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# A DPSIR conceptual framework for index-base flood risk assessment case study: Riverine flood in Sirajganj, Bangladesh

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**Abstract**

Assessment of flood risks is very important for the sustainable flood risk management in the flood affected area such as Bangladesh where estimated annual average flood damage is about 21 million USD. There are a lot of strategic flood risk assessment methods suggested by the researchers globally. In this paper, we propose a new way of assessing the flood risk by the method of indexing of indicators suitably identifying using Drivers-Pressure-State-Impact-Responses (DPSIR) conceptual framework. DPSIR framework is mostly applicable in enlisting and identifying potential indicators in several sectors of water management, sustainable development, terrestrial & marine environment, biodiversity, etc. The framework is also used in addressing problem, cause of problem, upcoming pressure, past & future probable impact, and the necessary planning strategies to solve the problem. First, we have developed a generic conceptual framework for the flood risk assessment for the different types of floods occurred in Bangladesh. Finally, Integrated Flood Risk Index (IFRI) has been formulated from three sub-indexes of hazard, vulnerability, and resilience where these three sub-indexes are computed from the selected indicators by mathematical aggregation. The developed framework is applied for riverine flood prone area of Sirajganj in Bangladesh as a case study. IFRI value has been considered in likelihood scale such as very low, low, moderate, high, and severe risk with equal class interval. Flood risk has been addressed in sub-district level locally upazila for the district. And outcome of the study represents that Shahjadpur and Sirajganj sadar are high risk zone out of nine sub-districts of Sirajganj district. However, as per interpretation of IFRI, planning and policy should be relevant to increase resilience, maintenance of existing structural intervention conjugate with non-structural measures for high-risk area.



*Keywords:* DPSIR, hazard, vulnerability, resilience, risk, indicator, index, key informants' interview.

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## 1. Introduction

Natural hazards such as earthquakes, land slide, volcanic activity, drought and flooding etc. are geophysical events which occur worldwide, and the impact is greater mostly in developing countries due to their frequencies and magnitudes. In most cases, the occurrence of natural disasters in these countries are due to two main factors. First, there is a relation with geographical location and geological-geomorphological settings. Developing or poor countries are located to a great extent in zones largely affected by those geophysical events. The second reason is linked to the historical development of these poor countries, where the economic, social, political, and cultural conditions are not good, and consequently act as factors of high vulnerability to natural disasters (economic, social political and cultural vulnerability). (Alca´ntara-Ayala, 2002)

The South-Asian country of Bangladesh faces different type of natural disaster as flood, drought, riverbank erosion, tropical cyclone, earthquake, and landslides. Out of those, flood is the phenomenon frequently brings sufferings to the people by socio-economical loss and damage. Physiographic feature of the country represents that 7.5% of three major river basins Ganges-Brahmaputra-Meghna (GBM) with approximately 311 tributaries and distributaries lies in Bangladesh. Thus, the country is one of largest river delta in the world. Flat topography where 60% out of total territory is lower than 6m MSL, leads to the inundation of 20.5% of the area annually where in extreme flood it reaches approximately 70% of area (Mirza, 2002; Moffitt et al., 2011). According to historical records of Flood Forecasting and Warning Centre (FFWC) of Bangladesh Water Development Board, Bangladesh faced catastrophic flood in 1954, 1955, 1974, 1987, 1988, 1998, 2004, 2007, 2017, 2019, and 2020, (BWDB, 2020). Among them the highest number of deaths was recorded in 1988 flood (2379 people) and the largest amount of damage caused by 1998 flood. Above all the estimated annual average flood damage is about 21 million USD (Dewan et al., 2003). Bangladesh faces different types of floods such as flash flood, riverine flood, rainfall induced flood, and cyclone & storm-surge flood etc. Sudden rise in water level due to the torrential precipitation in external catchment of India near North-East region of Bangladesh and some hilly area in Eastern-hilly region, flash flood normally occurred which create damage especially for the velocity component of flood. Spilling of rivers flow due to the trans-boundary river flow, riverine flood occurs where depth and duration component of flood is a major cause of damage. Local rainfall of high intense-short duration or low intense-long duration during monsoon create rainfall induced flood where intensity & timescale of precipitation, water level situation in major river and drainage facility are the main factors. In coastal area of Bangladesh, storm-surge flood occurs. Large estuary, extensive tidal flats, low-lying island, semi diurnal tide, tropical cyclone, Sea Level Rise (SLR) are the factors enforcing the flood damage (Mirza, 2002; Dewan et al., 2003; WMO/GWP, 2003; Choudhury, 2004; Karim, 2008).

Flood risk analysis is fundamental step before planning for the integrated flood management. There are several works done in the past related to the hazard, vulnerability and overall risk assessment for the flood. This study provides a new approach of index-based flood risk assessment using DPSIR conceptual framework. A generic DPSIR conceptual framework has been developed for four different types of flood in Bangladesh. Several potential indicators have been enlisted under each component of developed framework. A new index IFRI (integrated flood risk index) has been formulated from three sub-indexes of risk components as hazard, vulnerability and resilience. These three sub-indexes are formulated by mathematical aggregation from the standardized values of the selected indicators. Finally, IFRI is applied for the riverine flood prone area Sirajganj of Bangladesh to assess integrated flood risk in sub-district level.

## 2. Methodology and study area

### *2.1 Development of generic framework*

In this study, a generic framework of flood risk assessment has been developed based on the data and information gathered through literature review, focus group discussion (FGD) and key informant interview (KII), etc. Key informant interview is suitable for descriptive and qualitative data collection especially in anthropological field work rather structured technique of data gathering such as questionnaire survey due to difficulties and time consuming (Tremblay, 1957). However, researchers use various ways such as informal, formal, unstructured, structured, semi-structured interview technique with key informant to collect primary data for developing logic and conceptual model (Tremblay, 1957; Gugiu and Campos, 2007; Boon et al., 2009; Shaw et al., 2004). Different mode of survey such as noting down in paper, audio recording of interview, web-based survey, etc. are used by researchers in KII technique (Boon et al., 2009; Sherrieb et al., 2012). To develop conceptual DPSIR model framework for flood risk management, interview with key informants has been conducted as a better method for the collection of information. Identification of key informant depends whether the informants in a position or able to provide variety of information related to the followings:

- Four different flood types in Bangladesh
- Several causes of flood
- Environment and ecological pressures triggering flood extend and impact
- Pre and post situation arise due to flood
- Damage (direct-indirect, tangible-intangible) in several sectors
- Existing structural measures for risk management
- Existing non-structural measures in planning and response strategies
- Probable future planning and response strategies

For this research, semi-structured interview was conducted with key informants relevant to their expertise in water resources planning & management, hydrology-hydrodynamics-morphology, sociology, natural resources management, aquaculture management, disaster risk management etc. List of the expertise of key informants is presented in Table 1. Figure 1 shows the overall methodological framework of this research work.

Table 1
Characteristics of the key informant

| Sl. | Area of Work experience | No. of Informant |
|---|---|---|
| 01 | Water Resources Management (WRS Modelling, IWRM, SD) | 2 |
| 02 | Irrigation and Drainage Management | 2 |
| 03 | Flood Control and Drainage Management | 4 |
| 04 | Coastal Zone Management | 3 |
| 05 | Water Resource Planning | 3 |
| 06 | River Morphology | 2 |
| 07 | Hydrology | 2 |
| 08 | Sociology | 1 |
| 09 | Aquaculture & Fisheries Management | 1 |
| 10 | Natural Resources Management | 1 |
| 11 | Application of GIS & RS in risk management | 2 |
| 12 | Stakeholder | 1 |
| Total | | 24 |

## *2.2 Formulation of risk index*

Integrated flood risk index (IFRI) has been formulated from three sub-indexes of hazard sub-index (HSI), vulnerability sub-index (VSI) and resilience sub-index (RSI). Computation of IFRI is the mathematical aggregation of these three sub-indexes. These three sub-indexes are individually weighted aggregation of several potential indicators chosen under each component of developed generic DPSIR framework. The relation of the IFRI, HSI, VSI and RSI along with the enlisted indicators is as follows:

$$IFRI = f(HSI, VSI, RSI) = w_H * HSI + w_V * VSI + w_R * (1 - RSI)$$

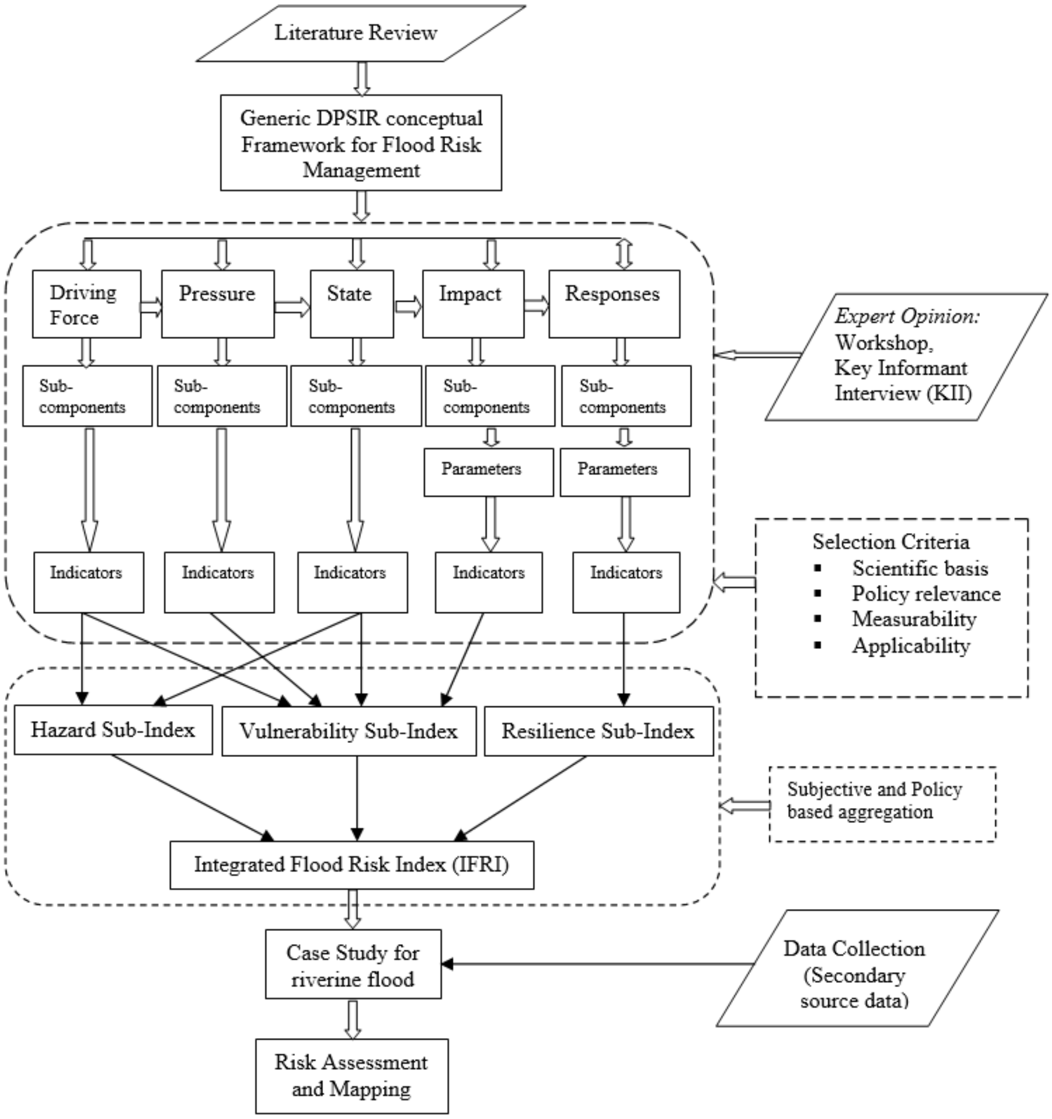


Fig. 1. Methodological flow chart representing the schematization of flood risk assessment using DPSIR framework.

Here in addition the resilience has been considered as a counter measure of risk as resilience for the long-term coping capacity is important for risk minimization. And subtraction from the unity has been referred to bring it in a same platform of addition with hazard and vulnerability. Here, wH, wV and wR are the weights for hazard, vulnerability and resilience respectively.

$Where\ w_H + w_V + w_R = 1$
$Hazard\ Subindex\ (HSI) = f(I_{Drivers}, I_{State})$
$Vulnerability\ Subindex\ (VSI) = f(I_{Drivers}, I_{Pressures}, I_{State}, I_{Impact})$
$Resilience\ Subindex\ (RSI) = f(I_{Responses})$

Selected indicators must be dimensionless by standardization thus considered in percentage or in ratios. Standardization has been done using the basic equation of rescaling technique (Routray, 2013; Nardo et al., 2005) as follows:

$$Standardization = \frac{(Actual\ value - Minimum\ value)}{(Maximum\ value - Minimum\ value)}$$

Thus, all the indicators are organized in a scale range from 0 to 1 as dimensionless in comparison platform. The three sub-indexes are calculated as:

Hazard Sub-Index, $HSI = \sum_{i=1}^{n} w_i HI_i$ Here, n = the no. of indicators
Vulnerability Sub-Index, $VSI = \sum_{i=1}^{n} w_i VI_i$ $W_i$ = the weight of i[th] indicator
Resilience Sub-Index, $RSI = \sum_{i=1}^{n} w_i RI_i$ $\sum_{i=1}^{n} w_i = 1$

And HI, VI and RI are the hazard, vulnerability and resilience indicators respectively. Weight of the indicators can be determined by several methods such as AHP, Fuzzy theorem, subjective weighting technique, etc. (Dang et al., 2011; Li et al., 2012; Routray, 2013). The sum of weights provided to each indicator under the sub-index of hazard, vulnerability and resilience is equal to 1.

Table 2
Interpretation of integrated flood risk index

| Integrated Flood Risk Index (IFRI) | Interpretation |
|---|---|
| Very Low (0 to 0.20) | Indicates very less affected by flood, less impacted area due to flood and very low importance for flood risk management. Planning and policy should be relevant to increase resilience |
| Low (0.20 to 0.40) | Indicates less affected by flood, less impacted area due to flood and lower importance for flood risk management. Planning and policy should be relevant to increase resilience |
| Moderate (0.40 to 0.60) | Frequently affected by flood, loss and damage in socio-economic sectors are more, more importance for flood risk management. Planning and policy should be relevant to increase resilience and emphasis on the maintenance of existing structural interventions and non-structural measures |
| High (0.60 to 0.80) | Highly affected by flood, highly impacted in socio-economic sectors, major importance for flood risk management. Planning and policy should be relevant to increase resilience, maintenance of existing structural intervention conjugates with non-structural measures. Planning for mitigation measures by new approaches which is not exist in the area. |
| Severe or very high (0.80 to 1) | Mostly affected by flood, severe loss and damage in socio-economic sectors, major importance for flood risk management. Planning and policy should be relevant to increase resilience, maintenance of existing structural intervention conjugates with non-structural measures. Most important area for future planning to mitigate flood by adopting new approaches which is not practiced yet. |

The process of computing the weights to all indicators relatively can be biased. In this study, equal weight of indicators for three sub-indexes are considered for IFRI computation as similar to the study for the assessment of national water security index by ADB (2013) and fresh water resources vulnerability assessment for Mekong river basin by Babel and Wahid (2009). Risk has been assessed for the study area under the computed IFRI in a likelihood scale of very low, low, moderate, high and severe. Interpretation of the index is represented in Table 2.

### 2.3 Study area profile

Sirajganj is one out of 64 districts in Bangladesh which falls on the basin of transboundary river Brahmaputra facing riverine flood almost every year. Geo-position of the district is 24º01' to 24º47' north latitude and 89º15' to 89º49' east longitude. Area of the district is approximately 2498 km2 (BBS, 2001) which is bounded by Bogra district on the north, Pabna district on the south, Tangail and Jamalpur districts on the east, Pabna, Natore and Bogra districts on the west. The district comprises 80 unions in 9 sub-districts locally called Upazila (BBS, 2001). Figure 2 (left) shows the location of the study area in Bangladesh. The study area faces sub-tropical monsoon climate. There is no existing climate station in the district. Nearby station Bogra (station ID: 10408) is representative to express the climate of the study area. The district faces 21.2°C to 33.3°C maximum variation of monthly temperature where monthly minimum temperature ranging from 9.4°C to 26.8°C (EPC, 2008). And annual average rainfall is 1610 mm for the district.

There are 11 nos. of rainfall measurement station inside and periphery of the study area established by BWDB. And four available water level station also established by BWDB. Figure 2 (right) shows the location of hydro-meteorological station in the study area. Discharge data is available for two stations, one in Bahadurabad on Brahmaputra river and another in Ullapara on Karatoya-Bangali river. Bahadurabad station location is outside of the study area but represents the trans-boundary flow passing through the major channel Jamuna located eastside of the district.

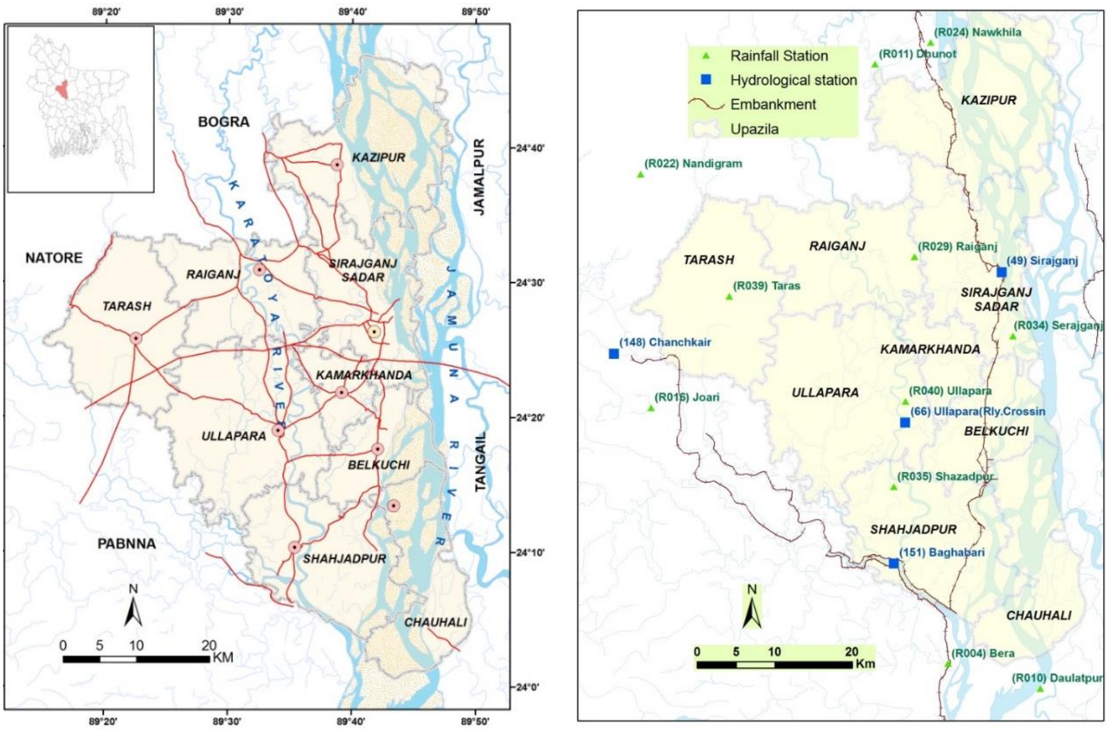

Fig. 2. Location map of the case study area (left) and locations of hydro-meteorological station (right).

Land elevation of the study area is ranged from 4.96 to 15.51 mPWD. The area faces mild slope from North-East to South-West. About 40% of the land lies below the average land level. Topography of the study area is viewed in Figure 3 (left). Major portion of the study area soil is characterized by Karatoya-Bangali river flood plain (EPC, 2008). Over all the soil of the area is covered by five types of agro-ecological zone (AEZ) such as AEZ 4, AEZ 5, AEZ 7, AEZ 12 and AEZ 25 as listed in the Table 3 and shown in Figure 3 (right).

Table 3
Agro-ecological zone in the study area (Source: EPC, 2008)

| AEZ Zone | Description | Area (%) | Soil Type |
|---|---|---|---|
| AEZ 4 | Karatoya-Bangali Floodplain | 73 | Grey silt loams and silty clay loams on ridges and grey or dark grey clays in basins |
| AEZ 5 | Lower Atrai Basin | 5 | Dark grey, heavy, acidic clays predominate |
| AEZ 7 | Active Jamuna Floodplain | 8 | Sandy and silty alluvium rich in minerals with slightly alkaline in reaction |
| AEZ 12 | Lower Ganges River Floodplain | 7 | Silt loams and silty clay loams on the ridges and silty clay loams to heavy clays on lower sites |
| AEZ 25 | Barind Land | 7 | Predominant soils have a grey silty puddled topsoil with ploughpan which either directly overlies grey heavy little weathered Madhupur Clay ormerges with the porous--silt loam or silty clay loam subsoils |

Major rivers in the study area are Jamuna, Karatoya, Bangali, Ichamati and Atrai-Hurasagar. The Jamuna River originates from Tibet on the northern slope of the Himalayas and drains snowmelt and rainfall from China, Bhutan, India and Bangladesh. It has 79km of length in the study area. The Karatoya rises as the Jamuneswari, which has only a very small contributing catchment in India. The Karatoya enters into Bangaldesh through the Panchagar district. It has 65km of length in the study area.

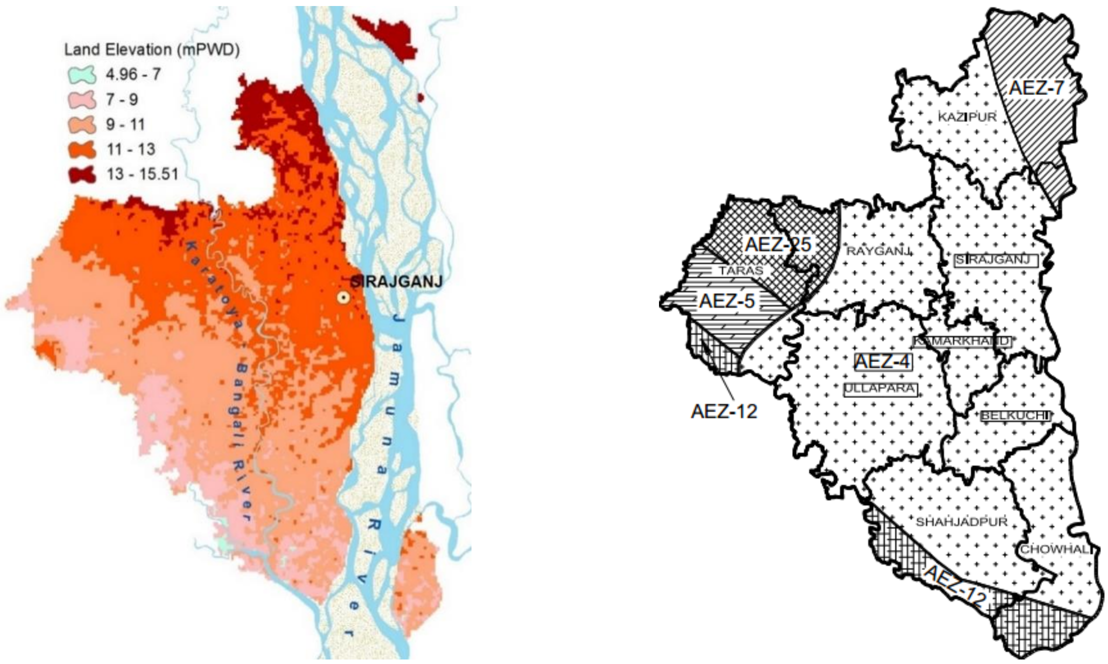


Fig. 3. Land level (left) and physiography (right) of the study area (Source: SoB and GSB).

The Bangali river originates from the confluence of Karatoa and Alai rivers at Mahimaganj of Gaibandha district. The Ichhamati river originates from the bifurcation of Bangali river in

Nimgachi Union of Dhunat Upazila, Bogra district. It has 30 km of length in the study area. Atrai-Hurasagar is the river termed after the confluence of Atrai with Karatoya-Bangali systems and outfall with Jamuna river. There are several small canals (knals) in the study area. These canals offtakes the local rainfall and drains to the major river systems. There are about 74 nos. water bodies locally termed as beels in the study area where most of the beels have been silted up.

Table 4
List of selected potential indicators under components of DPSIR for risk assessment of the case study area

| Type of Indicators | ID | Name of Indicators | DPSIR Components |
|---|---|---|---|
| Hazard | $HI_1$ | Average of Monsoon rainfall (May to October) | Drivers |
| | $HI_2$ | Average duration above danger level (day) | |
| | $HI_3$ | Average peak flow ($m^3/s$) | |
| | $HI_4$ | No. of flood affecting year | State |
| | $HI_5$ | No. of occurrence of major embankment breaching | |
| Vulnerability | $VI_{01}$ | Population dynamics (% rise or fall) | Drivers |
| | $VI_{02}$ | Population density(persons/$km^2$) | |
| | $VI_{03}$ | Area of urbanization ($km^2$) | Pressure |
| | $VI_{04}$ | Ratio of silted up river and canal over entire length | |
| | $VI_{05}$ | Maximum inundated area (%) | State |
| | $VI_{06}$ | Stakeholders' perception about vulnerability due to the location from embankment | |
| | $VI_{07}$ | No. of damaged house | Economic Impact |
| | $VI_{08}$ | No. of damaged educational institution | |
| | $VI_{09}$ | Length of damaged road (km) | |
| | $VI_{10}$ | Length of damaged embankment (km) | |
| | $VI_{11}$ | Area of damaged crops (hac) | |
| | $VI_{12}$ | No. of dead livestock | |
| | $VI_{13}$ | No. of dead people | Social Impact |
| | $VI_{14}$ | No. of affected people | |
| Resilience | $RI_{01}$ | Percentage of population with access to safe drinking water | Responses (Altering State) |
| | $RI_{02}$ | Percentage of population with access to adequate sanitation | |
| | $RI_{03}$ | % of protected land area | Responses (Minimizing Impact) |
| | $RI_{04}$ | No. of civil servants and volunteer per 1000 population | |
| | $RI_{05}$ | No. of permanent and temporary flood shelter | |
| | $RI_{06}$ | Flood forecasting technique | |
| | $RI_{07}$ | % Literacy rate 7 Years and over | |
| | $RI_{08}$ | No. of mobile telephone per 1000 people | |
| | $RI_{09}$ | % of flood proofed household | |
| | $RI_{10}$ | No. of organization and institution involved with water and disaster | |
| | $RI_{11}$ | % employed population of working age (economic activity rate) | |
| | $RI_{12}$ | GDP per capita (USD per capita) | |

## 3. Results and discussions

### *3.1 Generic DPSIR framework for flood risk management*

Generic DPSIR conceptual framework has been developed for flood risk management in Bangladesh. In generic sense causes of four different types of flood; situation and impact prevailed during past floods; existing non-structural and structural measures for flood mitigation; etc. has been addressed. Overall, the developed generic DPSIR framework is shown in Figure 4.

### *3.2 Potential indicators under developed DPSIR framework*

Under each sub-components and parameters of the DPSIR components shown in Figure 4, several indicators are reviewed and subsequently listed through literature survey. Some indicators are also noted during the conduction of SSI with key informants as per their expert opinion. Overall, the developed generic DPSIR framework for flood risk assessment addresses all four types of floods in Bangladesh. Table 4 presented the list of potential indicators selected for the riverine flood risk assessment of the case study area, Sirajganj district.

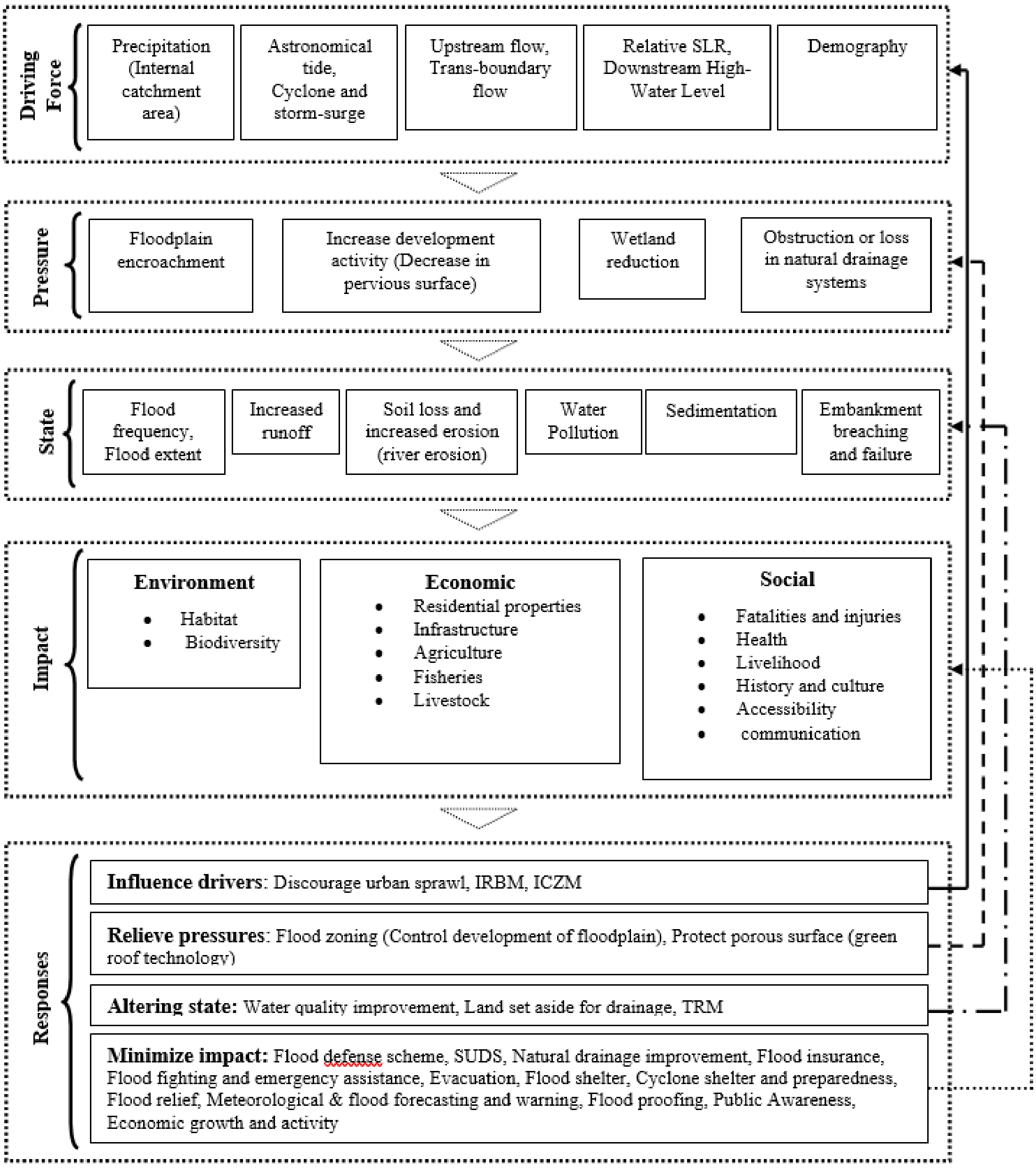


Fig. 4. Generic DPSIR conceptual framework for flood risk management for four different types of floods in Bangladesh.

### *3.3 Application of developed framework: Case study*

Selected five hazard indicators (listed in Table 4) are assessed to compute hazard sub-index for the study area for riverine flood where 3 indicators are under driving force and rest two are from the state component. Hazard sub-index is represented in five levels of likelihood scale in equal range of value. Figure 5 shows the hazard index value along with the standardized hazard indicators for all sub-districts of Sirajganj.

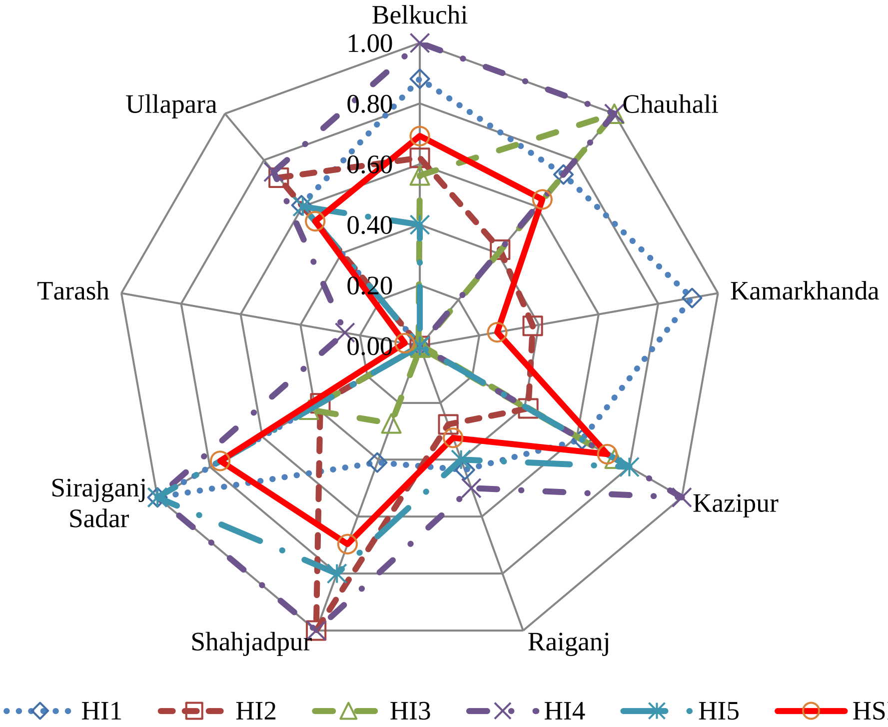


Fig. 5. Comparison of hazard indicators with sub-index for nine sub-districts.

Vulnerability is the consequence of hazard. For riverine flood in the study area, 14 nos. of indicators (presented in Table 4) are selected from developed generic DPSIR framework to assess the vulnerability. Vulnerability sub-index is also categorized in likelihood scale of five levels. Figure 6 shows the calculated values of all vulnerability indicators along with the vulnerability index. The findings show Shahjadpur sub-district is severely vulnerable, Sirajganj Sadar and Ullapara are highly vulnerable area, Belkuchi and Kazipur are moderately vulnerable, rest of four sub-districts of Chauhali, Kamarkhanda, Raiganj and Tarash are low vulnerable.

Resilience is assessed from the selected 12 indicators of responses component of developed DPSIR framework. Figure 7 shows the computed values of all resilience indicators and resilience index. It shows almost nearby moderate resilience for all the sub-district where Sirajganj Sadar is highly resilient as the main center of the district.

Finally, the flood risk for those nine sub-districts has been assessed by Integrated flood risk index (IFRI) as arithmetic aggregation of the computed three sub-indexes of hazard, vulnerability and resilience. Risk has positive relation with hazard and vulnerability where risk will be lowered due to increase of resilience. Overall, Table 5 represents the computation of IFRI for all sub-districts of the case study area.

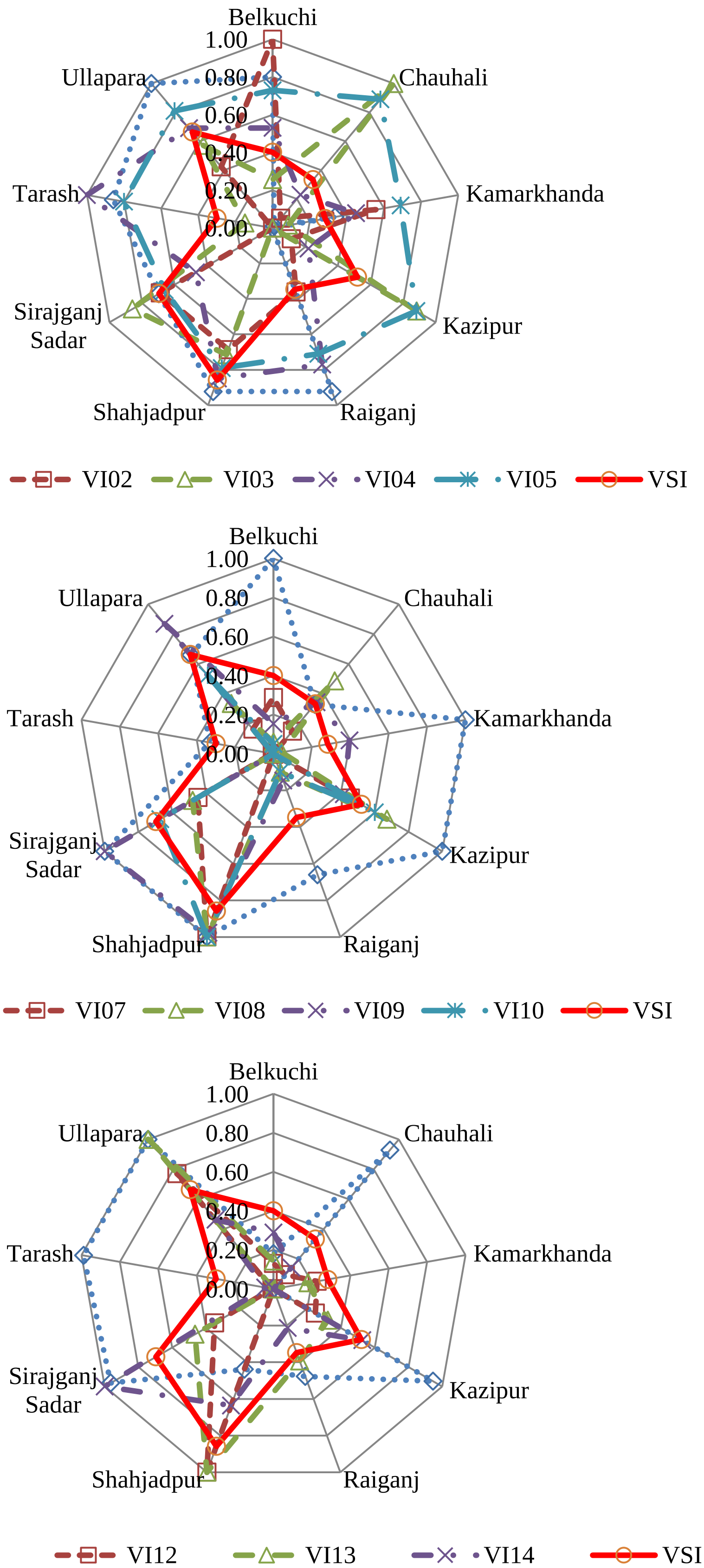


Fig. 6. Comparison of vulnerability indicators with sub-index for nine sub-districts.

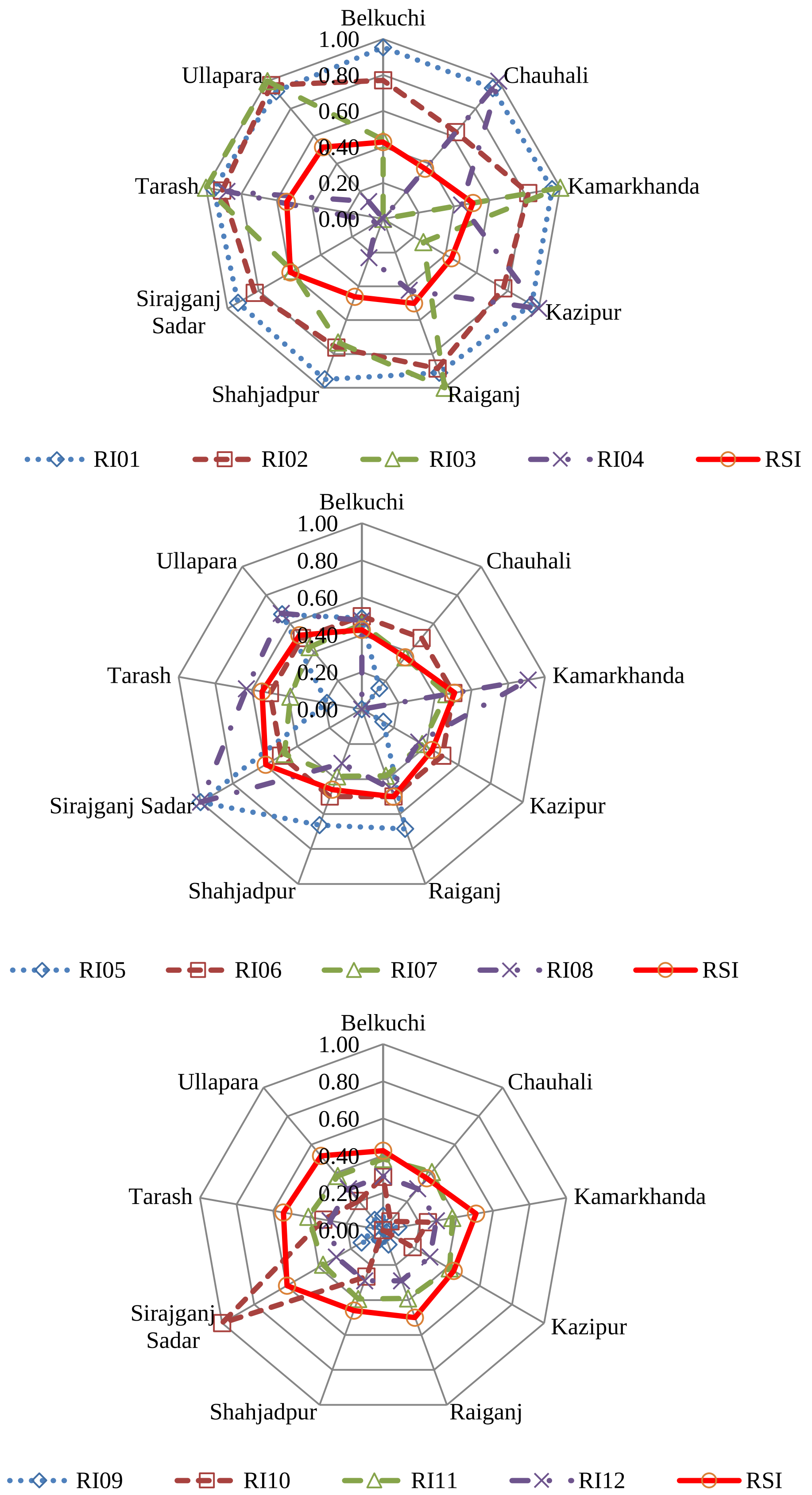


Fig. 7. Comparison of resilience indicators with sub-index for nine sub-districts.

Table 5
Integrated flood risk index for the study area

| Upazila | Hazard Index (HSI) | Vulnerability Index (VSI) | Resilience Index (RSI) | Integrated Flood Risk Index (IFRI) | Risk |
|---|---|---|---|---|---|
| Belkuchi | 0.69 | 0.40 | 0.43 | 0.56 | Moderate |
| Chauhali | 0.63 | 0.33 | 0.36 | 0.53 | Moderate |
| Kamarkhanda | 0.26 | 0.28 | 0.51 | 0.35 | Low |
| Kazipur | 0.72 | 0.52 | 0.44 | 0.60 | Moderate |
| Raiganj | 0.32 | 0.35 | 0.50 | 0.39 | Low |
| Shahjadpur | 0.70 | 0.86 | 0.46 | 0.70 | High |
| Sirajganj Sadar | 0.76 | 0.70 | 0.60 | 0.62 | High |
| Tarash | 0.05 | 0.30 | 0.54 | 0.27 | Low |
| Ullapara | 0.54 | 0.66 | 0.52 | 0.56 | Moderate |

Table 5 represents the computed value of IFRI for the nine sub-districts of the study area. Finally, IFRI is represented by likelihood scale of very low (0 to 0.2), low (0.2 to 0.4), moderate (0.4 to 0.6), high (0.6 to 0.8) and severe (0.8 to 1) by using equal class interval. Overall results for the study area show Shahjadpur and Sirajganj Sadar Upazila are highly risk prone area where Tarash, Kamarkhanda and Raiganj are low risk area for flood. And remaining four Upazila's of Belkuchi, Chauhali, Kazipur and Ullapara are moderate risk prone area. Figure 8 illustrates the IFRI in likelihood scale for the study area. And Figure 9 shows the comparison of three sub-indexes of hazard, vulnerability and resilience with integrated flood risk index (IFRI) for all of nine sub-districts in the study area.

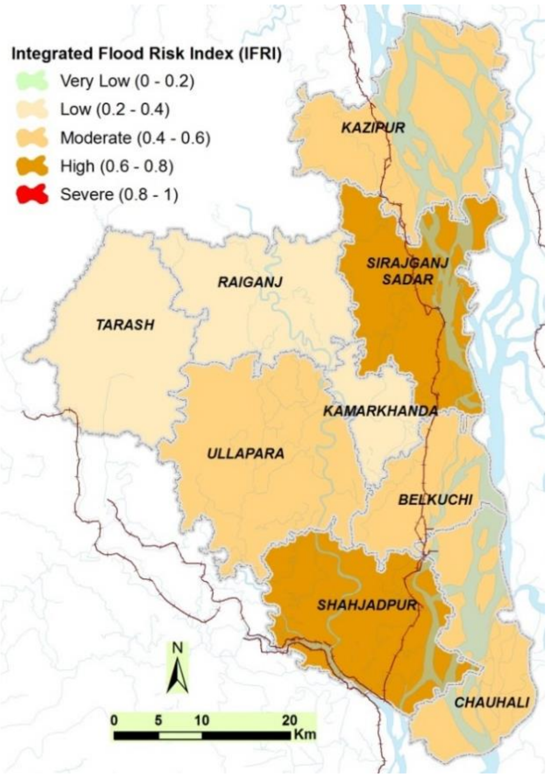


Fig. 8. Integrated Flood Risk Index (IFRI) for the study area.

### *3.4 Discussions on findings*

Upstream flow from trans-boundary river Brahmaputra-Jamuna and frequency of major embankment breaching are significant for flood hazard assessment. Again, socio-economic loss and damage where damaged house, damaged institution, affected people, fatalities, dead livestock, etc. creates major deviation of vulnerability among the sub-districts. And overall crop damage and maximum inundation are high for all sub-districts. Shahjadpur Upazila is severely vulnerable area due to socio-economic loss and damage in several sub-sectors shown in Figure 6. Thus, socio-economic impact in past flood is the major influencing indicators for the vulnerability of the study area. For resilience, no. of civil servants & volunteer per 1000 people, facility to the affected people in taking temporary shelter, government & NGO direct-indirect related to disaster management create deviation of coping capacity among the sub-districts. Flood forecasting system is same for the entire study area. Long range forecast may improve the resilience of the society by reducing economic impact.

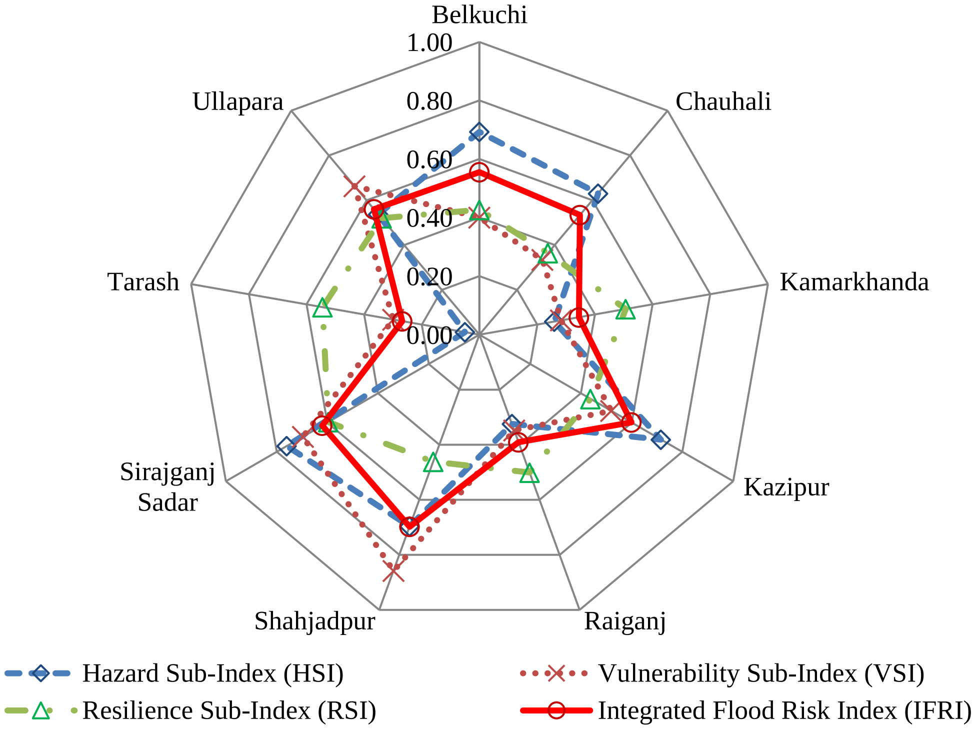


Fig. 9. Comparison of three sub-indexes with IFRI for nine sub-districts.

This index formulation will provide idea to the planners on those sectors to be improved to raise resilience of the study area such as establishing long range forecasting system, increasing literacy rate, flood proofing system by raising plinth level, creating employment opportunity to make self-dependency by economic growth & development, etc. which is clear with the comparison plotting of resilience indicators with sub-index in Figure 7. Computed integrated flood risk index (IFRI) shows two sub-districts of Shahjadpur and Sirajganj Sadar are highly risk prone area. Thus, planning should keep on emphasis on these two sub-districts to minimize impact to reduce vulnerability. Hazard is difficult to minimize as influencing driving force are not practiced yet. Government should concern about the policy development in integrated river basin management (IRBM) for the trans-boundary river Brahmaputra-Jamuna with neighboring countries such as Mekong river commission. Government should also concern about plan and application of flood zoning policy development to relieve pressures.

Major part of the study area has protected by flood defense structure on major river named Brahmaputra right embankment (BRE) where embankment breaching is one of major hazard indicators. Maintaining of the existing embankment will reduce impact of flood in Sirajganj Sadar Upazila. Shahjadpur Upazila is severely vulnerable area due to socio-economic impact. Planning should concern to raise resilience by flood proofing household, natural drainage improvement, flood shelter creation, long term forecast and warning system improvement by technological advancement, increasing public awareness & preparedness by increasing literacy rate, employment opportunity creation and technological advancement in communication sectors. Planners can introduce for other non-structural measures such as flood insurance to reduce impact by loss compensation.

## 4. Conclusion

The study is aimed with generic DPSIR framework development for flood risk management in Bangladesh which faces four different types of flood. DPSIR framework is preferable for risk identification, risk reduction and disaster management (Maxim et al., 2008). Another objective of this study is to assess risk as well as the applicability of the developed generic framework for a case study.

Generic DPSIR conceptual framework is generic in a sense of addressing all four different types of flood in Bangladesh such as riverine flood, rainfall induced flood, flash flood and cyclone & storm-surge flood. Wide range of variables and indicators has been integrated from several literature review, expert opinion through workshop and KII. All of these indicators are able to address several components such as drivers, pressures, states, impacts and responses in the framework. Development of this framework based on literature survey and expert opinion introduced different look for integrated flood risk management from conventional approaches. DPSIR framework is suitable for identification of policy & planning gap and indicate proper location of investing money for sustainable planning. Major achievement of this study is to develop a framework which can be applicable globally and regionally for different types of flood especial concern to the trans-boundary river basin.

Introducing a new index of Integrated Flood Risk Index (IFRI) is one of the achievements of this study, formulated on concept of risk definition which includes the drivers, pressures, state, and impact of flood along with responses measures translated by several indicators. IFRI is capable of addressing planning measures for improving the situation by identification of proper point of investment thus giving answer “Where and what should we do?”

Based on the result of integrated flood risk assessment for riverine flood in the case study area, Shahjadpur and Sirajganj Sadar Upazila are high risk prone area due to assessed high hazard and vulnerability of impeding drainage due to nearby confluence of periphery major river Brahmaputra & siltation of internal channel, prone to major embankment breaching, high annual growth rate of population, severe loss and damage in socio-economic sectors in past flood. Results in resilience assessment shows the corner of improvement of the situation in raising flood proofing household, increasing public consensus & awareness by increasing literacy rate, more employment opportunity and more involvement of organizations for awareness building as well as improvement of flood warning dissemination by more telecommunication facility. Overall non-structural measures should take importance to raise resilience to minimize impact of flood along with maintenance of existing structural intervention.

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