likely to report climate-related injuries and loss of animals compared to men. This heightened exposure reflects their dependency on natural resources for domestic survival and subsistence agriculture. Literature in the Himalayan regions has documented similar patterns showing that women's roles in food production and water collection directly link them to climate-sensitive environmental risks and amplify their exposure to hydro-meteorological hazards (Singh et al. 2023). At the same time, Aslam et al. (2022) and Shah, Rana, and Ali (2023) demonstrate that perceptions of GLOFs and floods are shaped by socio-economic variables, including gender and education, echoing the differentiated exposure found in this study. While men's exposure, in our case, was concentrated in livestock and cash crops, women's exposure spanned food, water, and health domains, underscoring the feminisation of exposure in mountain contexts. Women reported longer travel times to health facilities, higher prevalence of chronic illnesses, and more frequent nutritional deficiencies than men. Women-headed households were particularly disadvantaged, with lower adequacy of food throughout the year and greater dependence on non-timber forest products for survival. These findings are
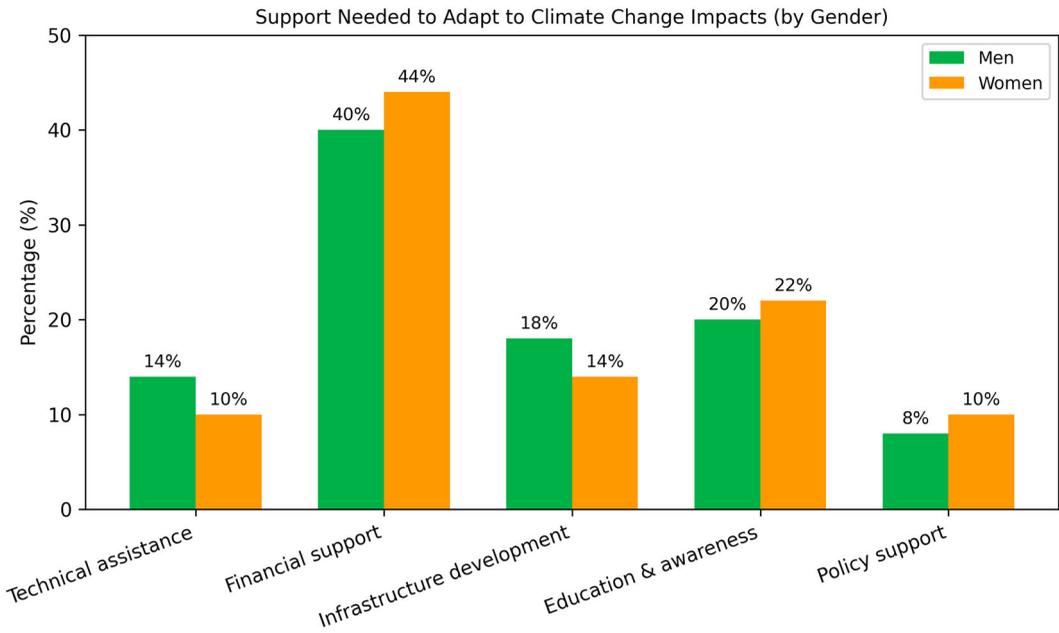
Figure 7. Support needed to adapt climate change impacts on gender vulnerabilities.

consistent with Wrigley-Asante et al. (2019), who observed that women in Ghana were more sensitive to climate impacts on food security due to their reliance on climate-sensitive crops. Similarly, Radonic and Jacob (2021) emphasised the disproportionate burdens women face in contexts of water scarcity, which this study also confirms through evidence of women's increased workload in water collection and related health risks.

The study found that women demonstrate systematically lower adaptive capacity than men across most domains. Educational disadvantage was a critical factor: women's lower levels of formal education reduced their ability to interpret climate information, adopt new technologies, and diversify livelihoods. These results align with Alhassan and Maiga (2025), who showed that lower education levels perpetuate intergenerational vulnerability by limiting adaptive choices. Livelihood strategies also reveal sharp gender differences. Women relied heavily on small-scale farming and crop production, while men engaged more in wage labour, business, and migration. The narrow livelihood base among women heightens their vulnerability, a finding consistent with Van Huong et al. (2022), who demonstrated that livelihood diversification is central to reducing climate vulnerability in rural Vietnam. At the community level, Khalid et al. (2021) highlight that multidimensional frameworks must integrate gender explicitly, a methodological choice this study adopts through the GVI. Similarly, Waseem and Rana (2025) identify structural and institutional barriers that hinder adaptation, which corresponds to the constraints faced by women in Darkut and Sosat, particularly in terms of education, health access, and livelihood opportunities.

Social networks emerged as another important dimension. Women reported greater reliance on borrowing and community support, while men reported stronger reciprocal and external connections. Although women's reliance on community-based networks provides short-term coping capacity, the dependency-oriented nature of these networks limits their potential to build resilience. This finding resonates with Phan, Jou, and Lin (2019), who emphasised that the quality of networks – trust, reciprocity, and resource mobilisation – is more critical than their mere presence. Shah and Rana (2023) also stress the weakness of institutional mechanisms in Gilgit, including limited participation, poor land-use planning, and resource constraints, which compounds the dependency

observed among women's networks. Additionally, rapid urbanisation in Gilgit, as documented by Shah et al. (2025), is straining natural resources and exacerbating hazard risks, further contextualising the constraints women face in adapting to climate change in mountain regions.

The study's results emphasise the need for gender-sensitive adaptation strategies that address structural inequalities alongside environmental risks. Policies should focus on improving women's access to education and healthcare, reducing domestic burdens through clean water and renewable energy infrastructure, expanding livelihood diversification, enhancing women's participation in co-operatives and local governance, and ensuring equitable access to communication technologies and climate information.

The urgency of addressing these gendered vulnerabilities is further underscored by the most recent floods in Gilgit-Baltistan during July – August 2025, which inflicted unprecedented damages across the region. In Ghizer, a glacial lake outburst flood created an artificial lake that submerged five to ten kilometres of road and hundreds of homes; these events, which also devastated agricultural land, orchards, irrigation channels, and public utilities, highlight both the intensifying frequency of extreme events and the compounding social and economic consequences for mountain communities. Situating the findings of this study within the context of the 2025 floods emphasises the urgent need for gender-responsive adaptation policies, as women are likely to bear the brunt of such escalating disasters.

5. Conclusion

This study examined gendered vulnerabilities to climate change in the Darkut and Sosat valleys of District Ghizer, Gilgit-Baltistan, by applying a Gender Vulnerability Index (GVI) framework. The findings show that women consistently face higher vulnerability across most dimensions, including health, food and nutrition, water access, livelihoods, and disaster exposure, reflecting not only their direct interaction with climate-sensitive resources but also the constraints imposed by entrenched socio-cultural norms. Men were comparatively more vulnerable in specific areas, such as dependency ratios and livestock losses, but their greater diversification of livelihood strategies and stronger social networks enhanced their adaptive capacity overall.

The results support and extend the sustainable livelihoods framework and feminist political ecology perspectives, showing that women's deficits in human, social, and financial capital intensify climate-related risks in mountain environments. Methodologically, the research demonstrates the value of applying a composite GVI to capture multi-dimensional and intersectional vulnerabilities at the community level. For policy, the evidence underscores the need for gender-responsive adaptation strategies that reduce women's sensitivity and enhance their adaptive capacity. Priority actions include expanding women's access to education, vocational skills, and credit facilities; strengthening their role in community decision-making forums; and improving access to health and water services. Equally important is the integration of Indigenous knowledge with scientific approaches to ensure locally relevant and culturally appropriate adaptation strategies.

While the study is limited to two valleys within Ghizer District and cannot be generalised to all mountain communities, its findings offer transferable lessons for other hazard-prone regions of Gilgit-Baltistan and similar high-altitude landscapes. Addressing gendered vulnerabilities is not only a matter of equity but also a critical pathway towards building sustainable resilience in climate-sensitive mountain societies.

Note

1. Dependency ratio here refers to the proportion of dependents (below 15 and above 64 years) to the working-age population (15–64 years), used as an economic indicator of household vulnerability.

Author contributions

CRediT: **Kifayat Ullah:** Conceptualization, Formal analysis, Methodology, Software; **Fatima Hasrat:** Data curation, Validation, Writing – original draft; **Zia Ud Din:** Investigation, Methodology, Supervision, Writing – review & editing; **Amjad Ali:** Project administration, Software, Writing – review & editing.

Disclosure statement

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