

THE EFFECT OF CLIMATE CHANGE ON WATER SUPPLY SERVICES: A CASE STUDY OF CHHATRESHWORI RURAL MUNICIPALITY OF NEPAL

Min Prasad Basnet¹, Khet Raj Dahal^{2*}, Prakash Gyawali³, Sita Ghimire Mainali⁴

¹Lumbini International Academy of Science and Technology (LIASST), Lalitpur, Nepal, min.basnet@gmail.com

²Lumbini International Academy of Science and Technology (LIASST), Lalitpur, Nepal, dahal.khetraj@gmail.com

³Lumbini International Academy of Science and Technology (LIASST), Lalitpur, Nepal, gyawaliprakash01@gmail.com

⁴CEO of Real estate NC, USA, sitadidi@gmail.com

ABSTRACT

Climate change poses significant challenges to water supply services worldwide, particularly in rural areas where vulnerabilities are heightened due to limited resources and infrastructure. Nepal, a country highly vulnerable to climate change impacts, is experiencing intensified droughts, floods, and other extreme weather events, exacerbating existing water scarcity and pollution issues. Chhatreshwori Rural Municipality, located in Salyan District, Karnali Province of Nepal, represents a pertinent case study due to its susceptibility to these climate-induced challenges and its reliance on local water supply services for daily needs. Field observation, in-depth interviews, focus group discussions, and a questionnaire survey were the major tools used during field investigation, conducted between September 2023 and February 2024 with 105 household respondents. Quantitative data were analyzed using descriptive statistics and the Relative Importance Index (RII), while qualitative data from interviews and focus group discussions were analyzed thematically. The findings show that droughts were ranked as the most severe climate-related problem affecting water supply services (RII = 0.94), followed by financial constraints (RII = 0.86) and water scarcity (RII = 0.84). Changes in precipitation patterns emerged as the leading cause of drought (RII = 0.98), while increased risk of waterborne disease and reduced water availability were identified as dominant effects across the causal chains examined. Unequal distribution of water resources recorded the lowest RII (0.66) among the major problems, though it remains a significant equity concern for marginalized groups. The study suggests that prioritizing community-led initiatives and capacity-building for sustainable water use and climate resilience is crucial. It emphasizes the need to maintain and upgrade water infrastructure based on climate projections, and recommends adopting integrated water resource management, inclusive policies, innovative financing, and knowledge exchange networks to effectively address climate impacts on water resources in rural Nepal.

Keywords: *Climate change, climate resilience, financing mechanisms, sustainable water, water supply services*

1. INTRODUCTION

Climate change has emerged as one of the most pressing global challenges of the twenty-first century, with far-reaching consequences for water resources, agriculture, ecosystems, and human livelihoods. The Intergovernmental Panel on Climate Change confirms that global warming is intensifying the frequency and severity of extreme weather events, including droughts, floods, and irregular precipitation patterns, with disproportionate impacts on developing and mountainous regions [1]. Mountain regions such as the Hindu Kush Himalaya, which supply water to nearly two billion people downstream, are experiencing accelerated glacial retreat, shifting monsoon patterns, and increasing hydrological variability that directly threaten water security [2], [9].

Nepal, situated in the central Himalaya, is recognized among the countries most vulnerable to climate change despite contributing minimally to global greenhouse gas emissions. The country's mountainous and hilly terrain,

fragile geology, and heavy reliance on climate-sensitive water sources make its rural water supply systems particularly susceptible to disruption from droughts, landslides, flash floods, and erratic rainfall [4], [7]. Water towers such as the Himalayan glaciers and snowpack that sustain Nepal's rivers throughout the dry season are themselves under threat from rising temperatures, compounding long-term water security concerns for downstream rural communities [8].

Rural water supply schemes in Nepal are typically gravity-fed systems dependent on spring and stream sources whose yields fluctuate substantially with seasonal and climatic variation. Unlike urban utilities, these schemes are managed by community-based Water User and Sanitation Committees (WUSCs) with limited technical and financial capacity to adapt infrastructure to changing hydrological conditions [10]. National policy frameworks, including the National Adaptation Programme of Action and the Climate Resilient Water Safety Plan guideline, have sought to mainstream climate resilience into water sector planning, yet translating these frameworks into functioning infrastructure at the rural municipality level remains a persistent challenge [6], [10].

Chhatreshwori Rural Municipality, located in Salyan District of Karnali Province, exemplifies these challenges. Spanning a wide elevation range from 839 to 2,800 metres above sea level across seven wards, the municipality's water supply schemes are exposed to a diverse set of climate-related hazards, from drought-induced source depletion in the dry season to landslide and flood damage to distribution infrastructure during the monsoon. Climate change disproportionately affects poor, women, and other marginalized groups within these communities, who bear a greater share of the burden of water collection when supply is disrupted [5]. Understanding how climate change is affecting water supply services in this context, and how communities and institutions are responding, is essential for designing effective, equitable adaptation strategies.

This study therefore assesses the effects of climate change on water supply services in Chhatreshwori Rural Municipality, with the objectives of: (a) identifying the major climate-related problems, causes, and effects affecting water supply services; (b) assessing the current status and functionality of water supply infrastructure in the municipality; and (c) identifying practical, community-informed solutions for building climate-resilient water supply services in rural Nepal.

2. MATERIALS AND METHODS

2.1 Study Area

Chhatreshwori Rural Municipality is one of ten local governments in Salyan District, Karnali Province, Nepal. The centre of the rural municipality is located at Bhotechaur in Ward No. 6. The municipality comprises seven wards and covers an area of 150.69 square kilometres, located at approximately 28.3791°N latitude and 82.3242°E longitude, with elevation ranging from 839 to 2,800 metres above mean sea level. As per the national census of 2021, the municipality has a population of 21,242 across 5,139 households.

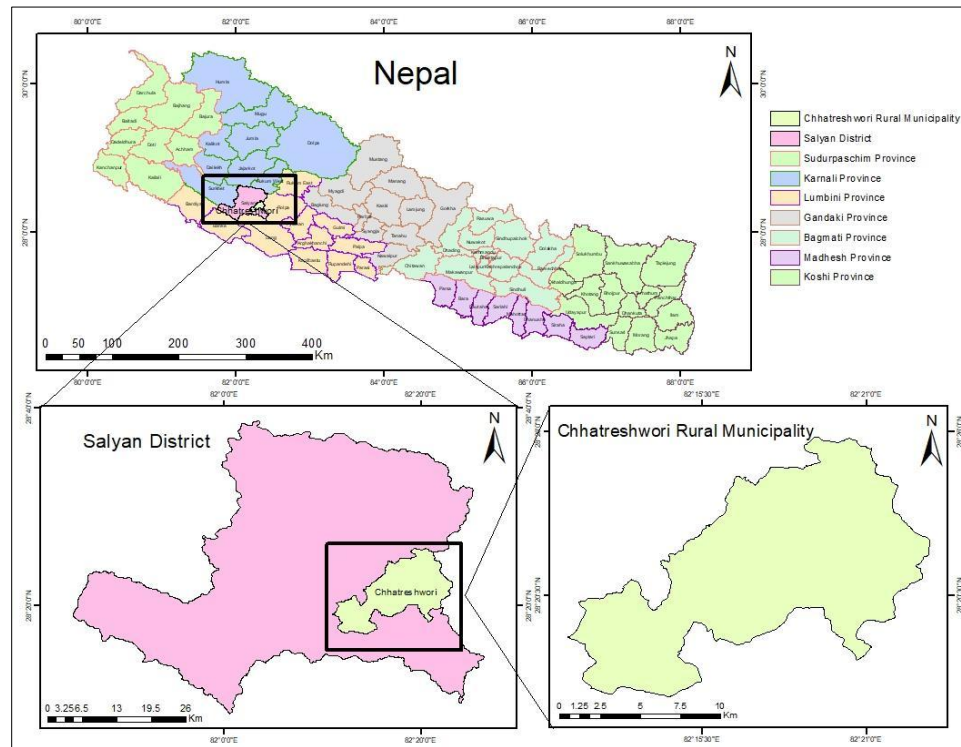


Fig. 2.1. Location map of Chhatreshwori Rural Municipality, Salyan District, Nepal

2.2 Research Design

A mixed-method research approach combining quantitative and qualitative techniques was adopted, integrating a structured questionnaire survey with field observations, in-depth interviews (IDI), and focus group discussions (FGD). Field observation was used to visit 7 water supply schemes, rivers, streams, landslide zones, and water sources to gather preliminary information on water supply conditions across different locations. In-depth interviews were conducted with rural municipality representatives and officials with firsthand experience relevant to the research topic, while focus group discussions engaged water user committee members, men's and women's groups, and persons with disabilities to capture diverse community perspectives on climate-related water supply challenges.

The required sample size for the household questionnaire survey was determined using the following formula for a finite population:

$$n = \frac{NZ^2p(1-p)}{[(N-1)E^2 + Z^2p(1-p)]} \quad \text{Equation (1)}$$

where n is the required sample size, N is the total population size, Z is the z-score corresponding to the desired confidence level, p is the estimated population proportion, and E is the desired margin of error. Taking $N = 5,139$ households (Census, 2021), $Z = 1.645$ (90% confidence level), $p = 0.5$, and $E = 0.08$, the calculated sample size was 105 households, distributed proportionally across the seven wards. In addition, four focus group discussions were held with women and men with disabilities from two wards, and seven focus group discussions were held with water user committees representing schemes from four wards.

Data analysis

Quantitative data were analyzed using the Relative Importance Index (RII), employed on a five-point Likert scale to determine the relative importance of the factors identified as problems, causes, effects, and solutions related to climate change impacts on water supply services. The value of RII was computed as:

$$RII = \Sigma W / (A \times N) = (5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1) / 5N \quad \text{Equation (2)}$$

where W is the weight assigned by each respondent (1–5), A is the highest weight (5), N is the total number of respondents, and n_1 – n_5 are the numbers of respondents selecting each rating category. The RII ranges from 0 to 1, with higher values indicating greater relative importance. Paired two-tailed t-tests at a 95% confidence interval were additionally used to compare selected quantitative indicators. Qualitative data from interviews and focus group discussions were analyzed thematically, with memo writing and triangulation across data sources used to enhance analytical validity.

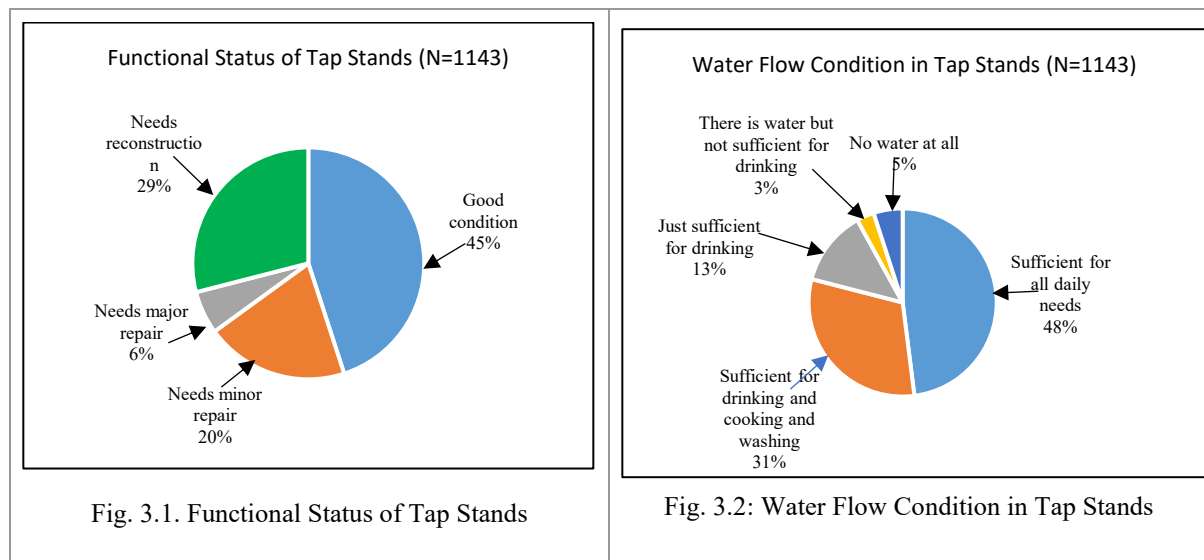
3. RESULTS AND DISCUSSION

3.1 Characteristics of respondents

Among the 105 questionnaire survey respondents, 73% were male and 27% were female (Fig. 3.1). Age, ethnicity, and educational attainment were also recorded to characterize the sample (Figs 3.2–3.4), alongside the gender and ethnicity composition of focus group discussion participants from Water User and Sanitation Committees (Figs 3.5–3.6).

3.2 Status of Water Supply Infrastructure

Assessment of the existing water supply infrastructure found that a substantial share of tap stands and reservoir tanks were only partially functional or non-functional at the time of the survey, with water flow condition and water quality (turbidity) also showing signs of climate-related stress across the sampled schemes (Figs 3.7–3.11). The spatial distribution of existing water supply schemes across the municipality's seven wards is presented in Fig. 3.11.



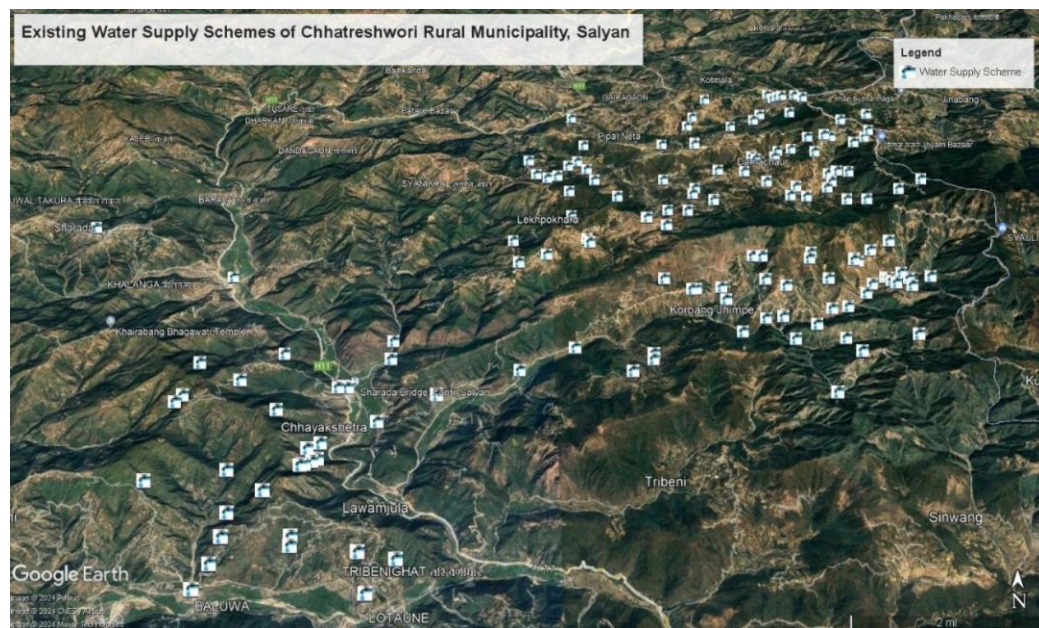
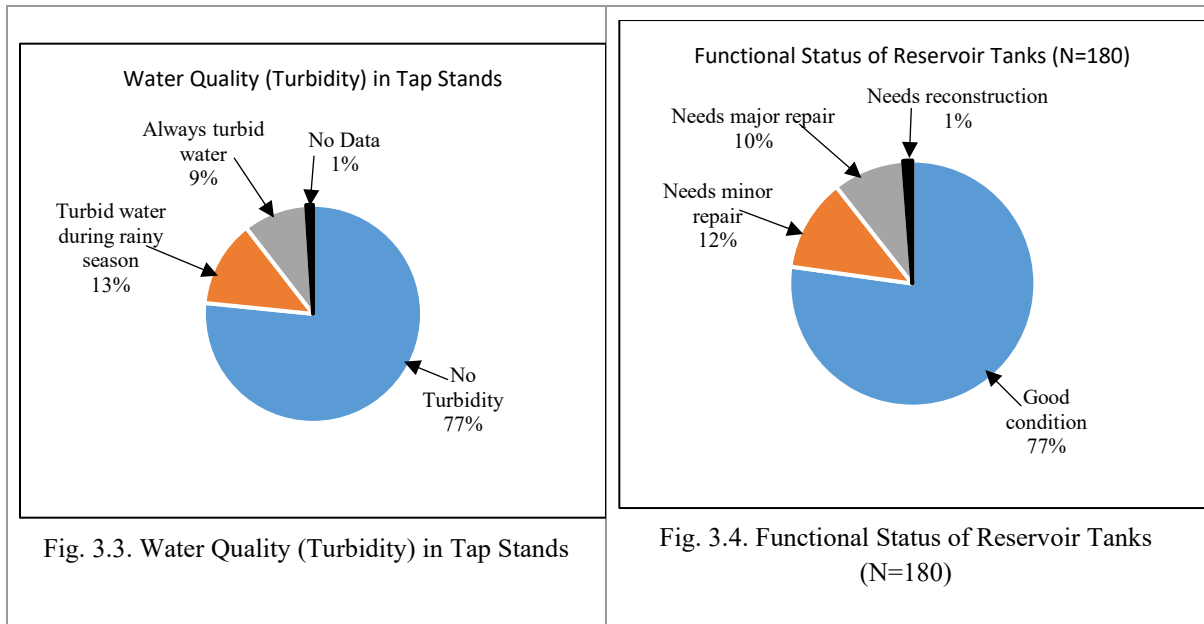
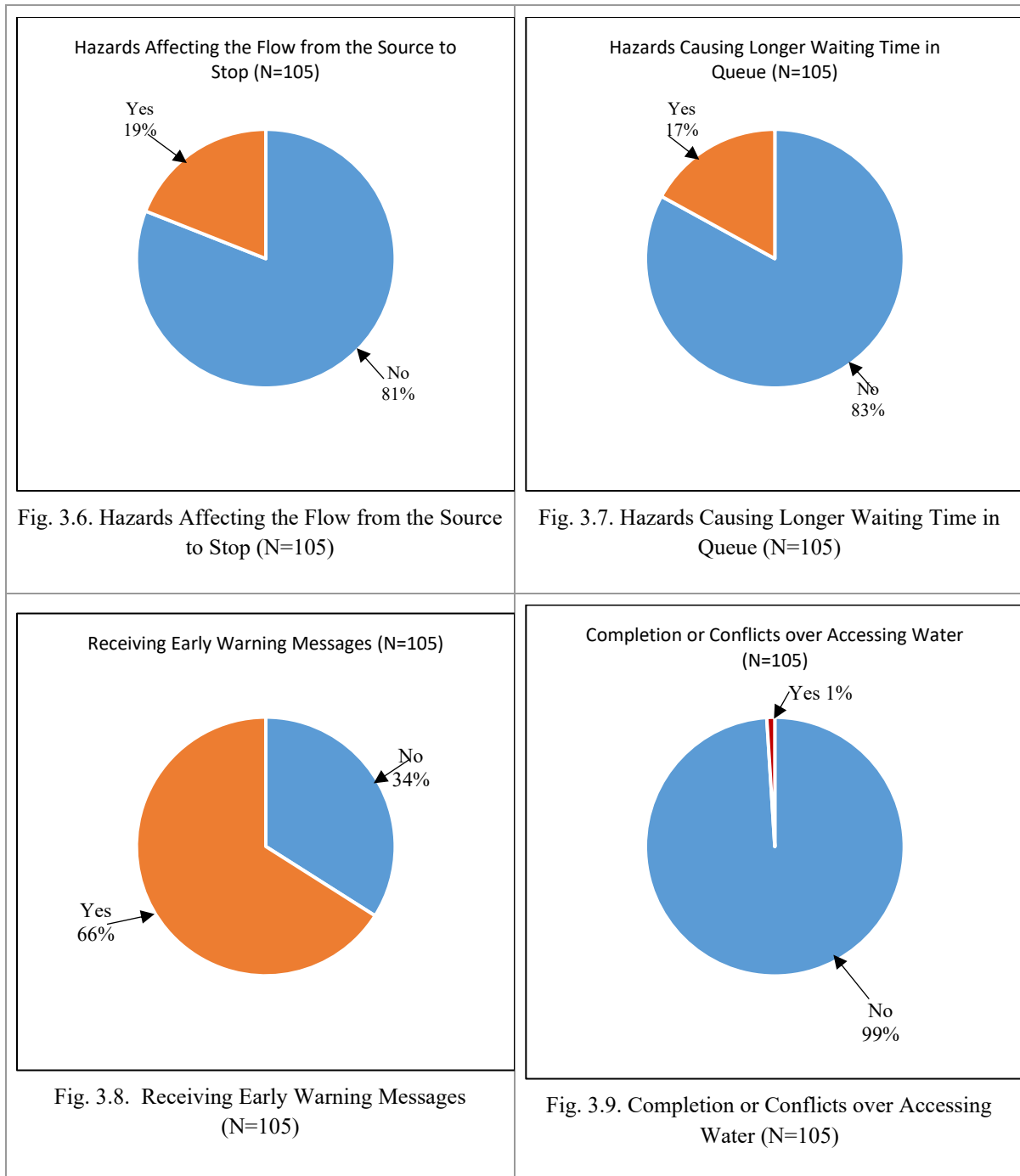


Fig. 3.5. Map showing existing water supply schemes in Chhatreshwori Rural Municipality

3.3 Household Perceptions of Hazard Exposure

Households were asked about their direct exposure to hazards affecting water supply continuity. A majority of respondents reported that hazards had, at some point, caused the main water source to fail, disrupted flow from the source, or led to longer waiting times in queues at tap stands (Figs 3.12–3.14); comparatively fewer respondents reported receiving early warning messages ahead of such disruptions, and a smaller share reported experiencing conflicts over water access (Fig. 3.15).



3.4 Major Climate Change Problems For Water Supply Services

Relative Importance Index analysis was applied to fifteen problem statements to identify the most significant climate-related challenges affecting water supply services. Droughts received the highest rank (RII = 0.94), followed by financial constraints (RII = 0.86) and water scarcity (RII = 0.84). Heavy rainfall (RII = 0.82), water pollution (RII = 0.81), erratic rainfall patterns (RII = 0.80), and damages to infrastructure (RII = 0.80) were the other problems ranked at or above 0.80. Limited institutional capacity (RII = 0.77), health risks (RII = 0.75), displacement (RII = 0.75), increased water competition and conflicts (RII = 0.73), floods (RII = 0.73), reduced

groundwater recharge (RII = 0.72), landslides (RII = 0.71), and gender and social disparities (RII = 0.70) followed, while unequal distribution recorded the lowest rank (RII = 0.66), as shown in Fig. 3.16.

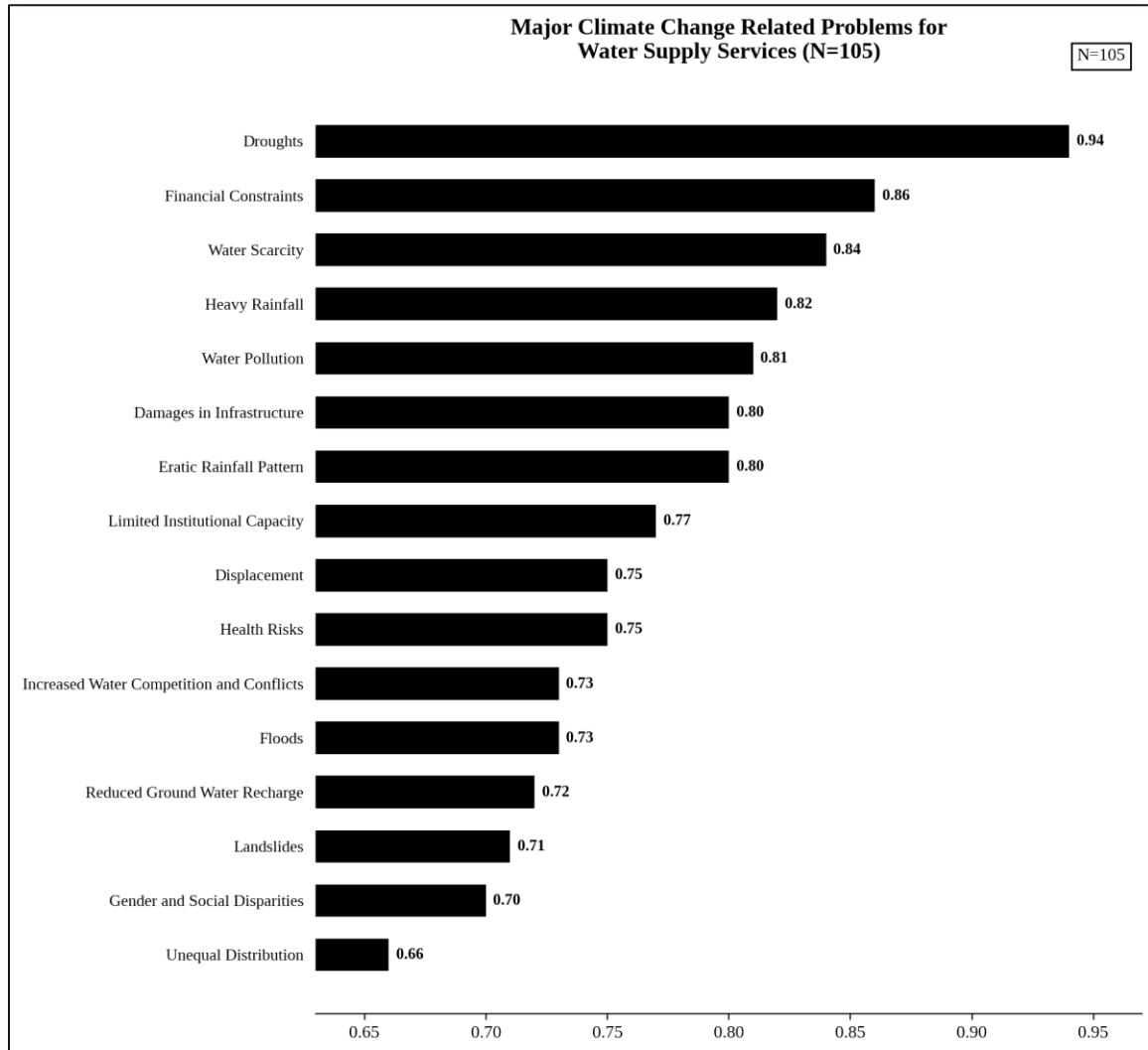


Fig. 3.10. Major Climate Change Related Problems for Water Supply Services in Chhatreshwori Rural Municipality, Salyan (Source: Field Survey, 2024)

3.5 Analysis Of Causes And Effects Of Climate Change Problems

For each of the fifteen problem areas identified in Section 3.4, the underlying causes and resulting effects were separately analyzed using RII, based on the weighted responses of the 105 survey participants. The ranked causes and effects for each issue, from droughts through to limited institutional capacity, are presented in Figs 3.11 through 3.48.

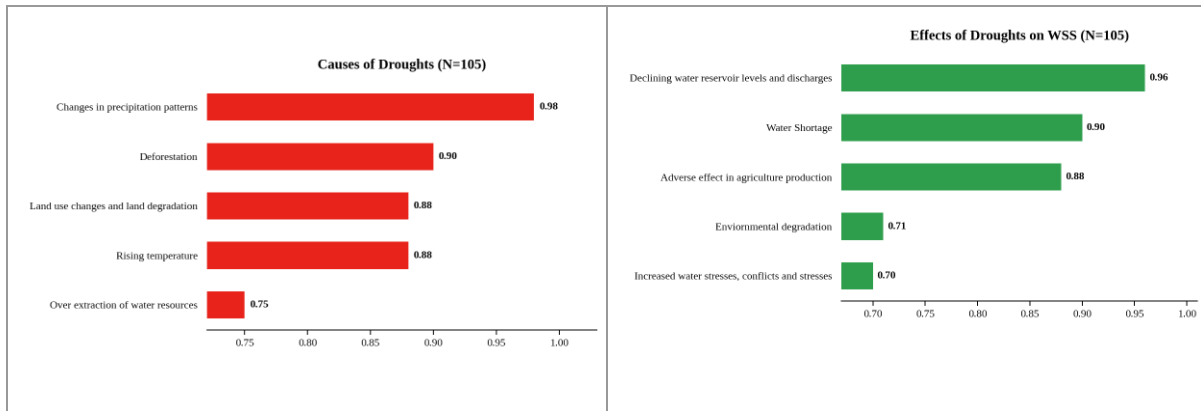


Fig. 3.11(a). Causes and Effects of Droughts

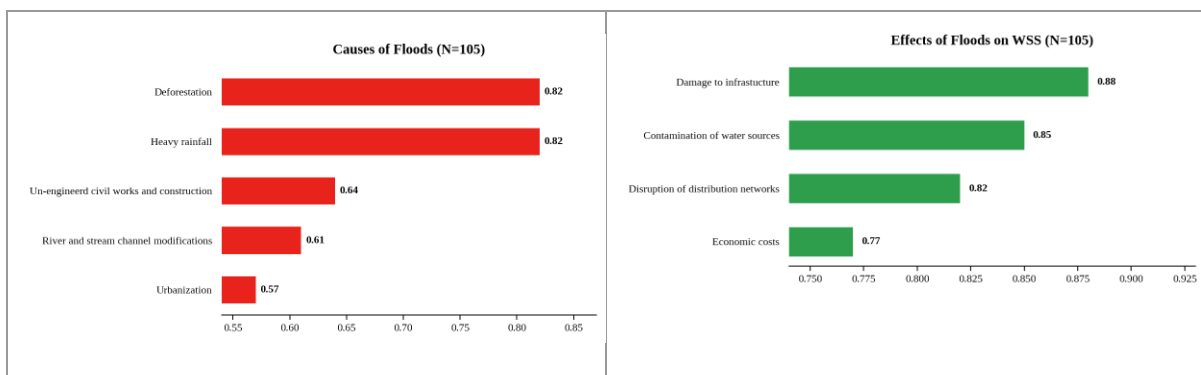


Fig. 3.11(b). Causes and Effects of Floods

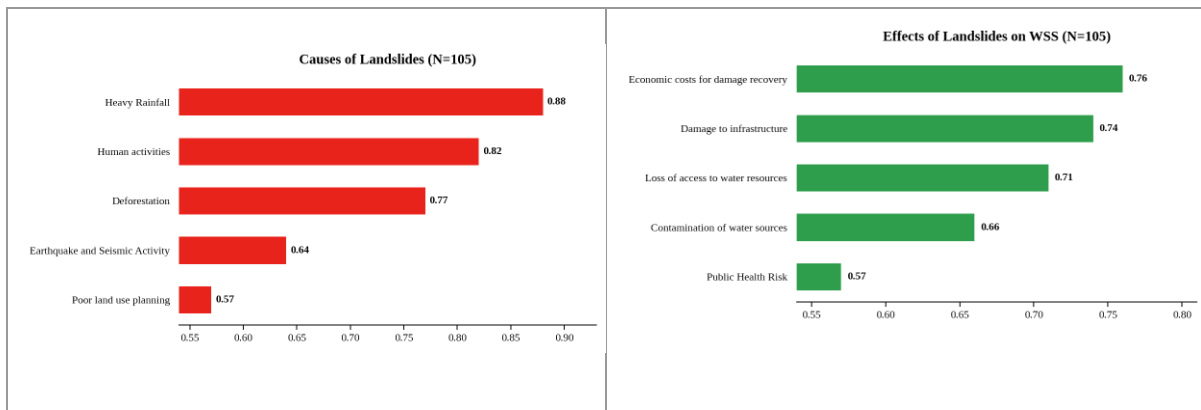


Fig. 3.11 (c). Causes and Effects of Landslides

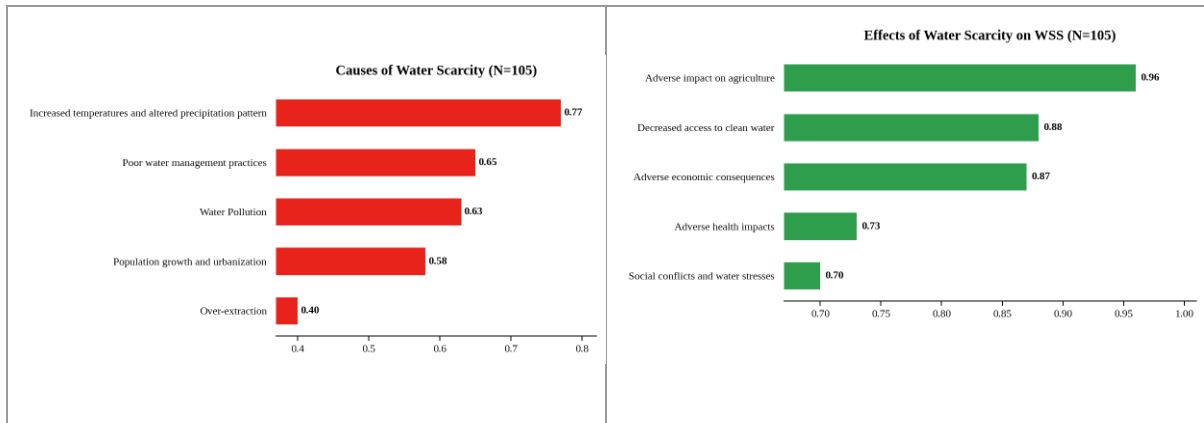


Fig. 3.11(d). Causes and Effects of Water Scarcity

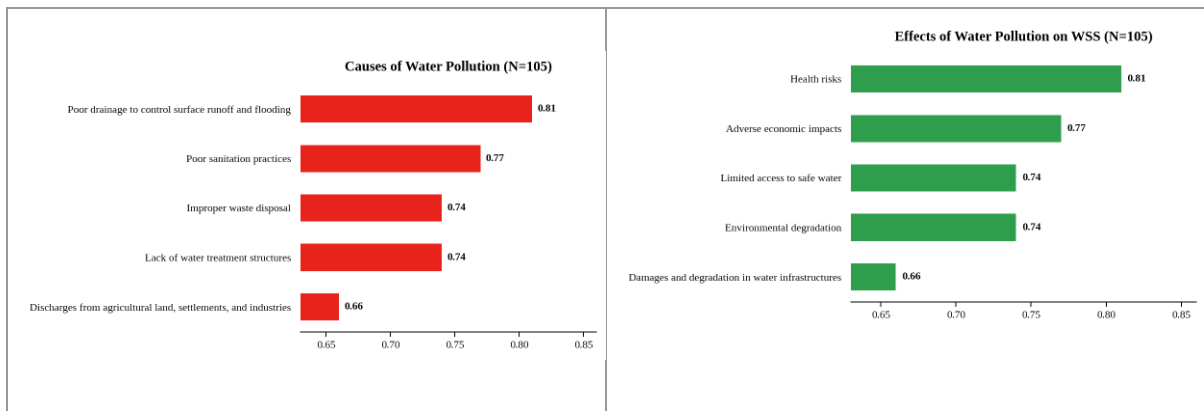


Fig. 3.11(e). Causes and Effects of Water Pollution

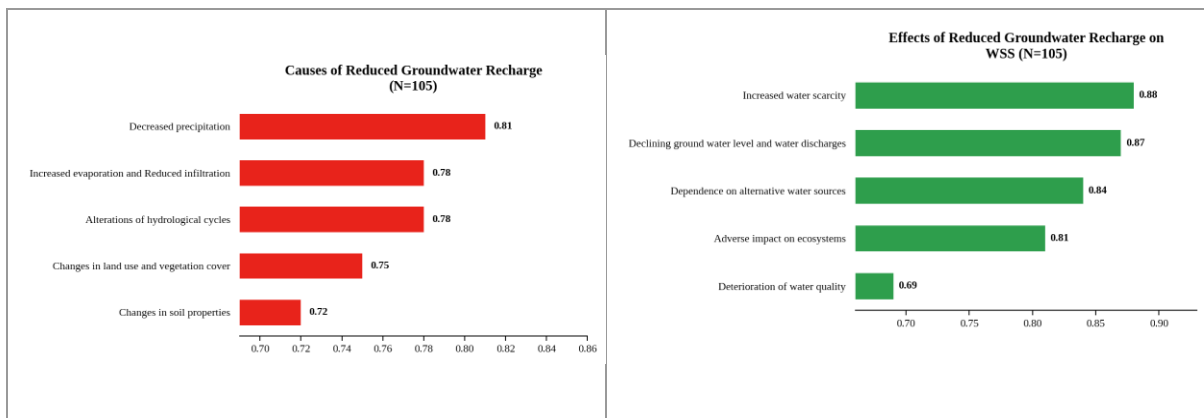


Fig. 3.11(f). Causes and Effects of Reduced Groundwater Recharge

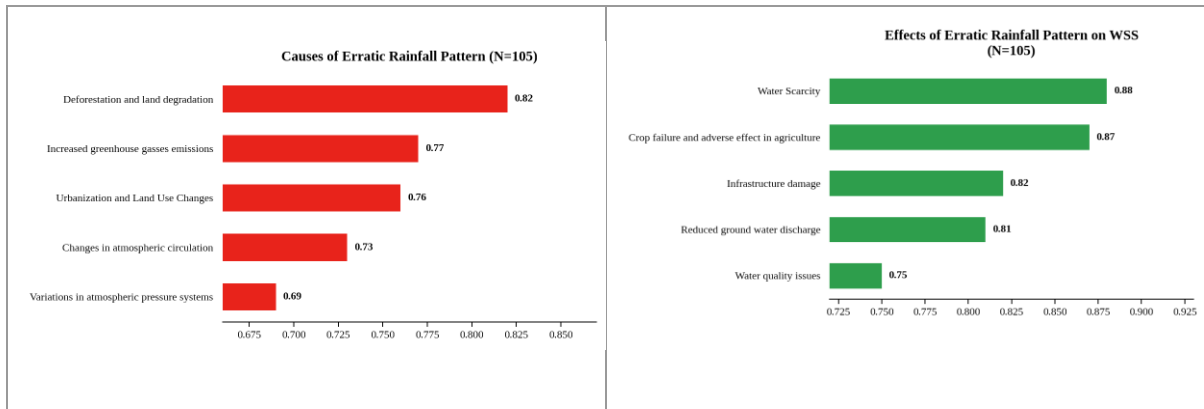


Fig. 3.11(g). Causes and Effects of Erratic Rainfall Pattern

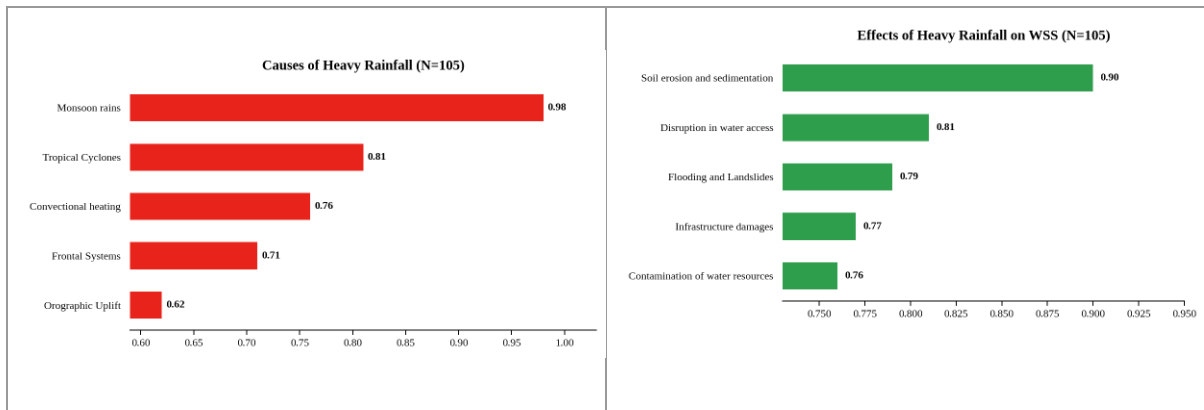


Fig. 3.11(h). Causes and Effects of Heavy Rainfall

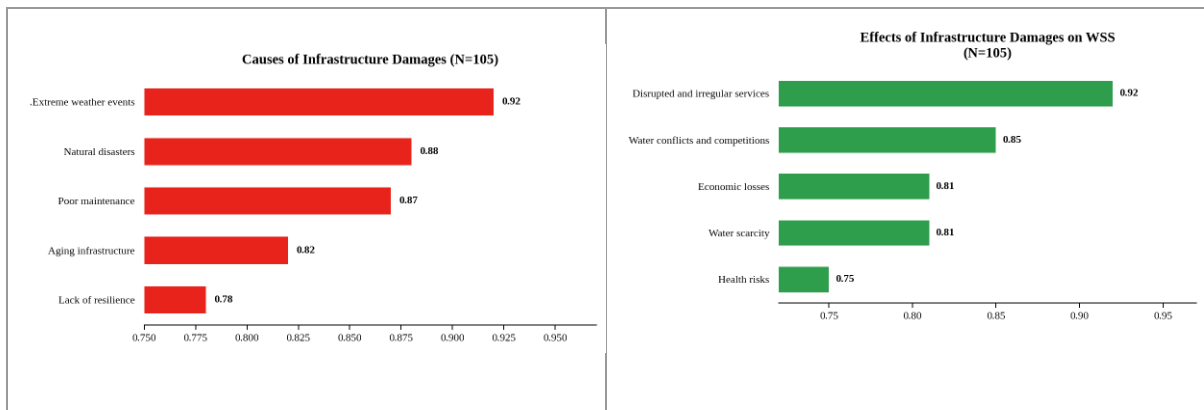


Fig. 3.11(i). Causes and Effects of Infrastructure Damages

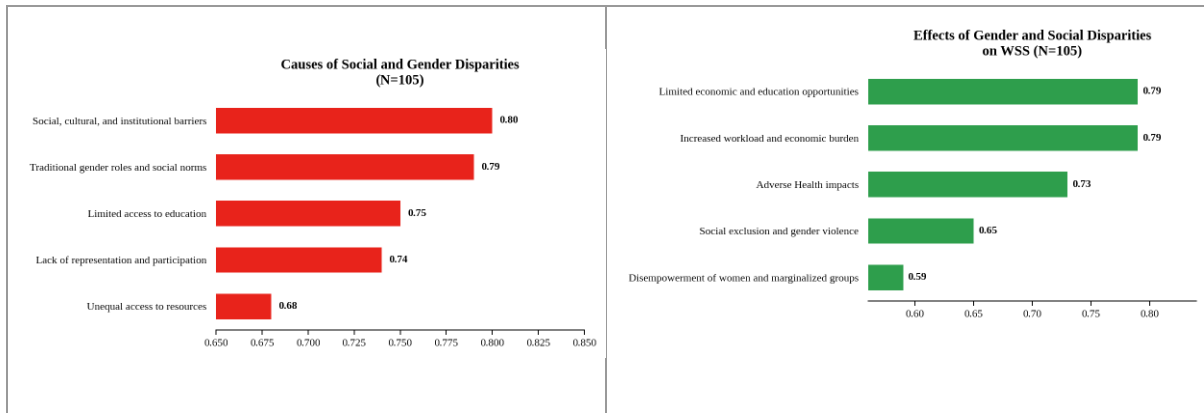


Fig. 3.11(j). Causes and Effects of Gender and Social Disparities

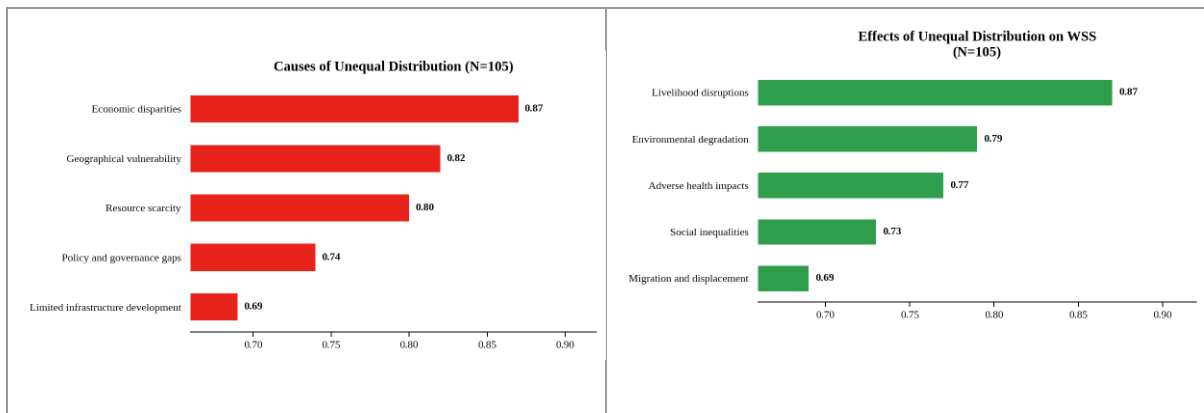


Fig. 3.11(k). Causes and Effects of Unequal Distribution

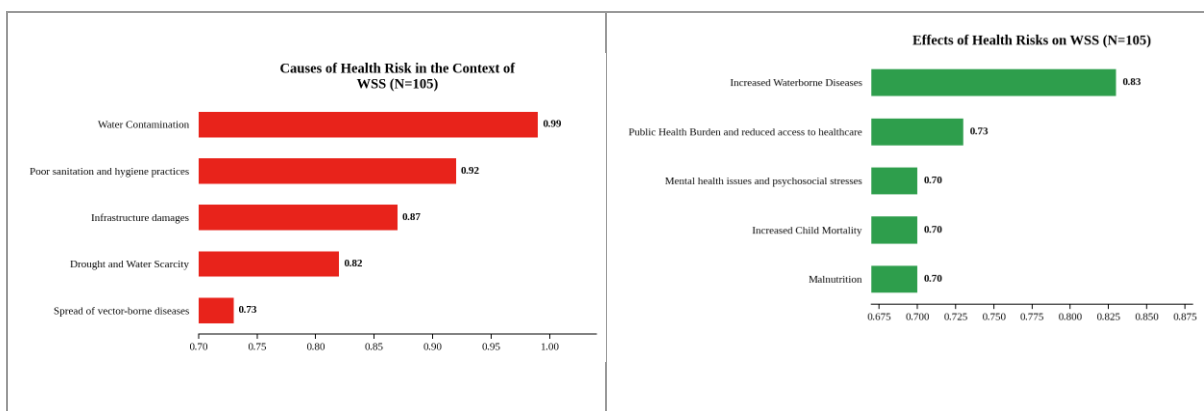


Fig. 3.11(l). Causes and Effects of Health Risk

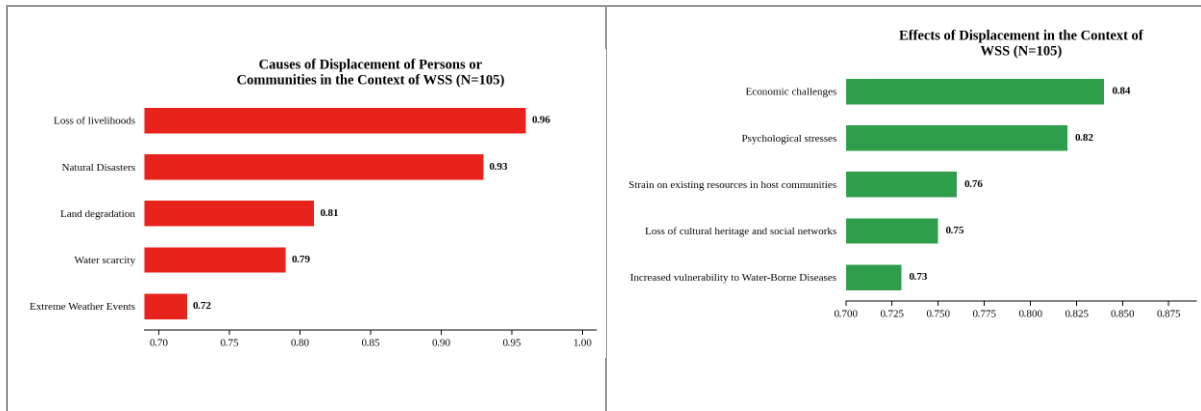


Fig. 3.11(m). Causes and Effects of Displacement of Persons or Communities

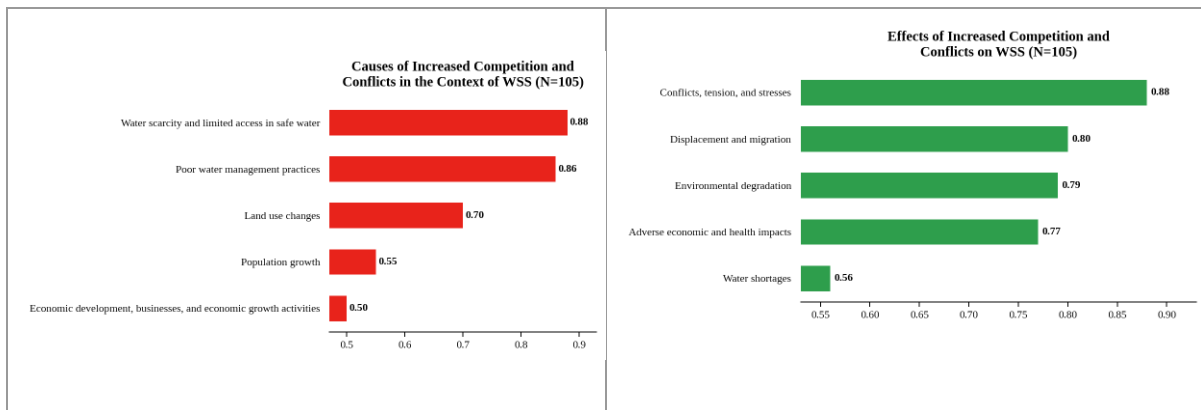


Fig. 3.11(n). Causes and Effects of Increased Water Competition and Conflicts

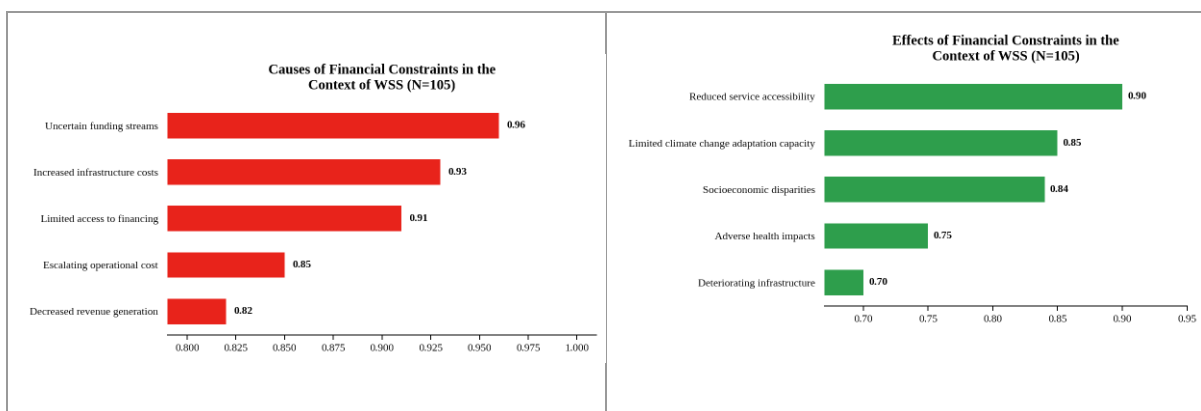


Fig. 3.11(o). Causes and Effects of Financial Constraints

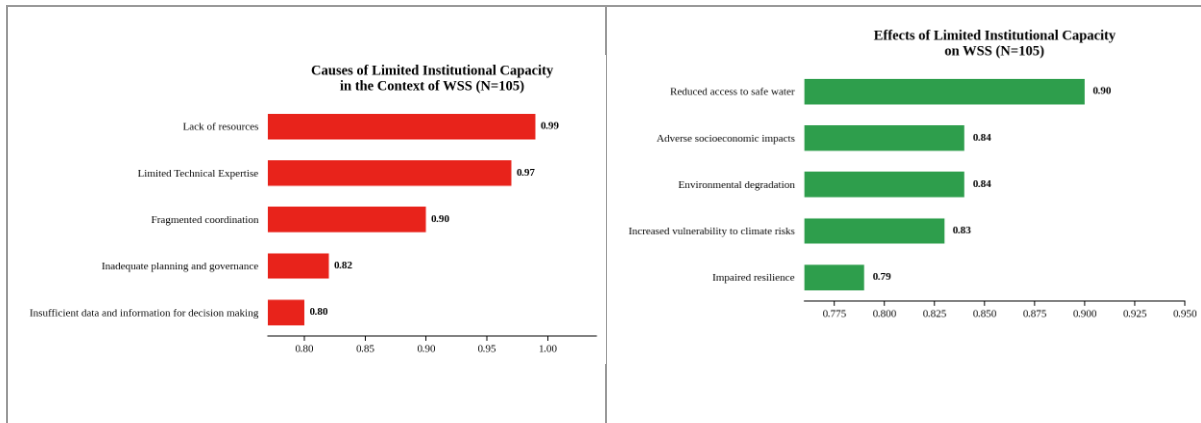


Fig. 3.11(p). Causes and Effects of Limited Institutional Capacity

3.6 Major solutions to climate change effects on water supply services

There were seventeen options for ranking. The value of climate resilient water supply system received as major solutions of climate challenge effects of water supply services received highest rank (RII=0.96) whereas green infrastructure development promoting the nature-based solutions and early warning system received the lowest rank (RII=0.77) as the climate change problem solution in the context of water supply services. Multi stake holder coordination and collaboration, and regular funding mechanism received the second highest rank with equal RII value 0.95. Community based water treatment and household level water purification (RII=0.93), integrated water resource management (RII= 0.92), community and local government level capacity building (RII=0.91), promotion of climate smart sustainable agriculture (RII=0.91) and Gender and social inclusion responsive water governance (RII=0.90) are also responded as major solutions with the RII value equal and greater than 0.90. All options and their respective value are presented in Fig. below.

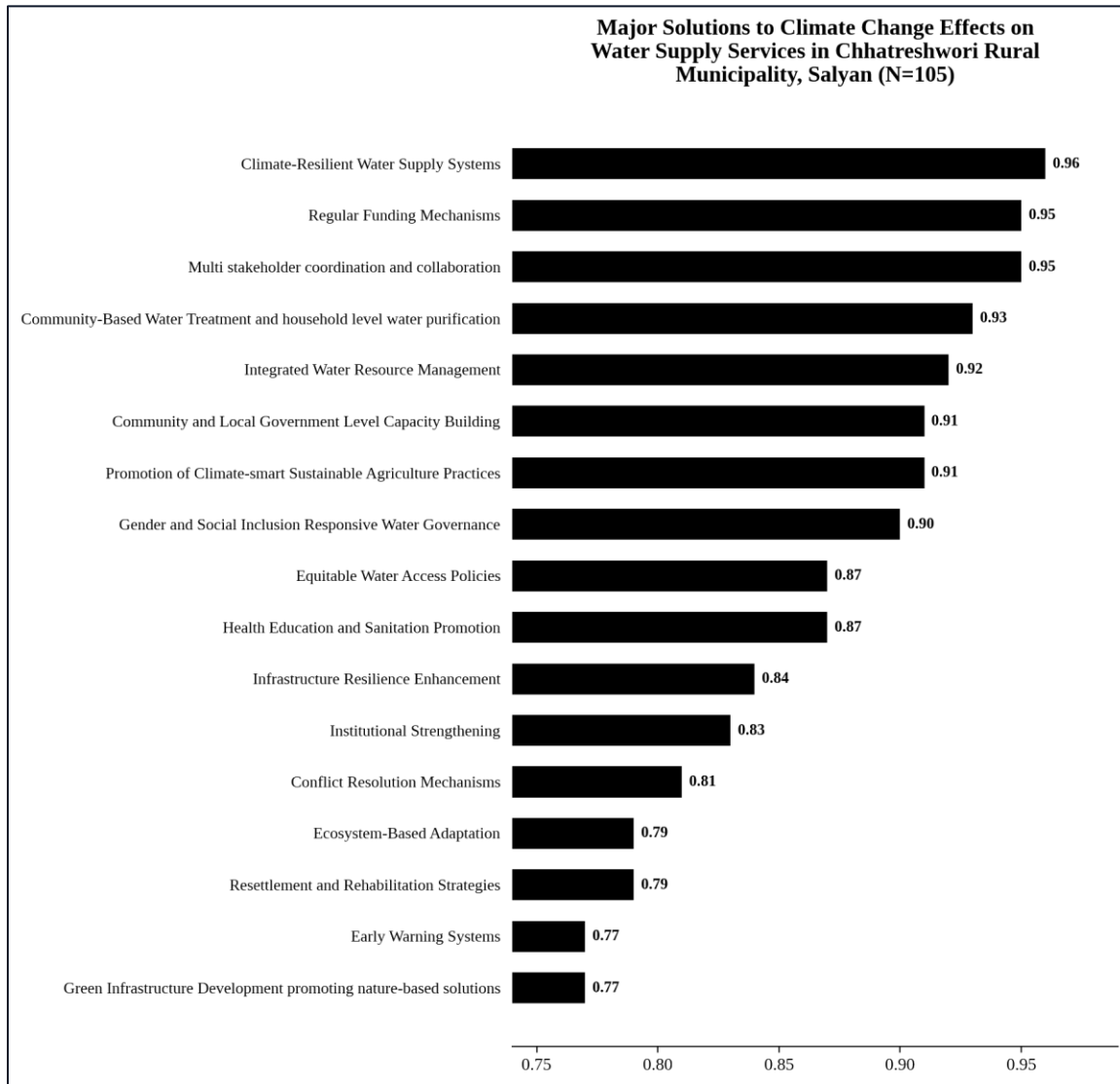


Fig. 3.12. Major Solutions to Climate Change Effects on Water Supply Services in Chhatreshwori Rural Municipality, Salyan (Source: Field Survey, 2024)

3.7 Discussion

In-depth interviews with rural municipality representatives and water user committee officials reinforced the quantitative findings, with participants consistently describing droughts and diminishing dry-season source yield as the most disruptive climate hazard affecting their water supply schemes. Officials noted that most existing schemes were designed several decades ago based on historical spring and stream discharge measurements, without accounting for the declining and increasingly erratic yields now being observed, echoing the RII finding that changes in precipitation patterns are the dominant cause of drought (RII = 0.98). Focus group discussions with women's groups and persons with disabilities highlighted that women and marginalized households bear a disproportionate share of the burden when water sources fail, spending significantly more time and effort fetching water from alternative, often distant sources during periods of scarcity.

Field observations at sampled water supply schemes corroborated the infrastructure findings, with visibly damaged intake structures, cracked distribution pipelines, and eroded catchment areas observed at several sites

visited, particularly those located in landslide-prone terrain. Community members in multiple wards reported that heavy monsoon rainfall events had become more intense and less predictable in recent years, consistent with the RII ranking of heavy rainfall and erratic rainfall patterns among the top climate-related problems. Participants across interviews and focus group discussions repeatedly emphasized the absence of dedicated funding mechanisms for climate-related infrastructure repair and upgrading, aligning with the identification of financial constraints as the second-ranked major problem overall.

These findings are consistent with the broader literature on climate change and water security in the Himalayan region. The prominence of drought and precipitation variability as leading concerns aligns with evidence that the Hindu Kush Himalaya's water towers, which sustain river systems across South Asia, are experiencing accelerated change under global warming, with direct downstream consequences for water availability [8], [9]. The vulnerability of community-managed rural water schemes to climate shocks, and the limited institutional capacity to adapt them, mirrors documented gaps between national adaptation policy frameworks and their implementation at the local level in Nepal [6], [10]. The disproportionate burden observed among women and marginalized groups is similarly consistent with established theory on community-based adaptation, which emphasizes that effective climate resilience strategies must explicitly address existing social and gender inequities rather than treating water scarcity as a purely technical problem [11], [12], [13].

4. CONCLUSIONS

This study reveals the urgent necessity for climate-resilient water supply services in rural communities, particularly as exemplified in Chhatreshwori Rural Municipality of Salyan District, Nepal, amidst escalating climate change-induced challenges such as intensified droughts, floods, landslides, water scarcity, and pollution. The research identifies critical gaps in the evaluation, inclusivity, socio-economic implications, and integration of adaptation strategies into policy frameworks and governance structures for climate-resilient water supply services, systematically analyzing the climate-related challenges, causes, and effects affecting water supply and assessing the barriers and facilitators to effective adaptation.

Community resilience emerges as insufficiently developed, though limited adaptive practices are evident, such as compromised and water-saving utilization, short-term storage practices during dry months, and purification methods during the rainy season; these reflect the pivotal role of local knowledge and community engagement in mitigating climate change impacts, even though such practices remain limited in scale and coverage. The study found that climate change disproportionately affects poor, women, and other marginalized groups, adding to the difficulties of water collection through poor access to water sources and increasing workload and financial burden relative to normal conditions.

The study underscores the significance of robust governance structures and long-term planning to address infrastructure vulnerabilities and maintenance needs, emphasizing multi-stakeholder collaboration, inclusive governance frameworks, and community engagement as indispensable elements for effective climate change adaptation. With clear policy implications, the research advocates for the development of climate-resilient water supply systems, the establishment of regular funding mechanisms, the adoption of integrated water resource management approaches, capacity-building initiatives, and heightened community involvement to ensure sustainable water security amidst changing climatic conditions in rural Nepal.

REFERENCES

- [1] Intergovernmental Panel on Climate Change. (2023). Climate change 2023 synthesis report: Summary for policymakers. IPCC.
- [2] International Centre for Integrated Mountain Development. (2019). Hindu Kush Himalayan assessment: Mountains, climate change, sustainability and people. ICIMOD.

- [3] Central Bureau of Statistics. (2021). National population and housing census 2021 (2078 BS). Government of Nepal.
- [4] Central Bureau of Statistics. (2016). National climate change impact survey 2016: A statistical report. Government of Nepal.
- [5] Government of Nepal, Ministry of Population and Environment. (2019). Nepal's second national communication to the United Nations Framework Convention on Climate Change. Ministry of Population and Environment.
- [6] Government of Nepal. (2010). National Adaptation Programme of Action (NAPA). Ministry of Environment.
- [7] Gautam, M. R., Timilsina, G. R., & Acharya, K. (2017). Changing monsoon patterns and implications for water resources in the Koshi River Basin, Nepal. *Journal of Hydrology: Regional Studies*, 10, 39–60. <https://doi.org/10.1016/j.ejrh.2017.01.006>
- [8] Immerzeel, W. W., Lutz, A. F., Andrade, M., Bahl, A., Biemans, H., Bolch, T., Hyde, S., Brumby, S., Davies, B. J., Elmore, A. C., Emmer, A., Feng, M., Fernandez, A., Haritashya, U., Kargel, J. S., Koppes, M., Kraaijenbrink, P. D. A., Kulkarni, A. V., Mayewski, P. A., ... Shea, J. M. (2020). Importance and vulnerability of the world's water towers. *Nature*, 577(7790), 364–369. <https://doi.org/10.1038/s41586-019-1822-y>
- [9] Bolch, T., Shea, J. M., Liu, S., Azam, M. F., Gao, Y., Gruber, S., Immerzeel, W. W., Kulkarni, A., Li, H., Tahir, A. A., Zhang, G., & Zhang, Y. (2019). Status and change of the cryosphere in the extended Hindu Kush Himalaya region. In P. Wester, A. Mishra, A. Mukherji, & A. B. Shrestha (Eds.), *The Hindu Kush Himalaya assessment: Mountains, climate change, sustainability and people* (pp. 209–255). Springer. https://doi.org/10.1007/978-3-319-92288-1_7
- [10] Ministry of Water Supply, Department of Water Supply and Sewerage Management. (2017). Climate Resilient Water Safety Plan (CR-WSP) guideline 2017. Government of Nepal.
- [11] Ayers, J. M., Huq, S., Wright, H., Faisal, A. M., & Hussain, S. T. (2011). Negotiating climate resilience in Nepal. *IDS Bulletin*, 45(5), 88–98.
- [12] Ensor, J., & Berger, R. (2009). Community-based adaptation and culture in theory and practice. In W. N. Adger, I. Lorenzoni, & K. L. O'Brien (Eds.), *Adapting to climate change: Thresholds, values, governance* (pp. 227–239). Cambridge University Press.
- [13] Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Global Environmental Change*, 15(2), 77–86. <https://doi.org/10.1016/j.gloenvcha.2004.12.005>
- [14] Department of Hydrology and Meteorology. (2017). Observed climate trend analysis in the districts and physiographic regions of Nepal (1971–2014). Government of Nepal.