Thesis for the Degree of Bachelor of Science in Environmental Management

Effectiveness of Chisapani station flood early warning system in Rajapur municipality, Bardiya

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November, 2024

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Supervised by Assoc. Prof. Ajay Bhakta Mathema

A thesis submitted in partial fulfilment of the requirements for the degree of Bachelor of Science in Environmental Management

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DECLARATION

I hereby declare that this study entitled **Effectiveness of Chisapani station flood early warning system in Rajapur municipality, Bardiya** is based on my original research work. Related works on the topic by other researchers have been duly acknowledged. I owe all the liabilities relating to the accuracy and authenticity of the data and any other information included hereunder.

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Anish Khadka

2019-1-41-0002

November, 2024

RECOMMENDATION

This is to certify that this thesis entitled **Effectiveness of Chisapani station flood early warning system in Rajapur municipality, Bardiya** prepared and submitted by **Anish Khadka**, in partial fulfillment of the requirements of the degree of Bachelor of Science (B.Sc.) in Environmental Management awarded by Pokhara University, has been completed under my supervision. We recommend the same for acceptance by Pokhara University.

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November, 2024

CERTIFICATE

This thesis entitled **Effectiveness of Chisapani station flood early warning system in Rajapur municipality, Bardiya** prepared and submitted by **Anish Khadka** has been examined by us and is accepted for the award of the degree of Bachelor of Science (B.Sc.) in Environmental Management in by Pokhara University.

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LETTER OF APPROVAL

This dissertation paper submitted by **Anish Khadka** entitled **Effectiveness of Chisapani station flood early warning system in Rajapur municipality, Bardiya** has been accepted for the partial fulfilment of Bachelor of Science in Environmental management from Pokhara University.

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ABSTRACT

Flood Early Warning Systems (FEWS) are essential for disaster preparedness and risk mitigation, particularly in flood-prone regions like Rajapur municipality, Bardiya. This thesis evaluates the effectiveness of the Chisapani Flood Early Warning System, focusing on its strengths and limitations in reducing flood risks. Employing a mixed-methods approach, the study utilizes deterministic forecast verification through the UN ESCAP toolkit, alongside a survey of 200 households, 32 key informant interviews (KIIs), and Focus Group Discussions (FGD) with the *Sana Kisan* women's group to assess communication and preparedness. The system demonstrates a commendable accuracy rate of 86%; however, it faces significant challenges, including a high false alarm ratio of 56% and a detection probability of only 63%, which undermine public trust and hinder effective event identification. The primary communication strategy relies on SMS alerts, supplemented by the *Barghar-Chaukidar* system that uses sirens and community networks, with SMS being the preferred method for most participants. Despite reporting an average advance notice of 2-3 hours, household preparedness remains at a neutral level, indicating a considerable gap between awareness and actual readiness. This research underscores the importance of integrating modern technologies with traditional practices, enhancing community training initiatives, and maintaining accessible evacuation sites to bolster overall disaster preparedness in Rajapur. By addressing these gaps, the community can improve its resilience to flooding and ensure a more effective response to future events.

Keywords: *Early warning system, Forecast verification, Communication and dissemination, Preparedness and response.*

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LIST OF ABBREVIATIONS

CBFEWS	Community Based Flood Early Warning System
DHM	Department of Hydrology and Meteorology
EPR	Emergency Preparedness and Response
ESCAP	Economic and Social Commission for Asia and the Pacific
EWS	Early Warning System
FEWS	Flood Early Warning System
FM	Frequency Modulation
GIS	Geographic Information System
GPS	Global Positioning System
ICIMOD	International Centre for Integrated Mountain Development
ILO	International Labour Organization
LDCRP	Local Disaster Climate and Resilient Plan
LEOC	Local Emergency Operation Centre
MoFE	Ministry of Forest and Environment
Ms. Excel	Microsoft Excel
NDRRMA	National Disaster Risk Reduction and Management Authority
NGOs	Non-governmental Organizations
PA	Practical Action
SMS	Short Message Service
SWOT	Strengths Weakness Opportunities and Threats
UNEP	United Nations Environmental Programme
UNU	United Nations University
US EPA	United State Environmental Protection Agency
USD	United States Dollar
WMO	World Meteorological Organization

CHAPTER 1

INTRODUCTION

1.1 Background

Floods are one of the most frequent meteorological and hydrological hazards worldwide. The World Meteorological Organization (WMO) describes flood as "*a rise, usually brief, in the water level of a stream or water body to a peak from which the water level recedes at a slower rate*." Climate change is expected to alter flood patterns. Some areas will experience more frequent and intense floods due to increased rain and evaporation. In contrast, others may experience less flooding due to changes in snowmelt and precipitation (*Climate change indicators: River flooding | US EPA*, 2023). The size and vulnerability of populations exposed to disasters and the frequency and severity of hydro-meteorological hazards increase the occurrence and impact of disasters (WMO, 2014).

1.1.1 Scenario of flood

Floods can cause widespread devastation, resulting in fatalities, property damage, and critical public health infrastructure. Between 1998 and 2017, floods affected more than 2 billion people globally with more than $40 billion in damage each year around the world. (*Flooding – ClimaHealth*, 2023). Floods have had a devastating impact on the Asian continent, particularly in vulnerable countries such as India, China, the Philippines, Iran, Bangladesh, and Nepal (WWAP, 2006). In Nepal, floods are mainly caused by heavy precipitation, with riverine floods being the most prevalent, along with flash floods, landslide lake outburst floods, glacial lake outburst floods, snowmelt floods, inundation, and breaches of embankments, each offering unique challenges (SOP for FEWS in Nepal, 2018). Nepal ranks 12th in the world based on the proportion of the population exposed to the threat of floods annually (24%) (UNDP 2004) and 2nd most vulnerable to flooding in South Asia (UNDP, 2009). Over the past 49 years (1971-2019), Nepal has experienced a staggering 3,443 flood events (MoFE, 2021). Between 1954 and 2018, these floods claimed the lives of 7,599 people, displaced 6.1 million, and caused economic losses of approximately 10.6 billion dollars. Annually, on average, 100 people have lost their lives due to floods in Nepal (Shrestha, Rai, and Marasini, 2020).

1.1.2 Early warning system

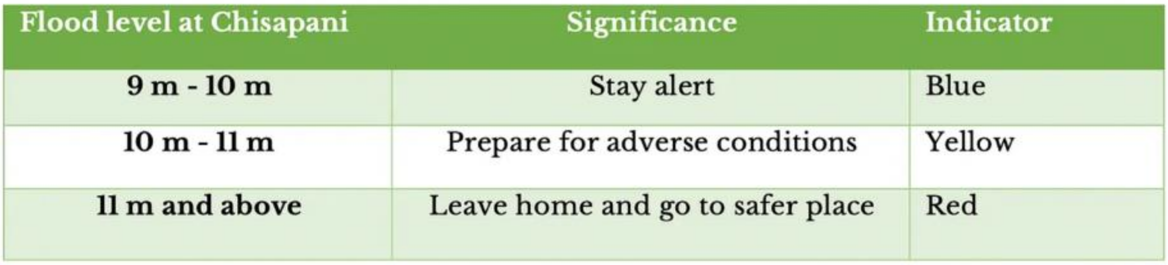
Communities worldwide are increasingly turning to early warning systems as a crucial tool for adapting to the changing reality of climate-induced disasters. The United Nations

Environment Programme (UNEP) defines early warning systems as "*the provision of timely and effective information through identified institutions, allowing individuals at risk to take action to reduce their risk, prepare for effective response, or avoid hazards altogether*" (UNEP, 2012). A community-based flood early warning system (CBFEWS) is a locally run network that plays a vital role in detecting rising floodwaters and issuing timely warnings. Designated caretakers within these communities disseminate this information to residents, government agencies, and other relevant stakeholders. The effectiveness of CBFEWS relies on the availability of accurate data, rapid dissemination of warnings, and educating the community on appropriate responses (Sharma, 2023). An effective early warning system can significantly reduce both lives lost and property damage, with estimates suggesting a 30% reduction in damages when activated 24 hours before a disaster (ILO, 2024). The Sendai Framework for Disaster Risk Reduction (2015-2030), supported by the United Nations Office for Disaster Risk Reduction, recommends actions at both national and local levels to enhance preparedness through the implementation of early warning systems. The United Nations commemorates October 13 as the International Day for Disaster Risk Reduction (IDDRR) to promote a global culture of disaster resilience. In 2022, the International Day focused on Sendai Framework Target G: "Substantially increase the availability and access to multi-hazard early warning systems and disaster risk information and assessments for people by 2030."

1.1.3 Rajapur municipality: A hotspot for flooding

Rajapur municipality is one of the flood-prone areas due to its flat topography and location between the Karnali and Geruwa rivers (*Flood risk communication through mural art*, 2024). Ministry of Forest and Environment (MoFE) has categorized Rajapur as having very high sensitivity (0.788–1) and vulnerability (0.686–1) rankings, indicating its susceptibility to flooding. The municipality has a history of devastating floods, with notable events occurring in 2014 and 2021. The 2014 flood resulted in the tragic loss of approximately 222 lives and impacted over 100,000 people. In October 2021, flooding in Rajapur affected 1,213 households and caused severe crop losses for 9,281 farmers. The municipality has a strong response system that includes a Community-Based Flood Early Warning System (CBFEWS) that was initiated by Practical Action (PA) at Chisapani in 2010 and a fully functional Local Emergency Operation Centre (LEOC). An SMS alert is sent to the Armed Police Force, Nepal Red Cross, municipal offices, and 74 flood-prone downstream villages during the monsoon season by Ms.Parbati Gurung (operator) when the water level at

Chisapani reaches a warning level of 9 m. There is a 3-4 hour lead time for the downstream communities of Tikapur, Janaki, Rajapur, Geruwa, and Madhuwan municipalities to prepare for a possible flood (Hub, 2024).



Flood level at Chisapani	Significance	Indicator
9 m - 10 m	Stay alert	Blue
10 m - 11 m	Prepare for adverse conditions	Yellow
11 m and above	Leave home and go to safer place	Red

Fig 1. 1 Flood level at Chisapani and their significance downstream (Hub, 2024)

1.1.4 Forecast verification

According to the National Oceanic and Atmospheric Administration (NOAA) *Forecast Verification Glossary*, forecast verification is the process of assessing the quality of forecasts, which involves comparing the statistical characteristics of the forecasts with actual observations. Various verification methods are available, and the choice of method depends on the forecast type and the specific objectives of the user. This process ensures that forecasts are reliable and accurate, aiding in effective decision-making. According to UN ESCAP toolkit, verification is the process of retrospectively comparing forecast (model-based) outputs to relevant observations to assess their quality, which is crucial for understanding model biases and refining the model or selecting a better model configuration. Forecasts can be either deterministic or probabilistic, with probabilistic forecasts representing the probability of occurrence within ranges of values for the variable in consideration.

According to UN ESCAP toolkit, deterministic forecast is a type of weather or climate prediction that provides a specific, singular outcome for a given variable at a particular time. Deterministic forecasts can be categorized into several types: continuous forecasts provide a specific value of the variable; dichotomous forecasts, which are binary, indicate yes/no outcomes (e.g., rain/no rain); multi-category forecasts classify conditions into categories such as light moderate, or heavy precipitation; visual forecasts present information in graphical form; and spatial forecasts convey information about geographical distribution.

1.2 Statement of the Problem

Nepal has 6,000 rivers and rivulets among them many rivers are prone to flooding, especially during the monsoon season (June-September). Major floods have occurred throughout history, with devastating consequences such as the Tinao Basin (1978), Koshi River (1980), Tadi River Basin (1985), Sunkoshi Basin (1987), and devastating cloud burst in the Kulekhani area (1993) which alone claimed the lives of 1336 people (*Nepal Disaster Risk Reduction Portal*). According to *NDRRMA* (2022), Nepal's overall score is 143.1 out of 360, and 39.8% of Nepal's Emergency Preparedness and Response systems are estimated to be either weak or insufficient.

Rajapur is a landmass built from Himalayan river deposits and has a long history of major floods. The Karnali River continuously reshaped the area and caused significant flooding events in 1983, 2009, 2013, and 2014 (Smith et al., 2016). Rajapur shares its boundaries with 2 tributaries of Karnali River so it experiences the impact of floods annually. The Disaster Risk Reduction and Management Act, of 2074: also established a separate fund for municipalities where Rajapur is funded NPR 5,000,000 annually (*EPR, 2022 - 2030*). Rajapur municipality is putting several strategies into practice, including Chisapani EWS, in addition to more conventional techniques like dykes, and mural arts communication realizing the critical role in reducing the risks of flooding and its potential to cause property damage and loss of life. However, the overall effectiveness of this EWS in adequately preparing the local population and mitigating flood-related damages needs to be understood better. Before and after the system is implemented, key aspects such as technical reliability, warning dissemination, community preparedness, and actual flood impacts must be evaluated systematically.

1.3 Research Questions

This study aims to assess the effectiveness of existing flood EWS by evaluating:

- *Accuracy and reliability of flood forecasts*: How well do warnings predict the floods?
- *Reach and comprehension of warnings*: Do warnings reach all at-risk populations, and are they understood clearly?
- *Community preparedness*: How effectively do communities respond to warnings?
- *Strengths and Weaknesses*: What are the strengths and weaknesses of EWS?
- *Opportunities and Threats*: What may be the opportunities and threats of EWS?

1.4 Research Objectives

1.4.1 General Objective

- To assess the effectiveness of the Chisapani Flood Early Warning System (FEWS) in Rajapur municipality, Bardiya.

1.4.2 Specific Objectives

- To evaluate the deterministic forecast verification measures.
- To assess the effectiveness of communication channels to disseminate flood warnings in Rajapur municipality.
- To analyze the community preparedness and response to flood warnings issued by the Chisapani FEWS.
- To conduct a SWOT analysis of EWS for effectiveness.

1.5 Rationale of the study

Kafle (2017) highlights that, both the Hyogo Framework for Disaster Reduction (2005-2015) and Sendai Framework for Disaster Risk Reduction (2015-2030) recognize EWS as an important component of disaster risk reduction and achieving sustainable development and livelihoods. An effective EWS informs concerned authorities and at-risk communities about local hazards, community vulnerability, impending risk, warning messages, and the development and mobilization of risk-reduction response capabilities. A study by United Nations University (2019) spanning 2000 to 2017 reveals a positive trend in flood disaster mitigation. The number of FEWS nearly doubled, alongside a decline in flood disasters (157 in 2000 to 126 in 2017) and a significant reduction in flood-related deaths (45% decrease, from 6,025 to 3,331 annually). Floods affected 73 million in 2000, dropping to 55 million by 2017 (a 24% decrease), while the 18-year flood casualty average (2000-2017) is 5,368, with 2017 recording 3,331 deaths which is 2,000 fewer than average (Perera et al., 2019). This study suggests that the increased use of FEWS, combined with other measures, has effectively saved lives and reduced the impact of floods.

The Chisapani Early Warning Station is essential to Rajapur municipality's flood adaptation efforts as floods in Rajapur grow more frequent and severe. Early warnings can significantly reduce flood risk by allowing residents to plan and evacuate. This can save lives, protect property, and reduce economic losses for the municipality. The information collected by the Chisapani station, such as river levels, can be used to assess specific flood risks in Rajapur.

Analyzing the effectiveness of the Chisapani EWS in Rajapur using factors such as deterministic measures, communication channels, and community response may assist in identifying weaknesses. Addressing these weaknesses strengthens the EWS, lowering the overall flood risk for the Rajapur municipality. However, there needs to be more research on the real-world effectiveness of such systems, particularly in developing countries such as Nepal.

This study addresses the knowledge gap by thoroughly evaluating the Chisapani early warning system. The findings will provide valuable information about the system's strengths, weaknesses, and areas for improvement. Furthermore, understanding the effectiveness of the Chisapani early warning system is critical for local governments, disaster management organizations, and communities to make evidence-based decisions about flood preparedness and response strategies. The findings can also contribute to a broader discussion about the role of technology-based early warning systems in increasing community resilience to climate-related disasters.

1.6 Limitations of the Study

Below are some of the limitations encountered throughout the study:

- Only highly and very highly vulnerable wards were selected as study areas.
- Only the warning issued from the Chisapani gauge station above 9m was included, but not other forecasting systems such as 3-day and 5-day forecasts.
- This study only includes the deterministic forecast verification measures and not probabilistic measures.
- This study includes forecasts up to 2021 and monthly data on warnings and flood events. Daily flood event data was not available for this analysis.
- This study is limited by a small sample size, which may not accurately represent the entire population of Rajapur municipality.
- Given the significant Tharu population in Rajapur municipality, language barriers could potentially hinder effective communication and understanding during data collection.

CHAPTER 2

LITERATURE REVIEW

2.1 EWS Effectiveness: A General Overview

According to UNISDR (2006), there are 4 major elements of effective flood early warning systems.

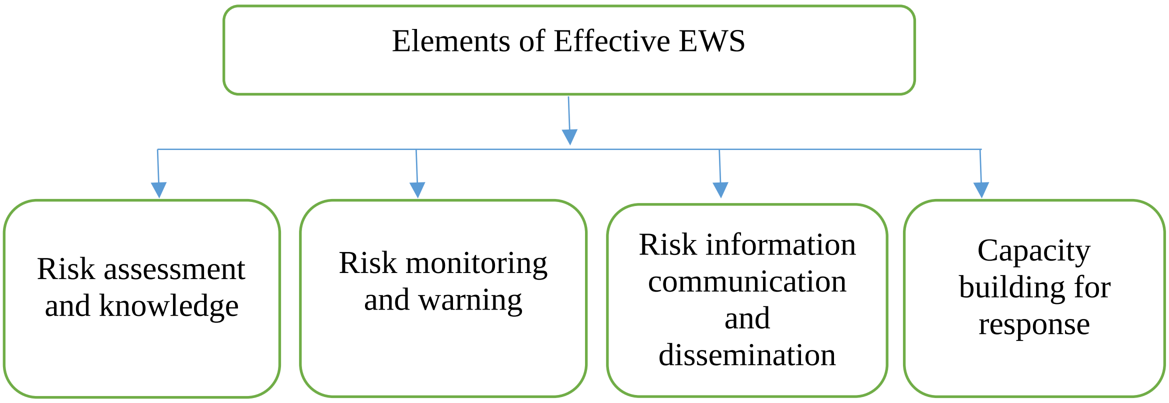


Fig 2. 1 Elements of early warning System (UNISDR 2006)

As per the UN's 2006 survey, the dissemination of warnings and the preparedness to respond are the weakest elements of early warning systems in developed and developing countries (Shrestha et al. 2014). The impacts of Hurricane Katrina in the United States, the tsunami in the Indian Ocean, and the floods in Pakistan and Uttarakhand, India, all point to inefficiency in the current early warning systems. For any early warning system to be successful, people must be at the center of it.

The status of Multi-Hazard Early Warning Systems (MHEWS) in Least Developed Countries (LDCs) 2024 report reveals significant challenges and opportunities. Less than half of LDCs report having MHEWS, particularly among African nations, although improvements have been made over the past decade. Effective MHEWS depends on strong risk governance and collaboration across sectors, yet disaster risk knowledge is often weak, limiting the use of advanced forecasting methods like Impact-Based Forecasting (IBF). Disseminating warnings to vulnerable communities remains challenging due to technology access gaps. Many LDCs lack the necessary infrastructure and equipment, with varying compliance to global standards. However, there is growing momentum for Anticipatory Action frameworks and recognition of young people’s crucial role in implementation.

Initiatives like EW4All foster inter-agency collaboration, but it is essential that MHEWS remain locally adapted and country-led to effectively meet community needs.

2.2 Early Warning System: A Global Perspective

According to the World Meteorological Organization, early warning systems are particularly "cost-effective and reliable" in protecting lives, property, and infrastructure against natural disasters. According to the United Nations Global Commission on Adaptation, investing just $800 million in such systems in developing countries would prevent losses ranging from $3 to $16 billion annually (GAR, 2010).

Murphy (1996) highlighted on Finley (1884) in which twice-daily tornado forecasts for eighteen regions of the United States east of the Rocky Mountains by using dichotomous forecast verification measures. Finley claimed 95.6% to 98.6% total accuracy over the first three months, depending on time and district, with certain districts obtaining 100% accuracy throughout. A research critic pointed out that 98.2% accuracy could be obtained just by forecasting "no tornado".

Gwimbi (2007) interviewed the civil protection department, non-governmental organizations (NGOs), 157 meteorological services, local communities, government officials, and Focus groups at three case study locations in Zimbabwe. The study highlighted that a maximum of 53.8% received the warning of flood during and after the flood only. Over 68% of villagers claimed they were unlikely to respond to the early warning system for flood damage. There was a negative correlation between flood deaths and respondent’s preparedness for flooding. In other words, higher flood deaths were linked to lower preparedness. Warnings from village leaders were more effective and perceived as genuine in reducing negative flood impacts among respondents. Despite significant crop damage (80%), home flooding (55%), flood-related illnesses, and high school absenteeism, the flood-prone areas studied lacked an early warning system and preparedness.

Diakakis, Skordoulis and Kyriakopoulos (2022), gathered data through a cross-sectional survey of 438 residents in Greece. The survey assessed the participants' knowledge, attitudes, and preparedness regarding flood and extreme weather early warning systems in the country. The survey questions focused on awareness of warning channels, perceived effectiveness of warnings, personal preparedness behaviors, and socio-demographic variable and analyzed using descriptive statistics, bivariate analysis, and multivariate regression models. Awareness of the existence of early warning systems was high (over

80% of respondents), but knowledge of specific warning protocols and communication channels was more limited.

Atreya et al. (2017) conducted a household survey in ten flood-prone communities in Tabasco, Mexico, highlighting the importance of socioeconomic factors in flood preparedness. Their statistical analysis found that access to flood risk maps, sharing experiences with family, having early warning systems, and availability of shelters significantly enhance household preparedness (protect their belongings, safe meeting place, and emergency preparedness training).

2.3 EWS Effectiveness in South Asia

Between 2000 and 2018, 5338 water-related disasters were reported, resulting in over 326,000 fatalities and global economic losses of more than USD 1.7 trillion annually. Floods accounted for approximately 54% of total water-related disasters. Asia appears to be the hardest-hit continent, accounting for 41% of all flood disasters, followed by Africa (23%), the Americas (21%), Europe (13%), and Oceania (3%). Floods were responsible for 93,470 deaths related to hydro meteorological hazards between 2001 and 2018 (Perera et al. 2020). South Asia is responsible for one-third of Asia's floods, half of the deaths, and more than one-third of those affected. Between 1976 and 2005, South Asia experienced 943 natural disasters, with floods causing one-third, primarily in the Indus, Ganges, and Brahmaputra basins (Shrestha et al. 2014).

Biswas et al. (2020) describe the creation of a computationally efficient flash flood early warning system for a mountainous, transboundary river basin in northeastern Bangladesh. The hydrologic model (SWAT) was calibrated and validated using satellite-based observations to accurately estimate the amount of transboundary and mountainous inflow into the flash flood-prone plains. Compared to Sentinel-1 satellite imagery, historical performance analysis revealed that the system can delineate flood inundation with at least 60% accuracy up to 5 days in advance. During the pre-monsoon seasons of 2016-2018, the system detected water and non-water features with a probability of over 60% for up to 5 days in advance.

Rana, Bhatti, and Jamshed (2020) investigated the effectiveness of the Flood Early Warning System (EWS) in three flood-prone communities (Rawalpindi, Sialkot, and Muzaffargarh) of Pakistan by gathering perspectives from local experts and communities. The findings revealed shortcomings in the system, the majority of households in Rawalpindi did not receive any warning about the last floods. The sources of warnings also varied between communities, with some relying more on district or local authorities than others. Perhaps most concerning, the study identified a low level of trust in government disaster plans among the communities surveyed. Approximately 34%, 9%, and 10% of respondents in Rawalpindi, Sialkot, and Muzaffargarh areas indicated moderate to high confidence in the government's disaster management policies. A study identified areas for improvement in the FEWS due to underfunding, communication gaps between communities and local governments, and a lack of clear guidelines for issuing warnings.

Khan et al. (2018) examine the possibility of setting up a community-based flood early warning system (CBFEWS) in Azad Jammu and Kashmir (AJ&K), Pakistan. It looks into traditional practices and methods that local communities already use to deal with the frequent flash floods in the region. The survey results indicate that most of the community (78%) believed they needed to be adequately informed about flood risks. In comparison, a minority (14%) were informed through official channels, and an even smaller percentage (8%) received information from informal community sources. The communities suggested using local capacities such as (58%) loudspeakers, (14%) sirens, and (28%) mobile SMS for the dissemination of early warnings. The study highlights the importance of incorporating the community's perspectives and local knowledge in designing and implementing an effective early warning system for flash floods.

Niraula (2017) used a case study approach, gathering primary data through interviews with key stakeholders and secondary data from government publications and literature. The flood early warning system (EWS) in Uttarakhand's two flood-prone districts, Uttarkashi and Rudraprayag, was evaluated using criteria such as institutional frameworks, monitoring and forecasting, communication and dissemination, and preparedness and response. Ginwala boasts the highest reception rate at 46.43%, followed by Khadri Khadak Maf (36.67%) and a significantly lower rate in Badal (4.35%). Interestingly, the most common source of warnings is local – either through individual observation (presumably of rising water levels) or from fellow community members (71.6%). Police announcements come in a distant second at 17.3%. Furthermore, the data suggests a difference in the lead time needed for response. Badal requires a quicker reaction window of 2-3 hours compared to the other villages where 1-2 hours is sufficient. This variation might be due to specific vulnerabilities faced by Badal, such as its proximity to a river or susceptibility to flash floods.

2.4 Nepal’s Scenario of EWS

Article 50 of the Constitution of Nepal (2015) emphasizes the protection of life and property, particularly through policies that establish advance warning systems, preparedness, rescue, relief, and rehabilitation to mitigate natural disaster risks. Sub-clause O of Clause 8 of the Disaster Risk Reduction and Management Act 2017 (DRRMA 2017) calls for the establishment and functioning of a national early warning system. Additionally, the act requires the enhancement of early warning systems through research and the development of suitable technologies. A significant step in this direction was the Water Resources Strategy (WECS, 2002), which advocated for improved disaster networking, the integration of all warning systems under the Department of Hydrology and Meteorology's flood warning system, and the promotion of international cooperation for flood forecasting and warning (SOP for FEWS in Nepal, 2018).

According to the Emergency Preparedness and Response report (2022-2030), Nepal has over 100 automatic and roughly 200 manual hydrological observation stations to monitor rainfall and assess hydrological hazards. Currently, there are 11 lightning observation systems, 1 X-band radar station, and 1 upper air radiosonde system, but more research is needed on their effectiveness, especially in developing countries like Nepal. The Terai region features a Flood Early Warning System (FEWS) across 12 major river basins to protect downstream communities, linked to community disaster management groups that respond to alerts. The Department of Hydrology and Meteorology (DHM) collaborates with Nepal Telecom and Ncell to send free SMS alerts to mobile phones in flood-prone areas when disaster risks exceed specific thresholds. Nepal is divided into 246 polygons based on rivers, population, and exposure to hazards, providing Early Warning messages 8-10 hours in advance for major rivers, 5-6 hours for smaller rivers, and 1-2 hours for flash floods. (*EPR, 2022 - 2030*).

Practical Action piloted the first CBEWS in Nepal in 2002 for the East Rapti River (Practical Action, 2008). The pilot program was expanded to include eight river basins in Nepal, including Karnali, West Rapti, Babai, East Rapti, Narayani, Bagmati, Kankai, and Koshi (Gautam and Phaiju, 2013). In 2015, the Community-Based Flood Early Warning System (CBFEWS) was implemented at three different sites along the Ratu River: Kalapani, Lalgadh, and Sarpallo providing vulnerable communities 2-3 hours of notice to prepare for flooding. To disseminate flood warnings, the system employs a variety of communication channels, including sirens, SMS, and social networks. The CBFEWS was discovered to be an effective nonstructural approach to addressing flood risk at the community level, thereby reducing loss of life and property. The active participation of local communities, government agencies, and individuals boosted confidence and ownership of the early warning system. During the flood disaster, nearly 14% of households reported that institutional work was very effective, 63% reported moderate effectiveness, and 23% reported ineffective. However, the percentage of households reported that the work needed to be improved during the baseline survey was 23%, which decreased to zero after implementing the CBFEWS (Bajracharya et al. 2021).

Rai et al. (2020), conducted a cost benefit analysis by household survey, focus group discussions and key informant information and concluded that households saved an average of NPR 117,027 (USD 1083) per flood on movable property, livestock, vehicles, and healthcare. The benefit-cost ratio was found to be 73/24, indicating a strong return on investment. 98% of residents were willing to pay an annual fee of NPR 79 (USD 0.70) for five years to maintain the community-managed EWS. This fee could cover the annual maintenance and operation costs (around NPR 694,426 or USD 6430). Increasing the flood warning lead time by just one hour could nearly increase cost savings by 1.83 times.

Thapa, Watanabe, and Regmi (2022) investigated mobile phone access and disaster preparedness in the Seti River Basin, revealing that 98.68% of residents aged 15 to 64 own mobile phones, with ownership rates of 98.61%, 98.80%, and 99% in Masinabagar, Laltinbazar, and KI-sing, respectively. This high penetration suggests that an early warning system utilizing mobile technology could effectively inform the community about impending disasters. However, the study also identified significant challenges, including inadequate evacuation routes and safe shelters for households in high inundation risk zones. To enhance safety, the authors recommend relocating buildings from these zones, emphasizing the need for financial support from governmental and non-governmental organizations, particularly as the affected populations often belong to lower-income categories.

2.5 Context of Rajapur Municipality

2.5.1 Risk and knowledge

According to Rajapur Municipality Monsoon Preparedness and Response Plan – 2024, Municipality faces a significant flood risk, with nearly 95% of its households (11,986 out of 12,707) being vulnerable. Among these, 4,374 households are at high risk, 2,310 are at medium risk, and 5,302 are at low risk. Rajapur's proximity to the river puts it at significant risk of flooding due to various factors. The construction of the Kailaspur Dam in India could exacerbate flooding downstream as it regulates water flow, potentially leading to increased water levels during heavy rainfall. The widening of the river due to rising water levels and erosion increases the flood risk area. The lack of effective early warning systems and limited community knowledge about flood risks compounds the vulnerability. Rapid population growth and migration have led to settlements near riverbanks, often in unorganized and poorly managed areas, increasing exposure to flood hazards. Destructive activities like unregulated sand extraction and deforestation along the riverbanks weaken natural defenses against flooding. Climate change, with its rising temperatures and changing precipitation patterns, can intensify flood events. These combined factors make Rajapur particularly susceptible to flooding, highlighting the urgent need for comprehensive flood mitigation measures. The ward wise description of risk assessment in based on ward is elaborated below in a table.

Table 2. 1 Ward-wise risk information for flood

Risk type	**Ward based household details**										**Total**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
High Risk	457	147	795	698	159	127	521	470	421	579	4374
Medium risk	387	123	200	200	146	134	107	260	321	432	2310
Low risk	424	1024	238	335	1136	981	194	253	256	461	5302

Source: Bipad portal

2.5.2 Lead time for preparedness

At the gauge station, flood conditions are monitored to determine if they are increasing, decreasing, or approaching warning or danger levels. During the monsoon, monitoring is done 24/7 since floods could occur at any time when there is continuously high rainfall in the river watershed. When it rains, the gauge readers visit the station more frequently to conduct physical verification. The gauge reader notifies the relevant parties and communities, particularly the chairperson of the DDRC and the chief or duty attendant at the DEOC, whenever it observes a rise in flood levels that exceed warning and danger levels. The lead time in the Karnali Rivers was determined using scientific techniques and confirmed through community involvement using floating objects, such as volleyballs or footballs (Practical Action, 2016).

Table 2. 2 Lead time for different communities in Rajapur municipality

S.N.	Name of Community	Wards		Lead time	Level of risk
		Before	Now		
1	Murghahawa	1	1	2hr 30m	High
2	Chanaura	2	1	2hr 35m	High
3	Premnagar	2	1	2hr 45m	High
4	Nangapur	5	3	2hr 55m	Medium
5	Tighra	6	3	3hr	High
6	Chakkapur	10	3	3hr	High
7	Tediya	10	3	3hr 10m	Medium
8	Anantapur	11	4	3hr 10m	Medium
9	Shangarshanagar	12	4	3hr 30m	Medium
10	Muktakamaiya Tol	13	4	4hr	High
11	Lahur Tol	13	7	4hr	High
12	Shankarpur	13	7	4hr	High

Note: Wards are merged and there are only 10 wards now.

Source: (Practical Action, 2016)

2.5.3 Communication and dissemination

A flood warning system employs a robust communication network to inform citizens during potential flooding. Data on water levels, collected by gauge readers in Chisapani station along rivers like the Karnali, is transmitted to various stakeholders. Formal channels involve the Department of Hydrology and Meteorology (DHM) issuing bulletins and website updates. District authorities, led by the Chief District Officer, verify the information and coordinate with local entities like the Red Cross and police. Nationally, the Emergency

Operation Center receives updates and disseminates them further. Informally, gauge readers directly contact community leaders and local FM radio stations to spread the message.

Telephone calls are the primary communication method, while SMS alerts reach key personnel when flood levels become critical. Real-time data is available on the DHM website, and local FM radio stations broadcast warnings and updates. Audio sirens and display boards at key locations provide additional visual and auditory alerts. At the community level, Early Warning Task Forces play a crucial role. They utilize hand sirens, megaphones, and even home visits to ensure everyone, especially vulnerable populations, receives the information. Mass SMS alerts are also sent to mobile users in flood-prone areas. Importantly, information is disseminated in local languages, and regular updates are provided throughout the flood event to keep residents informed and safe. This comprehensive communication system ensures timely warnings reach all levels of society in Nepal, ultimately protecting lives and property during potential floods (Practical Action, 2016).

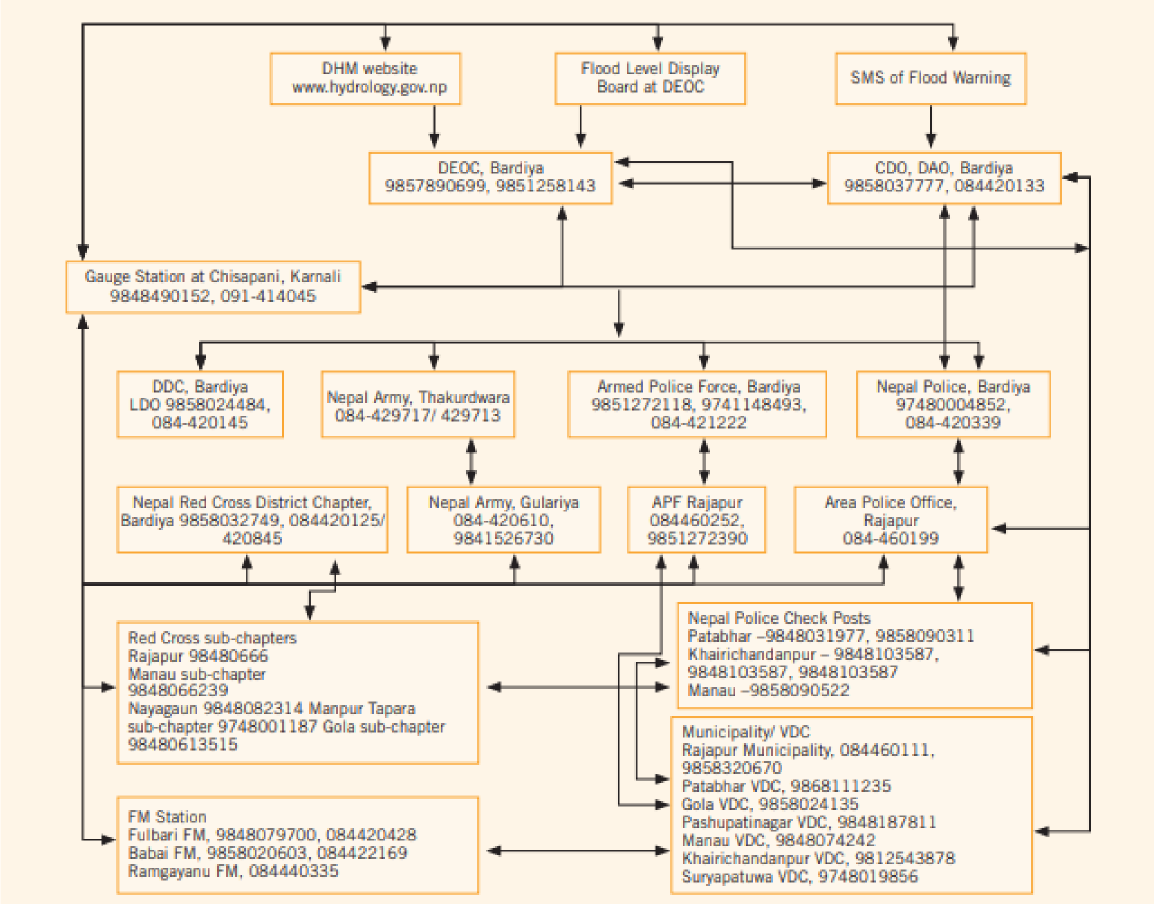


Fig 2. 2 Communication and dissemination channels, Bardiya for Karnali (PA, 2016)

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area

Rajapur municipality is situated in the Bardiya district of Lumbini Province which lies in the southwestern part of Nepal. Rajapur municipality possesses a geographical area of 127.08 sq. km and elevations ranging from 142 to 154 meters. Its east and north coordinates are 81°03'25.63"E to 81°12'52"E and 28°21'25.16"N to 28°29'43"N. Its southern boundary is Uttar Pradesh, India, and its northern border is the Geruwa Rural Municipality. The Karnali and Geruwa rivers shares its eastern and western borders with flat geography posing the risk of flooding annually. According to LDCRP (2022), the municipality comprises 10 wards among which 1, 3,4,7,9, and 10 were selected as study areas that are very highly vulnerable (7, 9, and 10) and highly vulnerable (1, 3, and 4). LDCRP (2022), estimates that the Rajapur Municipality is home to about 69,873 people with a household of 12,707 from various castes with the dominance of Indigenous Tharu communities of about 77.8% followed by Brahmin/Chettris at 10.8%. The selected study area consists of 7,647 households. According to DHM, Chisapani station is situated at a latitude of 28° 65 '30.55"N and longitude of 81° 28' 69.44"E which provides early warning alerts to Rajapur municipality. Due to Rajapur’s precarious geography, complex social and political history, and central position in several interventions to mitigate disasters, including PA’s CBEWS, I have selected the study area to examine whether the effectiveness of Chisapani EWS is sufficient to minimize the risks (Gladfelter 2018).

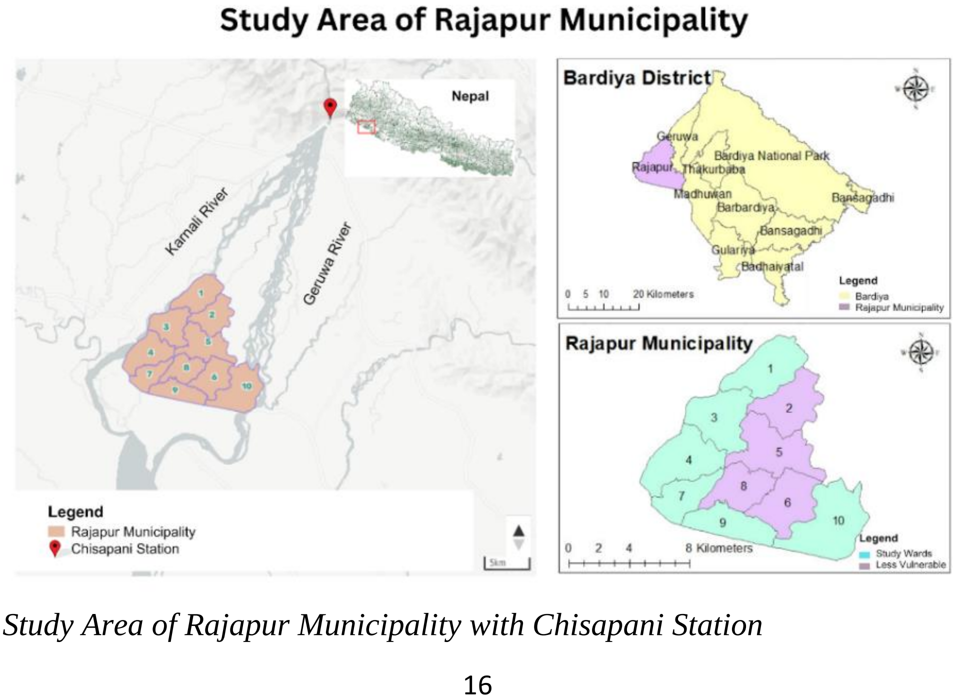


Fig 3. 1 Study Area of Rajapur Municipality with Chisapani Station

3.2 Research Design

The research work was carried out according to the designed conceptual framework in consultation with the supervisor.

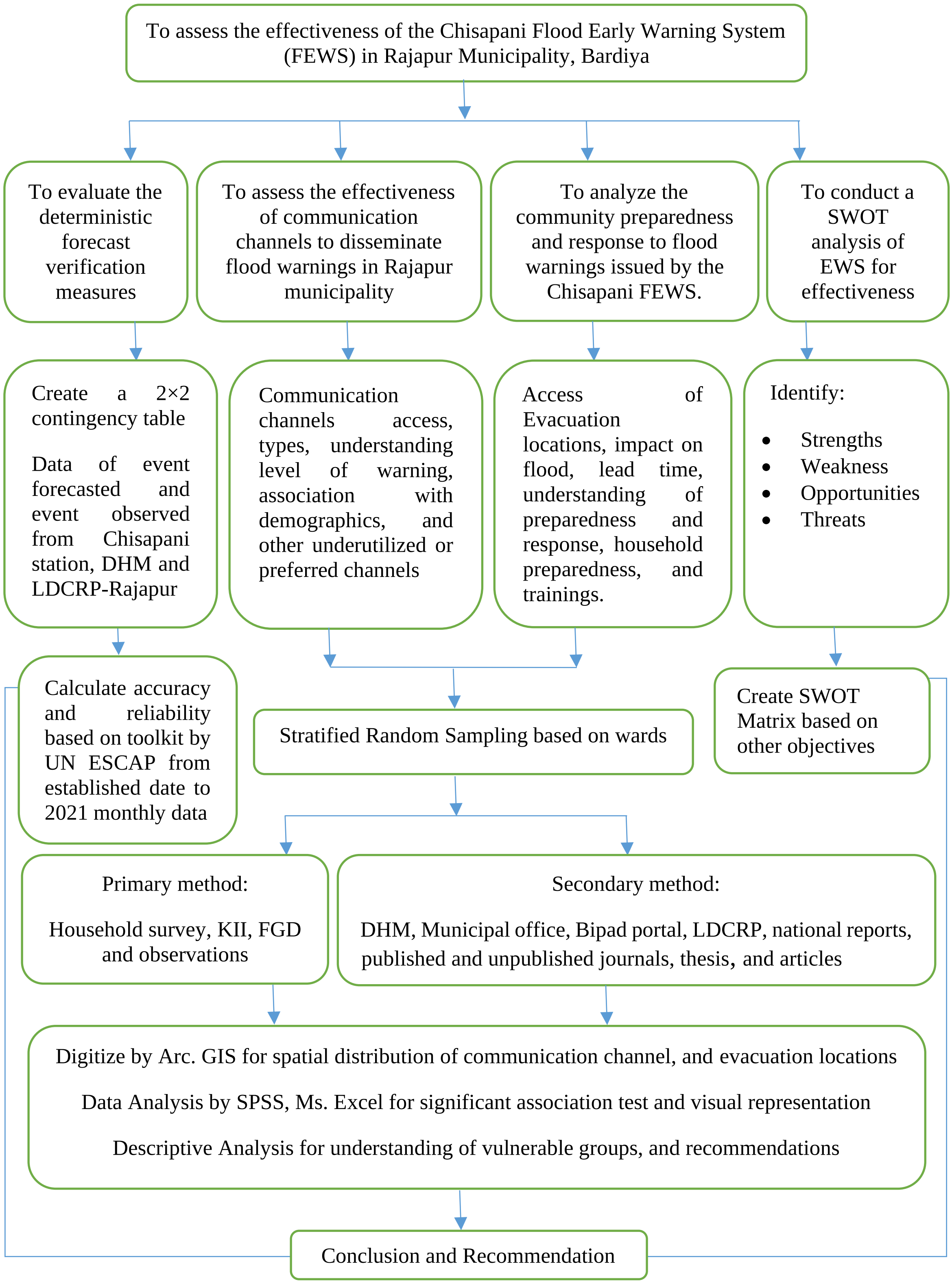


Fig 3. 2 Flowchart of Research Design

3.3 Objective-wise Research Matrix

The objective wise research matrix for completion of the study is given below in table.

Table 3. 1 Objective wise research matrix

S.N	Objectives	Variables	Data collection method	Data analysis
1.	To evaluate the deterministic forecast verification measures	Monthly Event forecast and events observed data from established year till 2021.	Data from DHM for event forecast and LDCRP of Rajapur for event observed based on the toolkit of UN ESCAP	Create a 2×2 contingency table on event forecast (Yes/No) and event observed (Yes/No) and measure the variables based on the formula provided by UN ESCAP by Ms. Excel.
2.	To assess the effectiveness of communication channels to disseminate flood warnings in Rajapur municipality.	Communication Channels	Field observation and Bipad portal	Collect the major communication channels by UTM Geo map. Mapping by digitizing the GPS location on Arc. GIS.
		Understanding level of warning	Household survey	Graphical representation (Pie-chart) and Likert scale analysis by Ms. Excel.
		Types of communication channels used (e.g., sirens, SMS, radio broadcasts)	Household survey, KII and FGDs	Cross-tabulations to identify relationships between demographics with preferred channels and use the Fisher’s exact test (95% LOC) and Cramer’s V

3.	To analyze the community preparedness and response to flood warnings issued by the Chisapani FEWS.	Evacuation shelters and quarantine centre	Field observation and Bipad portal	Collect the evacuation locations by UTM Geo map. Mapping by digitizing the GPS location on ArcGIS.
		Flood impact ranking	Household survey	Scoring the reduction in impact of flood after installation in Ms. Excel by weighted average index.
		Lead time to prepare from flood	Household survey, and FGD	Graphical representation (Pie-chart) and Likert scale analysis by Ms. Excel.
		Household preparedness actions and evacuation locations and vulnerable population	Household survey, observation, and municipal office	Graphical representation and descriptive analysis
		Trainings related to flood	Household survey, FGD and KII	Descriptive analysis
4.	Conduct a SWOT analysis of EWS.	Utilize findings from all previous sections	Identify: A) Strengths B) Weaknesses C) Opportunities D) Threats	Create a SWOT matrix to summarize.

3.4 Sampling Technique

The sampling was conducted by the multi-stage sampling method. Firstly, purposive sampling was performed in which highly and very highly vulnerable wards were only selected i.e. 1, 3,4,7,9, and 10 followed by the stratified random sampling method according to the ward.

3.4.1 Sample size selection

n_0 = required sample size for unknown population

n = required sample size for known population

Z = Z-score corresponding to the confidence level = 1.96 for a 95% confidence level

P = the (estimated) proportion of the population which has the attribute in question (0.05)

e = margin of error =7%= 0.07 (sufficient level of accuracy for the research study)

N = total number of households in the study area = 7,647

Calculations for sample size:

Using Cochran (1977) formula when population size is unknown,

$n_0 = (Z^2 \times p \times (1-p)) / e^2$

$n_0 = (1.96^2 \times 0.5 \times (1-0.5)) / 0.07^2$

$n_0 = 0.9604/0.0049$

$n_0 = 196$

Using Cochran (1977) formula when population size is known,

$n = n_0 / [1 + \{(n_o - 1)/N\}]$

$n = 196 / 1 + \{(196 - 1)/7{,}647\}]$

$n = 191.199$

$n \sim 192$

Since, minimum 192 sample was statistically significant for completion of this research, 200 households were selected.

3.4.2 Sample size based on ward

To estimate the sample size based on the wards of the selected study area:

Sample size (ss) = (total household in a ward / total household in the municipality) × n

Table 3. 2 Stratified Sample Size for different wards

Ward no.	Households based on ward	Sample size	Adjusted sample size	Actual sample taken for study
1	1,271	31.91	32	33
3	1,233	30.96	31	33
4	1,751	43.96	44	45
7	822	20.64	21	23
9	1,098	27.57	28	29
10	1,472	36.96	37	37
Total	7,647		193	200

3.5 Research Methods

Both primary and secondary data collection methods was used in this research for both qualitative and quantitative data collection

3.5.1 Primary data collection

This research methodology included a Household Survey (HHS), Key Informant Interviews (KIIs), Focus Group Discussions (FGDs), and observations to assess the effectiveness of the early warning system. A semi-structured questionnaire was used to collect data from available household members on communication channels, household preparedness actions, and the impact of the early warning system both before and after installation. Demographic data, such as age, gender distribution, educational background, and others, was also collected.

A. Household Survey (HHS)

A stratified random sampling technique was employed to gather data from households situated in six enumerated wards (1, 3, 4, 7, 9, and 10). Semi-structured questionnaires were administered to a total of 200 households, with each interview lasting approximately 10-20 minutes. The survey's objective was to collect information pertaining to communication channels, preparedness actions undertaken in response to flood warnings, and the impact of flooding both prior to and subsequent to the installation of mitigation measures. Additionally, demographic data was gathered.

B. Key Informant Interview (KII)

Total 32 key informant interviews were conducted including the operator of the Chisapani gauge station, the focal person for disaster risk reduction in Rajapur municipality, 6 ward representatives, representatives from Nepal Telecom and Sathi Radio FM Station, 2 senior project officers from Practical Action, DSP of the Armed Police Force, and 19 village heads *(Barghar)*. Through these interviews, the major strengths and weaknesses of the gauge station, communication channels, preparedness and response efforts, and the perspectives of vulnerable communities were gathered.

C. Focused Group Discussions (FGDs)

A focus group discussion was conducted with the "*Sana Kishan Women's Group*" to assess the gender perspective in early warning system. Topics explored included awareness of early warning systems, understanding of early warning messages, and trust in early warning information, accessibility and reliability of early warning channels, preparedness plans, evacuation procedures, gender-specific vulnerabilities, and recommendations for improvement. By engaging with women from the Sana Kishan group, the study aimed to gain valuable insights into the specific needs, concerns, and experiences of women in relation to early warning systems.

D. Observations

GPS data was gathered to map communication networks, evacuation shelters, and critical institutions involved in the early warning system. A mobile application (UTM Geo Map Version: 4.1.7) was used to collect this GPS data. Observations were conducted to assess the status of communication channels, household and community preparedness actions available, and the status of evacuation processes. These observations provided insights into how information was transmitted, how the community responded to potential threats, and the effectiveness of established shelters and support facilities.

3.5.2 Secondary data collection

Secondary data was collected from various published and unpublished sources, including articles, documents, reports, thesis, newspapers, and websites. Data on flood forecasts was obtained from the Department of Hydrology and Meteorology (DHM), while data on flood events was collected from the Local Disaster and Climate Resilience Plan (LDCRP). Other relevant data, such as information on evacuation shelters, educational institution, risk knowledge, was retrieved from the Bipad portal and Monsoon Preparedness Plan-2024.

3.6 Data analysis

- **Mapping:** Geographic Information System (GIS) software, such as ArcGIS was used to create spatial distribution of communication channels, and evacuation locations related to the Early Warning System (EWS).
- **Statistical Analysis:** Data was analyzed using software like Ms. Excel, and SPSS to identify significant association and visual presentation of preparedness actions, flood impact, demographics (age, education), and EWS effectiveness.
- **Qualitative Analysis:** Survey responses, Focus Group Discussions (FGDs), and Key Informant Interviews (KIIs) were analyzed to understand human factors influencing EWS effectiveness for all communities, especially vulnerable ones. This analysis helped generate recommendations for improvement.

3.6.1 Methods for dichotomous (yes/no) forecasts

According to the toolkit of UN ESCAP, a contingency table was created to validate the forecasts made by the Chisapani EWS. This table displayed the frequency of "yes" and "no" forecasts compared to actual occurrences with four possible combinations:

Table 3. 3 Forecast verification 2×2 contingency table

		Event Observed		
		YES	NO	Marginal Total
Event Forecasted	YES	a	b	a+b
	NO	b	d	c+d
	Marginal Total	a+c	b+d	Total (n)= a+b+c+d

Source: (UN ESCAP, 2016)

Where:

a: *hit* - event forecast to occur, and did occur`

b: *miss* - event forecast not to occur, but did occur

c: *false alarm* - event forecast to occur, but did not occur

d: *correct negative* - event forecast not to occur, and did not occur

Table 3. 4 Calculations for dichotomous deterministic flood forecast

Parameters	Formula	Description
Bias Score or Frequency Bias	BIAS = [(Hits + False Alarms) / Hits] + Misses	BIAS range: 0 to ∞ BIAS = 1 is perfect score BIAS > 1 means the system is over-forecasting BIAS < 1 means the system is under-forecasting
Accuracy	Accuracy = (Hits + Correct Negatives) / Total	Accuracy range: 0 to 1 Accuracy = 1 is a perfect score Proportion of forecast that is correct The measure is strongly influenced by the common category
Probability of Detection (POD) or Hit Rate	POD = Hits / (Hits + Misses)	POD range: 0 to 1 POD = 1 is a perfect score Gives the fraction of predicted YES events that occurred The measure is sensitive to misses
False Alarm Ratio (FAR)	FAR = False Alarms / (Hits+ False Alarms)	FAR range: 0 to 1 FAR = 0 is a perfect score

		Gives the fraction of predicted YES events that did not occur The measure is sensitive to false alarms, not misses
Probability of False Detection (False Alarm Rate)	POFD = False Alarms / (Correct Negatives + False Alarms)	POFD range: 0 to 1 POFD = 0 is a perfect score Gives the fraction of predicted NO events that were incorrectly forecast as YES
Threat Score (TS) or Critical Success Index (CSI)	TS = Hits / (Hits + Misses + False Alarms)	TS range: 0 to 1 TS = 1 is a perfect score Includes hit due to random forecast Measures forecast performance after removing correct simple NO forecasts from consideration
Equitable Threat Score (ETS)	ETS = (Hits – Random Hits) / (Hits + Misses + False Alarms – Random Hits) Where: Random Hits = [(Hits + Misses) x (Hits + False Alarms)] / Total	ETS range: 0 to 1 ETS = 1 is a perfect score Random Hits are the hits due to random forecasts
Heidke Skill Score (HSS)	HSS = 2(ad – bc) / [((a+c) (c+d)) + ((a+b) (b+d))]	HSS range: -∞ to 1 HSS = 1 is a perfect score HSS = 0 means no skill

		Negative HSS value means negative skill, i.e. chance forecast is better, or the model has a poor skill A positive HSS value means a positive (better) skill

3.6.2 Fisher’s exact test with Monte Carlo Simulation

Fisher's exact test is a statistical method used to determine the significance of the association between two categorical variables. It's particularly useful when dealing with small cell size (less than 5) or when the expected frequencies under the null hypothesis are too small.

While Fisher's exact test provides an exact p-value, calculating this can become computationally intensive for larger contingency tables. In such cases, Monte Carlo simulation offers a practical alternative.

- Null hypothesis (H_0): There is no association between the two categorical variables.
- Alternative hypothesis (H_1): There is an association between the two categorical variables.

If the p-value is less than the significance level (e.g., 0.05), we reject the null hypothesis and conclude that there is a significant association between the two categorical variables.

If the p-value is greater than or equal to the significance level, we fail to reject the null hypothesis and cannot conclude that there is a significant association between the two categorical variables.

3.6.3 Phi (φ) and Cramer's V

Phi (φ) and Cramer's V are two common statistical measures used to quantify the strength of the association between two categorical variables. Phi (φ) is primarily used for 2x2 contingency tables (i.e., when both variables have only two categories) while Cramer's V can be used for contingency tables of any size. Both Phi and Cramer's V range from 0 to 1.

- 0 indicates no association,
- 0.1 to 0.3 indicates a weak association,
- 0.3 to 0.5 indicates a moderate association,
- Above 0.5 indicates a strong association.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Results

4.1.1 Deterministic forecast verification

The data of event forecast was collected from Department of Hydrology and Meteorology (DHM) focusing on gauge reading above 9 meters and event observed from LPCRP-2022 report, covering a period from 2008/09 (since installation) to 2021/22. This analysis spans a total of 156 months, and a 2×2 contingency table has been created based on the findings.

Table 4. 1 2×2 contingency table for deterministic forecast verification

		Event Observed		
		YES	NO	Marginal Total
Event Forecasted	YES	12	7	19
	NO	15	122	137
	Marginal Total	27	129	Total (n)= 156

Hence, following results can be observed from the data for the effectiveness of early warning system.

Table 4. 2 Results for deterministic forecast

Parameters	Value	Description	Remarks
Bias Score or Frequency Bias	9.22	BIAS > 1 means the system is over-forecasting	The system is over-forecasting.
Accuracy	0.86	Accuracy = 1 is a perfect score	The system has a relatively high accuracy.
Probability of Detection (POD) or Hit Rate	0.63	POD = 1 is a perfect score	The system is detecting events reasonably well, but not perfectly.
False Alarm Ratio (FAR)	0.56	FAR = 0 is a perfect score	The system has a relatively high false alarm rate.

Probability of False Detection (False Alarm Rate)	0.11	POFD = 0 is a perfect score	The system has a relatively low false detection rate.
Threat Score (TS) or Critical Success Index (CSI)	0.35	TS = 1 is a perfect score	The system has a moderate threat score.
Equitable Threat Score (ETS)	0.28	ETS = 1 is a perfect score	The system has a moderate equitable threat score.
Heidke Skill Score (HSS)	0.44	A positive HSS value means a positive (better) skill	The system has a positive skill, indicating it's performing better than random chance.

Based on the above metrics, Chisapani early warning system demonstrates moderate effectiveness. While it exhibits strengths in accuracy and overall skill, there is room for improvement in certain areas. The system's accuracy of 86% indicates that it correctly predicts events a significant portion of the time. However, the false alarm ratio of 56% suggests that it may be generating unnecessary alerts, which can lead to public fatigue and decreased trust. The probability of detection of 63% is reasonable, but it could be improved to ensure that more critical events are accurately identified. A positive Heidke Skill Score (HSS) of 0.44 indicates that the system is outperforming random chance. This is a positive sign, but it doesn't guarantee perfect performance. The threat score of 0.35 and the equitable threat score of 0.28 are moderate, suggesting that the system could be improved in terms of balancing the detection of critical events with the avoidance of false alarms.

Overall, the system demonstrates a promising foundation but could benefit from further refinement to enhance its effectiveness. Specifically, efforts should be focused on reducing false alarms and improving the system's ability to accurately predict critical events. Additionally, gathering user feedback and considering the specific context of the system's operation can help identify areas for improvement and ensure that it is meeting the needs of its users. By addressing these areas, the system can be further optimized to provide more reliable and timely warnings, ultimately contributing to the safety and well-being of the communities it serves.

4.1.2 Socio-demographic information of respondents

Fig 4.1 illustrates the number of respondents based on stratified random sampling, highlighting the varying levels of engagement across different wards within Rajapur Municipality. The survey had the highest participation from Ward 4, with 45 respondents. Ward 10 follows with 37 respondents, demonstrating significant participation. Wards 1 and 3 each recorded 33 respondents, suggesting similar engagement levels in these areas. In contrast, Ward 9 had 29 respondents, while Ward 7 had the lowest participation at 23 respondents. Overall, the data presented in the graph provides valuable insights into the geographical reach and targeted nature of the household survey conducted in Rajapur Municipality.

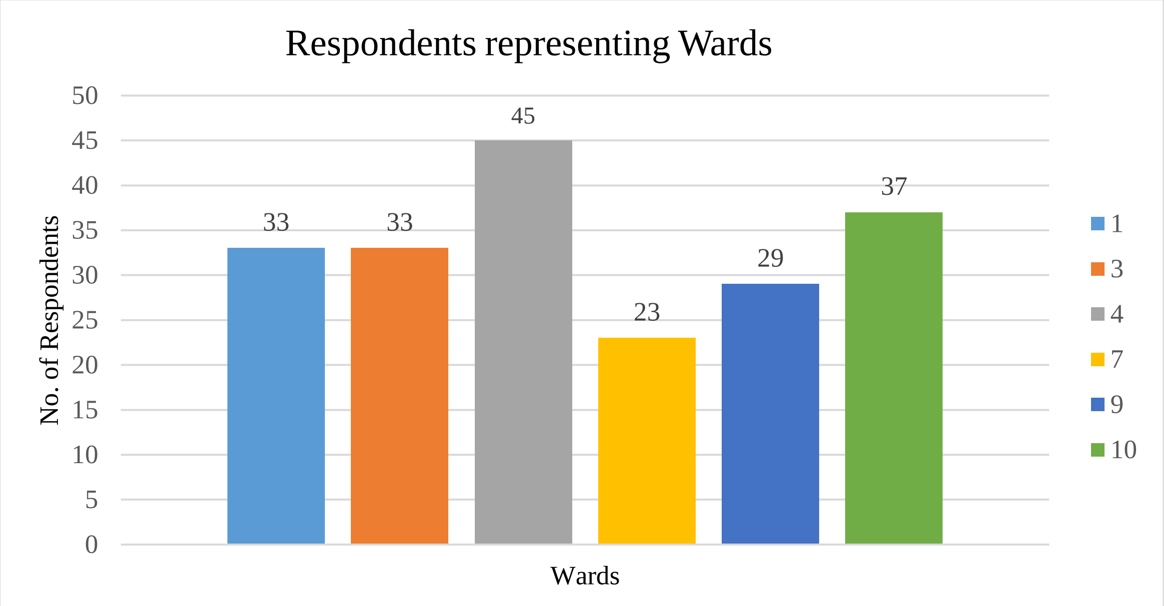


Fig 4. 1 Respondents representing the wards

The household survey was conducted in 3 very highly and 3 highly vulnerable wards of Rajapur municipality, focusing on the most vulnerable communities as identified by the Rajapur municipal office. Respondents were majorly selected from Ward No. 1 (*Tihuini, Chanaura, Premnagar*, and *Murgahawa*), Ward No. 3 (*Nangapur, Tighra, Chhakapur*, and *Tediya*), Ward No. 4 (*Dalahi, Anantapur*, and *Sangarshanagar*), Ward No. 7 (*Bhaluphanta, Sankharpur, Lalchipur*, and *Lahure Tole*), Ward No. 9 (Chainpur, Durganagar, Goddiyana, and *Chhotki Bhimapur*), and Ward No. 10 (*Lalpur, Majhra, Jhapti*, and *Pahadipur*). These areas were recognized as particularly vulnerable to flooding. Fig 4.2 provides a visual representation of the spatial distribution of these locations involved in the survey.

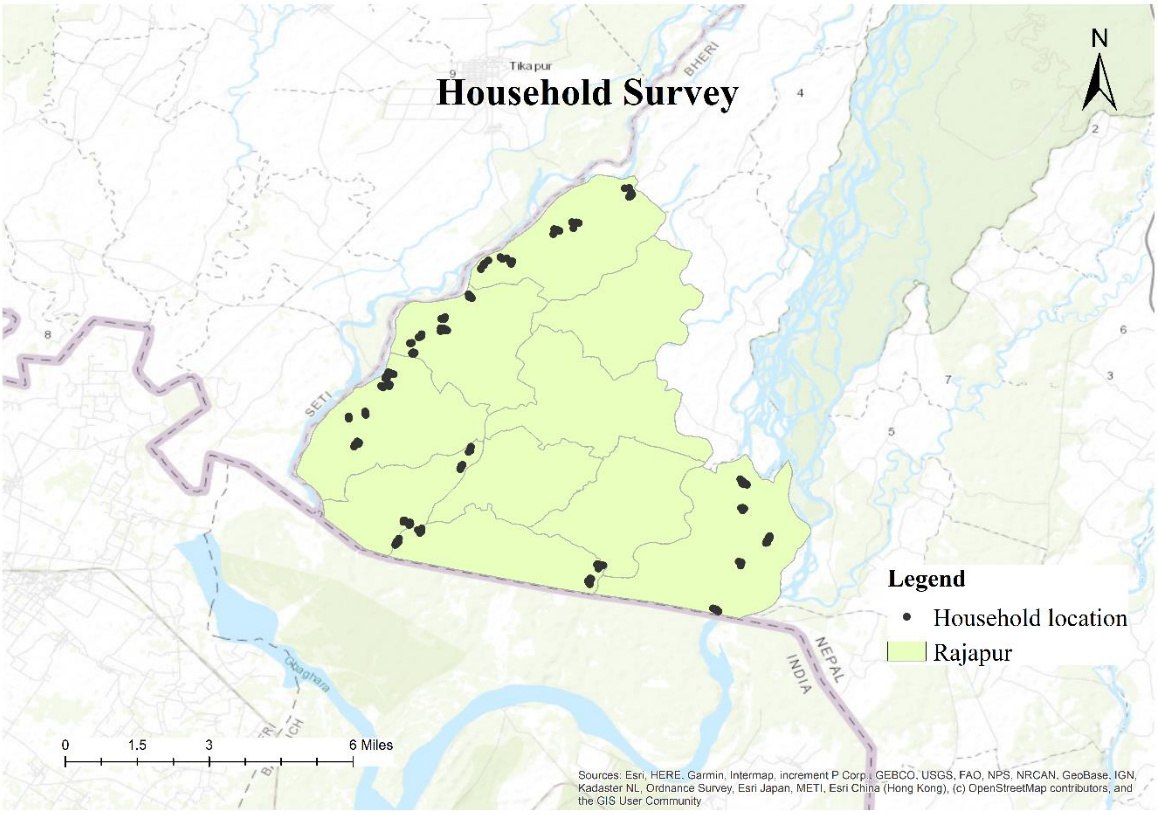


Fig 4. 2 Spatial distribution of household survey based on wards

Fig 4.3 represents that, 60% were female while 40% were male, indicating a substantial overrepresentation of women in the study. The overrepresentation of women in the study could be attributed to various factors, including their greater involvement in household activities.

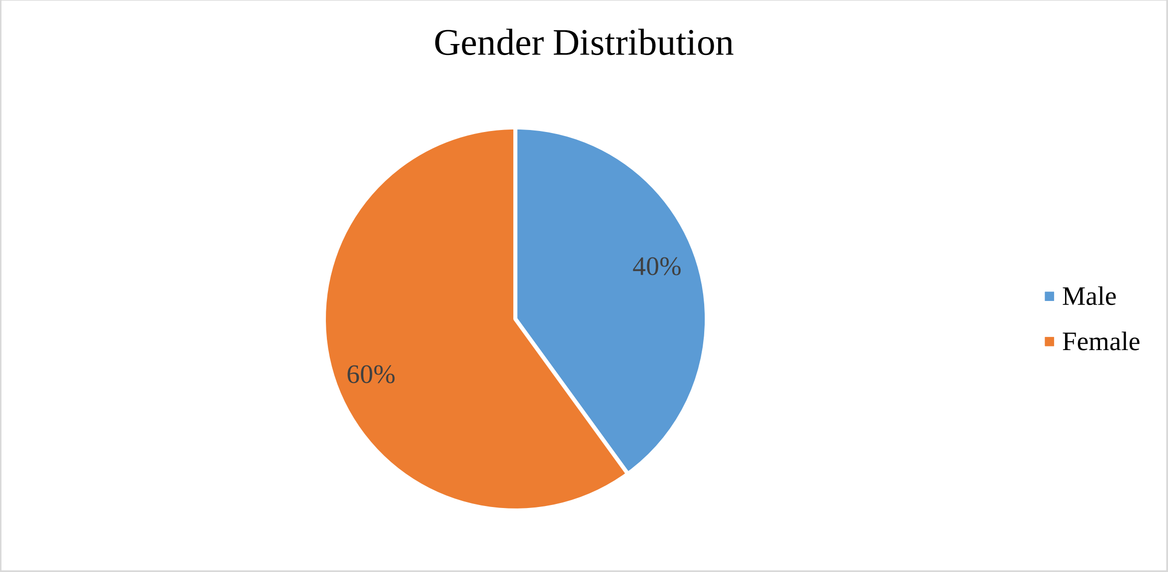


Fig 4. 3 Gender distribution of respondents

The age distribution of participants in Rajapur municipality reveals a diverse demographic profile among the total of 200 individuals surveyed. Fig. 4.4 shows that the largest group is aged 30-40, comprising 22% (44 participants), closely followed by the 20-30 age range at 21% (42 participants). In contrast, the smallest demographic is the 10-20 age group, accounting for just 5% (10 participants). Notably, individuals aged 60 and above represent 18% (36 participants) of the population, indicating a significant older demographic.

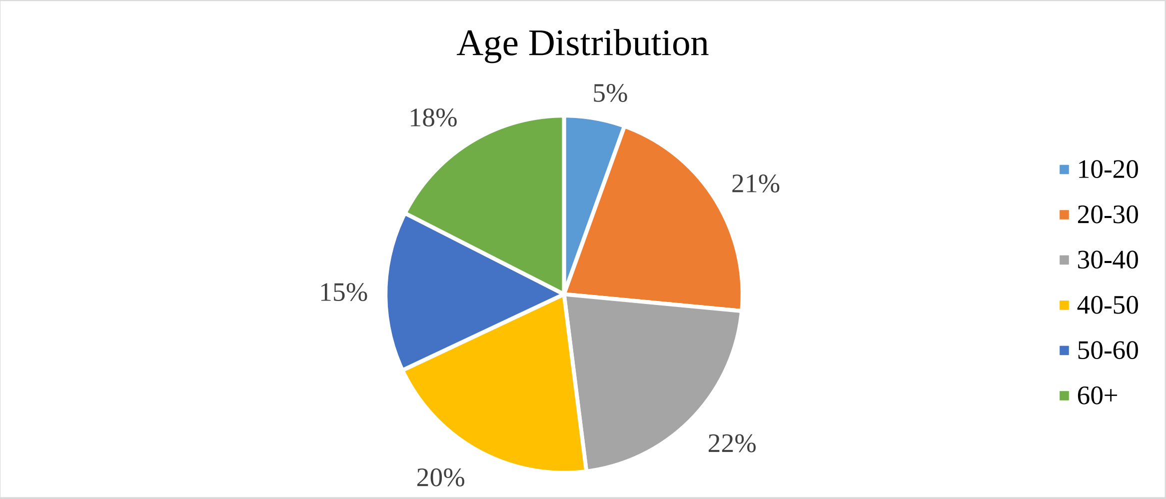


Fig 4. 4 Age distribution of respondents

Fig 4.5 shows that, 45.5% (91 individuals) have no formal education, indicating a substantial portion of the population lacking basic educational qualifications. Meanwhile, 24.5% (49 participants) completed primary school, and 25% (50 participants) attained secondary school education, showing a moderate level of educational progression. Only 5% (10 participants) hold a college or university degree, reflecting a limited presence of higher education within the community.

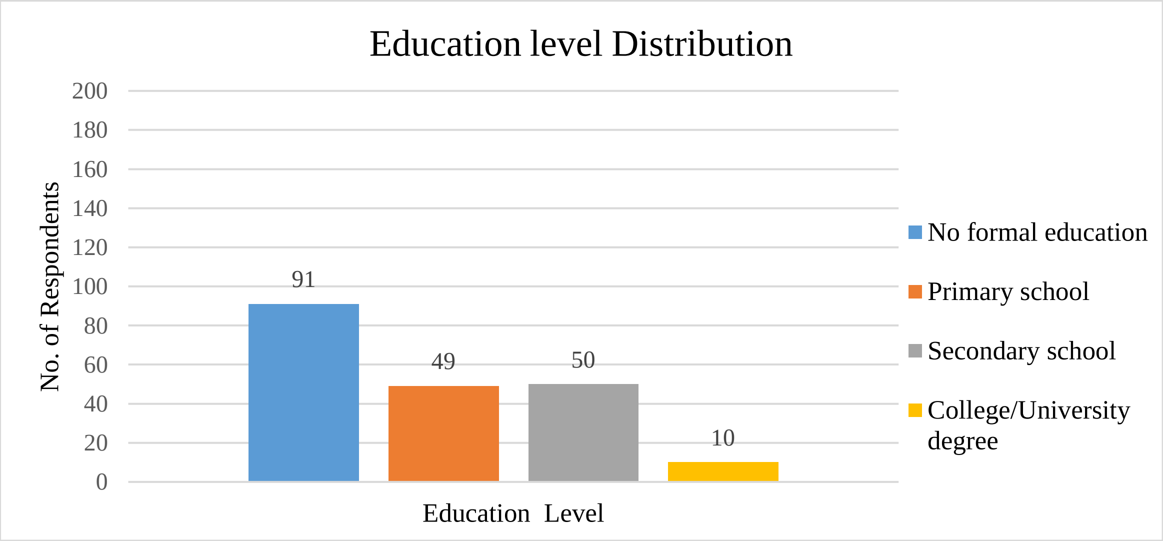


Fig 4. 5 Education level distribution of respondents

4.1.3 Communication channels and dissemination

4.1.3.1 Access to communication channel

The Chisapani flood early warning system utilized a variety of communication channels to ensure effective dissemination of information to the community. Fig 4.6 represents that the most prevalent channel was direct communication through neighbours, which accounted for 85% of the responses. This highlights the importance of community networks in spreading crucial information quickly. Following closely were sirens, utilized by 77% of respondents, serving as an audible alert to signal imminent danger. SMS messages were also significant, reaching 74.5% of the population, providing a rapid and reliable means of communication.

Door-to-door miking was employed by 45.5% of respondents, allowing for personal engagement and immediate broadcasting of warnings. Social media played a role as well, albeit to a lesser extent, with 18.5% indicating its use, reflecting a growing trend in digital communication. Radio broadcasts reached 9% of the community, while the use of flag colors as a visual alert was noted by 6%. Lastly, a small fraction, 0.5%, mentioned other unspecified channels such as direct contact into gauge station. This diverse range of communication methods underscores the importance of utilizing multiple platforms to ensure that critical information reaches all members of the community effectively.

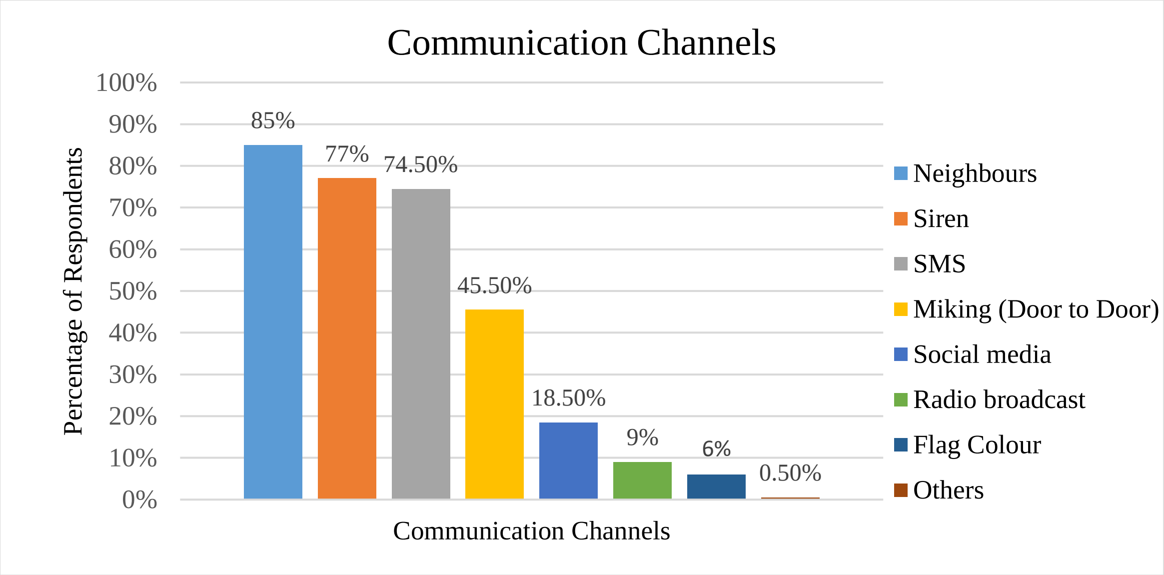
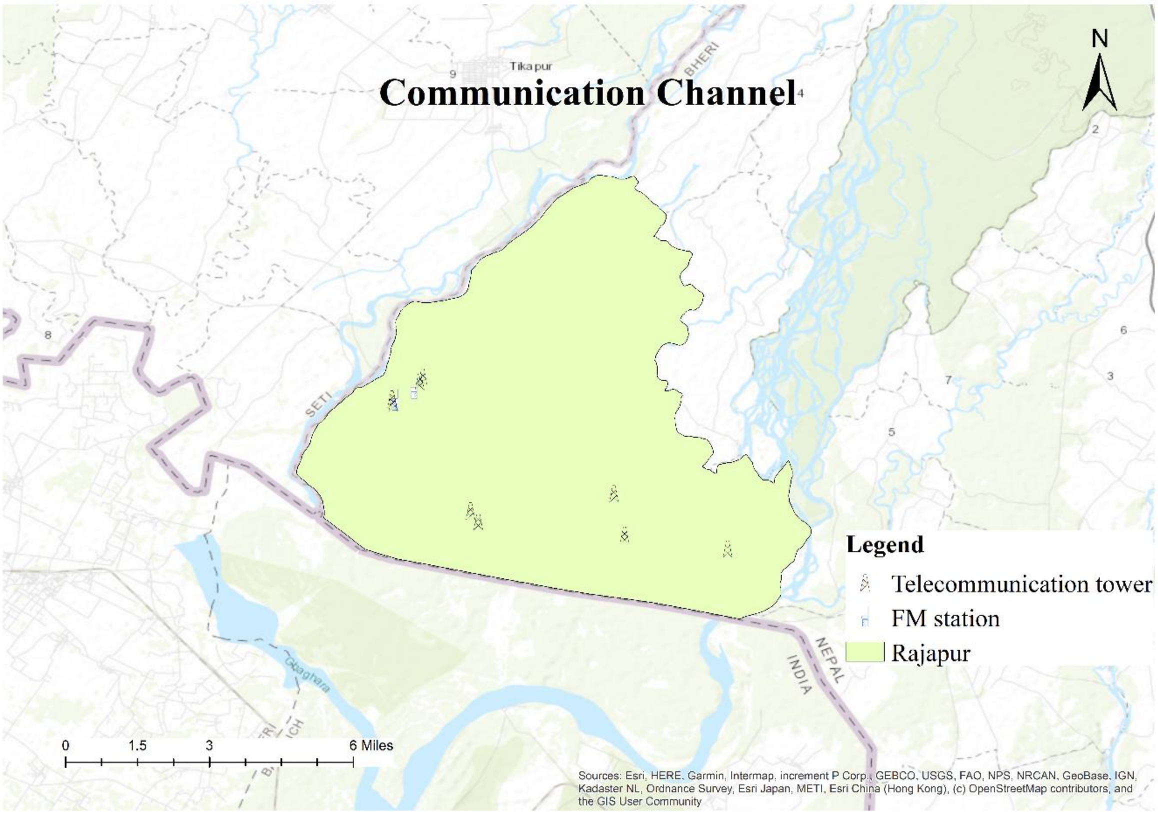


Fig 4. 6 Communication channels for dissemination of information

The household survey, focus group discussions (FGDs), and key informant interviews (KIIs) revealed the flow of information regarding flood warnings in the Rajapur. Information is initially issued from the Chisapani gauge station to the village head, (*Barghar*), who then disseminates it to the public through the helper (*Chaukidar*). The

Chaukidar utilizes a siren from predefined locations, covering a radius of 3 to 5 km, to alert the community. In addition to sirens, residents receive flood warnings via SMS, with a significant 74.5% of respondents reporting that they access these alerts. Among those receiving SMS notifications, 52% use Ncell, 18% rely on NTC, and 9.5% receive messages from both service providers. The presence of 9 telecommunication towers in Rajapur (4 of NTC and 5 of Ncell) enhances the reliability of these communications.

Beyond SMS, various methods are employed to convey urgent information. The use of a hand mike and colored flags indicates different levels of flood danger: blue flags signify a warning at 9 m, yellow at 10 m, and red at 11 m. This visual signaling is coordinated by an early warning task force, which helps to ensure that the community is aware of potential threats. Moreover, active social media users also receive updates through platforms like Facebook and online news sources. In instances of power outages, particularly during heavy rainfall, local FM stations such as (Sathi FM, Rajapur FM, and Bheri FM) serve as vital sources of information, broadcasting alerts and updates to keep the community informed. Fig 4.7 shows the spatial distribution of telecommunication tower (NTC and Ncell) and FM stations is illustrated below:



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Fig 4. 7 Spatial distribution of communication channels in Rajapur

4.1.3.2 Understanding level of warning

The responses regarding the ease of understanding the flood early warning system reveal a generally positive sentiment among the community. Fig 4.8 represents that a significant 42% of participants found the system "very easy" to comprehend, indicating that the majority felt well-informed and confident in the communication process. Additionally, 19.5% of respondents rated it as "somewhat easy," further emphasizing that a substantial portion of the community found the system accessible.

However, there are notable concerns, as 14.5% reported it as "somewhat difficult," and 10% described it as "very difficult," suggesting that a minority struggled with the system's clarity. Moreover, 14% remained neutral, indicating uncertainty or mixed feelings about the ease of understanding the warnings. Overall, while the majority finds the system user-friendly, somewhat easy to understand, and the feedback highlights areas for improvement to ensure that all community members can effectively grasp the flood warnings.

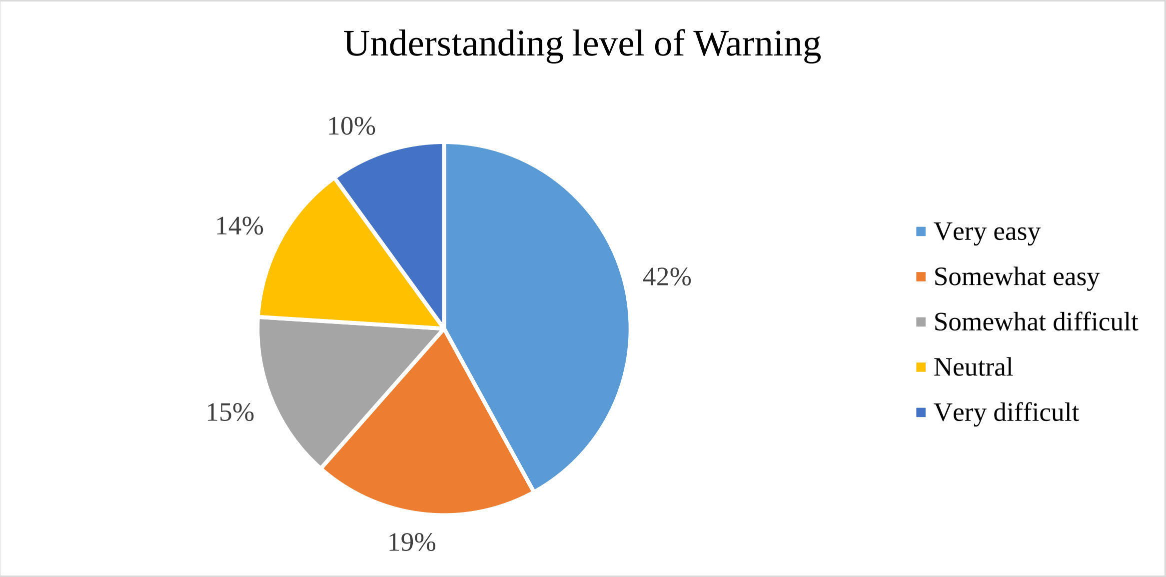


Fig 4. 8 Understanding level of warning

4.1.3.3 Future preferred channels

The survey results reveal the most preferred communication channels for the flood early warning system in the Rajapur municipality. Fig 4.9 shows that SMS emerges as the dominant choice, accounting for 53% of the responses. This preference for SMS-based alerts likely reflects the widespread use of mobile phones and the ability to quickly disseminate information directly to community members. Following SMS, the siren system is the second most preferred channel, comprising 23.5% of the responses. This traditional method of warning dissemination continues to hold significance, particularly for reaching those who may not have access to or familiarity with digital communication platforms.

Interestingly, the role of neighbors and community networks also features prominently, with 22% of respondents indicating this as their preferred source of information. This underscores the importance of local connections and informal channels in the early warning process, echoing findings from other studies that highlight the effectiveness of community-driven approaches. The remaining options, such as miking (public address system), flag color, and direct communication with individual households, account for smaller shares of the preferred channels, ranging from 0.5% to 1%. This suggests these methods may be less utilized or effective compared to the top three choices of SMS, sirens, and reliance on neighbors.

Overall, the data indicates a multi-pronged approach to early warning communication, with a primary emphasis on SMS-based alerts complemented by traditional siren systems and community-based information sharing. Understanding these preferences can help inform the design and implementation of more responsive and effective flood early warning systems in the study area.

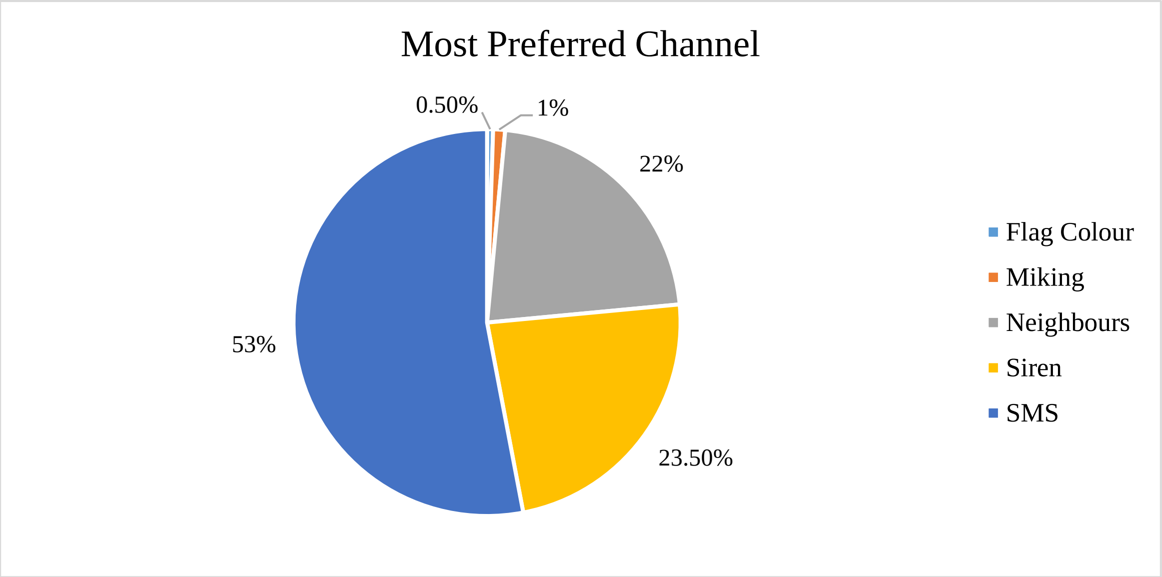


Fig 4. 9 Most preferred channel of warning

4.1.3.3.1 Relationship between demographics and most preferred communication channel

The cross-tabulation between demographics and the most preferred communication channel was created to analyze whether the relationship between them is statistically significant. Fisher's exact test was used to determine the significance of the association between demographics and preferred communication channel due to small cell sizes (less than 5). Since Fisher's exact test provides an exact p-value, it can become computationally intensive for larger contingency tables. Therefore, a Monte Carlo simulation was offered as a practical alternative to estimate the p-value more efficiently.

Hypothesis for gender,

- Null hypothesis (H_0): There is no association between the gender and most preferred channel.
- Alternative hypothesis (H_1): There is an association between the gender and most preferred channel.

Hypothesis for age,

- Null hypothesis (H_0): There is no association between the age and most preferred channel.
- Alternative hypothesis (H_1): There is an association between the age and most preferred channel.

Hypothesis for education level,

- Null hypothesis (H_0): There is no association between the education level and most preferred channel.
- Alternative hypothesis (H_1): There is an association between the education level and most preferred channel.

Table 4. 3 Fisher's exact test with Monte Carlo simulation for significant association

Independent variable	Fisher Exact value	p-value	Description	Remarks
Gender	12.239	0.005	p-value < 0.05	Significantly association
Age	84.062	~0.00	p-value < 0.05	Significantly association
Education level	180.199	~0.00	p-value < 0.05	Significantly association

Table 4.3 indicates significant associations between gender, age, and education level with preferred communication channels for warnings. For gender, the test statistic is 12.239 with a p-value of 0.005, indicating a significant relationship. Age shows a test statistic of 84.062 and a p-value of approximately 0.00, suggesting that preferences for communication channels vary significantly across different age groups, highlighting the importance of considering age in communication strategies. Education level exhibits an even higher test statistic of 180.199, also with a p-value around 0.00, confirming a strong and significant association. Together, these findings indicate that gender, age, and education are crucial factors in determining how individuals prefer to receive warnings, emphasizing the need for tailored communication strategies that account for these demographic characteristics. Additionally, Cramer's V test was performed to quantify the level of association among these variables.

Table 4. 4 Cramer's V test for strength of association

Independent variables	Cramer's V value	Description	Remarks
Gender	0.246	0.1-0.3	Weak association
Age	0.332	0.3-0.5	Moderate association
Education level	0.507	Above 0.5	Strong association

Table 4.4 reflects the analysis of Cramer's V values for the independent variables (gender, age, and education level) providing insight into the strength of their associations with the most preferred communication channel for warnings. For gender, the Cramer's V value is 0.246, indicating a weak association, as it falls within the range of 0.1 to 0.3. This suggests that while there is some relationship between gender and communication preferences, it is not particularly strong. In contrast, age has a Cramer's V value of 0.332, which falls within the range of 0.3 to 0.5, indicating a moderate association. This implies that there is a noticeable relationship between age and communication preferences, though it is not exceptionally strong. Education level exhibits a Cramer's V value of 0.507, which exceeds 0.5, indicating a strong association. This finding suggests that education level has a more significant impact on individuals' preferences for communication channels when receiving warnings. Together, these results highlight the varying degrees of influence that demographic factors have on communication preferences, underscoring the importance of understanding these associations to develop effective warning strategies that cater to the

specific needs and preferences of different age groups, educational backgrounds, and genders.

4.1.4 Preparedness and response

4.1.4.1 Reduction of flood impact after installation

The installation of the Chisapani flood early warning system has significantly mitigated the impact of flooding in Rajapur Municipality. Table 4.5 reflects that by prioritizing concerns such as loss of life or injury, which scored the highest at 0.78, the system enables timely alerts that allow residents to evacuate and take preventive measures, thereby reducing fatalities and injuries. The loss of belongings, with a score of 0.60, is also lessened as families can secure their valuables in advance. Additionally, the system aids in protecting livestock, which scored 0.39, by allowing farmers to relocate animals before floods occur, thus safeguarding their livelihoods. While property damage scored 0.26, the early warnings help residents reinforce structures and evacuate, minimizing extensive damage. Lastly, the organized evacuations facilitated by the system, reflected in the score of 0.22 for evacuation or displacement, reduce chaos and ensure that fewer individuals are caught off-guard.

Table 4. 5 Weighted ranking of reduction in impact after installation

Impact	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Score	WAI*	Rank
	Given weightage							
	1	0.5	0.33	0.25	0.2			
Loss of life or Injury	126	19.5	8.91	1.75	0.2	156.36	0.78	I
Loss of belongings	61	43.5	15.51	1.25	0	121.26	0.60	II
Loss of Livestock	8	31.5	34.98	4.25	1.2	79.93	0.39	III
Damage to property	4	3.5	5.28	27.5	12.6	52.88	0.26	IV
Evacuation or Displacement	1	2	1.32	15.25	26	45.57	0.22	V
Weightage Average Index (WAI)* = Score/N N is the total no. of sample (200)								

Overall, the early warning system has significantly lowered the impact of flooding by fostering a culture of preparedness and resilience within the community. Its multifaceted approach-combining timely information dissemination, community engagement, and data utilization-ensures that both individuals and local authorities are better equipped to handle flooding events effectively. This comprehensive strategy not only saves lives but also protects property and enhances the community's ability to recover from disasters.

4.1.4.2 Lead time for flood preparation

The lead time for community preparedness in response to potential flooding reveals a varied understanding of the time available for effective action. Fig 4.10 reflects a significant portion, comprising 39.5% of respondents, indicated a lead time of 2-3 hours, suggesting that many feel they have a reasonable window to prepare before flooding occurs. Closely following, 34% reported a lead time of 3-4 hours, further reinforcing the idea that a substantial number of community members believe they have adequate time to mobilize and respond to warnings.

However, 15.5% noted a shorter lead time of 1-2 hours, which could pose challenges for those needing to take swift action. A small group, 7%, indicated a lead time of over 4 hours, implying that they feel more secure in their ability to prepare well in advance. On the other hand, only 3.5% reported a lead time of 0-1 hour, indicating that very few community members feel rushed or have little time to respond. Overall, while many residents perceive a reasonable amount of lead time for preparations of about 2-3 hours in average, the variations suggest a need for continued education and awareness to ensure that everyone is ready to act when necessary.

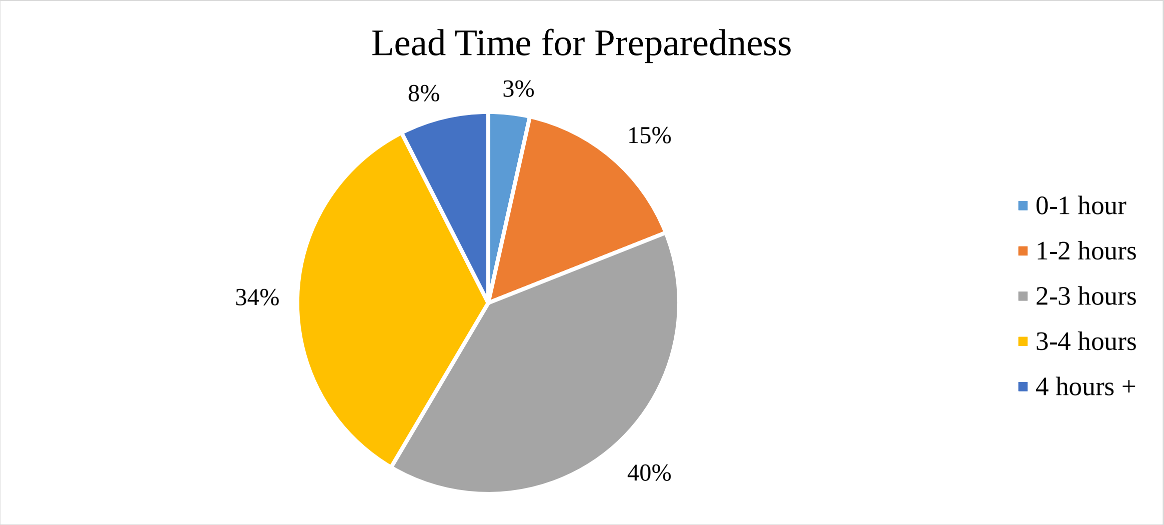


Fig 4. 10 Lead time for preparedness

4.1.4.3 Household preparedness action taken for flood

The responses regarding household preparedness for flooding reveal a mixed sense of readiness within the community. Fig 4.11 indicates that only 7% of respondents felt "very prepared," indicating a small fraction that is confident in their flood preparedness measures. In contrast, a larger segment, 38.5%, described themselves as "somewhat prepared," suggesting that while they have taken some actions, there may still be uncertainty or gaps in their readiness.

A notable 19% remained neutral, reflecting ambivalence or uncertainty about their preparedness status. Conversely, 33.5% reported being "not very prepared," indicating that a significant portion of the community may not have adequate measures in place to respond effectively to a flood. Lastly, 2% of respondents felt "not prepared at all," highlighting a small group that is particularly vulnerable. On average, household preparedness actions are at a neutral level. Overall, these results suggest that while some residents feel prepared, a considerable number express varying degrees of unpreparedness, underscoring the need for enhanced education and resources to improve overall community readiness for flood events.

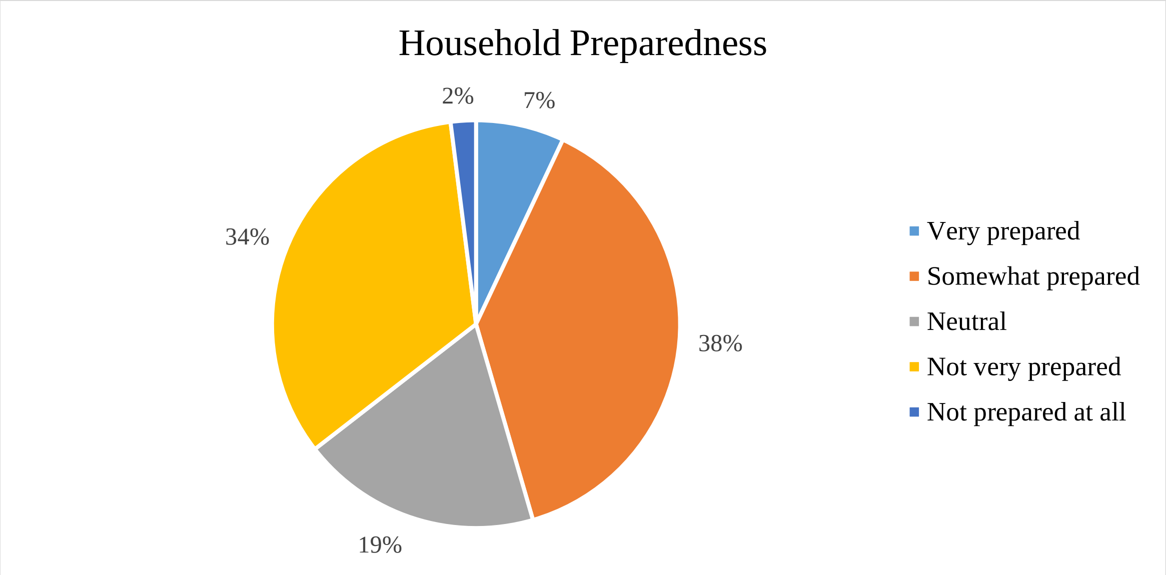


Fig 4. 11 Level of household preparedness

Fig 4.12 indicates results on household preparedness for flooding which reveal a strong commitment among community members to protect their homes and belongings. Notably, 98.5% of respondents reported securing important documents and valuables, indicating a high priority on safeguarding essential items. In terms of livestock protection, 56% of households took measures to ensure the safety of their animals, and 55.5% secured fuel wood, demonstrating awareness of resource maintenance during emergencies. Additionally, 38% implemented raised houses to elevate their homes against floodwaters. However, there are gaps in other preparedness actions: only 20.5% reported flood-proofing their homes, 11% developed a flood evacuation plan, and just 5% assembled an emergency kit. While many households actively protect their valuables and livestock, there is significant room for improvement in comprehensive flood preparedness strategies, particularly through enhanced infrastructure like raised houses to minimize flood damage.

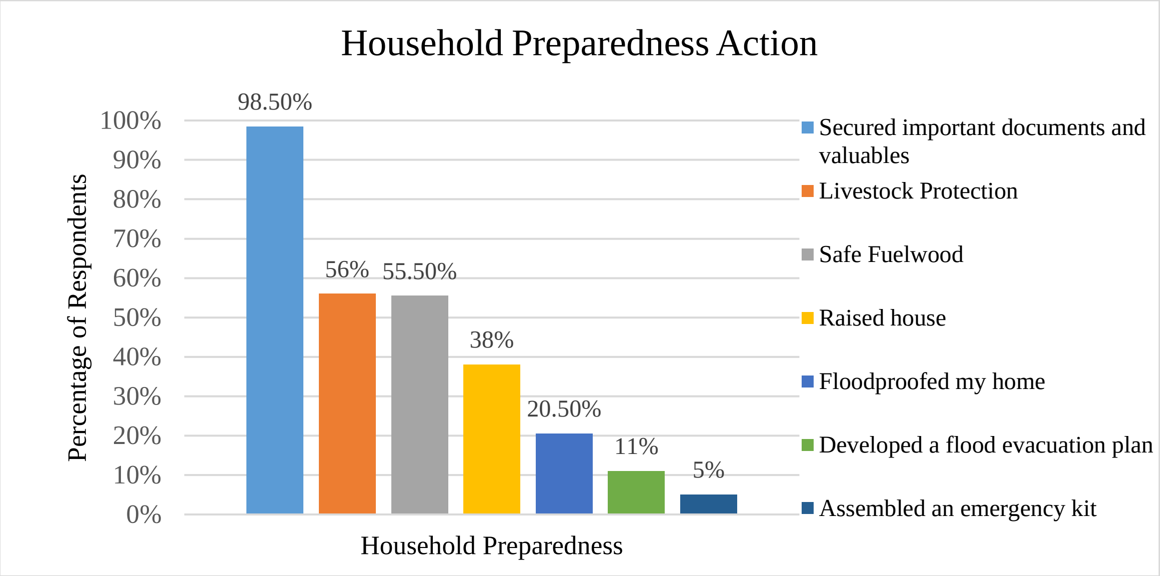


Fig 4. 12 Household preparedness actions taken by respondents

4.1.4.4 Access to location for response

The preferred evacuation locations for flood response among community members show a strong reliance on established structures for safety. According to Fig 4.13, 79.5% of respondents identified schools as their primary evacuation site, indicating their perception as safe and accessible during emergencies. Additionally, 51.5% have access to designated evacuation shelters, highlighting their importance in disaster preparedness. Community buildings were chosen by 38% of participants, while 27% indicated ward offices as potential evacuation sites, reflecting trust in local governance for support during crises. Open ground was noted by 12% of respondents, which may serve as a last resort for those unable to reach other facilities. Lastly, 10% mentioned "others," implying alternative locations such as relatives, and personal evacuation shelter (e.g. Residents of *Chanaura* village of ward no. 1 is most vulnerable village to flood so they has prepared personal safe tent house in the human made embankments).

Overall, these findings illustrate that the community is well-informed about various evacuation options available during flood events. This awareness is crucial for ensuring safety and effective response when emergencies arise. Among the different options, schools and designated shelters emerge as the most favored choices for residents seeking refuge.

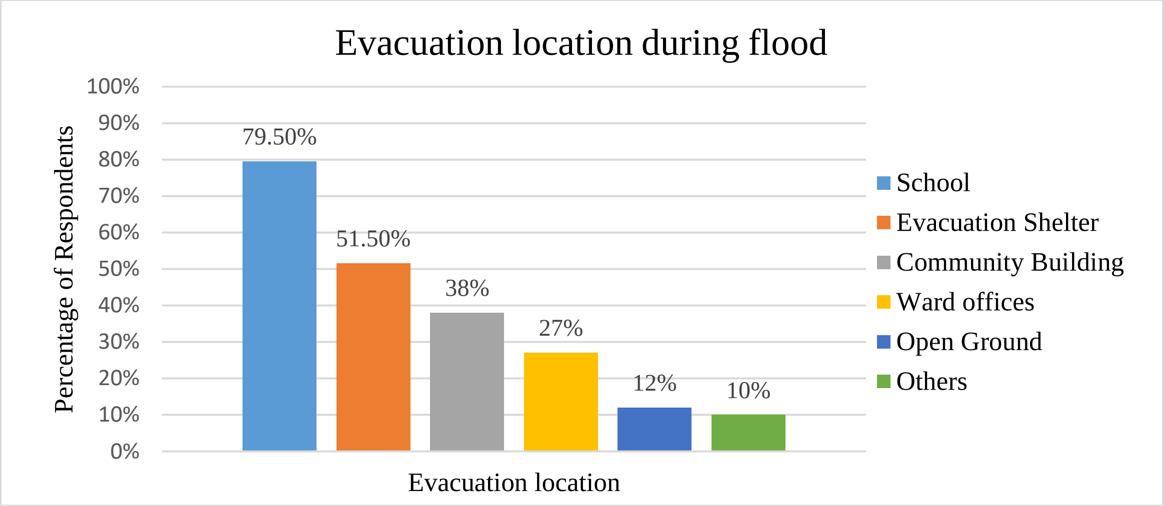


Fig 4. 13 Evacuation locations for responding flood

Based on household surveys, key informant interviews (KII), focus group discussions (FGDs), field observations, and the Monsoon Preparedness and Response Plan for 2024, various locations have been designated for evacuation during floods in Rajapur. The municipality with coordination of funding organizations such as ZURICH and EC has established 11 evacuation shelters with a total capacity of 850 people, of which 7 are in good condition and 4 are in average condition. These evacuation shelters are mainly prioritized to more vulnerable populations only after receiving the waning. Additionally, 18 schools have been declared as quarantine centers, accommodating 1,037 individuals. However, some communities are located far from these designated shelters, prompting the use of alternative spaces such as community buildings and ward offices. In some instances, residents choose to stay in open areas, find shelter with relatives, or construct makeshift evacuation shelters near dams, as observed in *Chanaura* village.

During the survey and interviews conducted in *Barghar*, respondents highlighted a critical concern regarding the available evacuation options for flood response. While many evacuation sites exist, participants noted that these options do not adequately meet the diverse needs of all segments of the population. This feedback points to significant gaps in accessibility and inclusivity within the current evacuation planning framework. According to the Rajapur municipal office, there are approximately 9,485 vulnerable individuals in the area for the fiscal year 2023/24 which includes children under 5 years, pregnant women, old people and disable people. Table 4.6 shows the details about the vulnerable populations in the Rajapur municipality.

Table 4. 6 Details of vulnerable population in Rajapur municipality in FY-2023/24

S.N.	Category	No. of individual	Data source
1.	Children under 5 years	3,840 (862 under 1 years)	Health section
2.	Pregnant women	809	Health section
3.	Old people	4,227	IT section
4.	Disable people	609 (178 fully and 431 partially)	IT section
Total		9,485	

Source: Rajapur municipal office, FY-2023/24

This situation underscores the critical necessity for enhanced access to safe and adequate evacuation options, particularly for vulnerable populations. Furthermore, community engagement plays a vital role in disaster preparedness. Fig 4.14 illustrates the spatial distribution of location for response.

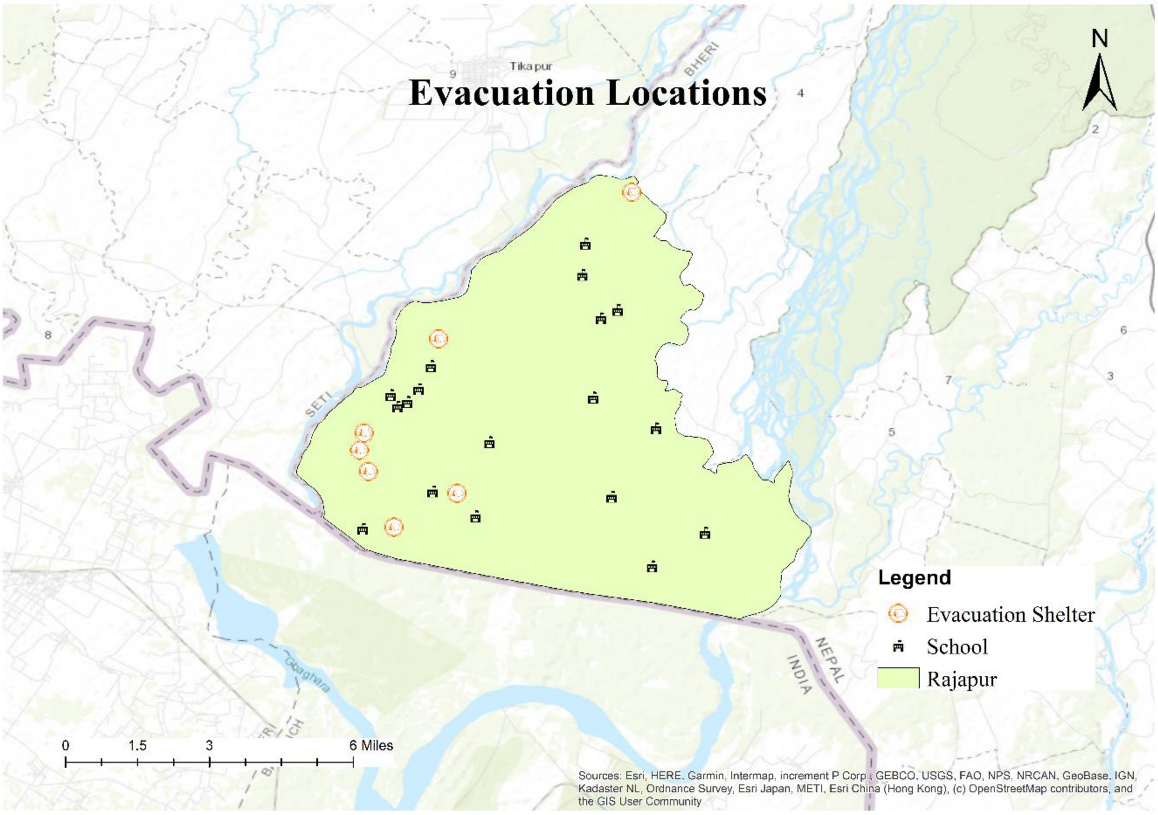


Fig 4. 14 Spatial distributions of evacuation locations in Rajapur municipality

4.1.4.5 Training for flood preparedness and response

Fig 4.15 reflects the data regarding training for flood preparedness. A substantial 85% of respondents indicated that they have not received any training related to flood response and preparedness. This suggests a significant gap in knowledge and skills that could be critical during flood emergencies. In contrast, only 15% of participants reported having received training, highlighting a small but potentially well-informed segment of the community. From FGD with *Sana Kishan Women's group* we can know that women's are also actively participated in trainings related to early warning taskforce as well as response actions such as emergency response and rescue training.

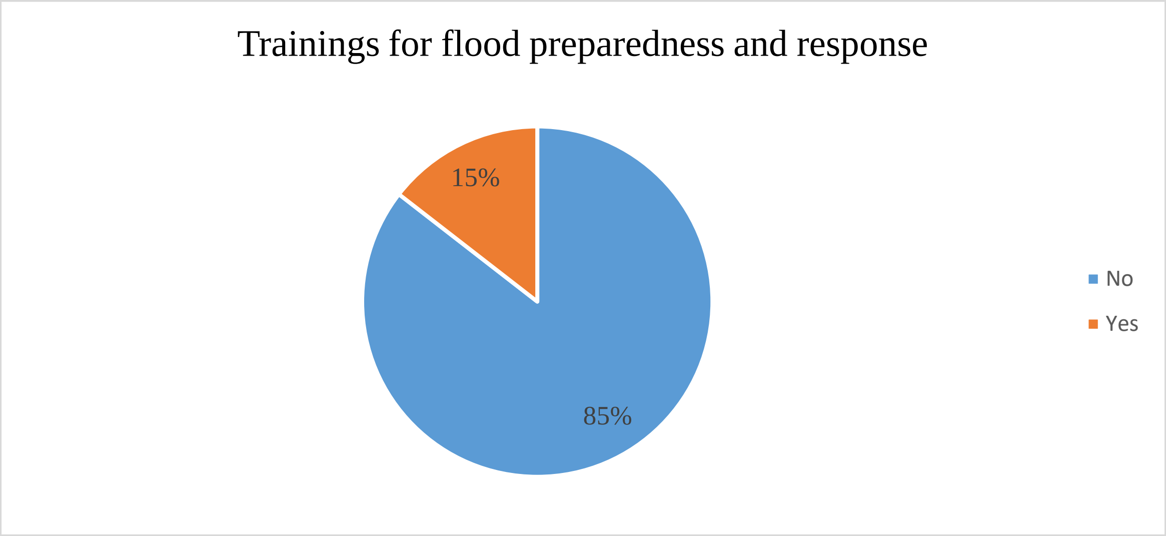


Fig 4. 15 Trainings for flood preparedness and response

The training received by community members for flood preparedness encompasses a diverse range of approaches aimed at enhancing both practical skills and awareness. Key types of training include emergency response and rescue training, where participants learn essential techniques such as using life jackets and performing safe rescues. A significant emphasis is placed on educational drama and mural art initiatives which communicate important preparedness messages visually, making them more memorable. Theoretical training sessions, including two-day programs focused on disaster management processes provided by Community Disaster Management Committee (CDMC) collaboration with different NGOs such as Tayar Nepal.

Overall, enhancing training opportunities could significantly improve the community's preparedness and resilience in the face of flood events. Comprehensive training programs can equip residents with the knowledge and skills necessary to respond effectively during emergencies, thereby reducing panic and confusion.

4.1.5 SWOT Analysis

Table 4.7 reflects the SWOT analysis table which provides a structured overview of the strengths, weaknesses, opportunities, and threats associated with the Chisapani Early Warning System in Rajapur municipality.

Table 4. 7 SWOT matrix for effectiveness of Chisapani early warning system

Strengths	Weakness
• Enhanced Monitoring: Upstream gauge stations effectively reduce flood impact by providing timely data. • Sustainable Management: Government oversight by the Department of Hydrology and Meteorology (DHM) ensures long-term sustainability. • Collaborative Framework: Strong partnerships with various agencies facilitate effective communication and resource sharing. • Community Engagement: Establishment of early warning taskforces in vulnerable areas enhances local response capabilities. • Training Programs: Regular community preparedness training fosters resilience and awareness.	• Scope Limitations: Current focus is restricted to Karnali and Geruwa Rivers, excluding critical factors like irrigation canal flooding and reverse flow dynamics. • Downstream Oversight: Lack of consideration for downstream precipitation impacts limits comprehensive flood management. • Communication Barriers: Challenges in conveying messages during night time evacuations can jeopardize safety. • Funding Constraints: Insufficient financial resources hinder effective household and community preparedness initiatives. • Training Gaps: Emphasis on theoretical knowledge over practical application reduces the effectiveness of preparedness training.

Opportunities	Threats
- Advanced Forecasting Capabilities: Integration of 3-day and 5-day forecasts, along with Chisapani gauge readings, can enhance predictive accuracy. - Data Utilization: Access to DHM's precipitation data can improve flood prediction models and establish return periods for risk assessment. - Expanded Infrastructure: Opportunities to connect with *Budi Kulo* canal for improved water management strategies. - Technological Innovations: Implementation of automatic sirens can streamline alert systems for faster community response.	- Erosion of Trust: Miscommunication regarding early warnings can lead to diminished trust among downstream communities, complicating future cooperation. - Resource Limitations: Inadequate evacuation shelters and emergency resources pose significant risks during flood. - Cultural Barriers: Language differences may hinder effective dissemination of warning messages, particularly in diverse communities. - Technological Divide: Older and less educated populations may struggle to access or respond to technological warnings, increasing vulnerability during emergencies.

The effectiveness of the Chisapani early warning system in Rajapur Municipality is influenced by several key factors. Strengths include timely data from upstream gauge stations, oversight by the Department of Hydrology and Meteorology (DHM), strong inter-agency collaboration, and robust community engagement. However, weaknesses such as a narrow focus on the Karnali and Geruwa Rivers, communication barriers during nighttime evacuations, and funding constraints for training hinder its overall impact. Opportunities for improvement lie in integrating advanced forecasting technologies, utilizing DHM precipitation data, and implementing automatic sirens for alerts. Nonetheless, threats like erosion of trust due to miscommunication, inadequate evacuation resources, cultural barriers, and a technological divide among older populations present significant challenges.

4.2 Discussion

4.2.1 Effectiveness of Chisapani early warning system in Rajapur

The verification results of the deterministic flood forecast highlight the moderate effectiveness of the Chisapani flood early warning system. With an accuracy of 86%, it shows reliable predictions, but the high false alarm ratio of 56% raises concerns about public fatigue and diminished trust. The system's detection probability of 63% indicates there is significant room for improvement in identifying critical flood events. While the positive Heidke Skill Score (HSS) of 0.44 suggests the system performs better than random chance, the threat score of 0.35 and equitable threat score of 0.28 imply a need for better balance between accurately detecting critical events and minimizing false alarms.

Historical context is provided by Murphy (1996), referencing Finley (1884), who reported a total accuracy of 95.6% to 98.6% in tornado forecasts across various U.S. regions which shows the more accuracy than forecast by Chisapani station. This highlights the importance of understanding the factors influencing the effectiveness of flood forecasting. Several factors contribute to the limitations of the Chisapani system:

- Critical Flood Warning Levels: The 9-meter flood warning level is a key threshold indicating potential danger. However, it is crucial to recognize that flooding risk varies by region due to local geography, climate conditions, and infrastructure. This means that while the warning level is important, it should not be the sole determinant of flood risk.
- Nature of flood: This area is particularly susceptible to flooding from upstream precipitation above Chisapani gauge station. Heavy rains in these upstream catchments can lead to rapid water accumulation in local rivers and streams, resulting in localized flooding. According to the Standard Operating Procedure (SOP) for the Flood Early Warning System in Nepal (2018), there are seven types of floods that can occur in Nepal. While Chisapani station may manage upstream precipitation and rising water level in Karnali and Geruwa river but heavy rainfall downstream can cause significant inundation, disrupting ecosystems and damaging crops, homes, and infrastructure.
- Drainage and Irrigation Management: Poor drainage and irrigation practices exacerbate flooding risks in Rajapur Municipality. Observations from field surveys and the Rajapur Municipality Monsoon Preparedness and Response Plan for 2024

raise concerns that the construction of the *Kailaspur* Dam may worsen flooding in specific wards, particularly 7, 9, and 10. These areas face significant risk due to potential reverse flow from canals when the dam is closed by neighboring country during floods. This situation underscores the urgent need for improved drainage maintenance, optimized irrigation practices, and effective flood response planning to mitigate these challenges and protect vulnerable communities.

In summary, while the Chisapani flood early warning system provides a valuable service, improving its accuracy and effectiveness requires addressing these interconnected factors. Enhancing the system's ability to balance detection and false alarms will be critical in building public trust and effectively mitigating flood risks in vulnerable areas.

4.2.2 Communication and dissemination

The *Barghar-Chaukidar* system plays a crucial role in facilitating effective information flow during flood emergencies in Rajapur municipality. When a warning is received from the gauge station, the *Barghar* assembles the *Chaukidar*, who is responsible for disseminating this information to the public using various methods, including a manual siren. Additionally, an early warning taskforce, composed of one coordinator and four members including women from the most vulnerable communities, further supports this communication effort. As highlighted in the Practical Action report (2016), various channels for information dissemination exist in Rajapur, such as data transmitted from gauge readers to formal entities like the Department of Hydrology and Meteorology, local authorities, and community leaders. Key communication methods include SMS alerts, siren, neighbours and local FM radio broadcasts, all bolstered by the early warning taskforce.

In comparing the Chisapani early warning system in Rajapur with other studies on flood warnings, several similarities and differences emerge. Notably, the most popular method for receiving warnings in Rajapur was SMS, preferred by 53% of respondents, followed by sirens at 23.5% and neighbors at 22%. This preference for SMS aligns with findings from Bajracharya et al. (2021) in Ratu River, Nepal, which identified SMS as an effective communication tool for warnings. Thapa, Watanabe, and Regmi (2022) also highlighted that the high mobile phone penetration in the Seti River Basin suggests the potential effectiveness of an early warning system that utilizes mobile technology to inform the community about impending disasters. The convenience of mobile phones allows for quick and direct communication, making SMS a vital source of information, particularly for educated individuals.

In contrast, the manual siren remains a primary communication tool for uneducated community members, reflecting a demographic divide in communication preferences. Younger individuals tend to rely on SMS for updates, while older adults and those with lower educational backgrounds often depend on neighbours and manual sirens for information. This illustrates the importance of local community connections, similar to the findings of Gwimbi (2007) in Zimbabwe, where local leaders played a key role in spreading warnings.

When it comes to understanding the warnings, 42% of respondents in Rajapur reported that the information was very easy to comprehend, while 19% found it somewhat easy. This clarity is essential for ensuring effective responses during emergencies. In average understanding level of warning for Rajapur was somewhat easy. However, some community members have suggested adopting modern technologies, such as automatic sirens, to enhance response times during floods. Such advancements would be particularly beneficial for disseminating information at night or in poor weather conditions, ensuring that all community members, regardless of their educational background, receive timely alerts and can take appropriate action.

Overall, the findings from Rajapur emphasize the need for effective communication strategies that account for local preferences and demographic differences. By integrating modern technology with traditional methods, the community can significantly enhance its preparedness and response to flooding events, ultimately improving resilience against natural disasters.

4.2.3 Preparedness and response

The Chisapani flood early warning system in Rajapur Municipality has made a significant difference in reducing flood impacts, especially in preventing loss of life, which was rated highest at 0.78. A study by Perera et al. (2019) in United Nations University also revealed similar trend of reduction in mortality rate by 45% globally within 18 years (2000-2017). This finding also matches Gwimbi (2007), who noted serious crop damage and home flooding in Zimbabwe, showing that effective warning systems are essential everywhere. Rai et al. (2020) also found that households in the Lower Karnali Basin of Nepal saved a lot of costs during floods due to timely alerts, highlighting the system's value in protecting belongings, which scored 0.60 in Rajapur.

In average respondents reported receiving a warning of 2-3 hours before flooding, which is similar to the 2.5 to 4 hours noted by Practical Action (2016) in Rajapur. While this advance notice is crucial for preparation, only 7% of participants felt "very prepared," indicating a significant gap between awareness and actual readiness. In general, communities in Rajapur are experiencing a neutral level of household preparedness action. This contrasts with findings from Bajracharya et al. (2021), who also observed similar lead times but emphasized a widespread lack of confidence in preparedness.

Though 98.5% of respondents took steps to secure important documents and 38% built raised houses, only 20.5% flood-proofed their homes. This suggests that while people are aware of the need to protect their belongings, they may not fully understand the importance of stronger infrastructure. Atreya et al. (2017) emphasized that a comprehensive approach to flood preparedness should combine protecting assets with improving building designs.

The evacuation sites and shelters in Rajapur municipality show both progress and challenges in emergency preparedness. While 79.5% of respondents identify schools as primary evacuation sites, their dual role during school hours raises concerns. The establishment of 11 evacuation shelters with a capacity for 850 people is positive, but only 7 are in good condition, indicating a need for regular maintenance. Prioritizing vulnerable populations for shelter is commendable, yet reliance on timely warnings poses risks if communication fails. The estimate of around 9,485 vulnerable individuals highlights the urgent need for improved evacuation options, as noted by Thapa, Watanabe, and Regmi (2022).

Community involvement is essential for enhancing disaster preparedness, as it fosters collaboration among local authorities, organizations, and residents. In Rajapur, this collective effort can significantly strengthen flood response strategies and build a sense of ownership among community members. Although only 15% of participants reported receiving training in emergency response and rescue techniques, increasing access to such training is crucial for empowering residents and boosting their confidence during crises. Innovative educational initiatives, such as drama and mural art, effectively communicate vital safety messages, making information more engaging and memorable. Overall, the Rajapur municipality has improved flood response and preparedness, but there is still work to be done to ensure communities are truly ready for future floods.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The Chisapani early warning system (EWS) in Rajapur is a vital adaptation strategy for mitigating flood risks, yet it presents both strengths and significant limitations. s

The *Barghar-Chaukidar* system is integral to the effective communication of flood warnings in Rajapur municipality, utilizing a combination of methods such as SMS alerts, sirens, and community networks to disseminate information. Notably, SMS is the preferred method for 53% of respondents, reflecting a trend towards mobile technology in emergency communication. However, a demographic divide exists, as younger individuals favor SMS, while older and less educated community members rely on manual sirens and neighbors for information. This highlights the importance of ensuring that communication strategies are inclusive and consider local demographics to avoid leaving vulnerable populations uninformed. Clarity in messaging is crucial, with 42% of respondents finding the information easy to understand, yet suggestions for modernizing communication tools, such as automatic sirens, point to a need for technological advancements to improve response times, particularly during adverse conditions. Overall, the findings underscore the necessity of integrating modern technologies with traditional methods to enhance community preparedness and resilience against flooding events, ensuring that all members can receive timely and comprehensible alerts.

The Chisapani flood early warning system in Rajapur Municipality has significantly reduced flood impacts, particularly in preventing loss of life, which was rated highest at 0.78, underscoring the system's critical role in safeguarding the community. Despite the valuable advance notice of 2-3 hours reported by 39.5% of respondents, only 7% felt "very prepared," revealing a concerning gap between awareness and actual readiness. While a majority of individuals took steps to protect their belongings, with 98.5% securing important documents and 38% constructing raised houses, only 20.5% engaged in flood-proofing their homes, indicating a lack of understanding about the importance of resilient infrastructure. The evacuation sites identified highlight both progress and challenges. Although the establishment of shelters is a positive step, only 7 are in good condition, necessitating regular maintenance to ensure safety for the estimated 9,485 vulnerable individuals in the area. Additionally, community involvement is crucial for enhancing disaster preparedness, as evidenced by the 15% of participants receiving training in emergency response. Overall, while Rajapur has made strides in flood response and preparedness, significant gaps remain in infrastructure resilience, community training, and effective communication, necessitating a comprehensive approach to ensure the community is truly equipped to handle future flooding events.

5.2 Recommendations

Based on this study, some suggested recommendations for more effective early warning systems in Rajapur municipalities are as follows:

- Enhance 3-day and 5-day forecasting systems, invest in advanced technologies to enhance detection accuracy, detection probability of critical flood events, thereby reducing the false alarm ratio and increasing public trust in the system.
- Implement modern technologies, such as automatic sirens, for improved communication and dissemination of alerts with more lead time for preparedness.
- Ensure proper management of drainage systems and canals to mitigate flooding risks and connect the *Budi kulo* automatic siren.
- Increase the number of evacuation shelters with access to basic services for better community safety. Regularly maintain and upgrade evacuation shelters to ensure they are equipped to handle emergencies effectively and safely.
- Foster community involvement through training programs in emergency response and preparedness, ensuring that residents understand the importance of flood-proofing their homes and participating in disaster readiness activities.
- Foster collaboration with a wider range of stakeholders, including humanitarian and funding agencies, for resource mobilization and support.

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APPENDICES

Appendices A: Flood forecast and flood event data

Flood warning *(source: DHM)*	**Flood events** *(source: LDCRP)*	**Wards** *(source: LDCRP)*
2065/04		
2065/05		
2065/06	2065/06	1,7
2066/04		
2066/05		
2066/06	2066/06	1
2067/04	2067/04	1,9
2067/05		
2068/04		
	2069/03	1
2069/05		
2070/03	2070/03	1,7
2070/04	2070/04	1
	2070/05	4
	2070/06	4
	2071/02	1
	2071/03	1,3,5,10
2071/04	2071/04	1,3,7,10
	2071/05	1,3,10
	2072/02	7
	2072/06	1
2073/04	2073/04	10
	2073/05	1
2074/04	2074/04	5,7
	2074/05	5
	2075/03	10
2075/04	2075/04	7,8
2075/05	2075/05	5,7,9
	2076/04	1,3,5,7,8
	2076/05	7
	2076/06	5
	2077/03	1,5,7,9
2077/04	2077/04	1,2,4,7,8,9,10
2077/05	2077/05	1,2,4,5,7,8

Note: Every dates mentioned above is in B.S.

Appendices B: FM station in Rajapur

S.N.	FM station name	Frequency	GPS location
1	Radio Sathi FM	95 MHz	28°26'0.01"N 81° 5'46.76"E
2	Radio Rajapur FM	88.6 MHz	28°25'48.16"N 81° 5'26.12"E

Source: Bipad Portal and Field Observation

Appendices C: Tele-communication tower details

S.N.	Tele-communication	Ward no.	Coverage radius (km)	GPS location
1	NTC	4	22	28°25'48.32"N 81° 5'23.19"E
		6	6	28°24'5.72"N 81° 9'24.38"E
		9	12	28°23'35.97"N 81° 6'56.97"E
		10	12	28°23'5.87"N 81°11'28.09"E
2	Ncell	4	23	28°26'12.58"N 81° 5'56.47"E
			12	28°26'8.20"N 81° 5'53.23"E
			6	28°25'44.28"N 81° 5'24.41"E
		6	6	28°23'20.73"N 81° 9'36.00"E
		9	12	28°23'46.94"N 81° 6'48.49"E

Source: Bipad Portal and Field Observation

Appendices D: Quarantine center during time of flood

S.N.	Quarantine center	Community	Capacity	GPS location
1	Shree Amar Sahid Multiple Campus	Rajapur	70	28°25'53.32"N 81° 5'21.62"E
2	Rajapur Shree Kalika SS	Chanaura	83	28°28'37.85"N 81° 8'52.99"E
3	Shree Nepal Rastriya SS	Nayagaun	113	28°27'25.67"N 81° 9'27.95"E
4	Shree Manpur SS	Tapara	103	28°24'2.65"N 81° 9'21.53"E
5	Shree Nepal Rastriya SS	Goddiyana	80	28°23'41.48"N 81° 6'53.87"E
6	Shree Janachetana SS	Mangalpur	85	28°23'23.71"N 81°11'3.03"E
7	Shree Padmakumari SS	Triveni Bazar	17	28°25'17.16"N 81°10'9.80"E
8	Shree Janajagriti Lower SS	Karmohani	55	28°22'47.24"N 81°10'5.75"E
9	Shree Buddha Basic School	Bhimapur	20	28°24'8.33"N 81° 6'7.19"E
10	Shree Kishan SS	Jayapur	70	28°25'50.64"N 81° 9'1.77"E
11	Renaissance Bording School	Rajapur	86	28°25'59.73"N 81° 5'51.82"E
12	Nepal Rastriya Lower SS	Tediya	30	28°26'24.76"N 81° 6'5.32"E
13	Shree Saraswoti Primary School	Laxmipur	15	28°25'40.74"N 81° 5'28.76"E
14	Amar Sahid SS	Rajapur	75	28°25'45.83"N 81° 5'39.64"E
15	Janajyoti Primary School	Chhokipur	47	28°28'3.66"N 81° 8'49.93"E
16	Saraswoti Bal Primary School	Sankharpur	32	28°23'27.77"N 81° 4'51.04"E
17	Bheri SS	Lalitapur	41	28°25'2.05"N 81° 7'9.06"E

18	Nepal Rastriya Lower SS	Ishworiganj	15	28°27'16.60"N 81° 9'9.94"E
Total			1,037	

Source: Bipad Portal and Field Observation

Appendices E: Evacuation shelter during flood

Ward no.	Community	No. of evacuation shelter	Capacity of evacuation shelter	Status	GPS location
1	Tihuini	1	100	Good	28°29'33.41"N 81° 9'43.62"E
	Chanaura	1	50		N/A
	Premnagar	1	50		N/A
3	Nangapur	1	200	Good	N/A
	Chakkapur	1	150		28°26'54.24"N 81° 6'13.68"E
4	Sangarshanagar	2	100	Good	28°24'53.15"N 81° 4'47.84"E
					28°25'11.69"N 81° 4'52.79"E
7	Sankharpur	1	50	Average	28°24'30.02"N 81° 4'57.36"E
	Bhaluphata	1	50		28°23'29.50"N 81° 5'25.21"E
9	Goddiyana	1	50	Average	28°24'6.33"N 81° 6'33.80"E
10	Jhapti	1	50	Average	N/A
Total		11	850		

Source: Monsoon Preparedness and Response Plan, 2024 & Field Observation

Appendices F: Relationship between gender and most preferred channel

Gender: * Preffered Communication Channel Crosstabulation

		Most Preferred Channel					Total
		Flag Colour	Miking	Neighbours	Siren	SMS	
Gender	Male	0	1	31	35	53	120
	Female	1	1	13	12	53	80
Total		1	2	44	47	106	200

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Monte Carlo Sig. (2-sided)		
				Significance	99% Confidence Interval	
					Lower Bound	Upper Bound
Pearson Chi-Square	12.103[a]	4	.017	.007[b]	.005	.009
Likelihood Ratio	12.670	4	.013	.009[b]	.006	.011
Fisher's Exact Test	12.239			.005[b]	.004	.007
N of Valid Cases	200					

a. 4 cells (40%) have expected count less than 5. The minimum expected count is .40.

b. Based on 10000 sampled tables with starting seed 2000000.

Symmetric Measures

		Value	Approximate Significance	Monte Carlo Significance		
				Significance	99% Confidence Interval	
					Lower Bound	Upper Bound
Nominal by Nominal	Phi	.246	.017	.007[c]	.005	.009
	Cramer's V	.246	.017	.007[c]	.005	.009
N of Valid Cases		200				

c Based on 10000 sampled tables with starting seed 2000000.

Appendices G: Relationship between age group and most preferred channel

Age × Most Preferred Channel Cross tabulation

		Most Preferred Channel					Total
		Flag Colour	Miking	Neighbours	Siren	SMS	
Age	10-20	0	0	0	1	10	11
	20-30	0	0	3	1	38	42
	30-40	0	0	9	8	26	43
	40-50	1	0	6	15	18	40
	50-60	0	1	6	16	6	29
	60+	0	1	20	6	8	35
Total		1	2	44	47	106	200

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Monte Carlo Sig. (2-sided)		
				Significance	99% Confidence Interval	
					Lower Bound	Upper Bound
Pearson Chi-Square	87.982[a]	20	.000	.000[b]	.000	.000
Likelihood Ratio	87.978	20	.000	.000[b]	.000	.000
Fisher's Exact Test	84.062			.000[b]	.000	.000
N of Valid Cases	200					

a. 14 cells (46.7%) have expected count less than 5. The minimum expected count is .06.

b. Based on 10000 sampled tables with starting seed 1314643744.

Symmetric Measures

		Value	Approximate Significance	Monte Carlo Significance		
				Significance	99% Confidence Interval	
					Lower Bound	Upper Bound
Nominal by Nominal	Phi	.663	.000	.000[c]	.000	.000
	Cramer's V	.332	.000	.000[c]	.000	.000
N of Valid Cases		200				

c. Based on 10000 sampled tables with starting seed 1314643744.

Appendices H: Relationship between education level and most preferred channel

Education level × Most Preferred Channel Cross tabulation

		Most Preferred Channel					Total
		Flag Colour	Miking	Neighbours	Siren	SMS	
Education level	College/University degree	0	0	0	0	10	10
	No formal education	1	2	41	42	5	91
	Primary school	0	0	3	5	41	49
	Secondary school	0	0	0	0	50	50
Total		1	2	44	47	106	200

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Monte Carlo Sig. (2-sided)		
				Significance	99% Confidence Interval	
					Lower Bound	Upper Bound
Pearson Chi-Square	154.508[a]	12	.000	.000[b]	.000	.000
Likelihood Ratio	195.151	12	.000	.000[b]	.000	.000
Fisher's Exact Test	180.199			.000[b]	.000	.000
N of Valid Cases	200					

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is .05.

b. Based on 10000 sampled tables with starting seed 743671174.

Symmetric Measures

		Value	Approximate Significance	Monte Carlo Significance		
				Significance	99% Confidence Interval	
					Lower Bound	Upper Bound
Nominal by Nominal	Phi	.879	.000	.000[c]	.000	.000
	Cramer's V	.507	.000	.000[c]	.000	.000
N of Valid Cases		200				

c. Based on 10000 sampled tables with starting seed 743671174.

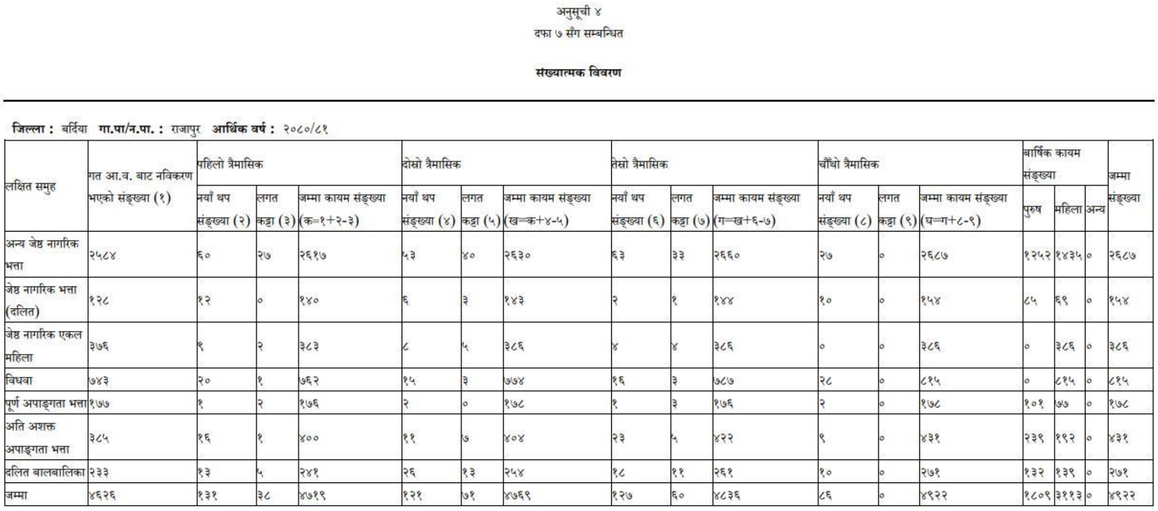
Appendices I: Likert scale analysis for warning level, lead time and preparedness

Understanding level of Warning	Score	Calculation	Score	Average
Very Easy	1.0-1.80	84×1=84	2.32	Somewhat Easy
Somewhat Easy	1.81-2.60	38×2=76		
Neutral	2.61-3.40	28×3=84		
Somewhat Difficult	3.41-4.20	30×4=120		
Very Difficult	4.21-5.0	20×5=100		
Total		464		

Lead time for preparedness	Score	Calculation	Score	Average
0-1 hrs.	1.0-1.80	6×1=6	3.29	2-3 hrs.
1-2 hrs.	1.81-2.60	30×2=60		
2-3 hrs.	2.61-3.40	80×3=240		
3-4 hrs.	3.41-4.20	68×4=272		
Above 4 hrs.	4.21-5.0	16×5=80		
Total		658		

Household preparedness	Score	Calculation	Score	Average
Very Prepared	1.0-1.80	14×1=14	2.83	Neutral
Somewhat Prepared	1.81-2.60	76×2=152		
Neutral	2.61-3.40	36×3=108		
Not Very Prepared	3.41-4.20	68×4=272		
Not Prepared at all	4.21-5.0	4×5=20		
Total		566		

Appendices J: Vulnerable population details from municipal office



अनुसूची ४
दफा ७ सँग सम्बन्धित

संख्यात्मक विवरण

जिल्ला : बर्दिया **गा.पा/न.पा. :** राजापुर **आर्थिक वर्ष :** २०८०/८१

लक्षित समुह	गत आ.व. बाट नविकरण भएको संङ्ख्या (१)	पहिलो त्रैमासिक			दोस्रो त्रैमासिक			तेस्रो त्रैमासिक			चौंथो त्रैमासिक			बार्षिक कायम संङ्ख्या			जम्मा संङ्ख्या
		नयाँ थप संङ्ख्या (२)	लगत कट्टा (३)	जम्मा कायम संङ्ख्या (क=१+२-३)	नयाँ थप संङ्ख्या (४)	लगत कट्टा (५)	जम्मा कायम संङ्ख्या (ख=क+४-५)	नयाँ थप संङ्ख्या (६)	लगत कट्टा (७)	जम्मा कायम संङ्ख्या (ग=ख+६-७)	नयाँ थप संङ्ख्या (८)	लगत कट्टा (९)	जम्मा कायम संङ्ख्या (घ=ग+८-९)	पुरुष	महिला	अन्य	
अन्य जेष्ठ नागरिक भत्ता	२५८४	६०	२७	२६१७	५३	४०	२६३०	६३	३३	२६६०	२७	०	२६८७	१२५२	१४३५	०	२६८७
जेष्ठ नागरिक भत्ता (दलित)	१२८	१२	०	१४०	६	३	१४३	२	१	१४४	१०	०	१५४	८५	६९	०	१५४
जेष्ठ नागरिक एकल महिला	३७६	९	२	३८३	८	५	३८६	४	४	३८६	०	०	३८६	०	३८६	०	३८६
विधवा	७४३	२०	१	७६२	१५	३	७७४	१६	३	७८७	२८	०	८१५	०	८१५	०	८१५
पूर्ण अपाङ्गता भत्ता	१७७	१	२	१७६	२	०	१७८	१	३	१७६	२	०	१७८	१०१	७७	०	१७८
अति अशक्त अपाङ्गता भत्ता	३८५	१६	१	४००	११	७	४०४	२३	५	४२२	९	०	४३१	२३९	१९२	०	४३१
दलित बालबालिका	२३३	१३	५	२४१	२६	१३	२५४	१८	११	२६१	१०	०	२७१	१३२	१३९	०	२७१
जम्मा	४६२६	१३१	३८	४७१९	१२१	७१	४७६९	१२७	६०	४८३६	८६	०	४९२२	१८०९	३११३	०	४९२२

Appendices K: Key stakeholder's interview

Key personnel	Name	Organization	Designation
Information provider	Mrs. Parbati Gurung	Chiapani station	Gauge reader
Municipal official	Mr. Khusiram Tharu	Rajapur municipality	IT officer & Disaster focal person
Ward level	Ms. Ranju Chaudary	Ward no.1	Ward secretary
	Mr. Prasadu Tharu	Ward no.3	Ward chairperson
	Mr. Bidur Pokhrel	Ward no.4	Ward chairperson
	Mr. Ramu Tharu	Ward no.7	Ward chairperson
	Mr. Bishnu Prasad Tharu	Ward no.9	Ward chairperson
	Mrs. Jamuna Shahi	Ward no.10	Ward secretary
Village head *(Barghar)*	Mr. Kesuram Tharu	Ward no. 1	Tihuni
	Mr. Jiudhal Tharu	Ward no. 3	Nangapur
	Mr. Nukal Tharu		Tighra
	Mr. Jaguwa Tharu		Chakkapur
	Mr. Risman Tharu		Tediya
	Mr. Karna Bahadur Tharu	Ward no. 4	Anantapur

	Mr. Khusiram Tharu		Sangarsanagar (Muktakamaiya Tol)
	Mr. Bhupendra Tharu	Ward no. 7	Bhaluphata
	Mr. Man Bahadur Ale		Sankharpur
	Mr. Govinda Rana		Lalchipur
	Mr. Min Bahadur Gurung		Lahure Tol
	Mr. Siddha Ram Tharu	Ward no. 9	Chainpur
	Mr. Dhani Ram Tharu		Durganagar
	Mr. Dharti Ram Tharu		Goddiyana
	Mr. Salik Ram Tharu		Chhotki Bhimapur
	Mr. Nok Bahadur Gharti Magar	Ward no. 10	Majhra
	Mr. Jit Bahadur Tharu		Jhapti
	Mr. Diule Tharu		Pahadipur
	Mr. Thakur Raj Tharu		Lalpur
Communication media channel	Mr. Min Prasad Adhikari	Sathi FM station	Station manager
	Mr. Bishnu Sharma	Nepal Telecom	Rajapur branch manager
Preparedness & response	Mr. Chakra Bahadur Bam & Mr. Ramesh Gautam	Practical Action, Rajapur	Senior project officer
	Mr. Ashok Bista	Armed Police Force (APF)	Deputy Superintendent of Police (DSP)

Appendices L: Household survey Questionnaire

This questionnaire has been designed for a study on the effectiveness of the Chisapani flood early warning system in Rajapur Municipality. The information collected through this survey will be used solely for research purposes, and all participant details and responses will remain confidential. By participating in this study, you will play a vital role in understanding the communication channels and dissemination, preparedness measures, and response actions taken in your community. Your insights will help identify effective practices and inform future planning, decision-making, and local policies related to flood management. I greatly appreciate your valuable time, honesty, and thoughtful responses. Your contribution is essential to enhancing the understanding of flood preparedness and response in our community. Thank you for your participation!

Part 1: Demographics

1. Name: (Optional)
2. Ward:
    - ○ 1
    - ○ 3
    - ○ 4
    - ○ 7
    - ○ 9
    - ○ 10
3. Community:
4. GPS location:
    - ○ X and Y coordinates
5. Age:
    - ○ 10-20 years
    - ○ 20-30 years
    - ○ 30-40 years
    - ○ 40-50 years
    - ○ 50-60 years
    - ○ 60+ years
6. Gender:
    - ○ Male
    - ○ Female
    - ○ I prefer not to say
7. What is the highest level of education you have completed?
    - ○ No formal education
    - ○ Primary school
    - ○ Secondary school
    - ○ College/University degree
8. Do your family member have any physical impairment?
    - ○ Yes (Please specify, optional)
    - ○ No
9. How much difficult is it to convey the message of warning and preparedness?

Part 2: Flood Warning Communication and dissemination

1. In the past year, have you received a flood warning?
    - ○ Yes
    - ○ No
2. If no, what were the reasons in your opinion?
3. If yes, which communication channels did you receive the flood warning through? (Select all that apply)
    - ○ Siren
    - ○ SMS (Please specify)
    - ○ Radio broadcast (Please specify station, if known)
    - ○ Neighbour
    - ○ Social media (Please specify the platform)
    - ○ Flag colour
    - ○ Miking
    - ○ Other (Please specify)
4. How easy was it for you to understand the flood warning you received?
    - ○ Very easy
    - ○ Somewhat easy
    - ○ Neutral
    - ○ Somewhat difficult
    - ○ Very difficult
5. Which communication channel would you prefer to receive flood warnings through in the future? (Rank 1 as most preferred, 7 as least preferred)
    - ○ Siren
    - ○ SMS (Please specify)
    - ○ Radio broadcast (Please specify station, if known)
    - ○ Neighbour
    - ○ Social media (Please specify the platform)
    - ○ Flag colour
    - ○ Miking
    - ○ Other (Please specify)
6. Do you have any suggestions on what other unutilized sources are? (Open-ended)
7. Are you satisfied? (Yes/No). Do you have any suggestions for improving flood warning communication in Rajapur? (Open-ended)

Part 3: Preparedness and response

1. Have you or your family ever been affected by a flood in Rajapur?
    - ○ Yes
    - ○ No
2. If no, what were the reasons in your opinion?
3. If yes, how did the flood impact you (Select all that apply)?
    - ○ Damage to property
    - ○ Loss of belongings
    - ○ Loss of Livestock
    - ○ Evacuation or Displacement
    - ○ Loss of life or Injury
    - ○ Other (Please specify)

4. In your opinion, which impact has decreased after the installation of the Chisapani Early Warning System? Please rank it.
    - Damage to property
    - Loss of belongings
    - Loss of Livestock
    - Evacuation or Displacement
    - Loss of life or Injury
    - Other (Please specify)
5. How much time you receive to response the flood?
    - Less than 1 hour
    - 1-2 hours
    - 2-3 hours
    - 3-4 hours
    - More than 4 hours
    - Unsure
6. In your opinion, how prepared is your household for a potential flood?
    - Very prepared
    - Somewhat prepared
    - Neutral
    - Not very prepared
    - Not prepared at all
7. Have you taken any specific actions to prepare your household for a flood? (Select all that apply)
    - Developed a flood evacuation plan
    - Assembled an emergency kit (food, water, first aid supplies)
    - Secured important documents and valuables
    - Flood proofed my home (e.g., sandbags)
    - Other (Please specify)
8. Are there any pre-identified locations for evacuation in your community in case of flood?
    - Yes
    - No
    - Don’t know
9. If yes where are these locations
    - School
    - Open Ground
    - Evacuation Shelter
    - Ward offices
    - Community Building
    - Others (Please specify)
10. What are the biggest challenges you face in preparing for a flood? (Open-ended)
11. What additional resources or information would help you better prepare your household for a flood? (Open-ended)
12. Have you received any type of trainings for preparedness?
    - Yes
    - No
13. If yes, what sort of trainings?

Appendices M: Photographs of field visit

Flooded paddy field & Flooded Karnali River

List of most vulnerable communities & Denotation of past flood

Manual siren in ward no.1, *Tihuni* & Automatic siren in LEOC for *Budi kulo*

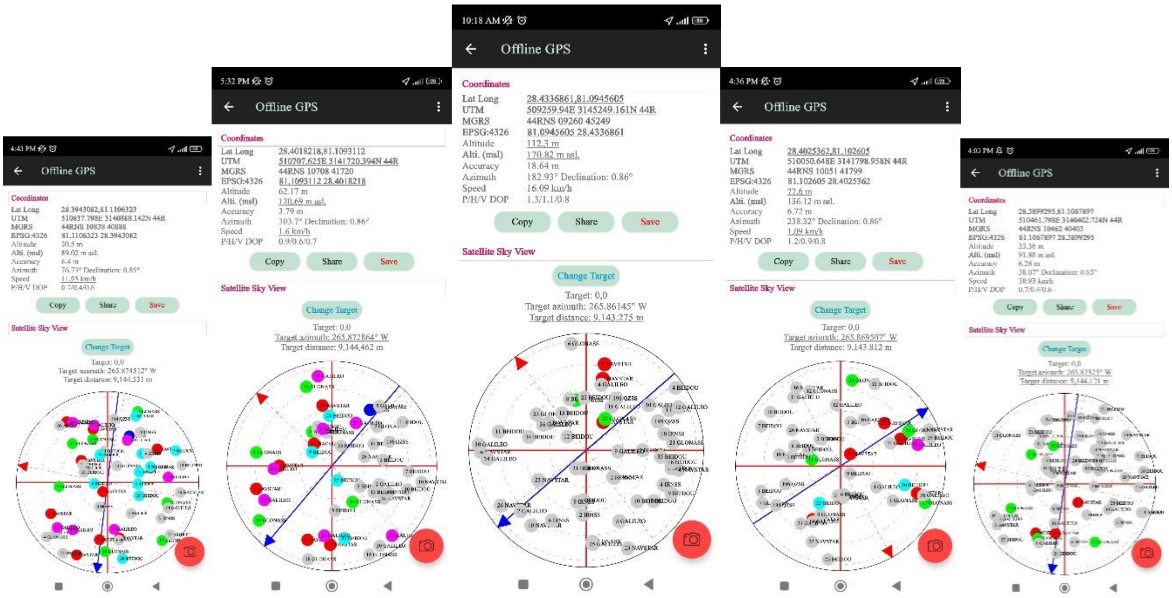
Raised house & *Thati* for keeping belongings safe

Personal evacuation shelter in *Chanaura*, Safe fuel wood & Livestock protection

Resources available for response, Embankment in *Budi kulo* & Raised tap

Evacuation shelter for flood response

Ward no.7 office, Community building & School for evacuation



4:43 PM

Lat Long	28.3943082,81.1106323
UTM	510837.798E 3140888.142N 44R
MGRS	44RNS 10838 40888
EPSG:4326	81.1106323 28.3943082
Altitude	30.5 m
Alti. (msl)	89.02 m asl.
Accuracy	6.4 m
Azimuth	76.73° Declination: 0.85°
Speed	11.93 km/h
P/H/V DOP	0.7/0.4/0.6

Target: 0,0
Target azimuth: 265.874512° W
Target distance: 9,144.531 m

5:32 PM

Lat Long	28.4018218,81.1093112
UTM	510707.625E 3141720.394N 44R
MGRS	44RNS 10708 41720
EPSG:4326	81.1093112 28.4018218
Altitude	62.17 m
Alti. (msl)	120.69 m asl.
Accuracy	3.79 m
Azimuth	303.7° Declination: 0.86°
Speed	1.6 km/h
P/H/V DOP	0.9/0.6/0.7

Target: 0,0
Target azimuth: 265.872864° W
Target distance: 9,144,462 m

10:18 AM

Lat Long	28.4336861,81.0945605
UTM	509259.94E 3145249.161N 44R
MGRS	44RNS 09260 45249
EPSG:4326	81.0945605 28.4336861
Altitude	112.3 m
Alti. (msl)	170.82 m asl.
Accuracy	18.64 m
Azimuth	182.93° Declination: 0.86°
Speed	16.09 km/h
P/H/V DOP	1.3/1.1/0.8

Target: 0,0
Target azimuth: 265.86145° W
Target distance: 9,143.275 m

4:36 PM

Lat Long	28.4025362,81.102605
UTM	510050.648E 3141798.958N 44R
MGRS	44RNS 10051 41799
EPSG:4326	81.102605 28.4025362
Altitude	77.6 m
Alti. (msl)	136.12 m asl.
Accuracy	6.72 m
Azimuth	238.32° Declination: 0.86°
Speed	1.09 km/h
P/H/V DOP	1.2/0.9/0.8

Target: 0,0
Target azimuth: 265.869507° W
Target distance: 9,143.812 m

4:03 PM

Lat Long	28.3899295,81.1067897
UTM	510461.798E 3140402.724N 44R
MGRS	44RNS 10462 40403
EPSG:4326	81.1067897 28.3899295
Altitude	33.36 m
Alti. (msl)	91.88 m asl.
Accuracy	6.28 m
Azimuth	38.07° Declination: 0.85°
Speed	10.93 km/h
P/H/V DOP	0.7/0.4/0.6

Target: 0,0
Target azimuth: 265.87323° W
Target distance: 9,144.121 m

GPS locations of different Communication channels & Evacuation locations

Glimpse of household survey data collection

FGD with *Sana Kishan* Women’s group

KII with Chisapani Station Gauge reader Ms. Parbati Gurung

KII with municipal disaster focal person & Ward representatives

KII with *Barghar* (village head)

KII related to communication channels (Sathi FM station manager & NT branch manager)

KII related to preparedness and response (DSP of APF & Senior project officers, PA)