Assessment of GIS and Remote Sensing-Based Flood Vulnerability of Shilabati River Basin Using AHP Method

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Abstract:

Floods in the Shilabati River basin (3,019 km^2) are due to both climatological reasons and a combination of other factors related to the catchment. The existing flood risk forecasting system by the Indian Meteorological Department is devoid of a sound flood forecasting system though the downstream catchment is frequently affected by flood every alternative year. Therefore, in this study an attempt has been made to develop a workable forecasting system, considering remotely sensed data for analysis. Both the multi-criteria-based weightage method and the based approach are considered for finding the flood risk zones of the basin. Most of the agricultural watersheds in India are ungauged, having no records of the rainfall-runoff processes. This has led to the development of techniques for estimating surface runoff from ungauged basins. From the several methods for runoff estimation of ungauged watersheds, the curve number method (SCS-CN) is used here as a distributed model whose method along with its derivatives has been widely applied to ungauged watershed systems and has proved to be a rapid and accurate estimator of surface runoff. This method was originally developed by the US Department of Agriculture, Soil Conservation Service and documented in detail in the National Engineering Handbook, Hydrology (NEH-SCS). Landsat satellite images were used to obtain land cover information through the ERDAS Imagine 9.2 platform. The thematic layers like soil map, elevation map, rainfall map, and land cover map were created in the TNT mips platform. Curve numbers are assigned for different land cover and soil types. In the present study, the runoff varies from 3.91 mm to 64.83 mm of the study area. From the above-said method, we create an index-based vulnerability analysis that predicts the risk zones of the study area. Finally, five categories of flood risk were established (very low risk to very high flood risk zones; 0.009 to 0.088). However, it can give the flood risk probability in the basin very precise and cost-effective.

Keywords: Flood vulnerability, Shilabati river basin, Geospatial technique, AHP, Flood risk index

1.1 Introduction

Overflow of tidal or inland water by rapid accumulation of runoff in normally dry regions as partially or completely is a general temporary condition of Flooding (Jeb and Aggarwal, 2008). Floods are considered one of the most vulnerable natural hazards and are generally turned into disasters (Alcantara Ayala, 2002). Precipitation mainly occurs in the monsoon months (Viz. June to September). Floods cannot be controlled

(Adeoye et al., 2009; Nmeribeh, 2011). In this period rivers carry heavy sediment load from their catchment area exceed their carrying capacity and are responsible for causing flood and riverbank erosion. (Correia et al.,1990). However, in some time extreme events like cyclones, cyclonic circulation, and cloud bursts can also cause flash floods. Floods are preluded as natural disasters considering about one-third of all deaths, injuries, and damages (Askew, 1999). This calamity always results in some profit and loss in nature and for human civilization and creates a balance between them (Smith, 1996). Flood vulnerability is a combined adverse consequence that directly or indirectly affects the adjoining environment, human health, and economy as well as cultural heritages (Ologunorisa, 2001, 2004). It can also be possible by anthropogenic activities by changing practices of land use patterns. (Balábanova, 2008; Kwak, 2008; Kwak & Kondoh, 2008; Balabanova & Vassilev, 2010). Flood risk analysis is challenging because it includes complex phenomena like flood exposure, hazard, vulnerability, and susceptibility parameters (Siam et al. 2022). To construct the flood vulnerability, map some factors are considered for analysis like elevation, slope, land use and land cover, rainfall, soil types, drainage density, etc. by using the multi-criteria decision technique within the GIS platform (Alemu & Belachew, 2011; Balan, 2014; Feloni et al., 2019; Desalegn & Mulu, 2021). Flood risk assessment and mitigation require specific criteria like population, environment, economy, society, etc. Flood vulnerability analysis is efficiently done by giving weights of these assessing factors with the help of the AHP method (Romero et al., 2018; Cai et al., 2021). Those flood factors were developed in the GIS environment from remote sensing data and overlay this with multi-criteria techniques we strategically developed flood hazard and risk maps combined (Gashew & Legesse, 2011; Safaripour et al., 2012). So, GIS GIS-based flood hazard map is derived from different causative factors map and finally prepared by the application of multi-criteria decision analysis (MCDA) and analytical hierarchy process (AHP) (Danumah et al., 2016; Allofta & Opp, 2021).

The present research work is designed to pursue the issues in the context of ‘Risk’ measurement of the Shilabati river basin. To choose the indicators of flood vulnerability analysis we follow the existing literature (Karmakar et al., 2010). After that flood risk are estimated by evaluation, monitoring the study area and management are given to reduce risk. But to identify and estimate the risk proper monitoring and evaluation of the collected samples are needed for better management of these risk issues (Gerrard, 1995). Flood risk is determined by three components. i.e.

- Hazards magnitude and occurrences as threatening natural event
- Exposure of the present location involved in terms of physical or human
- Vulnerability is designated as the destruction forces that are absent from any kind of resistance force.

The river Shilabati also renowned as the Silai River starts from beside Chak Gopalpur Village in the Hura Block of Puruliya district and discharges its flow (207 Km.) from the rugged terrain of the Chotanagpur plateau in a southeastward direction and finally joins with Dwarakeswar River and afterward named as River Rupnarayan near Ghatal region and finally drained with the Hugli River. Its entire stretch is covering the plateau between 86^0 40′E to 87^0 40′ E and 22^0 30′ N to 23^0 30′N. It is considered a river that has some problems (Kale, 1997) as extensive and recurring flooding with short-term changes in its course namely in

Banka, Khirpai, and Ghatal area (Sinha et al., 2008; Sinha, 2009). Substantial tributaries of this river are Ketia, Donai, Joyponda, Tamal, Parang and Kubai. A canal from Mukutmanipur- Kangsabati dam meets as Kadam Deuli dam near Khatra. The entire region becomes reconciled to a few large floods in both upstream and downstream regions by the transgression of embankments due to heavy pour of monsoonal rain or tidal intrusion (Chowdhury, 1998; Biswas et al., 2015; Kar & Das, 2020; Chaudhury, 2021; Malik & Pal, 2020, 2021; Roy et. al., 2021). The major adverse effects of the hazard in the study area have been observed as inundation, rise of stream bed, depletion of river energy, and increase of sediment flux on the floodplains. In this paper, we are inquisitive about the geomorphological controls of floods and hydro-morphological characteristics which could play a crucial role in managing this long-term flood scenario of the entire basin (Khalequzzaman., 1994).

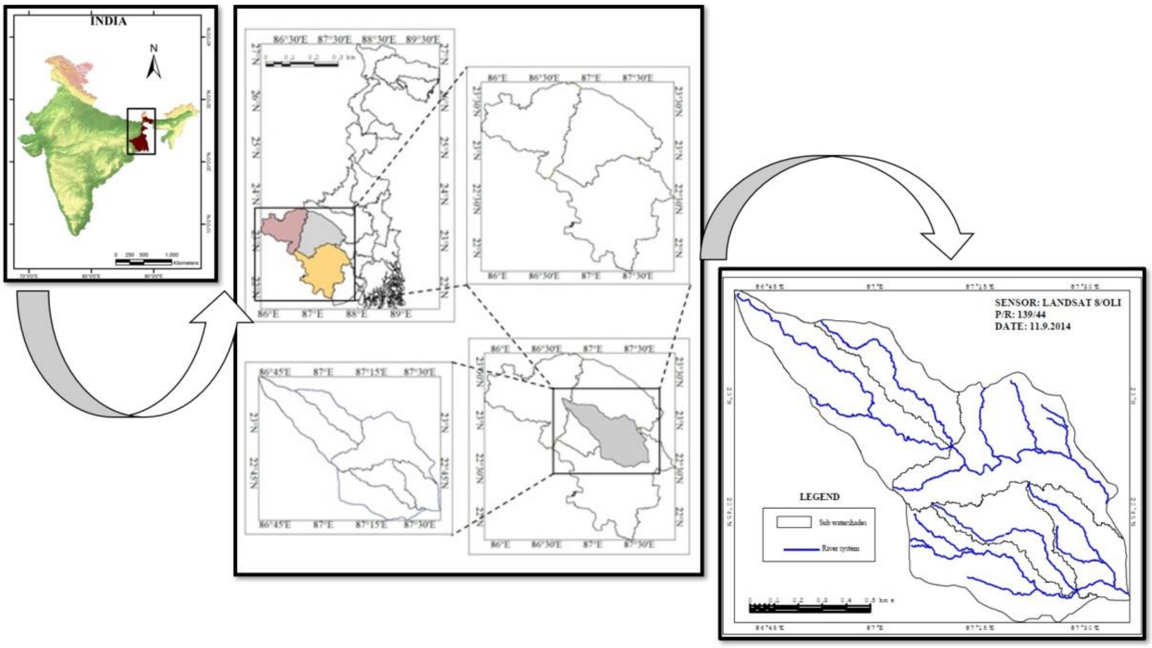

Figure 1: Location map of the study area

Table 1. Salient Features of the Shilabati River Basin

1. Total Drainage Area	4088 Sq. Km
2. Population Density	640 km^2
3. Water Resources	Above 50000 cusecs
4. Average Annual Rainfall	1535.50 Millimeter
5. Total Length of Main River	69 Km
6. Tributaries	Joyponda, Kubai, Ketia, Donai, Champayan

The main objective of this research is to assess flood risk by Remote Sensing and the GIS platform of the Shilabati basin based on watershed characteristics such as geomorphic, hydrologic, and agri-topographic. This research includes some important factors, that are-

a. Understand the relationship between geomorphic and climatic factors and the dynamicity of flooding in the Shilabati basin.

b. The dynamicity of flooding in the Shilabati basin depends on all the causative factors that should be examined by their relative importance.

c. Combine the entire database into a single framework for denoting/identifying floodplain risk zones in the entire basin.

1.1.1 Data used

Table 2.1. Lists of Satellite Data Used for Analysis

Data Type				Month/Year of acquisition
Satellite	Sensors	Path/Row	Spatial Resolution (mts)	
Landsat 8	OLI/ TIRS	139/44, 140/44	OLI-30, TIRS-100, PAN-15	14th April,2014

Table 2.2. Lists of Maps Used for Analysis

Data Type	Details	Data Source
Topographical Sheet	73 E/15	Survey Of India,1983
District Map with Blocks	West Bengal	www.mapsofindia.com (4th November, 2014)

1.2 Methodology

The following database is classified into sections or subsection as stated below-

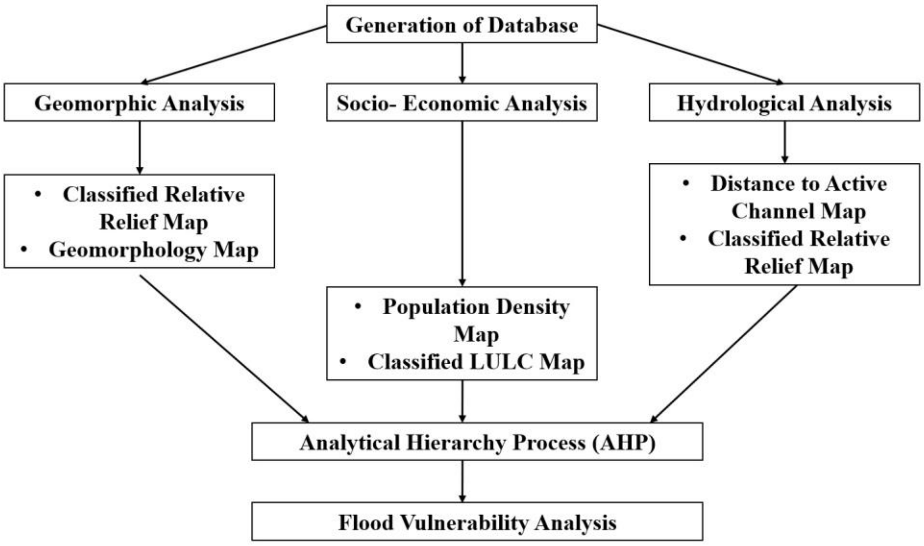

Figure 2: Workflow of Flood Vulnerability in RS & GIS Platform

1.2.1 The Analytic Hierarchy Process (AHP)

The analytical Hierarchy Process (AHP) method is applied to assemble the overall database in the GIS platform and hereafter based on a nine-point scale technique multi-criteria decision technique (MCDA) analysis is implied to get the final vulnerable zones (Saaty, 1980; Siddique et al., 1996). Sharma et.al. 2012, operate temporal satellite image-based data to evaluate flood risk zones. Zhang, 2003, presented a flood inundation model with a clear methodology and procedure to assess flood risk using GIS. In the AHP method first intensity of importance wise nine main classes and one reciprocal class are given absolute number (Table 3.1) and then after ‘decision factors’ and ‘sub-decision factors’ are given weight according to their relative importance and prepare a ‘decision hierarchy’ table (Table 3.2). Following that, each class has assigned relative importance weight (RIW) and whose sum is 1 for all classes. To give the result unit free each hierarchy component is converted by a normalized Eigen Vector decision matrix (Saaty, 1980). Ultimately, a Flood Risk Index (FRI) was calculated to identify risk zones.

Table 3.1. The Fundamental Scale of Absolute Number

Intensity of Importance	Definition	Explanation
1	Equal Importance	The activities contribute equally to the objective
2	Weak or Slight	
3	Moderate Importance	One activity started slightly over another activity for judgement and experience
4	Moderate Plus	
5	Strong Importance	One activity preluded strongly over another activity for judgement and experience
6	Strong Plus	
7	Very Strong or Demonstrated Importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, Very Strong	

9	Extreme Importance	One activity started highest possible order of affirmation over another activity for judgement and experience
Reciprocals of above	Non-zero numbers assigned to activity i when compared with activity j, then when compared with i, j has the reciprocal value	A reasonable assumption
1.1-1.9	If the activities are very close	The size of the small numbers would not be too noticeable when assign the best value by comparing activities. Though they can still indicate the activities with relative importance.

[1]saaty's (1980) scale of relative importance

AHP categorizes the tangible and intangible factors in a structured and systematic way which gives simple solutions to the decision-making problems. AHP is very apprehensive for those fields where risk and uncertainty can be found. The spatial analytical hierarchy process (SAHP), which is a combination of the AHP and GIS used to identify the flood risk zones and rank them according to preferences chosen by knowledge.

Estimation of Eigen Vectors estimated for each decision factor and their sub-factors using the following equation:

Estimated Eigen Vector of each element = $\sqrt[N]{a_1 * a_2 * a_3 * a_4 * a_N}$ … (i)

Dividing each Eigen Vector element by the sum of the Eigen Vector elements: normalized the eigen vector.

Normalization of Eigen Vector (RIW) = $\frac{\sqrt[N]{a_1 * a_2 * a_3 * a_4 * a_N}}{a_1 + a_2 + a_3 + a_4 + a_N}$ … (ii)

Where; a_1, a_2, a_3, a_4, a_N= values of the row elements, N= number of row elements

Aggregating RIWs at each level of the hierarchy using the following equation to obtain the FRI for each parameter

Flood Risk Index (FRI) = $\mathrm{FRI} = \sum_{i=1}^{N2} \mathrm{RIW}_i^2 * \mathrm{RIW}_{ij}^3$ …………… (iii)

Where; N_2= the number of level 2 decision factors, $RIW^2{}_i$= relative importance of level 2 decision factor I, and $RIW^3{}_{ij}$= relative importance of level 3 sub-factor j of level 2 decision factor I (Siddique et al., 1996).

1.2.2 RS/ GIS Integration of Different Sets of Databases

Out of eight databases (Population density, Distance to active channel, Relative relief, Land use and land cover, Geomorphic features, Rainfall, Road-river interaction density, and agricultural density), five layers are used to generate the flood risk index. Finally, the Matrix multiplication method determined the flood risk factor (Kafle et al. 2007). All the thematic layers are put forward to a common projection and datum for assimilation in a grid format. Arc GIS 10.1 version is mainly used for this spatial analysis and model building.

Table 3.2. Level 2 and 3 factors for Decision hierarchy and Relative Importance Weightage (RIW)

LEVEL-I	
Decision Factor	**RIW^2**
Population density	0.49
Distance to active channels	0.23
Relative relief	0.15
Land use and land cover	0.07
Geomorphic features	0.06
Total	**1.00**

LEVEL-II					
Decision Factor	**Sub-factors (cell attributes)**	**RIW^3**	**Decision Factor**	**Sub-factors (cell attributes)**	**RIW^3**
Population density(km/km^2)	$>0.0^{8}75$	0.77	Land use and land cover	River water	0.30
	$0.0^{9}6$ to $0.0^{8}75$	0.17		Cultivable wet	0.20
	$0.0^{9}3$ to $<0.0^{9}6$	0.06		Agricultural wetland	0.15
Total	**1.00**			Agricultural cropland	0.10
Distance to active channels (m)	0-500	0.40		Settlement	0.08
	501-1000	0.20		Open forest	0.06
	1001-2000	0.15		Dense forest	0.05
	2001-4000	0.13		Dry fallow land	0.03
	4001-6000	0.06		Rocky waste land	0.02

	6001-8000	0.04
	8001-14000	0.02
Total	**1.00**	
Relative relief (m)	164-172	0.35
	173-180	0.23
	181-188	0.15
	189-196	0.10
	197-204	0.07
	205-212	0.05
	213-220	0.03
	221-228	0.02
Total	**1.00**	

	Lateritic exposure	0.01
Total	**1.00**	
Geomorphic features	Active flood plain	0.50
	Valley fill deposits	0.25
	Moderate to low buried pediment with lateritic capping	0.10
	Deep to moderate buried pediment	0.07
	pediment	0.05
	Rolling plain	0.03
Total	**1.00**	

[1]Relative importance of weightage for decision factors (RIW) 2Relative importance of weightage for Sub-decision factors (RIW^2) 3Relative importance of weightage for Sub-decision cell attribute factors (RIW^3)

1.3 Results and Discussion:

1.3.1 Description of decision factors:

The use of automated models that incorporate river hydraulics, hydrology, and digital terrain of flood plains in the context of remote sensing and GIS are increasingly becoming the common and effective methods for the delineation of flood-vulnerable zones. In this study, we select some important data sets, that have a strong relation to flood hazards highlighting -

1.3.1.1 Population density: Population and its resources are the prime concern in reducing the flood risk. To quantify the economic assets under the potential threat block population density was chosen as an important variable. For this map, we have used the 2011 census data of West Bengal, India, and processed under the spatial data (2014 image). Then the Algorithm uses spatial data and imagery technology coupled with the census data within the administrative boundary, which had to be modified to match the data condition with the geographic extent of the individual blocks. Thus, it has more impact on the study of flood risk assessment.

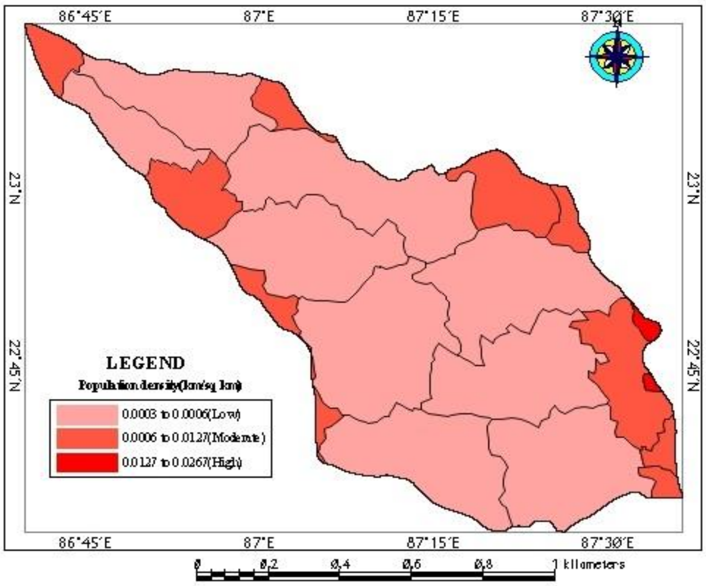

Figure 3: Population density map of the study area

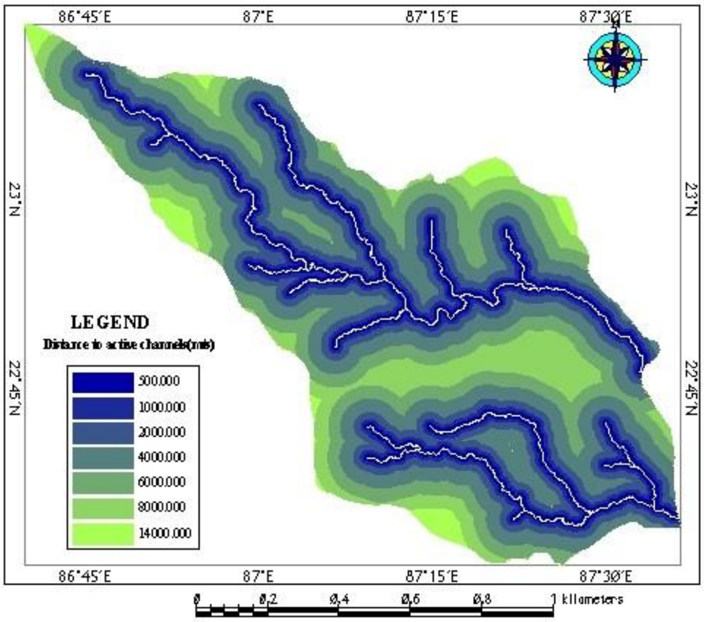

Figure 4: Distance to active channel map of the study area

1.3.1.2 Distance to the active channel: For the peak flow of the river active channels are the main bypassing. Thus, these channels were buffered by considering the distance up to the basin boundary as the damage to resources is significant in the whole basin area. This will also help to give an evacuation scheme for vulnerable people. The distance to the first buffer is 500 m and the highest buffer is 14000m. Based on the classes we can easily derive the more to less vulnerable zones for flood risk.

1.3.1.3 Relative relief: Relative relief is also affecting the flow and inundation of the area. For example, low relative relief decreases the runoff, causing high infiltration. Thus, the low relative relief areas will inundate first as compared to the high relative relief area during flooding. Those areas with steep slopes show high peak discharge as compared to the relative relief area and cause the depletion of the storage in the upstream areas. The relative relief governs the geomorphology of the area. High relative relief shows the terrain comprises hard rocks, the pediment zone comprises moderate relative relief and the active floodplain area has low relative relief. Hence, the relative relief decides the river behavior along with the geomorphology and directly contributes to the flood hazard.

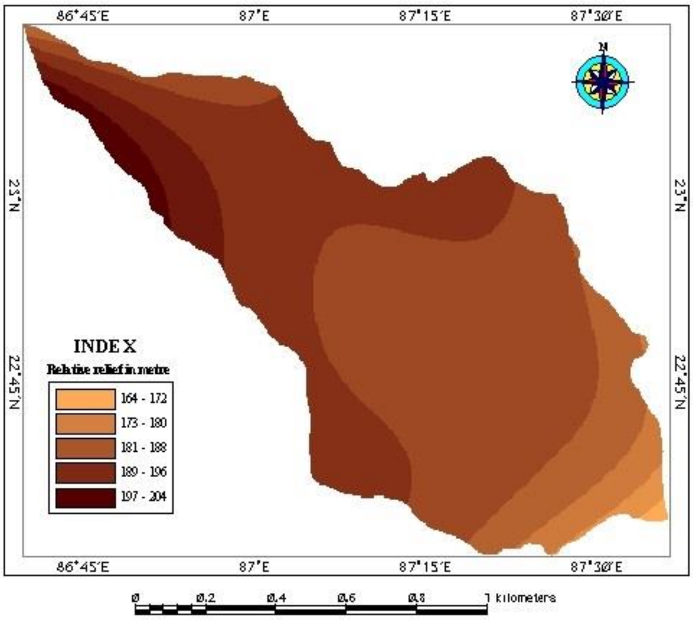

Figure 5: Relative relief map of Shilabati River basin

1.3.1.4 Land use and land cover: The Shilabati basin has experienced a large population growth in the last decades. The situation affects the land use planning and intensifies the flood-induced problems in the study area. In addition, there has been a change in land use, from forest to grassland or agricultural areas, especially in the upper basin. It has led to an increase in peak discharges, erosion, and the flood situation.

1.3.1.5 Geomorphology: Karagiozi et al. (2011) mapped the hydrological models into a GIS environment (Arc Hydro model) for flood hazard assessment. considering the geomorphologic characteristics of the study area the location of the main flood-affected blocks like Ghatal located at the lower part of the basin, has contributed frequently flood problems. The main other affected blocks are built just at the foot slopes, where there is an abrupt change in the slope angle. Therefore, the rivers come with a very high velocity from the upper plateau. The situation is aggravated by the presence of a very high radius of curvature of the river channels and a very high sediment load. Therefore, there is an interesting equilibrium nature between the morphology of the river bed and the behavior of the river during peak events (Garcia, 1990). The major rivers come from mountains formed by very weathered lavas, which are very impervious. For this reason, the infiltration in these plateaus is quite reduced and an important amount of rainfall is drained downslope through small water courses.

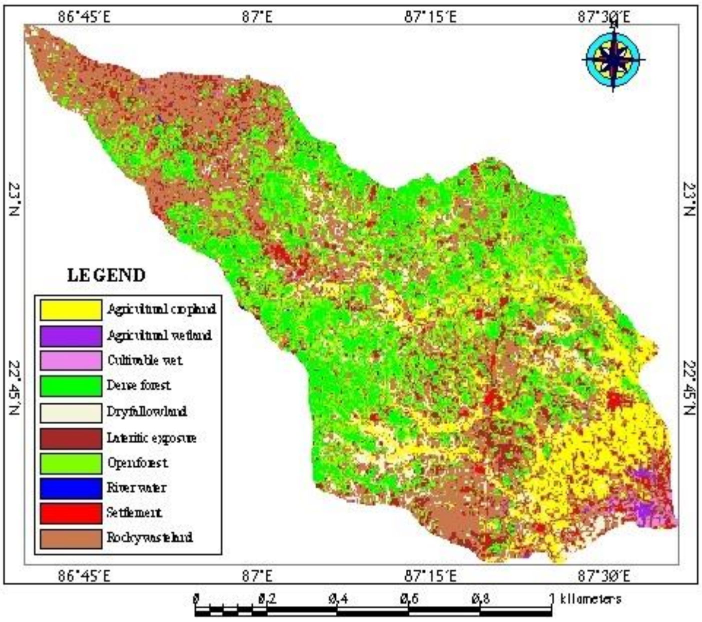

Figure 6: Land use and Land cover map of the study area

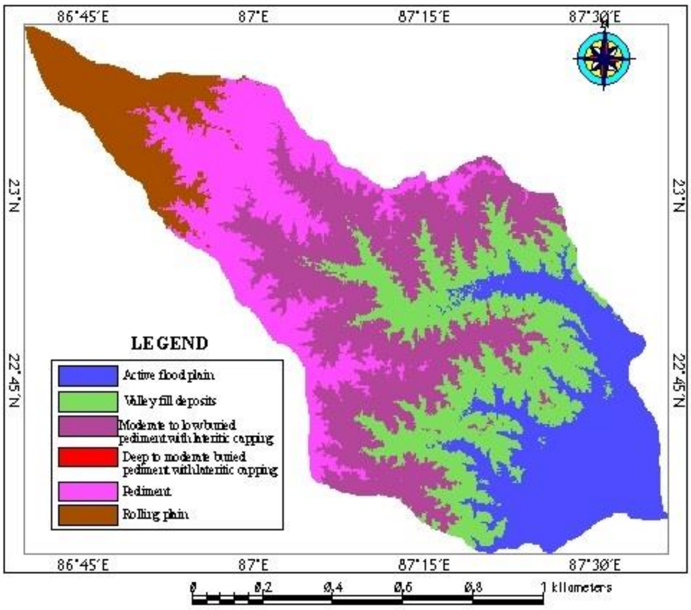

Figure 7: Geomorphology map of Shilabati River basin

Six major geomorphologic units have been identified in the study area using photo interpretation and fieldwork observations. They described as follows-

a. **Active flood plain:** A flood plain is a space for the river with different functionality. An active floodplain is regularly flooded on a periodic basis or defined as an area on either side of a river. A typical hydrological criterion to designate an active floodplain in a given reach is a 2.33-year return period of the flood.

b. **Valley fill deposits:** Unconsolidated sedimentary deposit, i.e., fills or partly fills a valley It is mainly deposited in the river bed but it although seen in the bank slope. It is produced by lateral erosion associated with bedrock erosion surfaces that remain unidentified due to commonly veneered alluvium.

c. **Moderate to low buried pediments with lateritic capping**: Lithologically, it consists of weathered and unconsolidated materials being composed of mainly sand mixed silt and clay although with local variation in terms of both proportion and depth. The slow-buried reddish is generally characterized by very thin soil covers and exposed patterns of rocks. They were marked by light red to mixed white tones on imagery, which denotes the presence of lateritic capping.

d. **Deep to moderate to low buried pediments with lateritic capping:** The moderate buried pediment constitutes relatively more depth of soil cover than shallow and the deep buried pediment denotes by thick soil cover.

e. **Pediment:** Pediment is gently sloping; rock floored or bedrock surfaces are rounded at the base of a mountain cliff. Pediments with thin soil cover have shown scanty vegetation in places while some of them have no vegetation due to lack of soil veneers. These are mostly wasteland covered with rock fragments and are well defined on the imagery by their association with hills, lower relative relief, fine to coarse texture, and high to light grey tone.

f. **Rolling plain:** Gently rolling region containing a range of lands bifurcated with rivers running from west to east. The Chotanagpur plateau on the northwest and the high plains on the southeast border it. Soils vary from fine sand to clays and clay loams.

1.3.2 Synthesis of model results:

Different datasets have been prepared from different sources and by the amalgamation of this on the remote sensing environment, we vividly understood the flood risk probability as well as its causative factors, which had dominated in the study area. From the above-mentioned five decision factors and sub-factors, we create a vulnerability analysis that predicts the risk zones of the study area.

Table 4.1. The result of parameters for the flood risk analysis

Point	Decision Factor	RI W^2	RIW ^{3}	FRI	NFRI	Point	Decision Factor	RI W^2	RI W^3	FRI	NFRI
1	i	0.49	0.06	0.0294	0.00988	15	i	0.49	0.06	0.0294	0.01952
	ii	0.23	0.06	0.0138			ii	0.23	0.15	0.0345	
	iii	0.15	0.02	0.003			iii	0.15	0.02	0.003	
	iv	0.07	0.02	0.0014			iv	0.07	0.01	0.0007	
	v	0.06	0.03	0.0018			v	0.06	0.5	0.03	
2	i	0.49	0.17	0.0833	0.02014	16	i	0.49	0.06	0.0294	0.01564
	ii	0.23	0.02	0.0046			ii	0.23	0.13	0.0299	

	iii	0.15	0.05	0.0075			iii	0.15	0.07	0.0105	
	iv	0.07	0.05	0.0035			iv	0.07	0.06	0.0042	
	v	0.06	0.03	0.0018			v	0.06	0.07	0.0042	
3	i	0.49	0.06	0.0294	0.02688	17	i	0.49	0.06	0.0294	0.02258
	ii	0.23	0.4	0.092			ii	0.23	0.2	0.046	
	iii	0.15	0.07	0.0105			iii	0.15	0.07	0.0105	
	iv	0.07	0.01	0.0007			iv	0.07	0.3	0.021	
	v	0.06	0.03	0.0018			v	0.06	0.1	0.006	
4	i	0.49	0.06	0.0294	0.03102	18	i	0.49	0.06	0.0294	0.01094
	ii	0.23	0.4	0.092			ii	0.23	0.04	0.0092	
	iii	0.15	0.07	0.0105			iii	0.15	0.05	0.0075	
	iv	0.07	0.01	0.0007			iv	0.07	0.08	0.0056	
	v	0.06	0.03	0.0018			v	0.06	0.05	0.003	
5	i	0.49	0.06	0.0294	0.03118	19	i	0.49	0.06	0.0294	0.01866
	ii	0.23	0.4	0.092			ii	0.23	0.2	0.046	
	iii	0.15	0.15	0.0225			iii	0.15	0.07	0.0105	
	iv	0.07	0.1	0.007			iv	0.07	0.08	0.0056	
	v	0.06	0.07	0.0042			v	0.06	0.03	0.0018	
6	i	0.49	0.06	0.0294	0.02308	20	i	0.49	0.06	0.0294	0.03982
	ii	0.23	0.4	0.092			ii	0.23	0.4	0.092	
	iii	0.15	0.05	0.0075			iii	0.15	0.35	0.0525	
	iv	0.07	0.3	0.021			iv	0.07	0.3	0.021	
	v	0.06	0.1	0.006			v	0.06	0.07	0.0042	
7	i	0.49	0.06	0.0294	0.01516	21	i	0.49	0.77	0.3773	0.08664
	ii	0.23	0.15	0.0345			ii	0.23	0.13	0.0299	
	iii	0.15	0.23	0.0345			iii	0.15	0.05	0.0075	
	iv	0.07	0.2	0.014			iv	0.07	0.05	0.003	

										5	
	v	0.06	0.05	0.003			v	0.06	0.25	0.015	
8	i	0.49	0.06	0.0294	0.01652	22	i	0.49	0.77	0.3773	0.08664
	ii	0.23	0.04	0.0092			ii	0.23	0.13	0.0299	
	iii	0.15	0.02	0.003			iii	0.15	0.05	0.0075	
	iv	0.07	0.06	0.0042			iv	0.07	0.05	0.0035	
	v	0.06	0.5	0.03			v	0.06	0.25	0.015	
9	i	0.49	0.06	0.0294	0.02098	23	i	0.49	0.06	0.0294	0.01292
	ii	0.23	0.04	0.0092			ii	0.23	0.04	0.0092	
	iii	0.15	0.07	0.0105			iii	0.15	0.05	0.0075	
	iv	0.07	0.05	0.0035			iv	0.07	0.05	0.0035	
	v	0.06	0.5	0.03			v	0.06	0.25	0.015	
10	i	0.49	0.17	0.0833	0.0163	24	i	0.49	0.06	0.0294	0.01564
	ii	0.23	0.02	0.0046			ii	0.23	0.04	0.0092	
	iii	0.15	0.07	0.0105			iii	0.15	0.05	0.0075	
	iv	0.07	0.05	0.0035			iv	0.07	0.03	0.0021	
	v	0.06	0.05	0.003			v	0.06	0.5	0.03	
11	i	0.49	0.07	0.0343	0.01754	25	i	0.49	0.77	0.3773	0.08024
	ii	0.23	0.04	0.0092			ii	0.23	0.04	0.0092	
	iii	0.15	0.03	0.0045			iii	0.15	0.05	0.0075	
	iv	0.07	0.05	0.0035			iv	0.07	0.06	0.0042	
	v	0.06	0.5	0.03			v	0.06	0.05	0.003	
12	i	0.49	0.06	0.0294	0.02378	26	i	0.49	0.17	0.0833	0.022
	ii	0.23	0.15	0.0345			ii	0.23	0.04	0.0092	
	iii	0.15	0.1	0.015			iii	0.15	0.05	0.0075	
	iv	0.07	0.1	0.007			iv	0.07	0.1	0.007	
	v	0.06	0.03	0.0018			v	0.06	0.05	0.003	
13	i	0.49	0.06	0.0294	0.01536	27	i	0.49	0.06	0.0294	0.03468

	ii	**0.23**	**0.2**	**0.046**			**ii**	**0.23**	**0.4**	**0.092**	
	iii	**0.15**	**0.05**	**0.0075**			**iii**	**0.15**	**0.1**	**0.015**	
	iv	**0.07**	**0.3**	**0.021**			**iv**	**0.07**	**0.1**	**0.007**	
	v	**0.06**	**0.25**	**0.015**			**v**	**0.06**	**0.5**	**0.03**	
14	**i**	**0.49**	**0.06**	**0.0294**	**0.02272**	**28**	**i**	**0.49**	**0.06**	**0.0294**	**0.02376**
	ii	**0.23**	**0.04**	**0.0092**			**ii**	**0.23**	**0.13**	**0.0299**	
	iii	**0.15**	**0.05**	**0.0075**			**iii**	**0.15**	**0.15**	**0.0225**	
	iv	**0.07**	**0.01**	**0.0007**			**iv**	**0.07**	**0.1**	**0.007**	
	v	**0.06**	**0.5**	**0.03**			**v**	**0.06**	**0.5**	**0.03**	

[1] calculation of flood risk index multiplying RIW[2] and RIW[3]

[2] calculation of normalized flood risk index is an average value of the sum of FRI

Table 4.2. Normalized Flood Risk Index

Ranges of NFRI	**Normalized Flood Risk Index (NFRI)**	**Associated Blocks**
0.009-0.017	Very Low Risk	Parang
0.017-0.020	Low Risk	Goaltore, Tamal
0.020-0.023	Moderate Risk	Kubai, Ketia
0.023-0.028	High Risk	Salboni
0.028-0.088	Very High Risk	Taldangra, Garhbetra, Ghatal

[1] assciation of flood zones with intervals

This index was obtained after an analysis of the flood hazard in the study area. A different degree of weightage is assigned to each decision factor based on its criteria. Finally, five categories of flood risk were established:

a) **Very High to High Flood Risk Zone:** This is mostly located in the middle part of the basin, which is frequently flooded by the main river and its tributaries. This unit has very low relative relief and it is formed by permeable materials and the inter-fluvial areas of lower parts have existed with very critical conditions like Ghatal.

b) **Moderate Flood Risk Zone:** This is located farther away from the main rivers and usually causes floods with less permeable surfaces. As the rivers of this sector reduce their valleys considerably, the probability of the flood increases.

c) **Low Flood Risk Zone:** The pediment zones are mostly of the west, north, and eastern parts of the study area included within this category. These are very moderate steep slopes and far away from major active rivers. There is no report of historical flooding also.

d) **Very Low Flood Risk Zone:** This is mainly comprised of the upper part of the basin or rolling plain region and considered as areas without flood hazards. Here the relative relief is optimum thus from this area concentration of runoff water is flows towards the lower basin and responsible for flood.

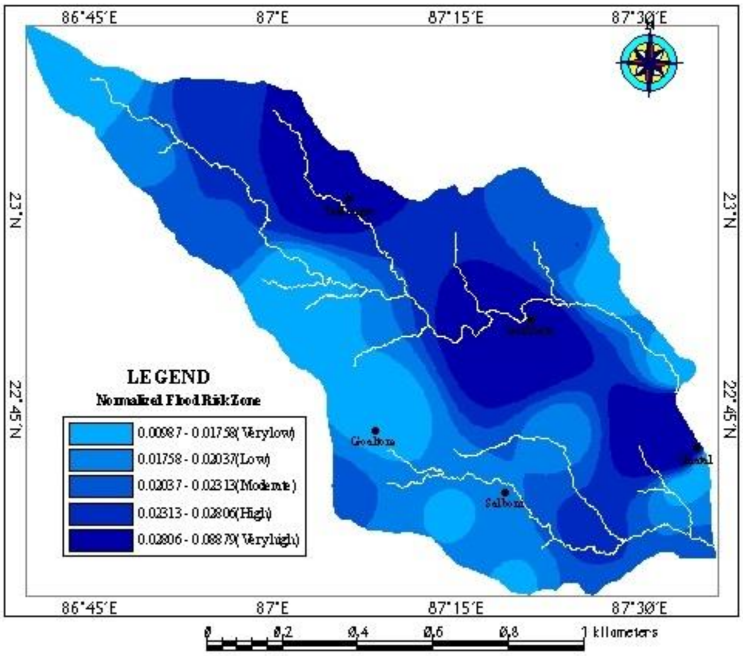

Figure 8: Normalized flood risk index map of the study area

1.4 Conclusion:

After the development of this detailed study, it would be possible to conclude the following facts:

I) Remote sensing-based mapping approach of the study area for flood risk analysis is a cost-effective way and applicable to other severe flood-prone areas.

II) The use of the AHP technique for flood risk monitoring is also very crucial and precise

III) To know the flood risk properly only the analysis of hydrological phenomenon is wrong though the integrated spatial responses of the basin are more precision factor.

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