CLIMATE CHANGE PERCEPTIONS AND WATER RESOURCE IMPACTS IN THREE HIMALAYAN TOWNS

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ABSTRACT: This study examines the perception of climate change and water resource impacts in three Himalayan towns, namely, Gilgit, Murree, and Abbottabad. The study used household-level data collected through a semi-structured survey to understand awareness and perceived Changes in water availability, perceived impacts on water resources and extreme weather events, changes in water usage patterns and adaptation Strategies, household concerns regarding water resources, perceived changes in climate patterns, and community perception of government response. Data is presented through comparative tables and visual charts highlighting differences and similarities across the towns. Results demonstrate that awareness of climate change is high in all three communities, and concern about increasing water scarcity, declining water quality, and increased extreme weather events is widespread. Increased temperatures and altered precipitation patterns also ranked high and reflected a strong awareness of the environment. Although adaptive responses, including reduced water use, collection of rainwater, and alternative water sources, were prevalent, economic incentives—particularly rising water prices—proved extremely influential in Murree and Abbottabad. Public dissatisfaction in national-level responses and perceptions of poor local climate and water governance were evident despite community-level understanding and adaptation, with most participants expressing disappointment in local governance of climate and water issues. The results across all the thematic areas reveal a multifaceted understanding of community perceptions surrounding climate change and water resource challenges in the Himalayan towns of Gilgit, Murree, and Abbottabad. These findings provide critical insights into how local populations are experiencing, interpreting, and adapting to environmental changes.

Key Words: Climate change perception, water resources, community awareness, adaptation strategies, Himalayan towns, water scarcity, water quality, local governance, climate resilience.

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INTRODUCTION

The Himalayas, an ecologically rich and geographically complex system, are not just a geographical feature but South Asia's water security lifeline. The Himalayas are known as the "Third Pole" outside the polar Region and have the second-highest reserve of glacial ice after the Arctic and Antarctic. It spans eight countries encompassing a 3.5 million square kilometer land area consisting of India, China, Pakistan, Afghanistan, Nepal, Bhutan, Myanmar, and Bangladesh (Sharma *et al*., 2015; Schimid *et al*., 2015). It provides essential freshwater to almost three billion people across an enormous network of rivers, glaciers, and lakes and acts as the "Water Tower of Asia" (ICIMOD, 2015). The Region provides a vital source of water for agriculture, drinking water, hydropower, and other socio-economic activities, and it is pivotal for livelihood and environmental sustainability throughout South Asia (Immerzeel *et al*., 2020).

However, the urgency of the situation is stark. Due to their importance, the Himalayas are subject to significant threats from climate change. Glaciers in Himalayan regions have been melting at an alarming rate with temperature increases. This has led to some glacial lakes risking glacial lake outburst floods (GLOFs) (Bajracharya *et al*., 2019). Changes in patterns of monsoons, as well as extreme weather events such as floods and droughts, have also increased in frequency and intensity, thereby contributing to increased scarcity and variations in water quality (IPCC, 2019). Combined with the rapid expansion of urban areas, increasing population, and weak governance, these climatic changes have exacerbated water-related problems in Himalayan towns. These towns are prone to irregular Rainfall, glacial melting, higher sedimentation rates, and extreme environmental events, which threaten the sustainability of water resources, and lead to water stress and socio-economic vulnerability (Bolch *et al*., 2012; Immerzeel *et al*., 2010).

The Himalayan region is not a homogenous area, with thousands of towns. Three, Gilgit, Murree, and Abbottabad, were selected for this research study because of their unique climatic conditions, water management issues, and distinct governance dynamics. Figure 1 represents the geographical location of Gilgit, Murree, and Abbottabad in the Himalayan region of Pakistan, south Asia.

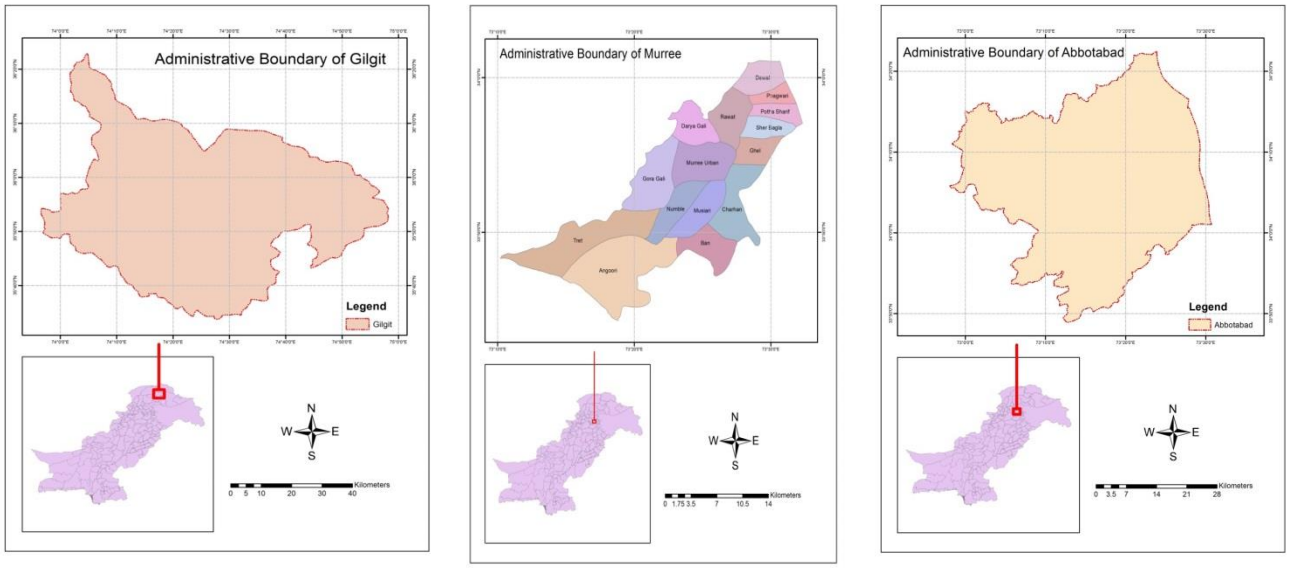

Figure 1 Geographic Location of Gilgit, Murree, and Abbottabad in the Himalayan Region of Pakistan, South Asia.

The main objective of this study is to assess how local communities in the Himalayan towns of Gilgit, Murree, and Abbottabad perceive the impacts of climate change, particularly concerning water availability, quality, and resource management. Therefore, this study seeks to explore six thematic areas: awareness and perceived Changes in water Availability, perceived impacts on water resources and extreme weather events, changes in water usage patterns and adaptation Strategies, per household concerns regarding water resources, perceived changes in climate patterns, and community perception of government response.

RESEARCH METHODOLOGY

A comprehensive semi-structured household survey was performed in Gilgit, Murree, and Abbottabad to explore climate change perceptions and water resource impacts. The questionnaire ensured consistency in data collection across the respondents and enabled comparability of data aggregated across the different selected Himalayan towns.

Sample Size Determination for Household Survey: Cochran's formula was applied to determine the sample size to maintain statistical validity. This formula, commonly used in public health and social science research, enables precise and cost-effective sampling.

Step 1 (Sample Size for an Infinite Population): The Cochran's infinite population formula is:

$$n_0 = \frac{Z^2 P(1-P)}{e^2}$$

Where:

- n_0 = required sample size for an infinite population
- Z = standard normal variate for 95% confidence level (1.96)
- P = estimated population proportion (0.5 for maximum variability)
- e = margin of error (5% or 0.05)

Substituting values:

$$n_0 = \frac{(1.96)^2 \times 0.5 \times (1-0.5)}{(0.05)^2}$$

$$n_0 = \frac{3.8416 \times 0.25}{0.0025} = \frac{0.9604}{0.0025} = 384.16$$

Now, the sample size is 384 households for an infinite population.

Step 2: Adjusting for Finite Populations: The adjusted sample size for each town is calculated according to the following formula:

$$n = \frac{n_0}{1 + \frac{n_0 - 1}{N}}$$

Where:

- n = adjusted sample size
- N = total number of households in each town

- n_0 = initial sample size (384)

Applying this formula for each town:

Gilgit (Total number of households in the urban municipality: 11,546; data source: GOP, 2017)

$$n = \frac{384}{1 + \frac{384 - 1}{11{,}546}}$$

$$n = \frac{384}{1 + \frac{383}{11{,}546}}$$

$$n = \frac{384}{1 + 0.0332} = \frac{384}{1.0332} = 372$$

Murree (Total number of households in an urban municipality: 26,650; data source: Population Census 2017, FBS, GOP)

$$n = \frac{384}{1 + \frac{384 - 1}{26{,}650}}$$

$$n = \frac{384}{1 + \frac{383}{26{,}650}}$$

$$n = \frac{384}{1 + 0.0144} = \frac{384}{1.0144} = 379$$

Abbottabad ((Total number of households in urban municipality: 44,308; data source: Population Census 2017, FBS, GOP)

$$n = \frac{384}{1 + \frac{384 - 1}{44{,}308}}$$

$$n = \frac{384}{1 + \frac{383}{44{,}308}}$$

$$n = \frac{384}{1 + 0.0086} = \frac{384}{1.0086} = 381$$

These sample sizes guarantee a statistically robust outcome with efficiency. The 95% confidence level & 5% margin of error ensure reliability in policy recommendations and governance strategies.

RESULTS AND DISCUSSION

Perceived Changes in Climate Patterns: In Gilgit, 82% of households reported a positive association with increasing temperatures. This significant majority suggests that most residents have observed regional warming in their local landscape. Seventy-three percent of households perceived a decline in rainfall, while only 27% reported an increase in rainfall. Additionally, 58% of households noted a rise in the number of extreme events, such as floods, landslides, and severe weather.

In Murree, 64% of households reported decreased rainfall, compared to 73% and 66% of households in Gilgit and Abbottabad, respectively, who experienced similar trends over the past decade. Interestingly, a larger proportion of Murree residents (36%) believed in an increase in rainfall compared to those in Gilgit. Notably, 63% of households in Murree, 64% in Abbottabad, and 58% in Gilgit were aware of the increasing frequency of extreme events, indicating a growing understanding of the risks posed by climate change. The results of the household survey are presented in Table 1.

A cluster bar chart (Figure 2) is derived from the numerical values in Table 1. The chart illustrates that residents in all three towns perceive a rise in extreme events, a decline in rainfall, and an increase in temperature. This visual representation of household responses highlights the critical need for adaptive measures and disaster risk reduction strategies. In conclusion, household perceptions in the three towns indicate notable changes in climate patterns, including rising temperatures, shifting rainfall trends, and an increase in extreme weather events.

Awareness and Perceived Changes in Water Availability: All the towns had high awareness levels regarding climate change, with the majority of the surveyed households recognizing that climate variation exists and has climate-related impacts, particularly for water availability. Such widespread awareness correlates with the strong perception of declining water resources, especially scarcity and deteriorating water quality as intensely reported by household residents in Gilgit and Abbottabad. Table 2 depicts the features of the awareness and perceived variation of water availability. This is the percentage of household residents who are aware of climate change and its effects on water resources and the percentage of household residents who have experienced a decrease in water availability.

Table 2 results also suggest fairly high awareness of climate change, with the households reporting high levels of awareness: 87% in Gilgit, 85% in Murree, and 84% in Abbottabad. Only 14% in Gilgit, 15% in Murree, and 16% in Abbottabad reported being unaware demonstrating that a majority are aware of ongoing climatic shifts and their consequences.

A majority of household residents say less water is available. In Gilgit and Abbottabad, 71% of households observed a decline in water access, while 68% in Murree reported the same. These figures reflect an increasing awareness of local water shortages To represent Table 1 data, a clustered bar graph (Figure 3) is generated with three clusters (Gilgit, Murree, and Abbottabad) for awareness, unawareness, and perceived decrease in water availability. In this chart, bars for climate change awareness are higher than those for unawareness, and perceived water availability declines, reinforcing the visual link between community awareness and water scarcity perception.

Perception of water scarcity and water quality degradation: The data analysis revealed that the perception of water scarcity in all three towns – 70% of

Gilgit, 68% of Murree, and 67% of Abbottabad – is high. The perception of high water scarcity is linked to geographical and climatic conditions. On the flip side, the perception of water quality deterioration is just as common, with the issue identified by 66% in Gilgit, 67% in Murree, and 65% in Abbottabad. There is an escalating perception that water quality is decreasing, potentially because more sediment is released as the glaciers retreat, cities are polluting the water due to their runoff, and inadequate waste management. Results are summarized in the following table 3.

The clustered bar graph (Figure 4) derived from this table vividly depicts the facts. Essentially, numerical values given in percentages highlight the need for priority water resource management and climate adaptation in the Himalayas.

Household Concerns Regarding Water Resources: The most serious issue in Gilgit is water scarcity, with 83% of households reporting it. It accounts for a significant percentage of the region's population, which already faces drinking water shortages that could worsen due to climate change effects such as glacial melting and shifts in precipitation patterns. For Murree, 72 % of households are concerned about a water shortage, another big but less urgent problem than in Gilgit. Water quality is another big problem, and 76% of Gilgit households report no satisfaction with water quality. The survey shows that only 7% of the households in Gilgit are worried about more expensive water, but water availability and quality are the main concerns. But in Murree, along with Abbottabad, household residents express strong interest, with an average interest in increased water bill percentage, with the affected household's percentage of 34%. All the results are reported in the following table 4.

Table 1: Perceived Changes in climate pattern in three Himalayan towns.

Town	Increased Temperature (%)	Decreased Rainfall (%)	Rainfall increased (%)	Increased Extreme Events (%)
Gilgit	82	73	27	58
Murree	76	64	36	63
Abbottabad	82	66	34	

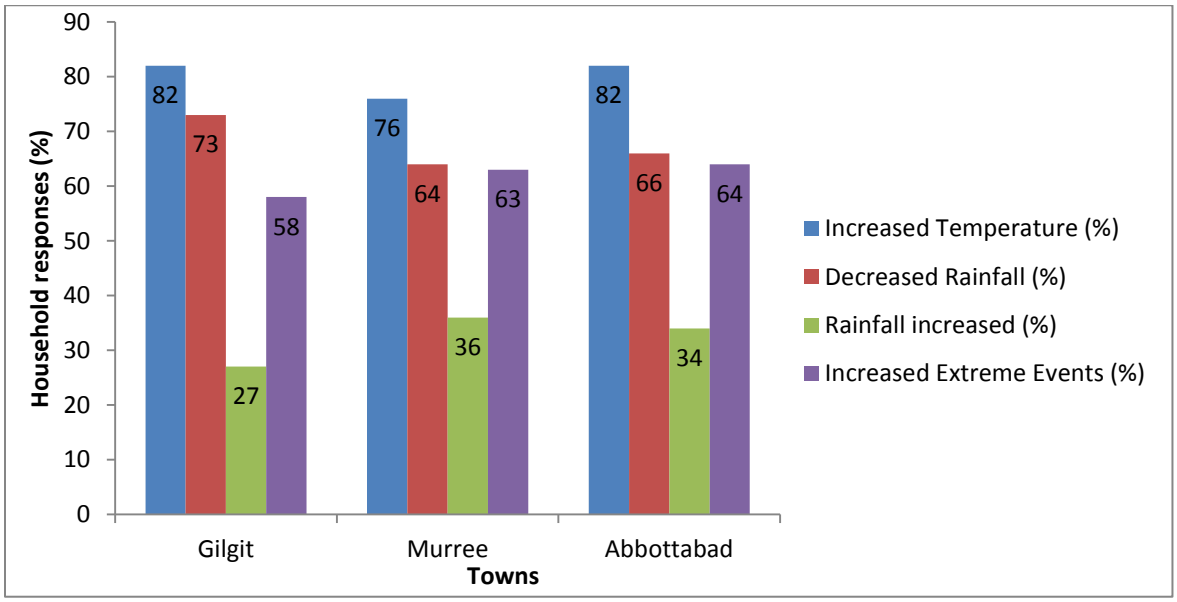

Figure 2 Perceived Changes in climate pattern in three Himalayan towns

Table 2: Awareness and Perceived Changes in Water Availability in three Himalayan towns.

Town	Aware (%)	Unaware (%)	Decrease in Water Availability (%)
Gilgit	87	14	71
Murree	85	15	68
Abbottabad	84	16	71

Note: Percentages may not total 100% due to rounding.

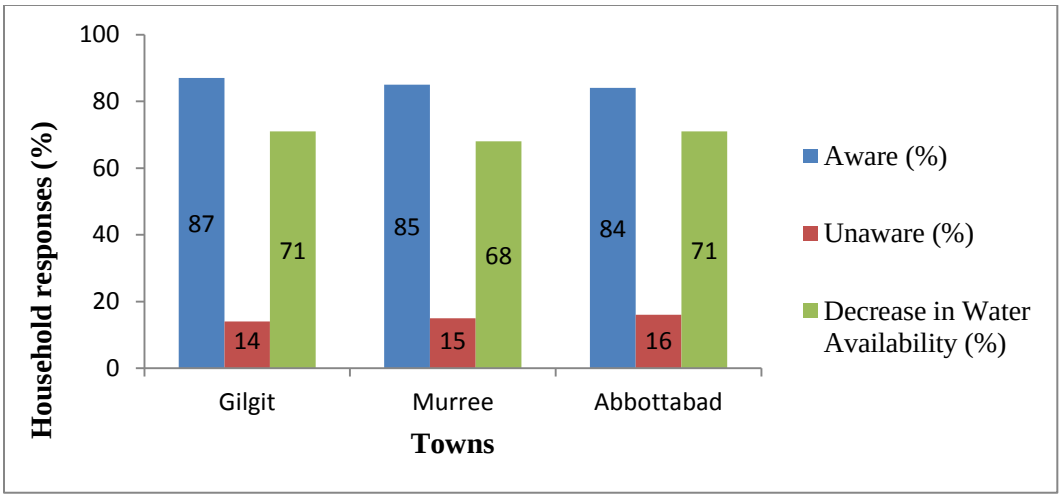

Figure 3:Awareness and Perceived Changes in Water Availability in three Himalayan towns

Table 3: Perception of water scarcity and water quality degradation in three Himalayan towns.

Town	Increased Water Scarcity (%)	Water Quality Degradation (%)
Gilgit	70	66
Murree	68	67
Abbottabad	67	65

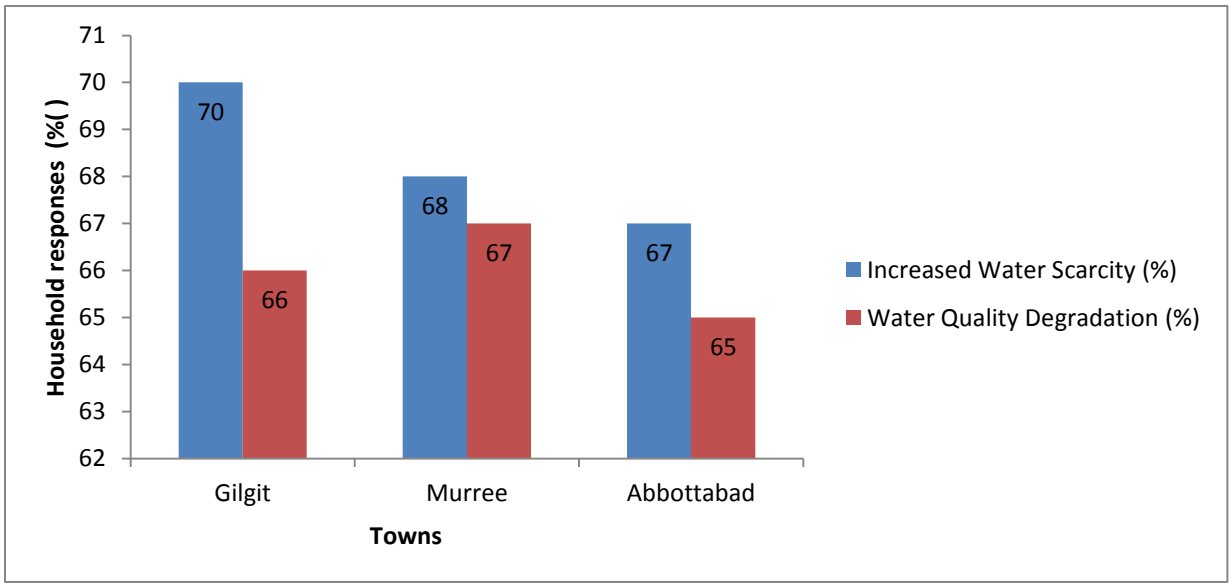

Figure 4: Perception of water scarcity and water quality degradation in three Himalayan towns

Table 4: Household Concerns Regarding Water Resources in three Himalayan towns.

Town	Water Scarcity (%)	Satisfaction with Water Quality (%)	Increased Water Costs (%)
Gilgit	83	76	7
Murree	72	67	37
Abbottabad	81	66	34

This data can be visually represented in a clustered bar chart (Figure 5). This visualization implies a need for targeted policy responses to these challenges.

Changes in Water Usage Patterns and Adaptation Strategies: The most pressing problem is water usage patterns; as Table 5 shows, 64 % of Murree households

are concerned about reduced water, the highest of the three towns. That is a drastic shortage in water usage due to diminished glacial melt, altered precipitation, and/or increasing water demand. Likewise, 63 % of households in Abbottabad are fearful of water shortage. Gilgit ranks lower on this household concern scale, although here, too. Household residents of the three towns shared the same concern – changes in water usage patterns, a generic concern across the region in light of both climatic changes and increases in the population pressure on available water resources.

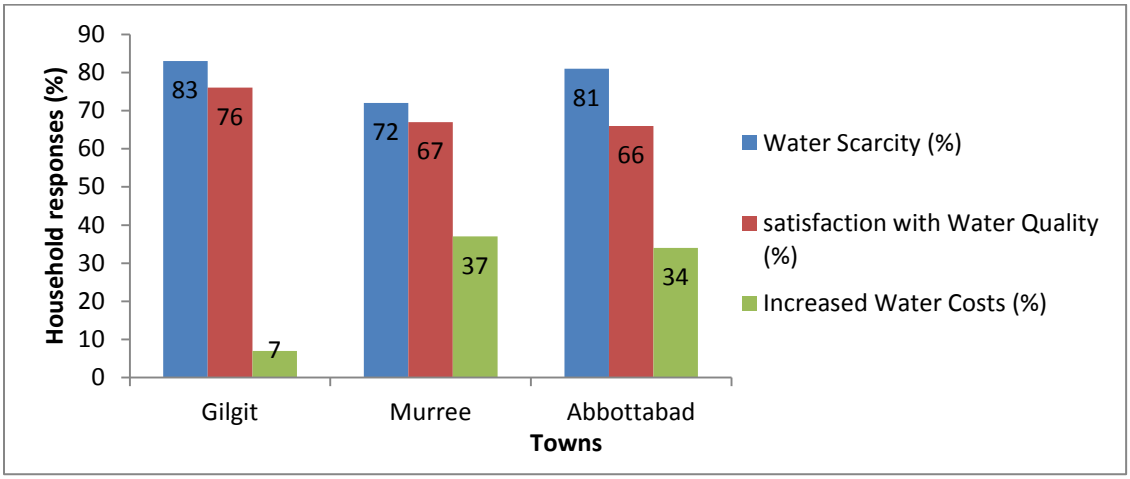

Figure 5 Household Concerns Regarding Water Resources Himalayan towns

Table 5: Changes in Water Usage Patterns and Adaptation Strategies in three Himalayan towns.

Town	Reduced Usage (%)	Adaptation Measures (%)	Rainwater Harvesting (%)	Water Storage (%)	Use of other Sources (%)
Gilgit	63	56	10	56	44
Murree	64	57	12	52	40
Abbottabad	63	58	11	54	42

Adaptation measures in the three towns tell a story of collective action. Abbottabad leads with the highest percentage of adaptation strategies, with 58 % of households being adaptive. Murree follows closely at 57 %, and Gilgit lags at 56 %. This data, along with the visual aids (Figure 6), is crucial in understanding how to approach the water challenges in the Himalayan towns. Importantly, the patterns of household adaptation, such as reduced water usage, rainwater harvesting, and diversified water sourcing, are clear indications of the inspiring community efforts to combat water stress.

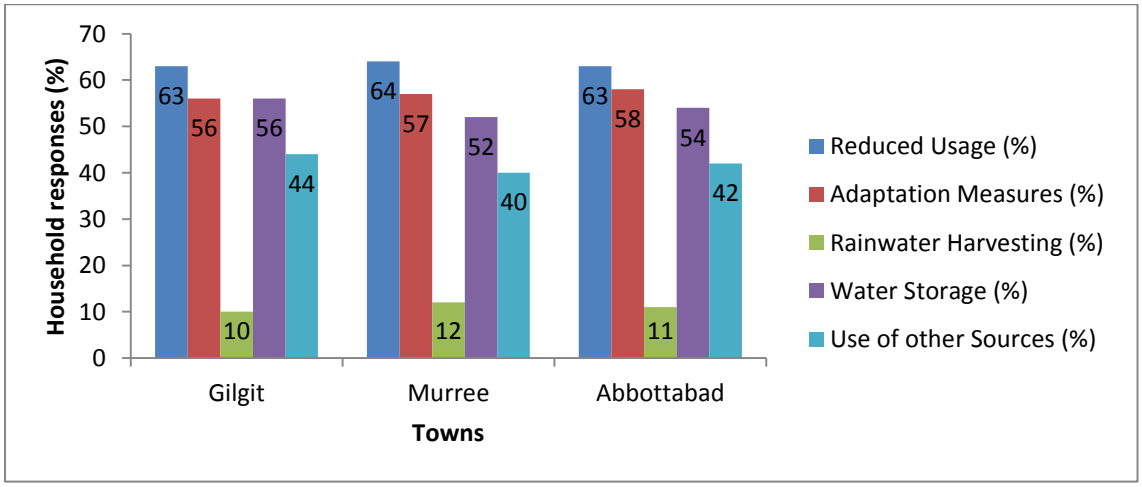

Figure 6. Changes in Water Usage Patterns and Adaptation Strategies in three Himalayan towns

Community Perception of Government Response: The pie charts shown in Figure 7 for each town can be interpreted symbolically to delineate the community's opinion of how content they are with the government's actions taken to counter the difficulties of climate and water resources in their respective towns. The Gilgit pie chart shows that satisfaction with revenue generation is balanced at 45% regarding unsatisfactory and 44% regarding satisfactory. This proves that the community in Gilgit is divided regarding the government's involvement in the matter and ensuring maximum satisfaction. However, the 11% who felt no response is a small and decent percentage, suggesting that only a few people might be in denial or not concerned. The pie chart leans too heavily on the community's anger towards the government. As depicted in the pie chart from Murree above, the non-satisfactory percentage of 51% was comparatively high if we observe the just satisfying responses, which were 40%. A high percentage demonstrates a high level of dissatisfaction among the household residents of Murree with water and climate management-related issues. The no response portion, 9%, is the lowest, which could suggest that the entire area understands the administration's target with the arrangements and monetary vulnerability.

On the other hand, the Abbottabad pie chart presents a more balanced breakdown, with 42% satisfied and 48% unsatisfied. This balance, though not ideal, shows an improvement in the community's perception of the government's actions. Overall, Figure 7 indicates the level of satisfaction in each town. The majority of responses suggest that significant towns are not fully satisfied, with some minor levels of indifference. However, the Abbottabad community's understanding of the administration's efforts and financial constraints is a positive aspect that should not be overlooked.

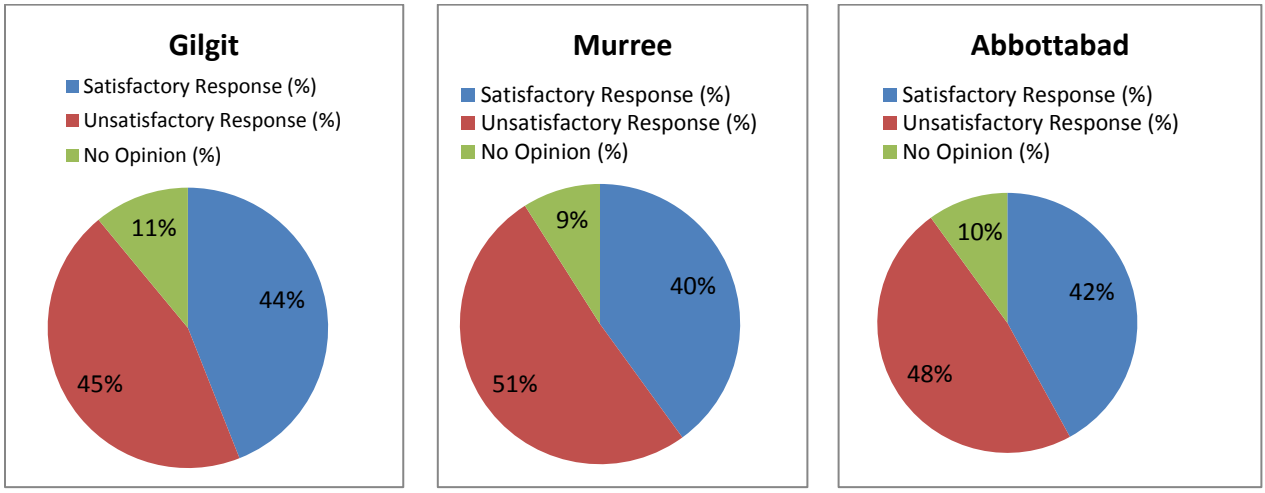

Figure 7 Community Perception of Government Response

Generally, the findings outlined in the six thematic areas offer a nuanced perspective on community perceptions regarding threats posed by climate change and water resources in the Himalayan towns of Gilgit, Murree, and Abbottabad. Such findings provide important clues about how local populations respond to, interpret, and adapt to environmental change. Moreover, these findings emphasize the importance of integrated, inclusive, and evidence-based approaches that bridge scientific understanding and local knowledge to develop adaptive and sustainable water and climate governance systems. And while communities demonstrate considerable awareness, innovation, and engagement, there are obvious limits to their capacity to handle rising climate stressors. Solutions for addressing these challenges need to be data-driven and context-specific, encompassing enhanced infrastructure and environmental management and economic vulnerabilities and governance (including power relations) gaps. The importance of bridging the insights from the community with the understanding from the scientific community through transparent, participatory policymaking to ensure effective, equitable, and long-term responses to climate change in the Himalayan region cannot be overstated.

Conclusion: This study highlights the perceptions and responses of communities in Gilgit, Murree, and Abbottabad regarding climate change impacts on water. Although high levels of awareness and household-level adaptations indicate substantial engagement, challenges like water scarcity, degradation of quality, and increasing costs remain intact. Governance data reinforce public dissatisfaction with government response. Moreover, the prevailing perception that climate change directly exacerbates existing water resource issues has heightened community concern, emphasizing the urgent need for integrated and locally informed water management strategies.

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