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Assessing flood vulnerability on livelihood of the local community: A case from southern Bagmati corridor of Nepal

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ABSTRACT

Flood is one of the prominent hazards in the Terai region of Nepal. This study was objectively conducted to assess the livelihood vulnerability of community living in the up-stream, mid-stream and down-stream regions at southern Bagmati River corridor, Nepal. To meet the objective, primary data were collected through house hold survey using random sampling technique with 25% (182 HHs) sample size, focus group discussion (6) and key informant interview (15) carried out in Rautahat and Sarlahi districts of Nepal to accomplish this task. A pre-tested semi-questionnaire and check list was prepared based on the method of LVI given. LVI- IPCC was also used to collect required information. The results showed that the highest indexed value of socio-economic component was 0.360 of community living in the down-stream region and the least value was 0.157 of local people living in the up-stream region. Similarly, the indexed value of livelihood component was the highest (about 0.493) of the community living in the mid-stream belt. The indexed value of social network component was the highest (about 0.590) of the community living at mid-stream belt. But the indexed value of financial component was the highest (0.686) in the down-stream region. The indexed value of physical component was the highest (1) of the community living in the mid-stream region. The highest indexed value (0.464) was found of community living in the down-stream area. The indexed value of water resource component was the highest (0.366) of community living in the down-stream area. Similarly, the indexed value of natural hazard and climate variability component was the highest (0.579) of community living in the down-stream region. The livelihood vulnerability index values were the highest (0.528) of the community living in the down-stream belt. This indicates that the community living in the down-stream area was the most vulnerable to flood, but the community living in the up-stream belt the least vulnerable (0.323). The value of exposure was the highest (about 0.579) of community living in the down-stream belt while this was the lowest (about 0.291) of the community living in the up-stream belt. The sensitivity value was the highest (around 0.465) of the community living in the down-stream belt. The adaptive capacity was the highest (around 0.496) of the community living in the down-stream region. This also indicates that communities living in the down-stream area are most vulnerable to the flood. This study helps the scientific community to understand the differential effect of flood on up-stream and down-stream communities

1. Introduction

Flood has been categorically mentioned as one of the most destructive natural hazards worldwide extensively damaging the built and natural environment, and devastating human settlements [43]. It affects thousands of people every year in the world. Recent flood in America affected about 75,000 citizens who had to leave their home. The flood in France in 2020 devastated hundreds of houses, roads and bridges. This is the situation of developed countries that are rich in resources. Flood in developing countries is more serious than these events as it massively affects people and their wealth every year. The examples of such devastations can be seen in India, Bangladesh, China, Bhutan and Sri Lanka, where it caused the loss of many people's relatives, homes and property [19,26,36]. Nepal cannot be an exception because it receives heavy rain in monsoon season and has mountainous geographical characteristics.

People living in hilly as well as plain areas are seriously affected by annual flood. Frequent occurrence of flash floods within the Hindu Kush-Himalayan region poses severe threats to lives, livelihoods and infrastructures, in both the mountains (upstream) and the Terai/plain (downstream) [28]. As a result, flood has been one of the most devastating disasters, especially in Asia [61]. Nepal is exposed to a variety of natural hazards and human induced disasters. More than 80% of the total population of Nepal is at risk from natural hazards, such as floods, landslides,

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windstorms, hailstorms, fires, earthquakes and Glacial Lake Outburst Floods (GLOFs).

Globally, Nepal ranks 4th and 11th in terms of its relative vulnerability to climate change and earthquakes, respectively (Maplecroft 2011, BCPR 2004 cited in MoHA 2015, GoN/MoHA 2017). The flood has most devastating effect in the Terai Section (southern part) of Nepal. Inundation of huge area of urban land indicates that in future human lives are more prone to flood disaster (Shakya, et al., 2006/Geoinformatics, Survey Department, Nepal). During monsoon from June to September, all the rivers here are in spate with bankfull discharges and cause flooding and inundation in several parts of the Terai. The problems of flooding and inundation in the Terai are more critical due to change in climate in general and change in the rainfall pattern/intensity in particular [2]. From the analysis of monthly rainfall data for the period of 30 years from 1976 to 2005 (166 meteorological stations) throughout Nepal, it is found that most part of the country, including the Terai and Siwalik, experienced increasing annual trend of pre-monsoon, monsoon, post monsoon and winter precipitation (Practical Action, 2009). The floods of 1985, 1993 and 2004 destroyed large tracks of land terraces, farmlands, pastures and orchards in Bhasedwa leaving the country food insecure [63]. Consequently, the poor, uneducated and unemployed people are compelled to make a living by settling in flood and land slide prone areas in the hills, Chure, Terai plains [17]. This research paper analyzes the impacts of flooding and inundation on livelihood of the Terai using Livelihood Vulnerability Index method given by [24] and LVI – IPCC methods.

2. Materials and methods

The research study focused on vulnerable communities and settlements of Bagmati River corridor of the Terai region, covering Rautahat and Sarlahi districts of Nepal expanding from the foothill of Chure range to the southern part of Nepal-India boarder. While conducting the study and field survey in the southern part of Bagmati corridor of the Terai (covering both Rautahat and Sarlahi districts), the research area was divided into 3 belts as it were the most susceptible zone to flood in rainy season. The upper belt/Up-Stream is the foothill of Chure range (Karmaiya area) where the Bagmati Irrigation Dam is constructed. This Bagmati River divides the two districts in this zone consisting of Ward no. 1 of Chandrapur Municipality of Rautahat district in west and ward no 11 of Bagmati Municipality of Sarlahi District in East. Similarly, Middle zone /Mid-stream also consists of two districts, ward no. 3 of Gadhimai Municipality of Rautahat district and ward no. 2 of Basbariya Rural Municipality of Sarlahi district. The Third zone/Down-stream consists of ward no. 2 and 5 of Durga Bhagwati Rural Municipality of Rautahat district, which is the southern part as well as nearer to the Indian border. Most of the people have subsistence livelihoods based on agriculture and small business along with private and government jobs. The absence of irrigation facilities, underdeveloped infrastructure, non-availability of agricultural inputs, and small and fragmented land holdings cause agriculture dependent households to suffer even more poverty in this zone [15]. The study are is highlighted in Fig. 2.

The duration of research study includes issue identification of the research site, preliminary field visit, formulating questionnaires and final visit for data collection carried out between July 2019 and December 2020.

The research procedure is expressed in Fig. 1 below.

2.1. Methodology

The field study was conducted in two stages: the preliminary visit was conducted in early October 2019 to find out the indexes and subcomponents to compute the Livelihood Vulnerability Index (LVI) and final field visit and interaction with community and relevant stakeholders were done in December 2019 to collect the required primary data and secondary data. The primary data were collected through household survey, conducted on the basis of random stratified sampling, by using 20% sample size (i.e. 182 sampled HHs out of total 922 HHs), for comparative analysis of livelihood vulnerability Index (LVI) of flood prone zone within the Bagmati Corridor of Rautahat and Sarlahi districts of Nepal. The data were collected from the households in all three belts using sample size formula relevant to 2011 national census survey for all major components like Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Social Networks (SN), Financial Aspects (FA), Physical structure and Facilities (PSF) Health (H), Food (F), Water (W), Forest (F) and Natural Hazard and Climate Variability (NDCV) and completed with secondary data on rainfall and temperature. The sample size for household survey was calculated and completed by using the formula of sample size (n), [4]. At 5% significance level, estimation of standard error to be ±0.05 and assuming the expected rate of occurrence of the attribute not less than 95%, the sample size for the semi-structured interview survey was estimated,

$$n = \left(NZ^2PQ\right)/\left(Ne^2 + Z^2PQ\right), \text{Where, } N = \text{total no.of households } (547)$$

$$Z = \text{the value of standard variant at } 95\% \text{confidence level } (1.96)$$

$$e = \text{Acceptable error } (\pm 0.05)$$

$$P = \text{the expected rate of occurrence of the attributes } (95\%, \text{that is } 0.95)$$

$$Q = \text{the expected rate of non} - \text{occurrence of the attributes } (100\text{–}95\% = 5\%, \text{that is } 0.05)$$

2.2. Substituting the values in the above formula, we get desired values

Six FGDs (Focused Group Discussions) were conducted in study areas while overall 15 KII (Key Informants Interview) and personal interview were conducted with key stakeholders, representatives of Governmental and Non-governmental Organizations working in flood risk and disaster management sector. While conducting KII and FGD, both male and female were chosen who represented farmers, teachers, government officer and representatives, health worker, housewife, students, etc. The data published by Central Bureau of Statistics, relevant researches, papers journals, relevant national policies, available data from Municipality and Rural Municipality, ancillary data sources including available resource maps, GIS maps were studied and used as secondary information. During field study and survey, gender perspectives and equal participation were ensured. The study area and number of households according is presented in Table 1.

2.3. Livelihood Vulnerability Index (LVI) using with added components and sub-components

This LVI assessment includes ten major components [1,3]: Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Social Networks (SN), Financial Aspects (FA), Physical structure and Facilities (PSF), Health (H), Food (F), Water (W), Forest (F) and Natural Hazard and Climate Variability (NHCV). Each component comprises several indicators or sub-components. The indicators were developed based on the review of literature, field analysis and expert consultation. The LVI uses a simple approach of applying equal weights to all major components [29,40,41]. Each of the sub-components was measured on a different scale; therefore, it was first necessary to standardize them for comparability. The equation for standardizing numerical values is the same as was used in constructing the Human Development Index— HDI:

$$\text{Index}S = \frac{S - S_{min}}{S_{max} - S_{min}} \tag{1}$$

Here, S = Original sub-component. S_{max}&S_{min} = maximum and minimum values reflecting low and high vulnerability.

An index for each major component of vulnerability was created by averaging the standardized sub-components, i.e.

$$M_i = \frac{\sum_{i=1}^{n} \text{index}S_i}{n} \tag{2}$$

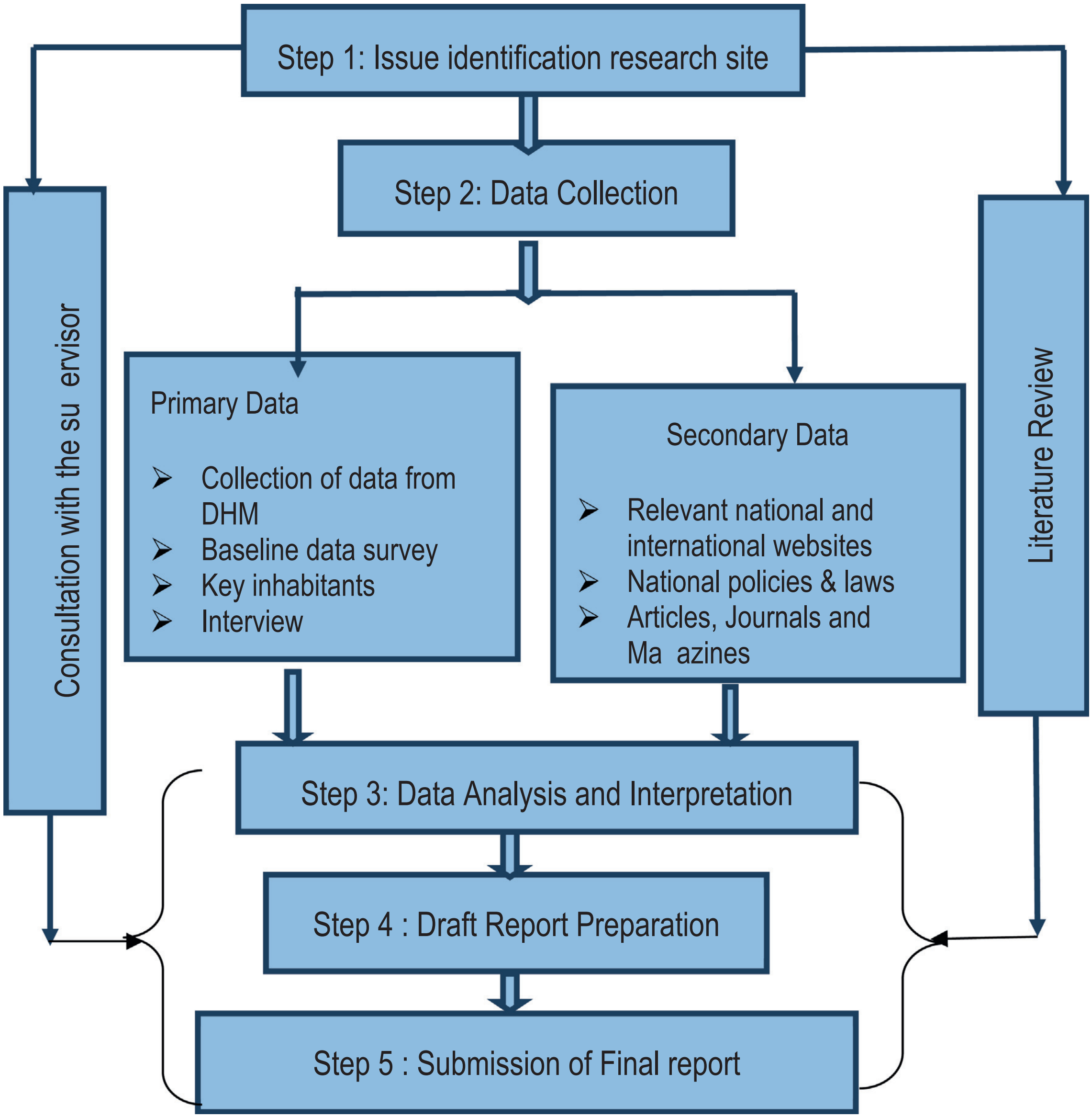

Fig. 1. Research flowchart.

Here, M_i = 0ne of the seven major components. S_i = sub components, indexed by i.n = number of subcomponents in each major components.

Once values for each of the seven major vulnerability components for a site calculated, they were averaged using equation:

$$LVI = \frac{\sum_{I=1}^{n} W_{m_i} M_i}{\sum_{i=1}^{8} W_{m_i}} \text{ which can be expressed as}$$

$$LVI = \frac{W_{SDP}SDP + W_{LS}LS + W_{SN}SN + W_{FA}FA + W_{PSF}PSF + W_{H}H + W_{F}F + W_{W}W + W_{FR}FR + W_{NDCV}NDCV}{W_{SDP} + W_{LS} + W_{H} + W_{SN} + W_{FA} + W_{PSF} + W_{F} + W_{W} + W_{FR} + W_{NDCV}} \quad (3)$$

Where, LVI = Livelihood Vulnerability Index. W_{mi} = Weights of each major components. M_i = Each major component.

The weights of each major component, W_{m_i}, are determined by the number of sub-components that make up each major component and are included to ensure that all sub-components contribute equally to the overall LVI [24]. In this study, the LVI was scaled from 0 (least vulnerable) to 1 (most vulnerable). This index is easier to compute because, with the exception of precipitation and temperature data, it uses primary data from households. The precipitation and rainfall data, used in this study, were obtained from Department of Hydrology and Meteorology (DHM).

2.4. Calculation of LVI–IPCC: IPCC framework approach

After the calculation of LVI using [24] method, an alternative method was used for calculating the LVI with incorporated IPCC vulnerability definition. Ten components in the LVI-IPCC framework and sub-components outlined below as well as equations were used to calculate the LVI-IPCC.

Category of major components into IPCC contributing factors to vulnerability:

- Exposure: Natural hazard and climate variability
- Adaptive Capacity: Socio-demographic Profile; Livelihood Strategies; Social Networks; Financial Aspects; Physical Structure and Facilities
- Sensitivity: Health; Food; Water; Forest

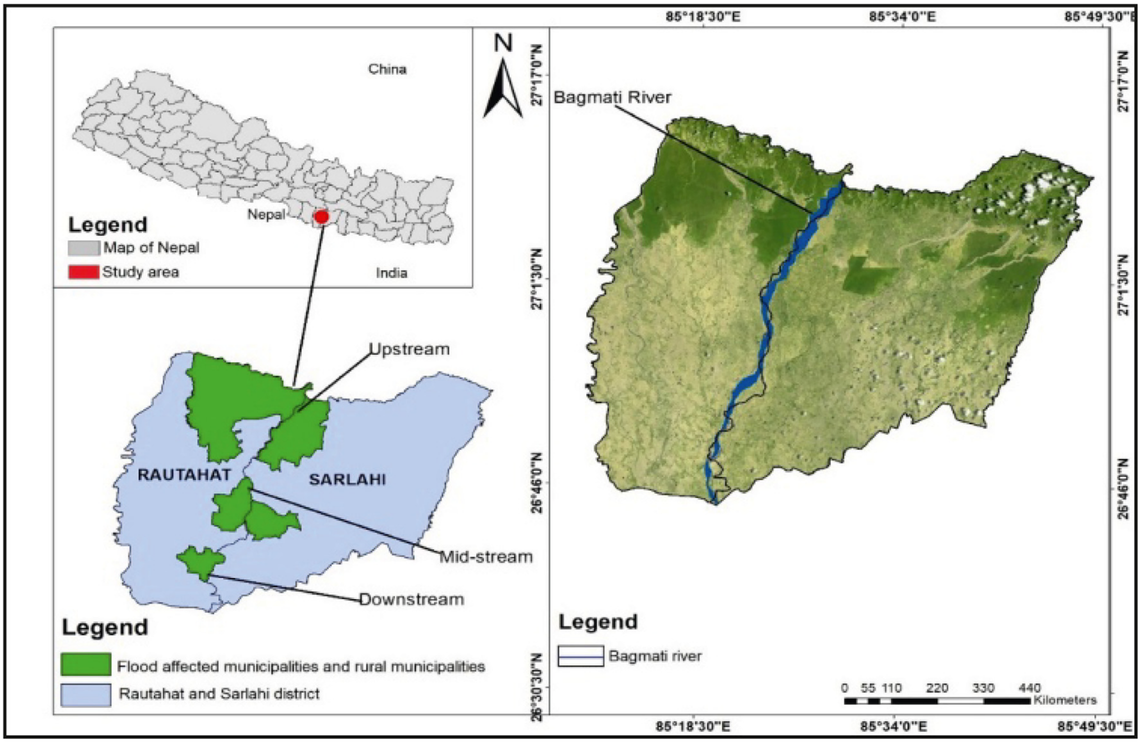

Fig. 2. Study area.

Table 1
Study Area and number of Households according to [9] and Sample Size.

S.N.	Study Section	Study Area			Households (HHs) Number	Total Households Number	Total Samples Size
		Settlement	Existing Administrative Division	Previous Administrative Division			
1	Up-stream	Gopalkuti	Chandrapur Municipality, Ward No.1, Rautahat	Paurai VDC, Ward No.1	255	498	67
		South Bagmati	Bagmati Municipality, Ward No. 12, Sarlahi	Karmaiya VDC, Ward No.4	243		
2	Mid-stream	Laxmipur	Gadhimai Municiaplity, Ward No. 3, Rautahat	Gamhariya VDC, Ward No. 8	85	208	57
		Manpur	Basbariya Rural Municiaplity, Ward No.2, Sarlahi	Manpur VDC, Ward No. 9	123		
3	Down-stream	Badarwa	Durgabhagwati Rural Municipality, Ward No. 2, Rautahat	Badharwa VDC, Ward No. 3	82	216	58
		Badarwa	Durgabhagwati Rural Municipality, Ward No. 5, Rautahat	Badharwa VDC, Ward No. 5	134		

Source: CBS (Central Bureau of Statistics), Nepal, 2011 [10,11].

The LVI–IPCC diverges from the LVI when the major components are combined. Rather than merging the major components into the LVI in one step, they are first combined according to the categorization scheme in the table below using the following equation:

$$CF = \frac{\sum_{i=1}^{n} W_M M_i}{\sum_{i=1}^{n} W_M} \tag{4}$$

where CF = Contributing Factor. W_M = Weight of each major component. M_i = Major component indexed by i.n = number of major components in each contributing factor.

Once exposure, sensitivity and adaptive capacity were calculated, the three contributing factors were combined using the following equation:

$$LVI\text{–}IPCC = (e-a)*s \tag{5}$$

Where LVI-IPCC = LVI expressed using the IPCC vulnerability framework. e = exposure, a = adaptive capacity, s = sensitivity

The scale of the LVI-IPCC ranges from −1(least vulnerable) to 1(most vulnerable).

2.5. Calculation of Flood Risk

$$\text{Risk} = \text{Hazard X Vulnerability or R} = \text{H X V} \tag{6}$$

Weighing and aggregating Hazards is done identically as with of indicators of vulnerability

$$H = \frac{\sum_{i=1}^{n} S_i}{n}$$

Indicating S = all the sub component of major components.

2.6. Statistical analysis of data

Statistical analysis of data was carried out after coding questionnaires in excel sheet. Statistical analysis was undertaken using the Kruskal Wallis test. The comprehensive analysis result with all findings has been presented in Annex. It can be referred for integrated data purpose.

In this study, to assess the LVI of households, data were collected from 3 belts (Up-stream, Mid-stream and Down-Stream) on the basis of 10 components (namely: Socio-demographic Profile, Livelihood, Social Networks, Financial Aspects, Physical Structure, Health, Food, Water, Forest and Natural Hazard & Climate Variability) with 55 sub-components which are presented in Annex I. The vulnerability indices of the major components ranged from 0 to 1 as shown in Annex. The 0 indicates the least vulnerable while the 1 indicates the most vulnerable. In the following section, vulnerability assessments are analyzed and described in detail of major components with all three belts.

3. Results and discussions

3.1. Livelihood Vulnerability Index of upstream, mid-stream and downstream using Hahn et al., method

The Livelihood index was analyzed using [24] method that includes socio-demographic, livelihood, social network, financial, physical, access to health facility, food, water resource, availability of forest resources and natural hazard and climate variability components.

3.2. Indexed value of socio-demographic components

The analysis of socio-economic component showed that the average indexed value was the highest (0.360) of local people living in downstream region while it was the least (around 0.157) of local people living in upstream region. There are many reasons behind this; however, as per subcomponents suggested by Hahhn et al., 2009 to calculate the LVI as social and demographic components, the values varied in three sites. The social demographic sub-components are dependency ratio, percentage of female headed households and so on (Table 2).

The education level is one of the important sub-components of social demographic component that importantly contribute in livelihood index. The results showed that, in the high indexed value with 0.877, the heads of households in downstream area had no formal education. This finding was also supported by [64].

3.3. Livelihood component

The livelihood indexed values varied in the communities living in upstream, mid-stream and down-stream regions. The estimated average indexed values of the communities living up-stream, mid-stream and down-stream were 0.358, 0.493 and 0.483 respectively. Statistically, Kruskal Wallis test showed that there was no significance difference in these average values at 95% confidence level since P-value was 0.445 ($p > 0.05$). However, the mean rank value showed similar values 12.07 and 12.36 of community living in the mid-stream and down-stream regions respectively but it was around 31% (8.57) less of up-stream.

The livelihood components include seven subcomponents such as percent of households with family member not working in a different community, percent of households dependent solely on agriculture as a source of income and so on. The indexed values of these sub-components differed in the down- stream and up-stream regions. This is the main reason of differences in average indexed values of livelihood component in these regions (Table 3).

One of the important reasons of varying indexed value of livelihood was:, the community living in the lower belt had limited awareness and livelihood opportunities than that in the upper belt. Most of the family members were expatriates for employment in cities within the country and in foreign countries like India and others. This was also supported by [65,66], who have stated that migration for income affects the livelihood of the people.

3.4. Social network component

The social network component also affects the lively vulnerability index value. This component considers five sub-components such as Average Receive: Give ratio, Percent of households that have not gone to their local government for assistance in the past 12 months, Percentage of HHs not receiving helps to cope with flood, Percentage of HHs that have not been members of any organization and Percent of HHs have no communicative devices (TV, radio, mobile etc.) at home. The result showed that estimated indexed values of livelihood vulnerability index were 0.298, 0.590 and 0.547 of local community living in the up-stream, mid-stream and down-stream regions respectively (Table 4). Statistically, Kruskal Wallis test showed that, there was no significant difference in indexed values of social network component at 95% confidence level (P-value = 0.523).

3.5. Financial component

One important livelihood vulnerability index developed by [24] considered financial component as one of the important components. This component comprises three sub-components namely average borrow: lend money ratio, percentage of households with no access to financial services of any financial institution and percentage of households with no family members working outside the village at a relatively developed place. The calculated average values of financial components were 0.495, 0.612 and 0.686 of the community living in the up-stream, mid-stream and down-stream areas respectively (Table 5).

This result has supported that substantiating income generation activity constituting livelihoods triggers the safety (Khatwada et al. [67], Gentle and Maraseni [68]) and households borrowing more money than they lend are more vulnerable [24]. The society with certain prosperous households and many dependents in these households aggravates the financial vulnerability. This is the exact situation of the middle belt and lower belt increasing poverty and expatriate. Most of them even do not have access to financial services and institutions which might reduce the vulnerability of society.

4. Physical component

There are seven subcomponents considered to calculate the average indexed value of physical structure component of the community. The estimated average value was recorded as the highest (0.764) of community living in the down-stream region but it was the lowest (0.245) of the community living in the up-stream region. Statistically,

Table 2
Socio-demographic component.

Sub-components	Up-Stream		Mid-Stream		Down-Stream	
	Value	Indexed	Value	Indexed	Value	Indexed
Dependency Ratio (<15 years and >65 years)	1.836	0.115	4.246	0.265	4.596	0.287
Percent of female-headed households	10.4	0.104	21.1	0.211	19.3	0.193
Percent of household heads with no formal education	32.8	0.328	96.5	0.965	87.7	0.877
Percent of households with orphans	3	0.03	7	0.070	3.5	0.035
Percentage of HH members with no formal or informal skills	26.9	0.269	45.6	0.456	59.6	0.596
Average Family size	7.014	0.240	9.67	0.386	10.14	0.406
Infant Mortality Rate	1.5	0.015	12.3	0.123	12.3	0.123
Average value	11.921	0.157	28.059	0.354	28.162	0.360
Kruskal Wallis test	No significant difference at 95% confidence level ($P = 0.201$)					

Table 3
Livelihoods component.

Sub-components	Up-stream		Mid-stream		Down-stream	
	Value	Indexed	Value	Indexed	Value	Indexed
Percent of households with family members not working in a different community	68.7	0.687	70.2	0.702	78.9	0.789
Percent of households solely dependent on agriculture as a source of income	17.9	0.179	29.8	0.298	21.1	0.211
Percentage of households without jobs	23.9	0.239	82.5	0.825	54.4	0.544
Percentage of households with no training to enhance livelihood	70.1	0.701	78.9	0.789	82.5	0.825
Percentage of households that changed their sowing and cropping schedule	29.9	0.299	24.6	0.246	29.8	0.298
Percentage of households that reported loss of livestock	6	0.06	33.3	0.333	43.9	0.439
Average Agricultural Livelihood Diversification Index	34.4	0.343	25.8	0.258	27.4	0.274
Average value	36.083	0.358	53.217	0.493	51.767	0.483
Mean rank values						
Kruskal Wallis test	Significance value (P-value) 0.445					

Table 4
Social network component.

Sub-components	Up-Stream		Mid-Stream		Down-Stream	
	Value	Indexed	Value	Indexed	Value	Indexed
Average Receive: Give ratio	92	0.92	81.1	0.811	83.9	0.839
Percent of households that have not gone to their local government for assistance in the past 12 months	32.8	0.328	50.9	0.509	70.2	0.702
Percentage of HHs not receiving helps due to flood	17.9	0.179	86	0.86	40.4	0.404
Percentage of HHs that have not been member of any organization	6	0.06	73.7	0.737	75.4	0.754
Percent of HHs have no communicative devices (TV, radio, mobile etc.) at home	0	0	3.5	0.035	3.5	0.035
Average value	29.74	0.298	53.525	0.590	47.375	0.547
Mean rank values	were 6.30, 9.30 and 8.50 of up-stream, mid-stream and down-stream respectively					
Kruskal Wallis test	Significance value (P-value) 0.523					

This insignificant variance in average indexed value was due to varying level of value of subcomponents, the local people living at these belts.

Table 5
Financial component.

Sub-components	Up-stream		Mid-stream		Down-stream	
	Value	Indexed	Value	Indexed	Value	Indexed
Average borrow: lend money ratio	72.4	0.724		0.591		0.671
% of households with no access to financial services to any financial institution	7.5	0.075	54.4	0.544	61.4	0.614
% of households with no family members working outside the village at a relatively developed place	68.7	0.687	70.2	0.702	77.2	0.772
Average value	49.533	0.495	62.300	0.612	69.300	0.686
Mean rank values						
Kruskal Wallis test	No significance difference since P value was 0.670 (less than 0.05)					

Table 6
Livelihoods aspect.

Sub-components	Up-Stream		Mid-Stream		Down-Stream	
	Value	Indexed	Value	Indexed	Value	Indexed
Percentage of households without concrete house	43.3	0.433	98.2	0.982	91.4	0.914
Percentage of households with house affected by floods	4.5	0.045	86	0.86	89.7	0.897
Percentage of households whose land is damaged by flood	26.9	0.269	96.5	0.965	100	1
Percentage of households without access to critical facilities (health post and water treatment plant.)	0	0	100	1	86.2	0.862
Percentage of households with access to emergency response (police, social community clubs, flood rescue center etc.)	0	0	40.4	0.404	65.5	0.655
Percentage of households with no access to road	0	0	0	0	5.2	0.052
Percentage of households without property Insurance	97	0.97	100	1	96.5	0.965
Average value	24.529	0.245	74.443	0.744	76.357	0.764
Mean rank values	6.50, 13.57 and 12.93 of up-stream, mid-stream and down-stream respectively					
Kruskal Wallis test	P-value = 0.06					

Kruskal Wallis test showed that there was no significant difference in mean value of indexed value of the community living in the up-stream, mid-stream and down-stream regions since P value was slightly greater than 0.05 (i.e. 0.06). There was variation in these values because of differences in the values of subcomponent in these areas (Table 6).

Table 7
Access to health facility.

Sub-components	Up-Stream		Mid-Stream		Down-Stream	
	Value	Indexed	Value	Indexed	Value	Indexed
Average time to health facility (in minute)	10.22	0.045	22.81	0.155	57.707	0.458
Percent of households with family member with chronic illness	28.4	0.284	31.6	0.316	37.9	0.379
Percent of households where a member had to miss work or school in the last 2 weeks due to illness	7.5	0.075	5.3	0.053	34.5	0.345
Average disease Exposure*prevention index (Modified)		0.054		0.228		0.53
Percent of households without toilet	0	0	22.8	0.228	41.4	0.414
Percentage of households not receiving proper facilities for child delivery and immunization	3	0.03	29.8	0.298	15.5	0.155
Percent of households without health insurance	88.1	0.881	100	1	96.6	0.966
Average value	22.870	0.196	35.385	0.325	47.268	0.464
Mean rank values						
Kruskal Wallis test	P-value = 0.033					

5. Access to Health facility

Another important component of livelihood vulnerability index was access of local community to the health facility. The highest value found was (0.464) for the community living in the down-stream while it was the lowest (0.196) for up-stream community. Statistically, Kruskal Wallis test showed that there was significant difference in the mean value of health component of the community living in the up-stream, mid-stream and down-stream regions at 95% confidence level since *P*-value was 0.033.

Total six components were applied to estimate the average indexed value associated with the access of local community to the health facility. The subcomponents values varied according to site. This is an important reason of varying index value of the local community living in the down-stream and up-stream regions (Table 7).

6. Food component

[24] also suggested using the food availability as a major component to assess the LVI. This component includes five sub components specifically percent of households dependent on family farm for food, average number of months households struggle to find food, average crop diversity index, percent of households that do not save crops and percent of households that do not save seeds. The calculated average indexed values were 0.339, 0.458 and 0.498 of the community living in the up-stream, mid-stream and down-stream regions respectively (Table 8). Statistically, Kruskal Wallis test showed that there was no significance difference in indexed values of food component of community living in the upstream, mid-stream and down-stream regions since *P*-value was 0.471.

7. Water resource component

The availability of water, especially the access to and utilization of water resource, is considered as the one of the important components to assess LVI. This component considers six sub-components especially percent of households reporting water conflicts, percent of households that utilize a natural water source, average time to water source, percent of households without water filter, percent of households that do not have a consistent water supply, and inverse of the average number of liters of water stored per household. The estimated average indexed values were 0.167, 0.362 and 0.366 of the community living in the up-stream, mid-stream and down-stream regions respectively. Statistically, Kruskal Wallis test showed that there was no significant different in indexed values of this component of community living in the upstream, mid-stream and down-stream regions since *P*-value was 0.335 (Table 9).

8. Availability of forest resources

The availability of forest resources and local community's access to them are considered as an important component to estimate LVI. The availability of the forest resource considers two major sub-components particularly percentage of households using only forest-based energy for cooking purpose and average time to fetch firewood. The average indexed values were 0.797, 0.753 and 0.494 of the community living in the up-stream, mid-stream and down-stream regions respectively. Statistically, Kruskal Wallis test showed that, there was no significant difference in mean value of this component of the communities living in the up-stream, mid-stream and down-stream regions at 95% confidence level since *P*-value was 0.670 (Table 10).

There are less forest areas in the Terai and down-stream people have less access to the forest resources. The consequence is the timber and firewood are less available to the local people living in the down-stream region. So, people in lower regions are more vulnerable than those in middle and upper regions in terms of forest resources component; thus the indexed value was least of local people living in down-stream. This issue was also stated in various researches (Nagendra 2002, Iversen et al. 2006).

9. Natural hazard and climate variability

The natural hazard and climate variability is a very important component of livelihood vulnerability index developed by [24]. This component considers five sub-components particularly average number of flood events in the past 6 years, percent of households that did not receive a warning about the pending natural hazard, percent of households with an injury or death as a result of the most severe natural in the past 6 years, mean standard deviation of the average maximum temperature by month, mean standard deviation of the average minimum temperature by month and mean standard deviation of average precipitation by month. The mean indexed values of this component were 0.292, 0.500 and 0.579 of the community living in the up-stream, mid-stream and down-stream regions respectively (Table 11).

United Nations (2004) distinguishes four groups of vulnerability factors that are relevant in the context of disaster reduction: (1) physical factors, which describe the exposure of vulnerable elements within a region; (2) economic factors, which describe the economic resources of individuals, populations groups, and communities; (3) social factors, which describe non-economic factors that determine the well-being of individuals, population groups, and communities, such as the level of education, security, access to basic human rights, and good governance; and (4) environmental factors, which describe the state of the environment within a region. All of these factors describe properties of the vulnerable system or community rather than of the external stressors. All of the 4 groups defined by UN as the factors to analyze the vulnerability are included in the LVI but the components along the 4 groups are vague that it can be selective in terms of study areas. The components need to incorporate local dimensions rather than global dimensions. The components in the study are relevant to local dimensions.

For vulnerability assessments to be effective in reducing vulnerability, they need have credible scientific information, and be salient to local level adaptation planners and beneficiaries of adaptation interventions to be effective (Chaudhury et al. [27]). By including vulnerability in our understanding of disaster risk, we acknowledge the fact that disaster risk not only depends on the severity of hazard or the number of people or assets

Table 8
Food component.

Sub-components	Up-Stream		Mid-Stream		Down-Stream	
	Value	Indexed	Value	Indexed	Value	Indexed
Percent of households dependent on family farm for food	13.4	0.134	29.8	0.298	19	0.19
Average number of months households struggle to find food	1.806	0.15	4.859	0.405	4.844	0.404
Average crop diversity index	1.58	0.145	1.351	0.27	1.034	0.259
Percent of households that do not save crops	77.6	0.776	86	0.86	1	1
Percent of households that do not save seeds	48.8	0.488	45.6	0.456	63.8	0.638
Average value	28.637	0.339	33.522	0.458	17.936	0.498
Mean rank value	6.0, 8.90 and 9.10 at upstream, mid-stream and down-stream respectively					
Kruskal Wallis test	P-value = 0.471					

The main reason of the varying indexed value was particularly the migration and preference for non-agricultural works. Similar was the finding of Chapagain and Gentle (2015). These authors stated that the decreasing the productivity of the community can lead to vulnerable society.

Table 9
Water resources.

Sub-components	Up-Stream		Mid-Stream		Down-Stream	
	Value	Indexed	Value	Indexed	Value	Indexed
Percent of households reporting water conflicts	70.1	0.701	77.2	0.772	93.1	0.931
Percent of households that utilize a natural water source	0	0	0	0	0	0
Average time to water source	30	0	33.68	0.033	30	0
Percent of households without water filter	16.42	0.164	87.71	0.877	87.93	0.879
Percent of households that do not have a consistent water supply	0	0	31.6	0.316	19	0.19
Inverse of the average number of liters of water stored per household	7.269	0.137	5.719	0.174	5.12	0.195
Average value	20.632	0.167	39.318	0.362	39.192	0.366
Mean rank value	6.92, 10.75 and 10.83 at upstream, mid-stream and down-stream respectively					
Kruskal Wallis test	P-value = 0.335					

Table 10
Forest resources availability.

Sub-components	Up-Stream		Mid-Stream		Down-Stream	
	Value	Indexed	Value	Indexed	Value	Indexed
Percentage of households using only Forest-based energy for cooking purpose	94.8	0.948	87.7	0.877	73.1	0.731
Average time to fetch firewood	6.47	0.0647	16.29	0.1629	25.68	0.257
Average value	50.635	0.7975	51.995	0.753	49.39	0.494
Mean rank value	4, 5 and 6 at upstream, mid-stream and down-stream respectively					
Kruskal Wallis test	P-value = 0.670					

Table 11
Natural hazard and climate variability.

Sub-components	Up-Stream		Mid-Stream		Down-Stream	
	Value	Indexed	Value	Indexed	Value	Indexed
Average number of flood events in the past 6 years	1.268	0.211	5.807	0.968	6	1
Percent of households that did not receive a warning about the pending natural hazard	17.9	0.179	68.4	0.684	72.4	0.724
Percent of households with an injury or death as a result of the most severe natural hazard in the past 6 years	3	0.03	22.8	0.228	55.2	0.552
Mean standard deviation of the average maximum temperature by month	1.19	0.53	5.37	0.37	5.37	0.37
Mean standard deviation of the average minimum temperature by month	5.71	0.57	6.47	0.47	6.47	0.47
Mean standard deviation of average precipitation by month	23.43	0.234	187.35	0.28	145.75	0.36
Average value	8.750	0.292	49.366	0.500	48.532	0.579
Mean rank value	6.17,10.175 and 12.17 at upstream, mid-stream and down-stream respectively					
Kruskal Wallis test	P-value = 0.140					

exposed, but that it is also a reflection of the susceptibility of people and economic assets to suffer loss and damage. Levels of vulnerability (and exposure) help to explain why some non-extreme hazards can lead to extreme impacts and disasters, while some extreme events do not. In the context of extensive risk in particular, it is often people's vulnerability that is the greatest factor in determining their risk (preventionweb.net, retrieved in 29/07/2021).

9.1. Comparative livelihood vulnerability index values

The sum of all these components showed that community living in the lower belt was most vulnerable (0.515), followed by middle belt with 0.493 but the community living in the upper belt was least vulnerable to flood with index value 0.306. The 7 major components like socio-demographic profile, financial aspects, physical structure, health, food, water and natural hazard and climate vulnerability make the lower belt most vulnerable. Similarly, the index value of local community living in the middle belt showed highest index values of components like livelihood, social networks and forest. The LVI-IPCC is an implementation of the sustainable livelihoods approach to development analysis (Chambers and Conway [69]), according to which communities are described in terms of their natural capital, social capital, financial capital, physical capital, and human capital. The comparative vulnerability spider diagram of the major components of the LVI for three belts is presented in Fig. 3.

9.1.1. Livelihood vulnerability index

Vulnerability assessment showed that livelihood vulnerability index was the highest 0.528 of the community living in the down-stream region and the lowest 0.323 of the community in the up-stream region. The value of this was 0.506 of the community living at mid-stream.

9.1.2. Livelihood vulnerability index using IPCC analysis

The value of exposure was the highest (about 0.579) of the community living in the down-stream region. It was followed by 0.5 of the community living in the down-stream belt, while this was the lowest (about 0.291) of the community living in the up-stream belt. The sensitivity value was the highest (around 0.465) of the community living in the down-stream belt but this was the least (about 0.271) of the community living in the up-stream belt. The adaptive capacity was the highest (around 0.496) of the community living in the down-stream region but this capacity was the lowest of community living in the up-stream region with 0.257. This also indicates that the community living in the down-stream region is the most vulnerable to the flood (Table 12).

9.2. Vulnerability triangle diagrams of three belts according to LVI-IPCC

The vulnerability triangle diagram shows that in the middle and lower belt, the utilization of agriculture land, increasing the productivity and better physical structure existed; then vulnerability can decrease as the values of sensitivity is lower than adaptive capacity. Although sensitivity value is lower than adaptive capacity, there is immense requirement of health, water and food facilities. The food requirement can be fulfilled if the flood interruption can be managed. The lack of nutrition and drinkable water causes more illness where proper health facilities are lacking and makes the belts more vulnerable. The uses of multiple indicators, relating to exposure and adaptive capacity, determine the sensitivity of the future impacts. This understanding with different indicators and their correlation with other indicator can contribute to the national policy advisors and concerned practitioners. The LVI provides a method for identifying points of intervention for tracking the potential impacts of climate change by presenting sectorial vulnerability scores in addition to the overall composite index. The vulnerability triangle diagrams of three belts according to LVI-IPCC is presented in Fig. 4.

As pointed out by Vincent in 2007, this means that subcomponent indices and the overall LVI are not comparable across future studies. The comparison of two components can differ with time [24].

10. Discussion

The socio-demographic components, livelihood component, social network component, financial component, physical component, access to health facility, food component, water resource component, availability of forest resource, natural hazard and climate variability are considered as the major components to estimate the livelihood vulnerability index [21,24,27]. The vulnerability of people depends upon their capacity and scale of adaptation [39]. These results support our research findings. The condition of these research relates to the context of vulnerability and our research also links with flood which is major problem in Terai (down-stream). The study done in western Nepal and Pakistan also supports our finding; the reason may be similar context and community as well [50]. Flood is the major disaster that affects the community living nearby river most [7,32], and hence the communities living in down-stream area nearby Bagmati river are most affected. This research finding is also supported by the studies done in Bihar India [56,57,59]. The downstream (Terai) and Bihar are linked geographically so the effects of flood are similar. The flood is one of the serious problems in India and Nepal [34,47]. The damage and loss caused by river affect southern part of Nepal and Northern part of India every year [18,37,55].

Livelihood vulnerability index assessed using IPCC tools helps understand the effect of disaster caused by flood [46]. Thus, this research compared with method developed by [24] showed similar results. This was also supported by study done by [12, 25, 52, 33]. also obtained similar results. Our research findings are matching with these research findings. The

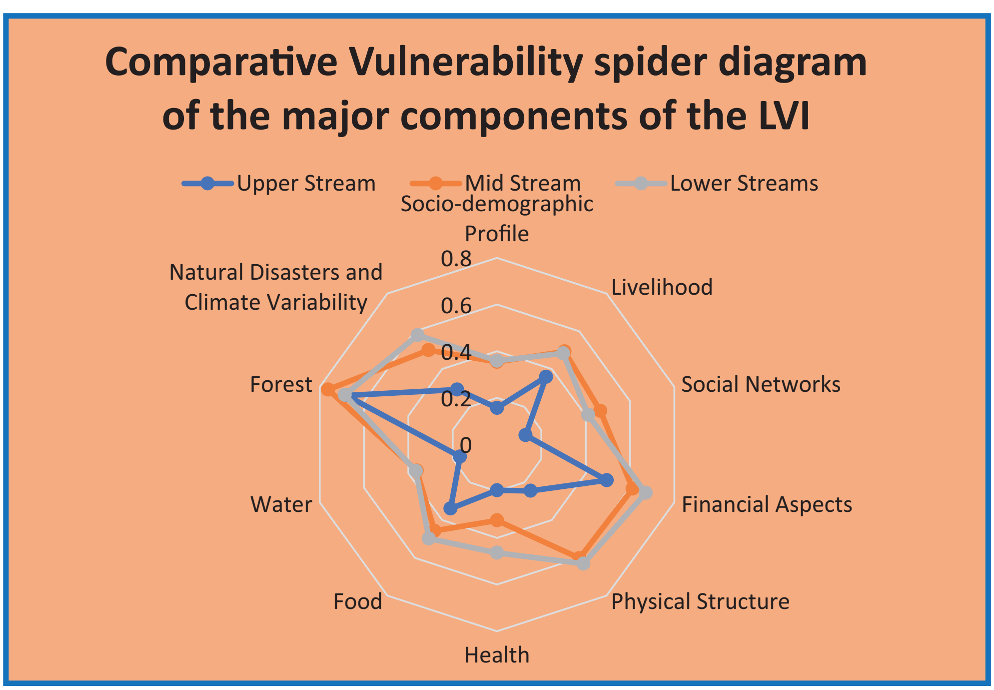

Fig. 3. Comparative Vulnerability spider diagram of the major components of the LVI for three belts.

Table 12
Calculation of LVI-IPCC Values of all belts.

Contributing Factors	Major Components	No. of Sub-Components	Upper Belt/Up-Stream			Middle Belt/ Mid-Stream			Lower Belt/ Low-Stream		
			Major Component Values	Contributing Factor Values	LVI-IPCC Value	Major Component Values	Contributing Factor Values	LVI-IPCC Value	Major Component Values	Contributing Factor Values	LVI-IPCC Value
Adaptive capacity	Socio-demographic profile	7	0.157	0.257		0.354	0.424		0.359	0.496	
	Livelihood	7	0.358			0.493			0.483		
	Social networks	5	0.129			0.466			0.411		
	Financial aspects	3	0.495			0.612			0.671		
	Physical structure and facilities	7	0.245			0.602			0.631		
Sensitivity	Health	7	0.196	0.271		0.325	0.413		0.464	0.465	
	Food	5	0.339			0.457			0.498		
	Water	6	0.167			0.362			0.366		
	Forest	2	0.68		0.009	0.762		0.031	0.687		0.038
Exposure	Natural hazard and climate variability	6	0.291	0.291		0.5	0.5		0.579	0.579	

reason behind this may be the similarity in context and condition of research discipline and field.

The flood is major problem in down-stream belt (Terai area) and that affects health and wealth of the community [13]. This problem is the lowest in the community living in up-stream areas particularly in Chure [54]. The community living in the upstream area in Chure is less vulnerable than the community living in the down-stream belt because of the disaster caused by flood. This finding is also supported by several authors [49]. The reason behind this is that most of the river systems originate in Chure area and flow to the Terai (Down-stream) [42]. These river systems carry massive boulders, sands, stones and soil that damage the agriculture land as well as houses and sometime cause casualty as well in the down-stream region [23]. This indicates that the local communities living in the down-stream regions are more vulnerable to flood.

In addition to that, this research paper has tried to be an eye opener concerning flood risk for Kathmandu Terai Fast Track (KTFT) on runoff cum *floods creating devastation to Bagmati River corridor, Terai, Nepal.*

Government of Nepal has launched the Kathmandu Terai Fast Track Project to link Terai in short distance 72.6 KM along the Bagmati corridor. This project has been seen as the backbone for the country's economic prosperity. Bagmati River has flooded and waterlogged the downstream region (Terai) every year during rainy seasons. The EIA review of the project shows it will use 30 KM agriculture land, 43 KM forest land and about 3 Km land in other use. Conversion of land use, particularly forest land into concrete 4 lane road with its right way, may significantly impact the hydrological process in the Bagmati River. Generally, forest land has potential for rainwater infiltration during rainy season rather runoff and minimize soil erosion. Construction of the 43 KM concrete structure in the forest area will stop the infiltration and all rainwater/runoff will be directly diverted into Bagmati River, which may significantly increase pick flow in the downstream Terai region. Additionally, since a significant portion of the road passes through forest land, clearing of forests in such a huge quantity will expose the land, leaving it vulnerable to excessive erosion, run off and landslides. Similarly, during the construction phase, the landslide and mass movement are likely to occur, which may result in the change in the topography and landform of the area, which in turn may also result in increased runoff and siltation in the downstream region. Furthermore, excavated materials and the waste materials that are generated during the construction phase may also be deposited in the Bagmati River and adjacent streams, which will further cause siltation and sedimentation in the downstream, if the disposed materials are not managed properly ([16]/Environmental Impact Assessment Report of Kathmandu terai fast-track) [45].

Broadly, it visualizes that if the environmental mitigation measures are not taken critically on time, there is high possibility that excess run off, nominal infiltration, heavy soil & water erosion, siltation, etc [8,21]. would pass in a haphazard way reaching finally to Bagmati River and Lal Bakaiya River. It shows that the peak flood level will be more than expected and go beyond the present flood preventive & mitigation measures and con-

Table 13
Risk calculation: Risk is calculated by using formulae, Risk = Hazard X Vulnerability or R = H X V. Here, the Weighing and aggregating Hazards is done identically as with of indicators of vulnerability; $H = \frac{\sum_{i=1}^{n} S_i}{n}$ Indicating S = all the sub component of major components So,

Details	Up Stream	Mid Stream	Down Stream
Sum of Indicators Values	15.473	27.192	28.817
Sum of all sub components	55	55	55
Hazards	0.281	0.494	0.524
Vulnerability	0.323	0.506	0.528
Risk	**0.09**	**0.250**	**0.277**

The risk value 0 indicates the lowest risk while 1 indicates the highest risk of flood (Table 13).

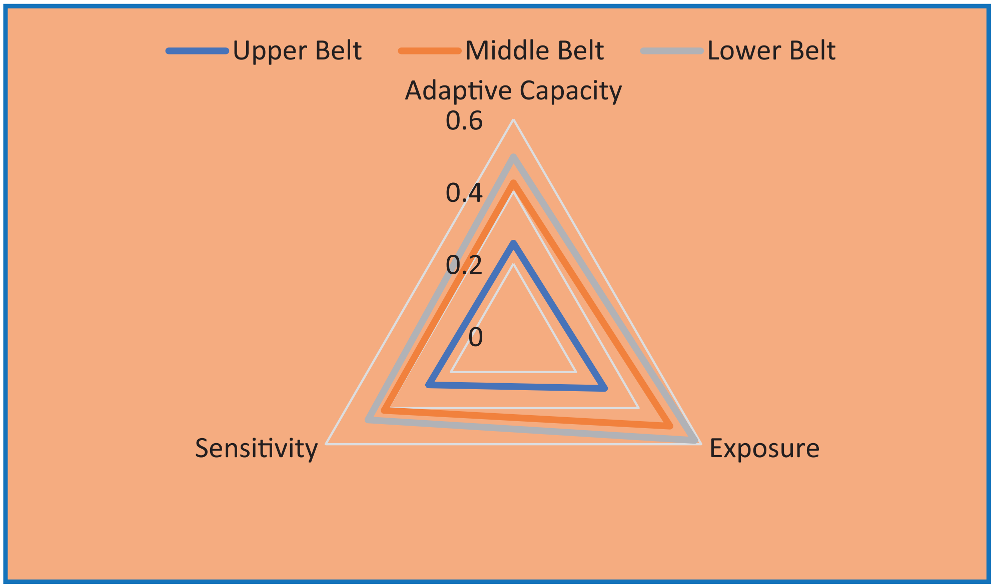

Fig. 4. Vulnerability triangle Diagrams of three belts according to LVI-IPCC.

structions. The existing flood preparedness and response mechanism may not work in place. There will be high chances of huge flood and water logging especially in the lower belt, Indian border areas. The existing embankment, flood control structures and mitigation measures may not work. And flood may even cross existing embankment, barrage, spurs and other physical structures within southern part of Nepal and Indo-Nepal southern belt (S. Khatiwada, et al., 2019).

In this context of the flooding and waterlogging problems in the downstream area of the Bagmati River bank, the existing flood control and water drainage structures should be reviewed to avoid human casualties and property loss due to future pick flow in the areas. The empirical approach and analysis (multivariate analysis with better preparedness & mitigation measures) of this research study could be used to reduce flood vulnerability, enhance adaptive capacity and lower the risk of sensitivity in this Kathmandu Terai Fast Track Road corridor [16].

11. Conclusions and recommendation

The highest indexed value of socio-economic component was recorded of community living in the down-stream region, but it was the least value of local people living at up-stream site. Similarly, the indexed value of livelihood component was the highest of the community living in the mid-stream region. The indexed value of financial component was the highest in the down-stream area. The indexed value of physical component was the highest (1) of the community living in the mid-stream area. The indexed value of natural hazard and climate variability component was the highest of community living in the down-stream region. The livelihood vulnerability index values were the highest of the community living in the down-stream region. The LVI-IPCC considers exposure, adaptive capacity and sensitivity. The value of exposure was the highest of community living in the down-stream belt. The sensitivity value was the highest of the community living in the down-stream belt. The adaptive capacity was the highest of the community living in the down-stream region. This indicates the community living in the down-stream region was the most vulnerable, but the lowest vulnerable community was in the up-stream belt because of flood.

LVI can be a vital tool to analyze vulnerability and implement livelihood activities. LIV can provide basic requirements and access to resources in accordance with their needs as they can develop mitigating programs to strengthen the vulnerable sectors and heighten adaptive capacity and sensitivity. This helps the scientific community to understand the differential effects of flood in upstream and down-stream regions. It is essential to review existing flood control and water drainage structures of the Kathmandu Terai Fast Track Road Project to avoid human casualties and property loss due to future pick flow of runoff water and flood in the downstream of the Bagmati River. Also, the multivariate analysis and the approach findings of this research paper could be used to reduce flood vulnerability, enhance adaptive capacity and lower the risk of sensitivity.

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Appendix

Annex 1
Statistical analysis.

Major components	Sub-components	Up-stream			Mid-stream			Down-stream		
		Value	Indexed	Average	Value	Indexed	Average	Value	Indexed	Average
Socio-demographic Profile	Dependency Ratio (<15 years and >65 years)	1.836	0.115	0.157	4.246	0.265	0.354	4.596	0.287	0.359
	Percent of female-headed households	10.4	0.104		21.1	0.211		19.3	0.193	
	Percent of households where head of household has not attended school	32.8	0.328		96.5	0.965		87.7	0.877	
	Percent of households with orphans	3	0.03		7	0.070		3.5	0.035	
	Percentage of HHs where member had no formal or informal skills	26.9	0.269		45.6	0.456		59.6	0.596	
	Average Family size	7.014	0.240		9.67	0.386		10.14	0.406	
	Infant Mortality Rate	1.5	0.015		12.3	0.123		12.3	0.123	
Livelihood	Percent of households with family member not working in a different community	68.7	0.687	0.358	70.2	0.702	0.493	78.9	0.789	0.483
	Percent of households dependent solely on agriculture as a source of income	17.9	0.179		29.8	0.298		21.1	0.211	
	Percentage of households without jobs	23.9	0.239		82.5	0.825		54.4	0.544	
	Percentage of households with no training to enhance livelihood	70.1	0.701		78.9	0.789		82.5	0.825	
	Percentage of households changed their sowing and cropping schedule	29.9	0.299		24.6	0.246		29.8	0.298	
	Percentage of households reported loss of livestock	6	0.06		33.3	0.333		43.9	0.439	
	Average Agricultural Livelihood Diversification Index		0.343			0.258			0.274	
Social Networks	Average Receive: Give ratio	92	0.92	0.298	81.1	0.811	0.590	83.9	0.839	0.547
	Percent of households that have not gone to their local government for assistance in the past 12 months	32.8	0.328		50.9	0.509		70.2	0.702	
	Percentage of HHs not receiving helps due to flood	17.9	0.179		86	0.86		40.4	0.404	
	Percentage of HHs that have not been member of any organization	6	0.06		73.7	0.737		75.4	0.754	
	Percent of HHs have no communicative devices (TV, radio, mobile etc.) at home	0	0		3.5	0.035		3.5	0.035	
Financial Aspects	Average Borrow: Lend Money ratio	72.4	0.724	0.495	59.1	0.591	0.612	67.1	0.671	0.671
	Percent of households who do not have access to financial services to any financial institution	7.5	0.075		54.4	0.544		61.4	0.614	
	Percent of households who do not have any family members working outside the village at relatively developed place	68.7	0.687		70.2	0.702		77.2	0.772	
Physical Structure	Percentage of households without solid house	43.3	0.433	0.245	98.2	0.982	0.744	91.4	0.914	0.764
	Percentage of households with house affected by Floods	4.5	0.045		86	0.860		89.7	0.897	
	Percentage of households whose Land is damaged by flood	26.9	0.269		96.5	0.965		100	1	
	Percentage of households without access to critical facilities (Health post and water treatment plant.)	0	0		100	1		86.2	0.862	
	Percentage of households with access to emergency response (police, social community clubs, flood rescue center etc.)	0	0		40.4	0.404		65.5	0.655	
	Percentage of households with no access to road	0	0		0	0		5.2	0.052	
	Percentage of households without property Insurance	97	0.97		100	1		96.5	0.965	
Health	Average time to health facility (in minute)	10.22	0.045	0.196	22.81	0.155	0.325	57.707	0.458	0.464
	Percent of households with family member with chronic illness	28.4	0.284		31.6	0.316		37.9	0.379	
	Percent of households where a family member had to miss work or school in the last 2 weeks due to illness	7.5	0.075		5.3	0.053		34.5	0.345	
	Average Disease Exposure*Prevention Index (Modified)		0.054			0.228			0.53	
	Percent of households without Toilet	0	0		22.8	0.228		41.4	0.414	
	Percentage of households not receiving proper facilities for child delivery and immunization	3	0.03		29.8	0.298		15.5	0.155	
	Percent of households without Health Insurance	88.1	0.881		100	1		96.6	0.966	
Food	Percent of households dependent on family farm for food	13.4	0.134	0.339	29.8	0.298	0.457	19	0.19	0.498
	Average number of months households struggle to find food	1.806	0.150		4.859	0.405		4.844	0.404	
	Average Crop Diversity Index	1.58	0.145		1.351	0.270		1.034	0.259	
	Percent of households that do not save crops	77.6	0.776		86	0.86		1	1	
	Percent of households that do not save seeds	48.8	0.488		45.6	0.456		63.8	0.638	
Water	Percent of households reporting water conflicts	70.1	0.701	0.167	77.2	0.772	0.362	93.1	0.931	0.366
	Percent of households that utilize a natural water source	0	0		0	0		0	0	
	Average time to water source	30	0		33.68	0.033		30	0	
	Percent of households without water filter	16.42	0.164		87.71	0.877		87.93	0.879	
	Percent of households that do not have a consistent water supply	0	0		31.6	0.316		19	0.190	
	Inverse of the average number of liters of water stored per household	7.269	0.137		5.719	0.174		5.12	0.195	
Forest	Percentage of households using only Forest-based energy for cooking purpose	94.8	0.948	0.797	87.7	0.877	0.753	73.1	0.731	0.494
	Average time to fetch firewood	6.47	0.647		16.29	0.629		25.68	0.257	

(continued on next page)

Annex 1 (*continued*)

Major components	Sub-components	Up-stream			Mid-stream			Down-stream		
		Value	Indexed	Average	Value	Indexed	Average	Value	Indexed	Average
Natural Hazard and Climate Variability	Average number of flood events in the past 6 years	1.268	0.211	0.291	5.807	0.968	0.500	6	1	0.579
	Percent of households that did not receive a warning about the pending natural hazard	17.9	0.179		68.4	0.684		72.4	0.724	
	Percent of households with an injury or death as a result of the most severe natural hazard in the past 6 years	3	0.03		22.8	0.228		55.2	0.552	
	Mean standard deviation of the average maximum temperature by month	1.19	0.530		5.37	0.37		5.37	0.37	
	Mean standard deviation of the average minimum temperature by month	5.71	0.57		6.47	0.47		6.47	0.47	
	Mean standard deviation of average precipitation by month	23.43	0.23		187.35	0.28		145.75	0.36	
LVI Values		Upper Belt/Up-Stream 0.323			Middle Belt/Mid-Stream 0.506			Lower Belt/ Down-Stream 0.528		

Values, Indexed of Sub-component and Average of components for the assessment of Livelihood Vulnerability Index (LVI) of flood prone settlement along the Bagmati Corridor of Rautahat and Sarlahi Districts, Nepal.

In this study, to assess the LVI of households, data were collected from 3 belts (Up-stream, Mid-stream and Down-Stream) on the basis of 10 components (namely: Socio-demographic Profile, Livelihood, Social Networks, Financial Aspects, Physical Structure, Health, Food, Water, Forest and Natural Hazard & Climate Variability) with 55 sub-components which are presented in above table. The vulnerability indices of the major components ranged from 0.129 to 0.762 as shown in above annex-1 table. In the following section, vulnerability assessments are analyzed and described in details of major components with all three belts.

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pdisas.2021.100199.

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