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An Assessment of the Downstream Effect of Dams on Livelihood Vulnerability of Riparian Dwellers: A Case of Mukutmanipur Dam, Kangsabati River, Eastern India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The present study investigates the downstream impacts of Mukutmanipur dam on livelihood vulnerability by using the livelihood vulnerability index (LVI) based on 7 components and 26 sub-components. Stratified random sampling together with purposive sampling methods has been used to collect primary data on the components. Information on socio-demographic profile of selected 367 sample households were collected together with data on livelihood strategies, water, health, food, social networks and natural disaster status. The contributing factors (exposure, sensitivity and

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adaptive capacity) were integrated to estimate the livelihood vulnerability index using LVI-IPCC approaches. For assessing the livelihood vulnerability index, the stretch of the river channel under investigation has been divided into 24 equal segments using 25 cross sections. Morphological changes in each of these segments have been assessed and on the basis of the intensity of morphological changes the segments have been grouped into three morphological change areas i.e. high, moderate and low. Results suggest that people living in areas of the high intensity of morphological change (LVI: 0.407) are more vulnerable to livelihood uncertainties than those living in areas of moderate (LVI: 0.341) and low intensity of morphological change (LVI: 0291). This study recommends that special emphasize should be given to peoples in the vulnerable areas on the implementation of various government and non-government scheme for the betterment of their lives and livelihoods.

Keywords: Kangsabati river; Mukutmanipur dam; livelihood vulnerability index; LVI-IPCC; morphological change area.

1. INTRODUCTION

River valleys and flood plains have been a dependable resource base for human livelihood and settlements since early historical period. However in recent years, anthropogenic regulation of hydrological regime of rivers through engineering works likes dam, designed for flood protection, bank erosion protection, irrigation, electricity generation, drinking and industrial purposes etc. have changed the natural behaviour of rivers besides, land use land cover changes due to habitation of the flood plains [1,2,3]. Dam is one a major interventions in a fluvial system that changes the overall morphology of river by altering water and sedimentary regime [4], together with adverse effects on the local habitats and livelihoods in upstream and downstream areas as well.

According to Graf [5] downstream impact of dam has been categorized as loss of materials, changes in the quality of water and damages to riverine ecology. Richter et al. [6] reported that river-dependent populations located downstream of dams have frequently faced a difficult upheaval of their livelihoods, loss of food security and other impacts to their physical, cultural well-being, while the benefits have primarily gone to urban centers or large-scale agricultural developments. While some flood protection and irrigation opportunities provided by dams may have assisted downstream river-dependent communities, detrimental effects generally overweigh, the benefits to downstream people, resulting in declining incomes and livelihoods insecurity.

The situation in the study area is not different [7]. Commissioning of dam in 1974 made significant changes in the flow regime of Kangsabati river [8]. A literature survey reveals that previous studies have recorded the geomorphology, geolithology, fluvial dynamics, land use and resource utilization of river Kangsabati through traditional and modern geographical techniques [8,9,10,11,12] but they did not pay attention to the livelihood vulnerability issues. Nandi and Sarkar [12] have explored the upstream effect of Kangsabati dam on livelihoods of agriculture-dependent communities and have reported that construction of dam negatively affects the livelihoods. Upstream agriculture-dependent communities have experienced the loss of livelihood assets resulted in increasing unemployment, shifting in occupation from cultivation to agricultural labour, deficient production, outmigration, rising poverty, deteriorating health conditions, and thereby facing scarcity of livelihood security. However, downstream impacts of Mukutmanipur dam on the livelihoods of riparian dwellers have not been explored. From the repeated field observations and reconnaissance survey of the study area, and in-depth interaction with the local people on the issue, it appears that major changes in bank erosion, channel shifting, channel sedimentation, formation of in-channel bars etc have happened in the middle and lower courses of Kangsabati river after the commissioning of dam. The locals have further reported that very often, the lower portion of Kangsabati river gets inundated due to higher discharge from Mukutmanipur dam synchronizing with high tide in river Haldi. All of these demonstrate sensitiveness of people’s life and livelihood as they depend directly or indirectly on the river resulting in gradual decline of river dependency and changing livelihood pattern of the people.

Thus, the present investigation intends to identify downstream impacts of Mukutmanipur dam on livelihood vulnerability by using the livelihood vulnerability index (LVI) approach. The present study applied the livelihood vulnerability index (LVI) using a particular methodological frame work that has been used by various researchers in the diverse field of study like landslides, floods, river bank erosion, etc. [13,14,15,16].

1.1 Study Area

Kangsabati river, also known as Kasai, Kansai and Cossye is an important right bank tributary of Bhagirathi-Hugli river system. Originating from Jabarban peak (641m) on Ghoramara hill (eastern Chotanagpur plateau), it flows south-east through the districts of Purulia, Bankura and Midnapore of West Bengal and ultimately joins river Hugli. Before entering Bankura district, the natural flow of river has been interrupted and controlled by Kangsabati reservoir. This comprises two dams i.e. Kangsabati dam and Kumari dam, constructed just above the confluence of Kumari river (a right bank tributary of Kangsabati river) at the border of Purulia and Bankura districts near to Mukutmanipur town, West Bengal in the year 1965 and 1973 respectively [8]. Thereafter, both the dams were connected together to form the Kangsabati reservoir (also known as Mukutmanipur dam).

The other two important right bank tributaries, Bhairabanki and Tarapheni join the river at Binpur block of Paschim Midnapore district. The combined flow of the river flows south-east and then eastward following the regional slope of the vast midnapore plain. After passing Midnapore town, the width (<200m) of the channel narrows down and flows eastward tortuously. At Kapastikri of Paschim Midnapore, Kangsabati bifurcates into two branches: Northern branch flows towards north east as Old Cossye. Before joining with river Rupnarayan Old Cossye again bifurcates into two branches. On the other hand, Southern branch flows south east as New Cossye and joins river Kaliaghai at Sauraberia to form river Haldi (Fig. 1). The selected study reach extends from the downstream of Mukutmanipur dam to the New Cossye confluence (Haldi branch) near to Sauraberia of Purba Midnapore districts in West Bengal. The selected study reach is enclosed between 22º09′ N. to 22º57′ N. latitudes and 86º45′ E. to 87º49′ E. longitudes with an area of about 2993.37 sq.km.Downstream reach has a population density of about 1000 persons/km^2 owing to the vast expanses of lateritic and alluvial soil which not only determine the agricultural activities but also other economic activities. This demonstrates the dependency of the people's livelihood on hydro-dynamic and morpho-dynamic fabric of this region.

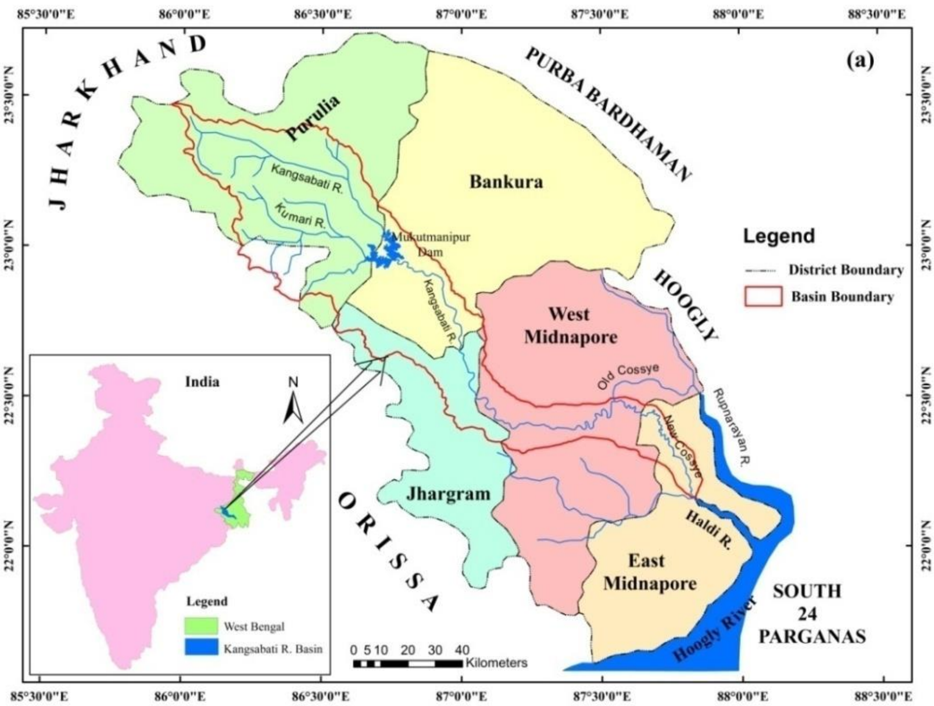

Fig. 1. Location map of Kangsabati river basin

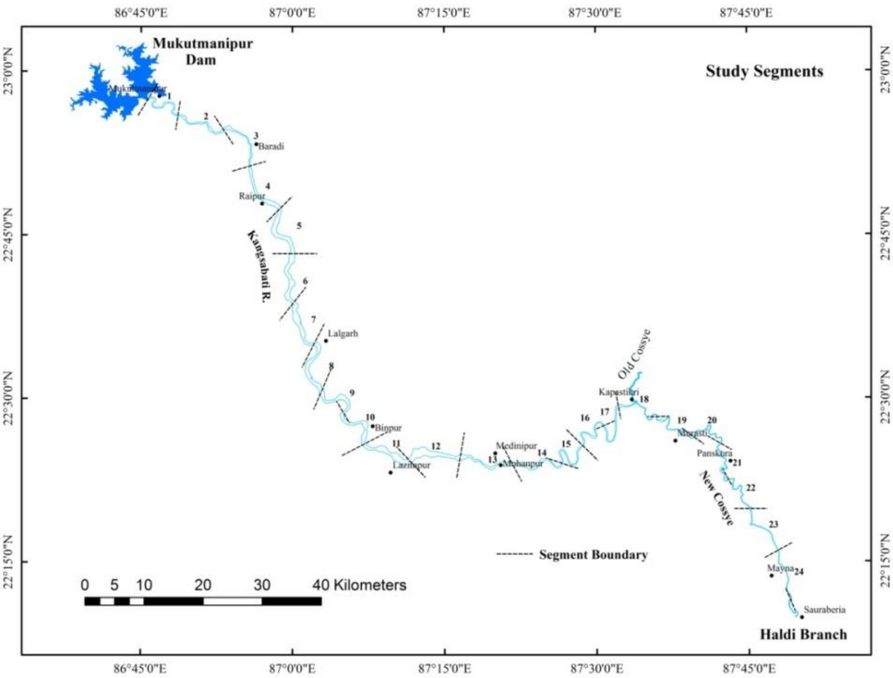

Fig. 2. Division of channel from Mukutmanipur dam to New Cossye confluence for morphological analysis

2. MATERIALS AND METHODS

2.1 Materials for Morphological Analysis of Channel

Quantitative assessments of Spatio-temporal changes in channel morphology and planform parameters have been made from six temporal datasets from various sources for the study period of 97 years. Using ARC GIS (10.6) software, a GIS data base has been prepared from all the collected maps and images of each study year (1921, 1978, 1988, 1998, 2008 and 2018). District maps of Bankura (surveyed during 1917-1921) and Undivided Medinipur (surveyed during 1911-1916) Published by Govt. of West Bengal have been considered as the base year (Taken as 1921's) for computing the spatio-temporal variability of different morphological parameters. Topographical maps of 1968-1978 published by the Survey of India were the next reference year (Taken as 1978's). Besides topographical map, a series of multi-temporal Satellite Images has been used for change detection. Six scenes of LANDSAT- TM of 1988, 1998, 2008 and 1 scene of LANDSAT-8 OLI of 2018 were used to cover the whole study area.

2.2 Materials for the Analysis of Livelihood Vulnerability Index

The present investigation is based on primary data collected through household survey on various subcomponent of LVI domain i.e. Socio-demographic profile, Livelihood strategies, Health, Food, Water, Social networks and Natural disasters. Secondary data have been collected from District Census Handbook (1951, 1961, 1971, 1981, 1991, 2001 and 2011), Mukutmanipur Gauge Stations and Irrigation and Waterways Department, Govt. of West Bengal.

2.3 Channel Morphological Parameters

In the present study, channel morphological parameters i.e. sinuosity, braiding, channel width and shift in the position of bank line and thalweg etc have been analysed to identify sites of morphological changes in the downstream of Mukutmanipur dam. To find out the spatial pattern of the magnitude of morphological changes downstream of Mukutmanipur dam (From Mukutmanipur dam to New Cossye confluence), the entire channel course has been divided into 24 equal segments by 25 cross sections arbitarily taken at an interval of 10 km distance along the longitudinal profile. Details of selected morphological parameters are shown in the Table 1.

Table 1. Descriptions of 5 selected morphological parameters

Major Theme	Parameters	Formula/Methods	Method followed by	Level of Observation		Years/Period of Observation	Remarks
				Hierarchyof Resolution	Area of Measurement		
Planform Analysis	Sinuosity Index	$P = L_{cmax}/L_R$ [Where L_{cmax} is the mid-channel length of the main channel in a reach and L_R is the straight line length of that reach.]	Friend and Sinha [17]	Micro level analysis	Segments	1921, 1978, 1988, 1998, 2008, 2018	A straight channel is represented by a lower sinuosity value, whereas a high value represents a meandering and braiding channel.
	Braiding Index	$BI=2(\sum L_i)/L_r$ [Where $\sum L_i$ is the total length of all the islands and bars in the reach and L_r is the midway length between the banks of the channel reach.]	Braice [18]	Micro level analysis	Segments	1921, 1978, 1988, 1998, 2008, 2018	A multiple-stream network with multiple channel bars is represented by high braiding index.
Morphological Analysis	Channel width	Using measurement scale in ARC GIS (10.6)	Ghosh and Mukhopadhyay [19]	Micro level analysis	Cross sections	1921, 1978, 1988, 1998, 2008, 2018	Width of the channel has been measured along 25 cross sections.
	Bank line shift and Channel centre line/Thalweg shift	Overlay analysis	Das et al. [20], Ghosh and Mukhopadhyay [19]	Micro level analysis	Cross sectons	1921-1978, 1978-1988, 1988-1998, 1998-2008, 2008-2018	To measure the shift in the position of the bank line and thalweg, 25 equidistant transects perpendicular to the channel in the study area have been taken and numbered from 1 to 25 towards the confluence.

Table 2. Morphological parameters under three different class ranges

Morphological Parameters	Magnitude of morphological change area		
	High	Moderate	Low
Sinuosity Index	>2	2 - 1.5	<1.5
Braiding Index	4.5 - 3	3 - 1.5	<1.5
Channel Width	>900	900 - 600	<600
Bank line shift (m/year)	51.98 - 0.13 (Channel oscillation +,-)	14.18 - 0.18 (Widening of channel +,+)	7.78 - 0.17 (Narrowing of channel -,-)
channel centre line shift (m/year)	64.5 - 43	43 - 21.5	21.5 - 0

2.4 Sample Design

2.4.1 Selection of sample sites for the identification of morphological change area

Based on the calculated values of five different morphological parameters in different segments and cross sections, all the segments and cross sections have been grouped under three different magnitude classes accordingly (Table 2).

Common segments and cross sections within categories of high, moderate and low morphological change areas in the pre and post dam years have not taken into consideration because they do not indicate temporal change. As for example, sinuosity value of segments 15 and 17 in the pre dam year 1921 belongs to high change area. No significant changes in the sinuosity value of segment 15 and 17 are noted in the post dam observation years. Therefore, segment 15 and 17 have not taken into consideration and segment 20 has been taken as it comes out in the post dam observation year 1978. These are shown in the Table 3. Accordingly, segments and cross sections in areas with different intensities of morphological change have been selected for assessment. Finally, to identify the sites of morphological changes, maximum numbers of common segments and cross sections (11, 12 and 13 in case of high change area) of five different morphological parameters have been selected as area of maximum morphological change (Table 3). Thereafter, from each of these categories, sample moujas have been selected to assess the impact of morphological changes on the nature and pattern of livelihoods of riparian dwellers in the downstream of Mukutmanipur dam.

Table 3. Segments/cross sections under different intensity of Morphological change area

Sinuosity Index				
Time period	Year	High (>2)	Moderate (2-1.5)	Low (<1.5)
Pre-dam	1921	15,17	1, 9, 10, 11, 16, 20, 22	2, 3, 4, 5, 6, 7, 8, 12, 13, 14, 18, 19, 21, 23, 24
Post dam	1978	15, 17, 20	1, 8, 9, 10, 16, 19, 22	2, 3, 4, 5, 6, 7, 11, 12, 13, 14, 18, 21, 23, 24
	1988	15, 17, 20	1, 8, 9, 10, 16, 19, 21, 22	2, 3, 4, 5, 6,7, 11, 12, 13, 14, 18, 23, 24
	1998	15, 17, 20	1, 9, 10, 16, 19, 21, 22	2, 3, 4, 5, 6, 7, 8, 11, 12, 13, 14, 18, 23, 24
	2008	15, 17, 20	1, 9, 10, 16, 19, 21, 22	2, 3, 4, 5, 6, 7, 8, 11, 12, 13, 14, 18, 23, 24
	2018	15, 17, 20	1, 9, 10, 16, 21, 22	2, 3, 4, 5, 6, 7, 8, 11, 12, 13, 14, 18, 19, 23, 24

Unit of Observation	Planform Parameters	Segments under different intensity of morphological changes		
		High	Moderate	Low
Segments	Sinuosity	20	8, 19	11, 21
	Braiding	7, 9, 11, 12	3, 14, 15, 17	1, 4, 5, 6
Cross Section	Channel Width (m)	6, 11, 13	7, 8, 10	12
	Bank Line Shift (m/year)	12	4, 7, 8, 11, 19, 20, 23, 24	1, 2, 3, 5, 21
	Channel Centre Line Shift (m/year)	9, 13,	10, 16, 18, 19,	3, 4
Selected sample segments and cross sections as morphological change area		**11, 12, 13**	**8, 9, 10, 19**	**3, 4, 5, 21**

Note: 1. Numbers within cell represents segments and cross section numbers. Selected Sample segments and cross sections are highlighted in bold.2. 25 equidistant (10km) cross section perpendicular to the channel have been taken and numbered 1 to 25 from Mukutmanipur dam towards New Cossye confluence. 3. Stretch of the river between two cross section have been designated as Segments. Segments are also been numbered (1 to 24) systematically. Segment 1 follows cross section 1 making them more or less co-terminus

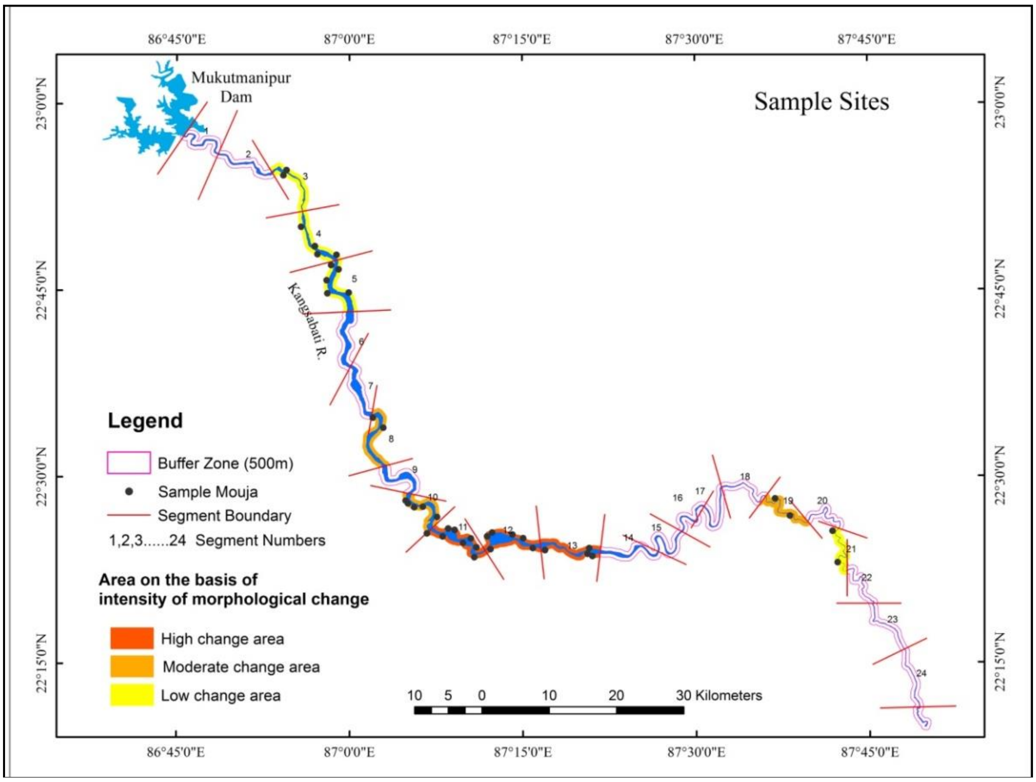

Fig. 3. Location of sample mouja

To assess the livelihood vulnerability status of riparian dwellers, moujas located within 500m river corridor/buffer of high, moderate and low change area along the kangsabati river have been arbitarily taken into consideration as shown in the Fig. 3. The arbitary selection is because Width/lateral extension of riparian zone varies from small isolated patches rarely more than 300 m wide [21] to fragmented patches of mosaic forests within river corridors characterized by a hydrologic regime, floods and meandering pattern of the stream [22].

2.4.2 Sampling method and sample size for LVI analysis

For assessing livelihood vulnerability in downstream of Mukutmanipur dam, three different areas with different intensity of morphological changes, have been taken as sample sites. Primary data (both quantitative and qualitative data) using *stratified random* and *purposive sampling* methods have been collected during January, 2020 and March, 2023, involving questionnaire surveyes and focus group discussions at various levels for the analysis. Questionnaire are structured based on socio-demographic profile of the respondents, livelihood conditions, health, food, water, social networks and prevailing natural hazards of the study area. The sample size for household survey was calculated and completed by using the sample size (s) formula of Krejcie and Morgan [23] at 5 percent significance level with an estimation of standard error to be ± 0.05 and assuming the expected rate of occurrence of the attribute to be not less than 95 percent.

$$s = \frac{X^2NP(1-P)}{d^2(N-1) + X^2P(1-P)}$$

[Where, s = required sample size, X2 = the table value of chi-square for 1 degree of freedom at the desired confidence level (3.841), N = the population size, P = the population proportion (assumed to be .50 since this would provide the maximum sample size), d = the degree of accuracy expressed as a proportion (.05)].

$$s = \frac{3.8416 \times 8287 \times 0.50(1-0.50)}{0.05^2 \times (8287-1) + 3.8416 \times 0.50(1-0.50)}$$

$$s = 367.18$$

Based on the sample size calculation, 367 households have been selected from 8287 households of 40 moujas. The selected 367

Table 4. Sampled households in three different morphological change areas

Area (On the basis of intensity of morphological changes)	Segment/ Cross Sections	Number of Mouja (Located along Kangsabati river within 500 meters buffer)	Number of households	Sampled households	Percentage
High	11, 12, 13	18	3628	161	44
Moderate	8, 10, 19	9	991	44	12
Low	3, 4, 5, 21	13	3668	162	44
			N=8287	**367**	**100**

households have been stratified proportionately into 161, 44 and 162 for corresponding to intensities of the high, moderate and low change area respectively. Among 18, 9 and 13 moujas of high, moderate and low change area, the required sample households of each area are randomly selected. In this stage, *random sampling* methods are followed because in this method each and every household have an equal chance of being selected. Categorizations of sampled households for three different morphological change areas are shown in detail in the Table 4.

To collect qualitative data, *purposive sampling* methods have been used. From each of the areas 9 elderly persons above 60 years of ages (3 elderly people for each area) were interviewed to know the pre dam condition of dam. For the in-depth knowledge about the overall current situation of downstream reach, discussion with 4 government employees (B.D.O. of Mukutmanipur Gauge Station, Ex-manager of Kangsabati Project, Superintending Engineer of Kangsabati Circle –I and S.D.O. of Kangsabati Left Bank Sub-division-II) have been done.

2.5 Livelihood Vulnerability Index

Vulnerability is a condition of an individual or community to stress due to changes in environmental and socio economic conditions disrupting livelihoods [13, 15]. Livelihood vulnerability assessment is a systematic approach for measuring the susceptible people in the natural hazards and socio-economic changes [13].

2.5.1 Calculating LVI: Composite Index approach

The LVI includes seven major components: Socio-demographic profile (SDP), Livelihood strategies (LS), Health (H), Food (F), Water (W), Social networks (SN) and Natural disasters (ND). Each major component is comprised of several indicators or sub-components (Table 6). These subcomponents are developed based on previous literature. LVI is a balanced weighted average approach where each sub-component has an equal importance to form the overall index though each major component is comprised of a different number of sub-components. This approach is very similar to the calculation of Human Development Index (HDI). Each sub-component is measured on a different scale. Therefore, each sub-component has been standardized as an index value for comparability. The standardization process of each sub-component is followed by using equation (*1*).

$$Index_{S_a} = \frac{S_a - S_{min}}{S_{max} - S_{min}} \tag{1}$$

Where, $\mathbf{S_a}$ is an actual sub-component value of area a, $\mathbf{S_{max}}$ and $\mathbf{S_{min}}$ represent the maximum and minimum value of each sub-component respectively. The maximum and minimum values are used to transform the sub-components into a standardized index. In case of percentage frequencies 0 and 100 values are used as a minimum and maximum value and for other sub-components, the observed maximum and minimum valuesare used to standardize the process. After making each sub-component standardized, these are averaged using equation (*2*) to obtain the index value of each major component.

$$M_a = \frac{\sum_{i=1}^{n} Index_{Sa_i}}{n} \tag{2}$$

Where,$\mathbf{M_a}$ is the value of major component [Socio Demographic Profile (SDP), Livelihood Strategies (LS), Health (H), Food (F), Water (W), Social Networks (SN) and Natural Hazards (ND)] for area a, $\mathbf{Index_{sai}}$ denotes the subcomponent value index by **i** of major components $\mathbf{M_a}$; **n** represents the number of subcomponents in the major component **M**.

Once values for each of the seven major components are calculated, they are averaged using equation (*3*) to obtain the LVI of an individual area.

$$LVI_a = \frac{\sum_{i=1}^{7} W_{M_i} M_{ai}}{\sum_{i=1}^{7} W_{M_i}} \quad (3)$$

Which can also be expressed as

$$LVI_a = \frac{W_{SDP}SDP_a + W_{LS}LS_a + W_H H_a + W_F F_a + W_W W_a + W_{SN}SN_a + W_{ND}ND_a}{W_{SDP} + W_{LS} + W_H + W_F + W_W + W_{SN} + W_{ND}} \quad (4)$$

Where, LVI_a is the Livelihood vulnerability Index of area a. $W_{Mi}$is the weightage of components i. W_{SDP}, W_{LS}, W_H, W_F, W_W, W_{SN} and W_{ND} are the weight value of Socio demographic profile, livelihood strategies, social networks, health, food, water, and natural hazards seven major components respectively. The weights of each component (W_{Mi}) were determined by the number of sub-components. The value of LVI ranges from 0 (least vulnerable) to 0.5 (most vulnerable).

2.5.2 Calculating LVI-IPCC: IPCC framework approach

An alternative method is applied to calculate LVI using IPCC vulnerability framework. According to this, vulnerability is a function of exposure, sensitivity, and adaptive capacity (Table 5). Vulnerability is usually positively correlated with a system's exposure and sensitivity but inversely correlated with adaptive capability [16, 24]. The components and subcomponents are the same as the LVI framework proposed by IPCC.

Table 5. Categorization of major components to IPCC contributing factors to vulnerability

Contributing factors	Major components
Adaptive capacity	Socio-demographic profile
	Livelihood strategies
	Social networks
Sensitivity	Health
	Food
	Water
Exposure	Natural disasters and climate variability

Table 5 shows the three major components of the IPCC frameworks and their correspondings subcomponents.The sub-components are the same as that of general LVI outlined in Table 6 and equations (*1* to *3*) used to calculate the LVI-IPCC are the same. The LVI-IPCC differs from the LVI when the major components are combined. Three major components are combined according to categorization scheme outlined in Table 5 using the following equation (*5*).

$$CF_a = \frac{\sum_{i=1}^{n} W_{M_i} M_{ai}}{\sum_{i=1}^{n} W_{M_i}} \quad (5)$$

Where, CF_a is an IPCC-defined contributing factor (Exposure, Sensitivity and adaptive capacity) for the area a, M_{ai} are the major components of the area a indexed by i, W_{mi} is the weight of each major component and n is the number of major components in each contributing factor.

Index value of exposure was calculated using the following formula:

$$Exp = \frac{W_{exp_1}ND + W_{exp_2}CV}{W_{exp_1} + W_{exp_2}} \quad (6)$$

Where, W_{exp1} and W_{exp2} denote the weighted for ND. It is equal to the number of sub-components.

Index value of adaptive capacity was calculated using the following formula:

$$AdapCap = \frac{W_{ad_1}SDP + W_{ad_2}LS + W_{ad_3}SN}{W_{ad_1} + W_{ad_2} + W_{ad_3}} \quad (7)$$

Where, W_{ad1}, W_{ad2} and W_{ad3} represent the weights of the SDP, LS, and SN, respectively.

Index value of sensitivity was calculated using the following formula:

$$Sen = \frac{W_{sen_1}H + W_{sen_2}F + W_{sen_3}W}{W_{sen_1} + W_{sen_2} + W_{sen_3}} \quad (8)$$

Where, W_{sen1}, W_{sen2} and W_{sen3} are the weights of the major components of H, F and W respectively.

Once the values of three contributing factors are calculated, these three factors are combined using the equation (*9*).

$$LVI - IPCC_a = (Exp - AdapCap) \times Sen \quad (9)$$

Where, LVI – $IPCC_a$ is the LVI for areas expressed using the IPCC vulnerability framework. The LVI-IPCC value ranges from -1 (least vulnerable) to 1 (most vulnerable).

A detail methodology of the study is shown in the Fig. 4.

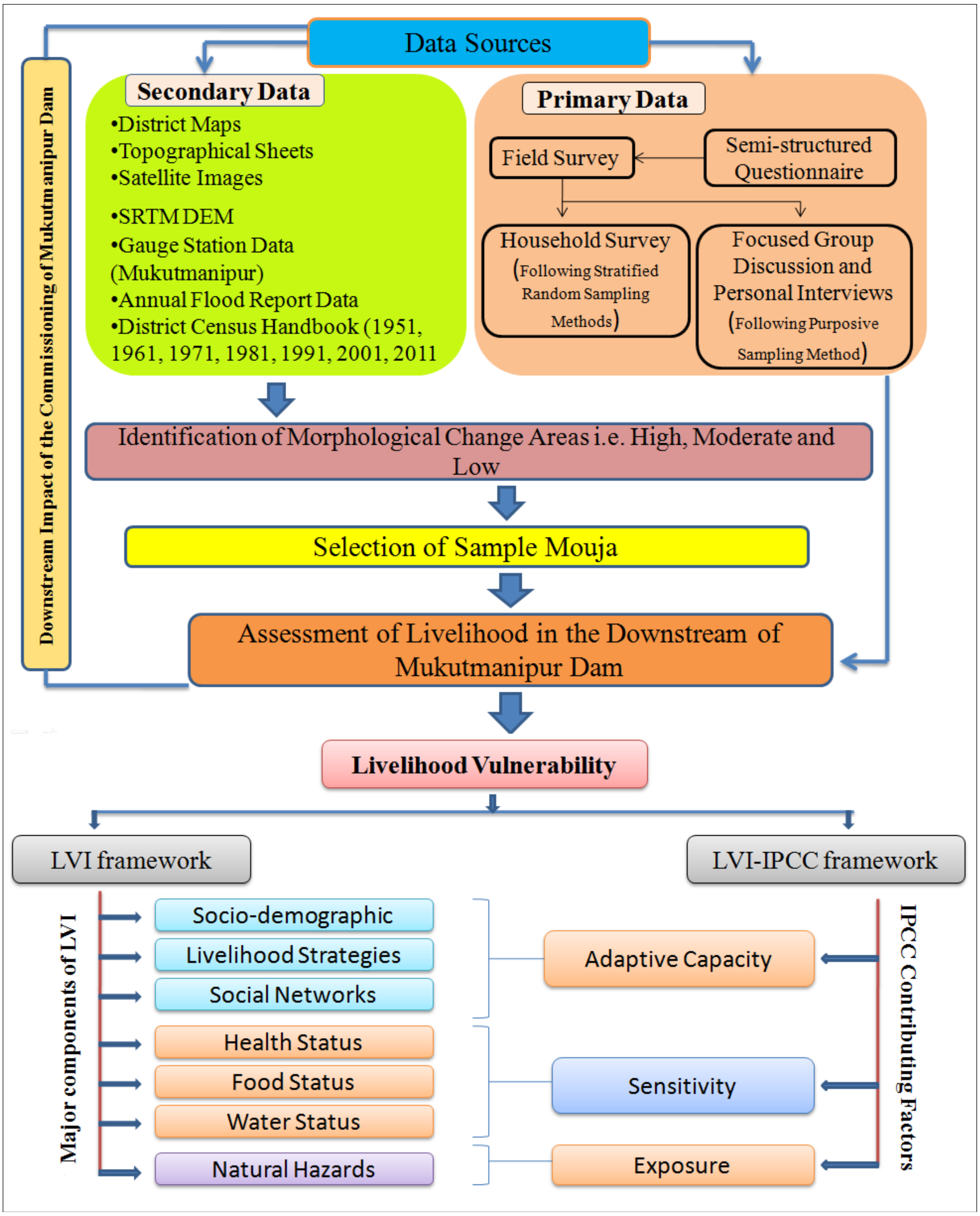

Fig. 4. Methodological flow chart of the study

3. RESULTS AND DISCUSSION

This section presents LVI and LVI-IPCC for three areas with different intensities of morphological change in the downstream of Mukutmanipur dam. The sub components together with their maximum and minimum values are represented in Table 6. Table 7 shows the indexed value of subcomponents.

3.1 Livelihood Vulnerability Index

The estimated LVI of high, moderate and low change area indicates different levels of vulnerability. Indices of major component and overall LVI of three different morphological change areas are shown in Table 8.

Differential impacts of the dam on livelihoods of downstream riparian dwellers are reflected through the variations of the levels of vulnerability of major components of LVI in three different morphological change areas.

The study reveals significant difference in livelihood vulnerability among high (LVI: 0.407), moderate (LVI: 0.341) and low change areas (LVI: 0.291), the highest LVI of 0.407 corresponding to the area of high morphological change.

Results of this study further reveal that the vulnerability indices of the major components value of LVI ranges from 0.122 to 0.618 (Table 8). The first major component, socio demographic profile (SDP), comprises four sub components. The analysis of SDP shows that high change area recorded the highest component value of SDP (0.406) than the moderate (0.318) and low (0.257) change areas. Higher dependency ratio (0.40), higher proportion of household head who didn't attend school (44.84%) and higher percentage of female headed household (41.02%) etc are the main reasons behind this. Hahn et al. [13] also suggest that low levels of education increases vulnerability.High dependency ratio in high change area indicates a less number of active working populations who are engaged in different livelihood activities. On the other hand, low dependency ratio in low change area (0.24) implies a large active working population.

Livelihood strategy (LS) is the second most important Major Component of LVI analyses with three subcomponents. The study reveals that a greater vulnerability score of LS is recorded among the people living in areas of moderate morphological change (0.484) compared to high (0.458) and low change areas (0.409). The percentage of migrated worker is higher in the low change area (64.60%) than the high (52.63%) and moderate change area (57.05%). Livelihood strategies include cultivation of crops, raising animals and collection of natural resources i.e. fishing, extraction of sand and stone quarrying from river bed etc. The households in the high and moderate change area reported a larger proportion, about 68.42% and 72.05% of people who are dependent on agriculture as the major source of income than low change area (52.02%). Here, it may be noted that beside agricultural activities, the number of various alternative source of income is higher in the low change area than the high and moderate change area. This is reflected through the average livelihood diversification index of 0.33, 0.33 and 0.20 in the high, moderate and low change area respectively.

Health is the third major component of livelihood vulnerability index comprising three sub components relate to accessibility of local community to the health facility.High and moderate change area shows more vulnerability of health status (0.360 and 0.408 respectively) than the low change area (0.271). It has been reported that households in high and moderate change area spend a longer average time to access the nearest health facility compared to low change area. Besides, a large proportion of households (42.10% and 50.20%) in the high and moderate change area did not seek medical help during illness because they are not conscious about their health [14, 24, 25].

Food is another major component of LVI domain, with three sub components. Food component value in high change area (0.511) shows higher vulnerability than moderate (0.397) and low (0.440) change area. About 72.05% and 65.20% of reported households in high change area does not save crops and seeds for the next year respectively, while households in low change area reported difficulities to access adequate food for their families. This is reflected in high average crop diversity index (0.50) in low change area compared to the high (0.33) and moderate (0.25) change area.

Major component, Water, comprise three sub-components of availability and accessibility. In the high and low change area, a higher percentage (50.50% and 57.89%) of

Table 6. LVI sub components with their maximum and minimum valuesinareas with different intensities of morphological change

Major component	Sub-component	Units	High Change area	Moderate change area	Low change area	Maximum value	Minimum value
Socio-demographic profile	Dependency ratio	Ratio	0.40	0.37	0.24	1.5	0
	Percent of households where the head of the household did not attend school	Percent	44.84	37.40	32.50	100	0
	Average number of family members in household	Count	5	4	4	8	2
	Percentage of female headed household	Percent	41.02	32.06	21.05	100	0
Livelihood strategies	Percentage of households where family members migrate to work in a different community	Percent	52.63	57.05	64.60	100	0
	Percentage of households solely dependent on agriculture and livestock as their source of income	Percent	68.42	72.05	52.02	100	0
	Average livelihood diversification index	1/(numbers of livelihoods+1)	0.33	0.33	0.25	1	0.2
Health	Average time to health facility	Minutes	30	35	25	60	0
	Percentage of households with family members who are chronically ill	Percent	15.78	14.02	12.60	100	0
	Percentage of households who do not attend a local doctor during illness	Percent	42.10	50.20	35.50	100	0
Food	Average crop diversity index	1/(numbers of crops+1)	0.33	0.25	0.50	1	0.2
	Percentage of HHs that does not save crops	Percent	72.05	62.30	52.63	100	0
	Percentage of HHs who does not save seeds	Percent	65.20	50.60	42.10	100	0
Water	Percentage of households reporting water conflicts	Percent	50.50	40.50	57.89	100	0
	Percentage of households that utilize a natural water source	Percent	65.14	55.53	52.63	100	0
	Average time to safe drinking water source	Minutes	17	16	15	20	10
Social networks	Average give: received ratio	Ratio	1.33	1.66	1.20	3.5	0.3
	Average borrow: lend ratio	Ratio	1.25	1.03	1.01	2	0.5
	Percentage of households not receiving any assistance from their local government and NGOs	Percent	19.38	14.44	10.53	100	0
Natural disasters	Average number of floods, drought and cyclone events in the past 10 years	Count	7	5	5	10	4
	Percentage of households with an injury or death as a result of natural disasters in the past10 years	Percent	5.26	3.50	2.10	100	0
	Percentage of households with an injury or death to their livestock as a result of natural disasters in the past 10 years	Percent	26.31	15.20	10.34	100	0
	Percentage of households with losses of agricultural land due to	Percent	21.05	10.07	5.01	100	0

Major component	Sub-component	Units	High Change area	Moderate change area	Low change area	Maximum value	Minimum value
	riverbank erosion and flood						
	Percentage of households affected by bank erosion	Percent	15.78	25.02	3.01	100	0
	Percentage of households affected by flood/inundation/sand splay	Percent	21.05	10.01	2.05	100	0
	Percentage of households that does not receive a warning before a natural disaster	Percent	72.01	55.06	47.40	100	0

Table 7. Indexed value of subcomponents for LVI analysis

Major component	Sub-component	Units	High Change area	Moderate change area	Low change area
Socio-demographic profile	Dependency ratio	Ratio	0.266	0.247	0.160
	Percent of households where the head of the household did not attend school	Percent	0.448	0.374	0.325
	Average number of family members in household	Count	0.500	0.333	0.333
	Percentage of female headed household	Percent	0.410	0.320	0.210
Livelihood strategies	Percentage of households where family members migrate to work in a different community	Percent	0.526	0.570	0.646
	Percentage of households solely dependent on agriculture and livestock as their source of income	Percent	0.684	0.720	0.520
	Average livelihood diversification index	1/(number of livelihoods+1)	0.163	0.163	0.062
Health	Average time to health facility	Minutes	0.500	0.583	0.333
	Percentage of households with family members who are chronically ill	Percent	0.158	0.140	0.126
	Percentage of households who do not attend a local doctor during illness	Percent	0.421	0.502	0.355
Food	Average crop diversity index	1/(numbers of crops+1)	0.163	0.063	0.375
	Percentage of HHs that does not save crops	Percent	0.720	0.623	0.526
	Percentage of HHs who does not save seeds	Percent	0.652	0.506	0.421
Water	Percentage of households reporting water conflicts	Percent	0.505	0.405	0.578
	Percentage of households that utilize a natural water source	Percent	0.651	0.555	0.526
	Average time to safe drinking water source	Minutes	0.700	0.600	0.500
Social networks	Average give: received ratio	Ratio	0.322	0.425	0.281
	Average borrow: lend ratio	Ratio	0.500	0.353	0.340
	Percentage of households not receiving any assistance from their local government and NGOs	Percent	0.193	0.144	0.105
Natural disasters	Average number of floods, drought and cyclone events in the past 10 years	Count	0.500	0.160	0.160

Major component	Sub-component	Units	High Change area	Moderate change area	Low change area
	Percentage of households with an injury or death as a result of natural disasters in the past10 years	Percent	0.053	0.035	0.021
	Percentage of households with an injury or death to their livestock as a result of natural disasters in the past 10 years	Percent	0.261	0.052	0.103
	Percentage of households with losses of agricultural land due to riverbank erosion and flood	Percent	0.210	0.100	0.050
	Percentage of households affected by bank erosion	Percent	0.158	0.250	0.030
	Percentage of households affected by flood/inundation/sand splay	Percent	0.210	0.100	0.020
	Percentage of households that does not receive a warning before a natural disaster	Percent	0.720	0.550	0.474

Table 8. Major component value and overall LVI value of high, moderate and low change area

Major components	High change area	Moderate change area	Low change area
Socio demographic profile	0.406	0.318	0.257
Livelihood strategies	0.458	0.484	0.409
Health	0.360	0.408	0.271
Food	0.511	0.397	0.440
Water	0.618	0.520	0.534
Social networks	0.338	0.307	0.242
Natural hazards	0.301	0.178	0.122
LVI	**0.407**	**0.341**	**0.291**

respondents has reported water scarcity during lean season. On the other hand, 65.14% of reported households in high change area use water from natural water source in compared to low (52.63%) change area.The average time taken to access safe drinking water is higher in the high change area. When all the sub-components of water have been combined, the overall component value of water in high (0.618), moderate (0.520) and low change area (0.534) reveals a vulnerable condition of water resources. No significant differences have been noted among areas of different intensities of morphological change.

The major component Social Networks comprises three sub-components. It implies community level relationship which affects livelihood vulnerability index. Social network score reveals more vulnerability for both high (0.338) andmoderate (0.307) change area than and low (0.242) change area in social bonding. Average give:received ratio and borrow: lend ratio is very high in both the high and moderate change area. Survey shows that about 19.38% of respondents in the high change area have not received any assistance from their local government and NGOs in compared to 14.44% and 10.53% in the moderate and low change area.

Natural disaster is the seventh or last major component of LVI analysis which considers seven sub components. Vulnerability score of natural disaster reveals that people living in the high change area (0.301) is more vulnerable to natural disasters compared to the moderate (0.178) and low (0.122) change area. The occurrence of natural disaster in high change area (7) is higher than the low change area (5) in the past 10 years. It has been reported that average percentage of death or injuries, as a result of natural disaster was higher in case of high change area (5.26%) than low change area (2.10%) in the last ten years. Respondents in the high change area have reported a higher percentage (21.05%) of loss of agricultural land due to river bank erosion and flood than low change area (5.01%). The majority of respondents (72.01%) in the high change area reported not to have received any warnings before a potential floods and drought incidence.There are sometimes communication gaps regarding when the spillways will be opened. Sudden release of water through spillways often resulted in the destruction of flood plain agriculture in the downstream areas. Similar communication gaps have been reported by Adams [26]. Comparatively, this percentage is low in case of moderate (55.06%) and low (47.40%) change area.

Different vulnerability status of seven major components of LVI analysis has been shown through a spider diagram (Fig. 5).

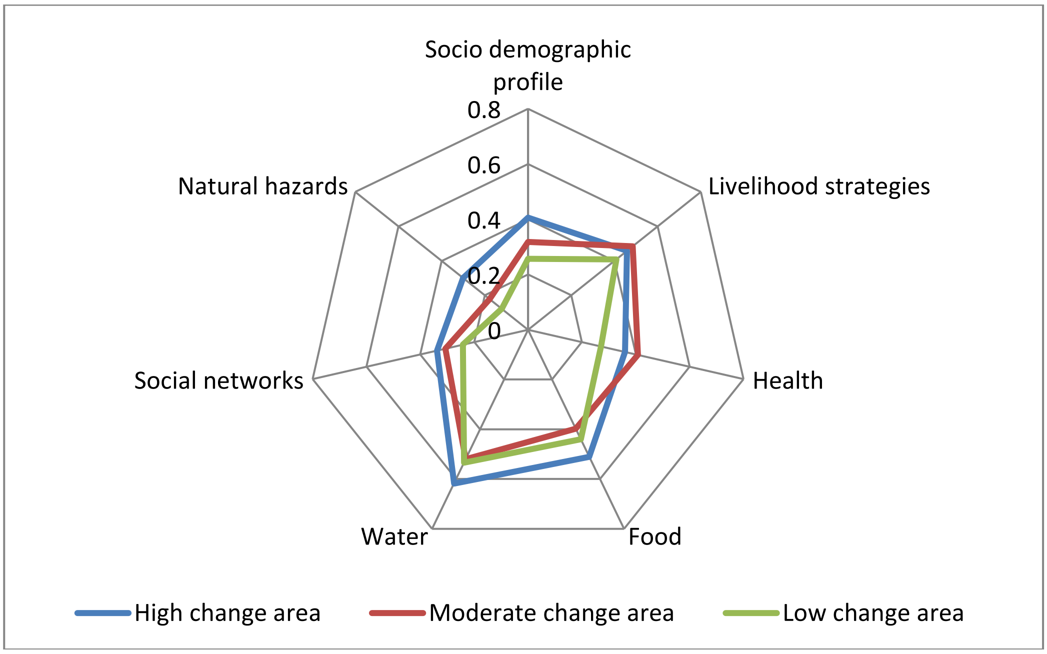

Fig. 5. Vulnerability Spider diagram of LVI

Table 9. Index value of LVI based on LVI-IPCC

IPCC contributing factors to vulnerability	High change area	Moderate change area	Low change area
Exposure (Natural disaster and climate variability)	0.301	0.178	0.122
Adaptive capacity (Socio demographic profile, livelihood strategies and social networks)	0.401	0.364	0.298
Sensitivity (Health, food and water)	0.496	0.441	0.415
LVI-IPCC	**-0.049**	**-0.082**	**-0.073**

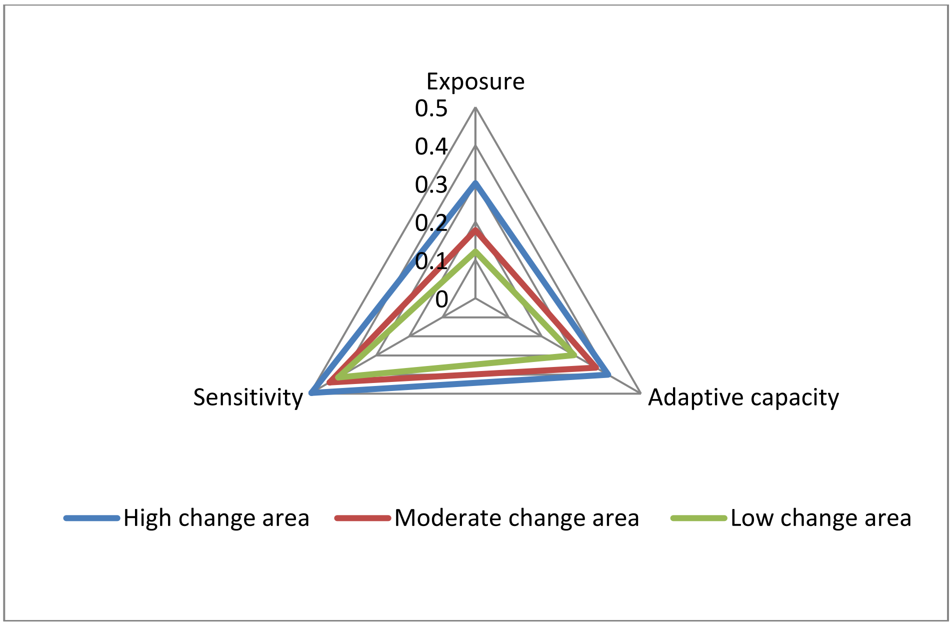

Fig. 6. Vulnerability triangle diagram of LVI-IPCC

3.2 Livelihood Vulnerability Index: IPCC Framework

Table 9 represents the index value of three major contributing factors to vulnerability and the overall LVI-IPCC value of three different morphological change areas.

LVI-IPCC value varies from -1 to1. In the present study, LVI-IPCC value ranges from -0.049 to -0.082. This reveals that high change area (-0.049) is more susceptible than moderate (-0.082) and low (-0.073) change area. The calculated score of three contributing factors of LVI-IPCC i.e. exposure, sensitivity and adaptive capacity are shown in the vulnerability triangle diagram (Fig. 6).

The above diagram shows that high change area is more exposed (0.301) to natural disasters than moderate (0.178) and low (0.122) change area. Further, high change area is more sensitive (0.496) in terms of health, food and water compared to moderate (0.441) and low (0.415) change area. The aggregate index of socio demographic characteristics, livelihood strategies and social networks reveal that high change area has higher adaptive capacity (0.401) than moderate (0.364) and low (0.298) change areas. The overall LVI-IPCC values indicate that households in the high change area are more vulnerable than moderate and low change area.

Analyses of the above LVI and LVI-IPCC value reveals a vulnerable livelihood of downstream dwellers in three different areas of morphological change, triggered by components like socio-demographic profile, livelihood strategies, food, water, health status and natural hazards. Among 7 major components of LVI, commissioning of dam significantly impacted water availability because of diversion of water through left bank feeder canal, right bank main canal. Because of this, downstream of dam was left at the mercy of water discharge through spillway alone. It may be mentioned here that only 5.9% water has been diverted through spillway (Data source: Mukutmanipur Gauge Station, 2019). This is the most serious downstream impact of the dam as reported by the respondents. High and moderate change area corresponds to alluvial tract of middle reach of the downstream channel where agriculture is the primary economic activities of the people. High dependency on agricultural-based livelihood has incresed vulnerability in high and moderate change area. Similar findings have been reported by Alam et al. [14], Singha and Pal [16] and Talukdar et al. [24]. Though, Zhou et al. [27] and Yang et al. [28] argued that income from various agricultural sources significantly impacts livelihood resilience, as higher capital stock farmers earn more income and invest more in productive resources to sustain their livelihood base. Duflo and Pande [29] reported that downstream areas of dam usually benefit from improving agricultural production and irrigation facilities.The irrigation water diverted through left bank feeder canal and right bank main canal does not satisfy the water requirments of the inhabitants along river sides locations downstream of Mukutmanipur dam while ironically it serves command areas beyond the basin boundary.

In contrast, low change area shows no significant changes of channel morphology consequent to the commissioning of dam during the observation periods resulting in low level of livelihood vulnerability.

The overall findings of LVI-IPCC also reveal that high change area is more vulnerable inspite of having high adaptive capacity in compared to moderate and low change area. This is anomalous to the findings of LVI-IPCC report i.e. high livelihood vulnerabilty corresponds to low adaptive capacity and vice-versa [16, 30]. This may be due to reason that high exposure to natural disaster overwhelms the adaptive capacity of the people living in the high change area. On the other hand, low level of livelihood vulnerability correspond to low adaptive capacity, low exposure and low sensitivity of the people in low change area is reflected through the high rate of outmigration. Accoring to Ellis [31] migration is a crucial coping strategy for socio-economic and environmental changes, particularly when livelihoods are threatened due to disruption of existing agricultural systems by dam construction [32]. Nandi and Sarkar [12] stated that more than 60% of income earned by most households comes from migration, which meets their basic needs [33-35].

4. CONCLUSION

The present research work is an effort to investigate the livelihood vulnerabilityin the downstream riparian dwellers in relation to morphological changes as a consequence of the commissioning of Mukutmanipur dam on Kangsabati river using LVI and LVI-IPCC approaches. Results highlight that the dam has disrupted the livelihoods of river-dependent people located along side of Kangsabati river in the downstream of Mukutmanipur dam. But the levels of livelihood vulnerability in the downstream reach varies spatially and there is a significant difference in livelihood vulnerability of high (LVI: 0.407), moderate (LVI: 0.341) and low change area (LVI: 0291), whereas LVI value of high change area (LVI: 0.407) indicates more vulnerable status in compared to moderate and low change area. LVI-IPCC value in high change area (-0.049) further indicates the same. From the overall findings and subsequent discussions of the study, finally, it can be concluded that LVI can be a vital tool to identify vulnerable areas for regional planners and policymakers to get a baseline for effective policy planning and their implementation.

5. RECOMMENDATIONS

1. The present study recommends food security, employment generation etc by both the govt and non-govt organizations to the vulnerable areas.
2. Further, downstream flow through the spillway discharge from dam during lean season should be accentuated to aid existing agricultural systems in the downstream reach and enhance the accessibility to water for various domestic needs.
3. Lastly, setting up health centres and educational institutions are also recommended.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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