Socio-Economic Vulnerability to Potential Flood in Tamakoshi River in Nepal

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Submitted: May 26, 2023, Accepted: March 29, 2024, Published: July 26, 2024

DOI: https://doi.org/10.3126/hr.v45i1.68166

Abstract: Tamakoshi, a transboundary river flowing from Tibet, China to Nepal has experienced several disastrous flash floods resulting in the loss of lives, infrastructures, settlements, lands, and other assets. Many households, populations, and public and private properties such as houses, land, roads, bridges, etc. are likely to be affected by the potential flash floods. This study discusses the occurrence of flash floods, losses and damages from such floods in the past, and socio-economic vulnerability to potential flash floods. It further discusses the preparedness and response activities and identifies the measures for flood risk reduction. The methods adopted for data collection included observation, household surveys, and focus group discussions. The villages selected for detailed study are Gongarkhola, Jagat, Jamune, Bhorle, and Sigati bazaar, identified as the most vulnerable settlements along the Tama Koshi River. It is found that flash floods and high-intensity precipitation occur frequently in the study area resulting in loss of life and properties, and people and properties are exposed to the potential flash floods. Local people are still feeling vulnerable to such flash floods. The government authorities alone are not able to achieve greater success in carrying out preparedness and response activities for flood risk reduction without the active involvement and participation of the vulnerable communities. Development and effective implementation of land-use guidelines and building codes, watershed management, early warning systems, and networking among the people residing across the river are some of the activities identified to reduce flood risk. Although people have a good understanding and knowledge about floods and their occurrences, they pay less attention to preparedness and mitigation. It is also concluded that structural measures alone are not sufficient and effective enough for flood risk reduction.

Keywords: Vulnerability, Disaster, Flash flood, Mitigation Measures, Adaptation

1. Introduction

Understanding the risk associated with flash floods and adopting mitigation and adaptation measures is necessary for designing and implementing risk reduction activities. Community awareness is pivotal for flash flood risk reduction. Risk reduction is more complex than mitigation and requires the involvement of all stakeholders at the community as well as district and national levels to be effective (Shrestha & Bajracharya, 2013). However, the risk of flash floods cannot be eliminated but can be reduced only. Insufficient public awareness, lack of disaster preparedness, ineffective governance, poor coordination among government agencies, limited financial resources, and inadequate technical knowledge contribute to the high number of human casualties and damage to public and private property resulting from natural disasters (Tuladhar et al., 2015).

Nepal, which is one of the landlocked mountainous countries in south Asia, has about 30 million inhabitants in 147,516 square kilometers area (NTB, 2020). The country is located in the central Himalayan region and is characterized by weak geological formations active seismic conditions, occasional glacier lake outburst, concentrated monsoon rains, and unscientific land utilization are some of the major reasons for water-induced disasters in Nepal (DWIDP, 2013). It has a variation

of altitude ranging from 59 meters to 8848.86 meters above the sea level below 200 kilometers distance has led to creating a high energy environment and thus very dynamic geomorphic processes leading to the occurrence of natural disasters mainly flash floods and landslides (MoHA, 2019). The steep landscape, unstable slopes, and active geological formations of a young mountain range along with heavy monsoon rainfall render Nepal one of the most hazardous areas in the world. Nepal is a disaster hot spot due to the vulnerability of the population and the regular and frequent occurrence of different natural hazards (MoHA, 2009). Flash floods such as Glacial Lake Outburst Floods (GLOF), Landslide Dam Outburst Floods (LDOF), and floods resulting from high-intensity precipitation cause tremendous loss of life and property in the country. Flood damages and losses are also closely linked with man-made factors such as poor or unplanned infrastructural construction, deforestation, blocked drainage systems, and a culture of ignoring (Gautam & Phaiju, 2013; Rijal et al., 2018; Sharma et al., 2019). Human beings are suffered from the result of their non-foresighted work.

Floods are one of the oldest disasters that have been threatening humanity throughout the history of civilizations. Direct impacts like death or other human vulnerability and indirect impacts like loss and damage to agricultural products and infrastructures are the results of floods. The frequency and magnitude of flash floods are likely to increase due to increasing snow and ice melts and changes to regional rainfall patterns in the context of recent climate change. One of the challenges is how to reduce the loss of life and properties from flash floods. Research on the risk of flash floods in the Tama Koshi River is lacking in terms of its thematic, spatial, and temporal scope (Khanal et al., 2009, 2015; ICIMOD, 2011). The general objective of this study is to understand the risk of flash floods, and the specific objectives are to i) discuss the occurrence of different types of flash floods, ii) losses, and damages, iv) socio-economic vulnerabilities, v) explore the local people's perception of flood disaster management and vi) existing adaptive and mitigation measures to reduce the adverse impact of flood disasters.

2. Conceptual Framework of the Study

A framework has been developed for this study. A step-by-step process has been adopted. It starts from the analysis of the occurrence of flash floods to the losses and damages, elements exposed to the hazard, vulnerability, and risk reduction strategies and activities (Figure 1). Risk reduction strategies and activities include awareness, mitigation, and adaptation.

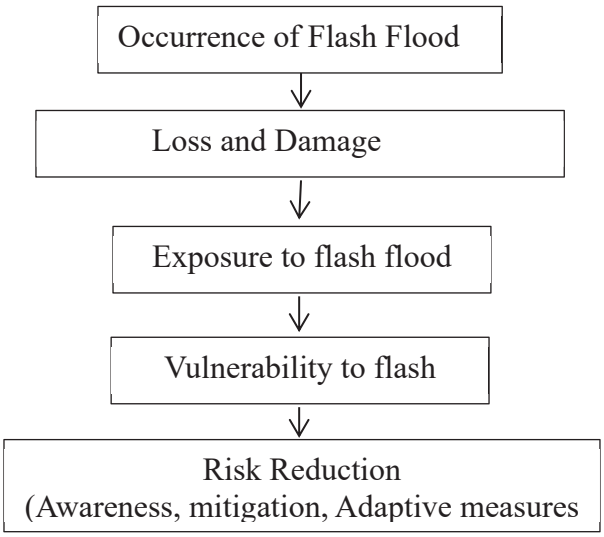

Figure 1. Framework for the Study of Flash Flood Risk and its Management

It is also important to understand how residents perceive flood risks in their areas and what type of consciousness and capacities the residents have regarding disaster preparedness actions. The study of risk perception involves the examination of people's awareness and behaviour about disaster. Flood risk awareness is the cornerstone of non-structural flood risk management. All actions to minimize the impact of flooding hinge upon stakeholders becoming aware these are both necessary and desirable. Awareness may be naturally high in areas where flooding occurs regularly but is often deficient in locations subject to low-frequency but high-impact events. In an ideal world, heightened awareness of flood risk would lead to mitigation activities and preparedness, which in turn reduce the impact of flood events (Jha, Bloch & Lamond, 2012). Public awareness helps to understand the reality, an understanding of the types, frequency, magnitude, and causes of flood events compels people to accept vulnerable conditions. Based on their long experience and accepting their ground reality they began to change their behaviour for disaster management. Moreover, people's awareness, actual understanding, and knowledge are important to change their behaviour. Figure 2 further shows the processes of behaviour change of local people to accept and implement mitigation and adaptation activities in reducing the flood risk. Based on this conceptual framework, this study was carried out.

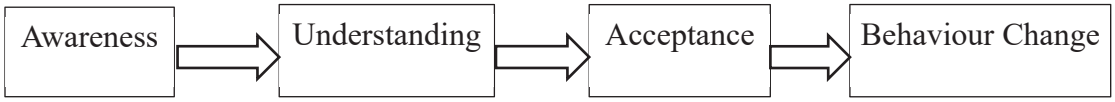

Figure 2. Communications Continuum

Source: University Corporation for Atmospheric Research 2010 Cited in Jha, Bloch & Lamond, 2012.

3. Methodology

3.1 Study Area

The Tama Koshi is a transboundary river originating on the southern slopes of the Himalayas from the Rongshar Chu and Lapchi Gang rivers close to the Nepal-Tibet border. The Tamakoshi River is one of the major tributaries of the Saptakoshi River System. Tama Koshi basin has a total area of 4130 sq km of which 2688 sq km lies in Nepal and the remaining 1442 lies in Tibet Autonomous Region (TAR), China. The altitude of the basin ranges from about 500 m at the confluence of Tama Koshi with Sun Koshi in Khurkot in the south to more than 7000 in the north. The region is exposed to multiple geomorphologic and geological hazards like earthquakes, landslides, flood, debris flow, and glacial lake outbursts flood (Dhakal, 2013). The topography is highly rugged with high mountain peaks and steep slopes to deep river valleys. The northern part of the basin is covered with snow and ice. There is a total of 307 glacial lakes covering 14.68 sq km. The average area of glacial lake is 0.05 sq. km. Among 307 glacial lakes in the basin, 219 are moraine dammed, 38 are ice-dammed, and 50-bed rock dammed. Eight glacial lakes one in Nepal and 7 in TAR, China have been identified as potentially dangerous. Those are Tsho Rolpa in Nepal, and those located in TAR, China are unnamed lakes (Bajracharya et al., 2020). The location of potentially dangerous lakes in the basin shows the potential risk of GLOF. Similarly, The sharp incline alongside a narrow river. channels has a risk of potential landslide dam outburst flood. The occurrence of high-intensity rainfall during the monsoon period is another source of flash flood in the Tama Koshi River resulting the losses and damage to life and properties.

The detailed study is focused only on three settlements located between Singati (942 m) in the south to Chetchet (1428 m) in the north in the central part of the basin (Figure 3). This area was

identified as the most vulnerable to flash floods especially the glacial lake outburst flood in the basin (Khanal et al., 2015). The studied settlements are Gongarkhola, Jagat, Jamune, Bhorle, and Singati.

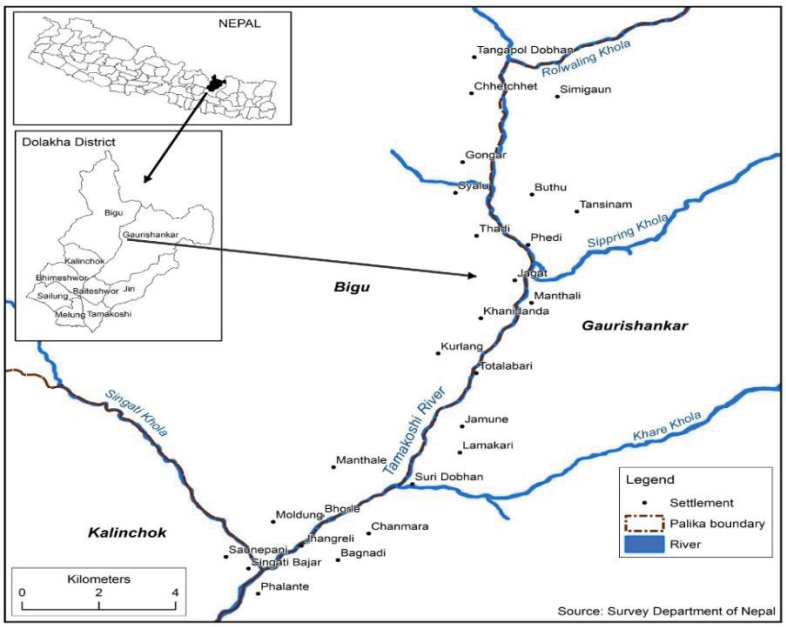

Figure 3. Location Map of the Study Area

3.2 Data and Method

This study was primarily based on an extensive field survey. Both the primary and secondary sources of information were collected and used. The data and information were also obtained from secondary sources in order to explain the relationship among key variables obtained from primary sources. Research reports, articles, and related national and international publications were collected and consulted for acquiring supporting information. Basically, the publications of the Ministry of Home Affairs (MoHA), Central Bureau of Statistics (CBS), National Statistics Office (NSO), Department of Hydrology and Meteorology (DHM), and International Centre for Integrated Mountain Development (ICIMOD) were consulted. The primary data was obtained through Transact Walk, Focus Group Discussions (FGDs) with social mapping, and Key Informant Interviews (KIIs). Checklists were prepared and used for the systematic recording of the responses. Transect walks and observation were carried out in the study area to identify and map the major elements exposed to a potential flood risk. Five FGDs were carried out with the people from five settlements: Gongarkhola, Jagat, Jamune, Bhorle, and Singati. In addition, three key informant interviews (KIIs) from each settlement were carried out with local teachers, and leaders in the settlements to collect. Information regarding the general perception of flood risks, elements exposed to potential floods, adaptation strategies adopted by local people to reduce flood risk, and institutional capacities were collected using both the FGD and KIIs. The overall methodological framework is presented in Figure 4.

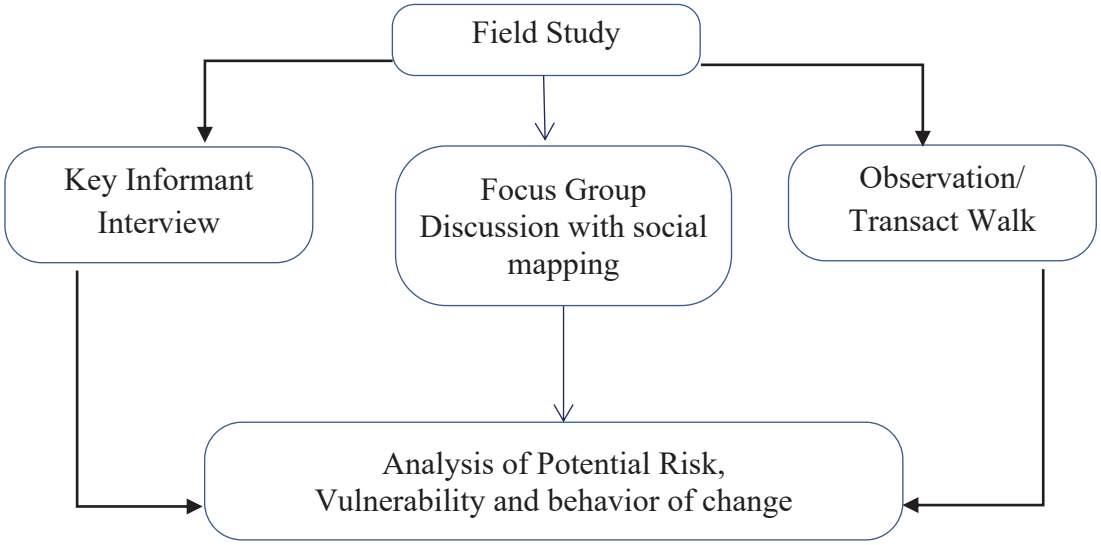

Figure 4. Methodological Framework

4. Results and Discussion

4.1 Occurrence of Flash Floods and its Damages in the Past

Major floods occurring year in the Tamakoshi River, their losses/damages, affected areas, and main reasons for flood obtained from FGD and KIIs are presented (Table 1). Seven major flood events with substantial losses have been reported by local people. The major floods were in 1964 in the Jamune area, in 1985 in the Jagat, Jamune, Bhorle, and Singati area, in 1988 in Jagat and Jamune area, in 1995 in all study areas 2007 in Bhorle and Singati areas and 2010 in Jagat, Jamune, Bhorle, and Singati areas. Major floods are caused by heavy rainfall, GLOF, LDOF, and torrential rainfall. The GLOF event of 1991 resulted in damages in the Gongarkhola and Jagat areas.

Table 1. Major Flood Events in Tamakosi and its Losses and Damages

Year	Losses/Damages	Reported from	Major reason
1964	2 persons, 8 animals, 1 house, 5 ropani khet, 7 ropani bari, 8 ropani forest, 1.95 MT paddy, 1.58 MT maize, 0.36 MT millet, 0.2 MT potato, 1.5 km trail and 0.5 km embankment	Jamune	heavy rainfall
1985	21 person, 113 animals, 8 houses, 206 ropani khet, 53 ropani bari, 22 ropani forest, 35.61 MT paddy, 7.81 MT maize, 1.29 MT millet, 4.96 MT potato, 6.2 km trail, 2.3 km embankment, 4.2 km irrigation canal	Jagat, Jamune, Bhorle, Singati,	heavy and long rainfall
1988	2 people, 8 animals, 1 house, 5 ropani khet, 8 ropani bari, 2 ropani forest, 7.32 MT paddy, 2.52 MT maize, 0.36 MT millet, 0.4 MT potato, 1 km trail, 0.5 km embankment, 0.5 km irrigation canal	Jagat, Jamune	heavy rainfall
1991	2 animals, 1 house, 2 ropani khet, 1 ropani bari, 0.08 MT potato, 1 km trail	Gongarkhola, Jagat	GLOF
1995	1 person, 56 animals, 4 houses, 333 ropani khet, 98 ropani bari, 41 ropani forest, 57.16 MT paddy, 33.27 MT maize, 6.73 MT millet, 4.92 MT potato, 11.3 km trail, 5.9 km embankment, 8.2 km irrigation canal	Gongarkhola, Jagat, Jamune, Bhorle, Singati,	heavy rainfall
2007	2 persons, 14 animals, 3 houses, 7 sheds, 8 ropani khet, 7 ropani forests, 12 MT paddy, 7MT maize,3MT potato,	Bhorle, Singati	LDOF

	1.5 km road, 6.2 km trail, 0.2km embankment, 1,2 km irrigation channel, and 1 paper industry		
2010	3 animal,1water mill, 4 sheds, 3ropani khet, 2ropani bari,1.5 ropani forest,1fish pond,0,6km road,3MT paddy,1.5MT maize.	Jagat, Jamune, Bhorle, Singati	heavy rainfall

Source: Field Survey, 2020

4.2 Exposure Houses Buildings

Of the total 880 houses with 797 families in the study area, 365 houses are exposed to flood risk which 227 houses in Singati, 50 in Jamune, 38 in Bhorle, 36 in Jagat, and 14 in Gongarkhola are at risk of flash flood in Tamakoshi (Figure 5). Generally, the buildings are used for residential purposes and some buildings in Singati and Jagat are used for industry, hotels, retail businesses, tea shops, and offices. Many of these are located in the market centers along the Singati-Lamabagar road and other trails.

Table 2. Number of House Buildings in the Study Areas

Settlements	Total no. of houses	No. of houses exposed to flood risk
Singati	478	227
Bhorle	55	38
Jamune	163	50
Jagat	131	36
Gongarkhola	53	14
Total	880	365

Field Survey, 2020

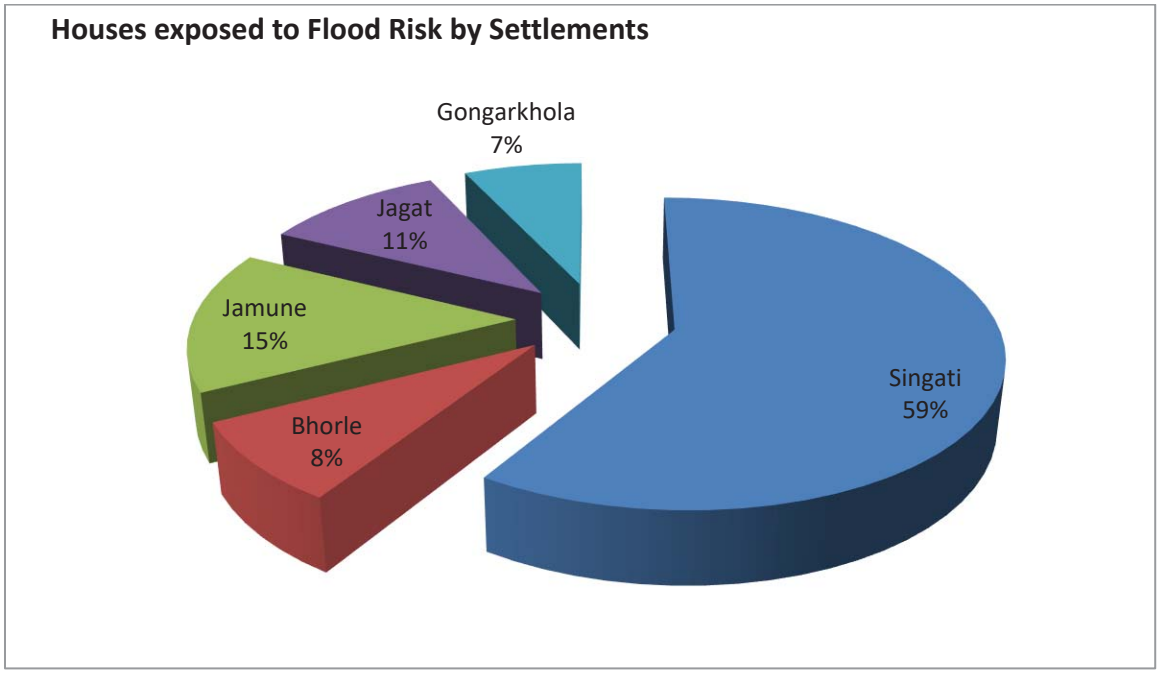

Figure 5. Houses Exposed to Potential Floods

4.3 Infrastructure Elements Exposed to Flood Risk

The Singati-Lamabagar and Singati-Suri road passes along and across the Tamakoshi river are likely to be washed away by the flash flood. As a result, traffic flow from Singati to Lamabagar and Singati to Suri is likely to be stopped for several days. A total of 11.5 km of road and 34.1 km of trail are likely to be damaged by flood. Similarly, 1.8 km of river embankment, 7.6 km of irrigation canal, and 10.9 km of transmission line are at high flood risk. There are 3 motorable bridges (one in Bhorle, one in Jamune, and one in Jagat) that are likely to be damaged due to flash floods. One hydropower in Suridovan and another one in Jagat are likely to be damaged by flood in Tamakoshi. Three sirens for early warning of flood in Gongarkhola, Jagat, and Singati are also at risk. Altogether four paper industries are located in Singati and Jagat and those are likely to be damaged by potential floods.

Table 3. Elements Exposed to Potential Floods

Infrastructure	Singati	Bhorle	Jamune	Jagat	Gongarkhola	Total
Road (km)	0.8	0.7	5.5	3	1.5	11.5
Trail (km)	2.1	2.3	15.5	7	7.2	34.1
River embankment (km)	0.5	0.3	0.5	0.2	0.3	1.8
Irrigation canal (km)	0.3	0.3	1.5	5.3	0.2	7.6
Transmission line (km)	0.9	1.5	4.5	2.5	1.5	10.9
Bridge (Number)	0	1	1	1	0	3
Suspension bridge (Number)	2	1	2	2	1	8
Hydropower (Number)	0	1	0	1	0	2
Siren (Number)	1	0	0	1	1	3
Paper Industry (Number)	3	0	0	1	0	4

Source: Field survey, 2020

4.4 Socio-economic Vulnerability

Vulnerability is the people, assets, or a system's susceptibility to the impacts of hazards and is determined by physical, social, economic, and environmental vulnerability factors or processes, such as available resources and assets, food security, and coping capacity (UNDRR, 2020). Socioeconomic vulnerability refers to the socioeconomic and political conditions in which people exposed to disaster are living, whereas Spatial vulnerability is a function of location, exposure to hazards, and the physical performance of a structure. (ICIMOD, 2007) Because of the challenging component of risk and its complexity in nature, it was argued that vulnerability cannot be measured by simply using one indicator (Adger, 2006).

4.4.1 Households and Population

More than nine caste/ethnic groups are living in those five settlements. detailed study. Among them, Tamang, Chhetri, Newar, Sherpa, Dalit, and Brahmin are major groups. In the study area, 797 households with a 3981 population are likely to be affected by flood which could be occurred in the future. Disadvantaged and marginalized ethnic groups such as Tamang, Sherpa, and Dalit are more vulnerable since they have less access to decision-making processes.

Table 4. Households and Population by Ethnicity

Ethnicity	Singati		Bhorle		Jamune		Jagat		Gongar khola		Total	
	Households	population	Households	population	Households	population	Households	population	Households	population	Households	population
Tamang	145	805	67	301	75	340	28	132	17	83	332	1661
Chhetri	99	433	10	40	18	80	8	30	4	17	139	600
Gurung	15	90	6	30	0	0	5	25	6	26	32	171
Magar	20	110	0	0	0	0	13	58	2	5	35	173
Brahmin	26	117	4	16	8	30	6	24	3	14	47	201
Newar	55	281	7	28	2	10	6	23	1	3	71	345
Dalit	40	291	3	19	7	35	5	26	2	10	57	381
Sherpa	37	214	6	30	10	45	9	41	7	38	69	368
Thami	8	49	0	0	0	0	0	0	0	0	8	49
Others	5	25	0	0	0	0	0	0	2	7	7	32
Total	450	2415	103	464	120	540	80	359	44	203	797	3981

Source: Field survey, 2020

4.4.2 Sources of Family Income

Trade and business, agriculture, wage, and service are the major sources of family income of the households that are likely to be affected by potential flash floods in the study area. More than 45% of the households get their income from trade and business, 27.10% from agriculture, and 18.07% from wages. Trade and business are major sources of livelihood for the people living in the market center like Singati and agriculture is a major family income source in rural areas like Jamune and Bhorle.

Table 5. Major Sources of Family Income

Major sources of family income	No. of households					Total	Percent
	Singati	Bhorle	Jamune	Jagat	Gongarkhola		
Agriculture	60	45	80	27	4	216	27.10
Service	12	5	6	5	2	30	3.76
Trade and business	296	22	12	13	17	360	45.17
Industry	4	3	2	2	0	11	1.38
Wage	70	22	15	23	14	144	18.07
Porterage	0	0	3	7	5	15	1.89
Remittances and pension	8	6	2	3	2	21	2.63
Total	450	103	120	80	44	797	100.00

Source: Field survey 2020

4.4.3 Landholding Size

Among the 797 families, about 39% likely to be affected by flash floods are landless with less than one *ropani* of land. Less than five percent (4.14%) of families are farmers with more than 10 *ropani* of land. Families with small size of landholdings (landless, marginal, and small) are more vulnerable to flood risk.

Table 6. Landholding Size

Size of landholding (Ropani)	Number of households					Total	Percent
	Singati	Bhorle	Jamune	Jagat	Gongarkhola		
Landless (< 1 ropani)	296	8	0	2	3	309	38.77
Marginal (1-2 ropani)	80	64	40	24	19	227	28.48
Small (2-5 ropani)	50	15	28	32	15	140	17.57
Medium (5-10 ropani)	22	13	30	17	6	88	11.04
Large (> 10 ropani)	2	3	22	5	1	33	4.14
Total	450	103	120	80	44	797	100.00

Note: One ropani of land equals 0.051 hectare. Source: Field survey 2020

4.4.4 Level of Food Sufficiency

The number of households by the level of food sufficiency from their own production is shown in table 7. It shows that less than eight percent (7.91%) of families have surplus food from their own production. About 32% of families have food deficit and they import food items from outside in order to fulfill their food requirement. Those who do not have income from trade and business depend mainly on agriculture and have less production than their requirement of food are more vulnerable to flood risk.

Table 7. Level of Food Sufficiency

Level of food sufficiency	Number of Households					Total	Percent
	Singati	Bhorle	Jamune	Jagat	Gongarkhola		
< 3 months	230	12	5	7	5	259	32.50
3-6 months	115	30	20	15	12	192	24.09
6-9 months	50	35	40	36	17	178	22.33
9-12 months	35	19	30	13	8	105	13.17
Well of surplus	20	7	25	9	2	63	7.91
Total	450	103	120	80	44	797	100.00

Source: Field survey, 2020

4.5 Awareness, Practices, and Behaviour Change

People become aware of themselves and by some external forces while others change their behaviour because of their peers. The government has also played to make them aware of possible risks and hazards.

4.5.1 Awareness and Understanding

Awareness can be considered as a concept referring to the ability of a person to perceive, feel, or to directly aware of any events (Gafoor, 2012). Local people formulate their perception of flood risk based on their past experiences of the frequency and magnitude of floods, their causes, and their effects on their properties and livelihood. Local people realized that the disaster risks are

localized. This has two dimensions. First, small and medium scale flood occurs more frequently than large-scale flood which, is experienced in localized regions. Secondly, the impact of floods is mainly experienced at the local level. Local people in the study area have a feeling that they are at risk of different types of flash floods due to GLOF, LDOF, and high-intensity rainfall. During the focus group discussion, it was reported that the fragile condition of surrounding mountains and the increasing trend of torrential rainfall in the study area are the major reasons for higher flood risk. Unmanaged spoils obtained from road construction have resulted in an increase in the level of river beds and hence an increase in flood levels and thus the risk. Since the road is constructed haphazardly without proper engineering, it has increased the probability of landslide occurrences resulting in the increasing risk of LDOF particularly in monsoon season. Similarly, the location of settlements near the river bank, the absence of an effective early warning system, and the absence of institutions with roles and responsibilities to manage flood risk are some of the other contributing factors to vulnerability and risk. It is also reported that there is a positive relationship between poverty and vulnerability. The degree of landlessness and unproductive land due to very steep slopes also promotes vulnerabilities. About 39% of people in the study area are landless. When floods and landslides block the road for a long time, a slowdown of business creates an extra burden on the family and increases vulnerabilities.

4.5.2 Acceptance and Practices

Most of the people in the study area commonly accepted that they were living in flood risk zones due to their geographical situation. They are familiar with the possible damage and destruction. Theoretically, they know the disaster management cycle and the concepts such as prevention, mitigation, preparedness, and response. They also realize that preparedness is one of the important components.

People in the study area demonstrated some knowledge and skills to deal with the risk of flood and designed and implemented some of the flood risk management activities. Those activities for preparedness and management before, during, and after the flood are given in Table 8.

Table 8. Community Preparedness and Management Practices for Flood Risk

Before flood	During flood	After flood
• Storage of the valuable materials in a fixed place • Arrangement of evacuation place and routes • Management of basic materials in advance • Preparation of informal self-plan for evacuation • Improvement of drainage • Plantation • Storage of dry food for livestock • Construction of river embankment, retaining, and gabion wall.	• Caring for children and elderly with priority • Keeping valuable goods safely • Help rescue victims • Informing police officers, Red Cross, and other stakeholders • Taking shelter at an appropriate place • Using tents and plastics to stay • Observing flood by turn at night	• Construction/repairing of roads and trails • Relocating houses and sheds • Informal Damage assessment • Use of local treatments to manage waterborne diseases • Management of food and clothes • Use of NTFP as medicine to treat human beings and livestock

Source: Field survey 2020

4.5.3 Formal and Informal Institutions

Local institutions/organizations have a key role in managing flood risks before; during and after the occurrence of flood, as they have an important role in risk preparedness and response. During the discussion, people reported that an effective emergency response by the local people collectively can play an important role in saving lives in the aftermath of a flood. According to them, the government authorities alone may not be able to achieve greater success in flood reduction, preparedness, and response without the active involvement and participation of the vulnerable communities because effective risk reduction requires action by all vulnerable individuals, families, communities, and organizations. Therefore, the involvement of the local community through their organization is essential to ensure local people's participation and to take ownership of the activities. UNDP, World Bank, CARE Nepal, DWIDP, District Watershed and Soil Conservation Office, Nepal Red Cross Society, and Tama Koshi hydropower project are major national, district, and local level organizations working for the reduction of the impact of flood disasters in the Tamakoshi watershed. However, coverage of the work is very limited. Different local organizations such as the women's group, farmer's group, CFUGs, Armed Police Force, Nepal Police, Scout, Youth club, etc. are also working in the local community. During the discussion, local people reported that governmental, non-governmental, and community-based organizations can have a very crucial role in creating public awareness, disseminating information, rescuing, and mobilizing resources.

4.5.4 Behaviour Change

People in the study area have had various bitter experiences from floods in the past. They have changed their behaviours from realizing their mistakes to adapting to local geographical reality. They follow the building code of conduct formulated by local and federal governments. They have a feeling that they need some long-term and short-term flood mitigation measures for the watershed. The long-term measures include awareness creation, preparing flood disaster mapping, strengthening local institutions for disaster mitigation, collective voice for addressing river control through permanent structures such as RCC wall and river embankment; lobbying for the construction of a bridge with proper design considering flood level and re-installation of an efficient early warning system along the Tamakoshi River. They have also advocated and involved life insurance schemes for people living in areas susceptible to flood hazards. Other activities carried out by the local people for flood risk reduction and adaptations are afforestation in some places along the river bank and initiation to allocate a budget for flood control by government institutions. Similarly, a flood information sharing system between people living in upstream and downstream has also been developed.

5. Conclusion

Flood is a common natural disaster in the Tamakoshi River. A considerable number of private and public properties were destroyed by the flash floods in the area. There is also a high possibility of the occurrence of flash floods such as GLOF, LDOF, and those caused due to high-intensity rainfall. People's perceptions regarding the trend of occurrence of devastating flood reveal that both the frequency and loss from floods and river bank cutting has increased in the study area. Rises in the river bed due to siltation and deposition of sand and gravel along the river channel are also common in this river. Many people, infrastructure, properties, and sources of livelihood of local people are highly vulnerable to flood risk but local people's capacity to cope, and implement mitigation measures and adaptation is very low as indicated by different parameters of vulnerabilities such as landholding, food sufficiency, etc. So, efforts to improve their livelihood

condition and their capacity to manage disaster risk need to be designed and implemented. It is concluded that flood has multiple effects on the community (effects of flood in one sector can affect other sectors of society). The problems of increasing risk and vulnerability are not associated with physical features only, but also with socio-economic conditions. Programs well integrated with physical processes and socio-economic developments are therefore needed. Responses to flood hazards are confined to rescue and relief during flooding and some mitigation measures such as the construction of embankments, retaining walls, and forest conservation. Structural measures alone are not sufficient for flash flood risk management.

It is realized that complete control of floods is beyond the capability of human efforts. However, the magnitude of flooding and its impact can be reduced to a certain extent through the development and effective implementation of land-use zoning guidelines, building codes, and improving development activities. Watershed conservation, implementation of programs related to the control of landslides, drainage management, awareness creation, and plantation activities should be prioritized. The activities to manage flash floods in terms of prevention, preparedness, response, and reconstruction are insufficient and not effective in the study area. From this study, it is realized that based community-based early warning system with strong involvement from upstream and downstream communities is a very important and effective tool in the context of flood disaster management. This system is very cost-effective and easy to operate. Interactive flood hazard mapping is a very important tool not only to assess vulnerability and risk but also to create awareness among key stakeholders and improve their capacity for preparedness. Public-private partnerships (government, hydropower developer, local community) can be the best way for institutionalization to manage the flash flood risk in a sustained way in the future.

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