Flood Susceptibility Assessment of Chandpur Sadar Upazila Using Analytical Hierarchy Process and Frequency Ratio Model

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Abstract:
Flood susceptibility is a critical aspect of natural hazard assessment and disaster risk reduction. The objective of this study finds out flood risk zone of Chandpur sadar upazila using the Flood frequency ratio (FFR) and Analytical hierarchy process (AHP). The article explores the complex idea of flood susceptibility, focusing on analytical techniques used. The integration of twelve spatial data layers, such as Sediment Transport Index (STI), elevation, Topographic Wetness Index (TWI), slope, aspect, Land Use Land Cover (LULC), soil type, rainfall patterns, Normalize Difference Vegetation Index (NDVI), drainage density and distance from the river, is required for the assessment of flood vulnerability. A flood inventory map was buildup and using these methods, two vulnerability map was created, it was discovered that 60% & 48% of Chandpur's territory is categorized by very high to high-risk zone. Flood has dangerous effect on livelihood. I was hoped that it will be a helpful study for researcher and people of this upazila will be benefited.

Keywords: Flood; GIS; Susceptibility*;* Analytical hierarchy process; Flood frequency

1. Introduction:

One of the most dangerous hydro-meteorological hazards in the world is flooding. Frequently, flooding causes severe human casualties as well as socioeconomic destruction. According to data from the United Nations Office for Catastrophe Risk Reduction (UNISDR), there were approximately 150,061 flood events globally happened from 1995 to 2015 and around 157,000 mortalities connected to floods, which represented 11.1% of all catastrophe losses. (Anand & Pradhan, 2023). According to numerous investigations, global floods cause harm to almost 200 million people each year. (Abu Reza Md et al., 2020).

Bangladesh is the extreme vulnerable country for natural disasters among the worldwide. Floods in Bangladesh are mostly caused by flat terrain, shallow riverbeds, intense monsoonal rainfall, and massive sediment release (Rahman et al., 2019). According to Statista, an index was developed between 0 and 10, greater the score and the higher the risk, established on the projected amount of individual occurrence of floods annually. Bangladesh receives a higher score (10) indicating a high risk of flood, built on exposure and demographic data from 2015 to 2021 (Statista, 2023). The three-river basin Ganges, Brahmaputra, and Meghna are located downstream of Bangladesh. These basins have a combined catchment area is 1.72 million km2, roughly 93% of which is located outside Bangladeshi territory. Only 7.5% of these basins

are located in Bangladesh; the continuing 92.5% are in Nepal, China, Bhutan, and India. (Mirza, 1997). Among the overall flood, major flood occurred at1988, 1998, 2004, 2007, and 2014 year in Bangladesh (Hossain & Adhikary, 2022). According to the Bangladesh Department of Disaster Management (2014), every year 18% of the country gets flooded on average. Typically, during the monsoon season, approximately 20-25% of the country is inundated. At least eight extreme flood events that have affected 50% of the land area have occurred in the past fifty years. Up to 65% of the nation was submerged in the biggest flood ever recorded, which occurred in 1998. The IPCC AR4 (2007) also reported that significant and frequent floods were detected in 2002, 2003, and 2004. Approximately $175 million is lost to flooding in a typical year, but in severe cases—like in 1998, when almost two-thirds of the nation was submerged—damage can reach two billion dollars. (Climate: Observations, projections and impacts: Bangladesh)
Flood vulnerability mapping is a crucial instrument for mitigating and preventing upcoming flood situations because it identifies the maximum risk area constructed on consistent data, enabling societies and administration agencies to exactly appliance strategies besides analyze flood anticipation methods. Several studies have prepared flood susceptibility mapping during the past few decades using various techniques. These techniques include frequency ratio techniques and the integrated Analytical Hierarchy Process. (Addis, 2023)

2. Materials and method

2.1. Description of Study area

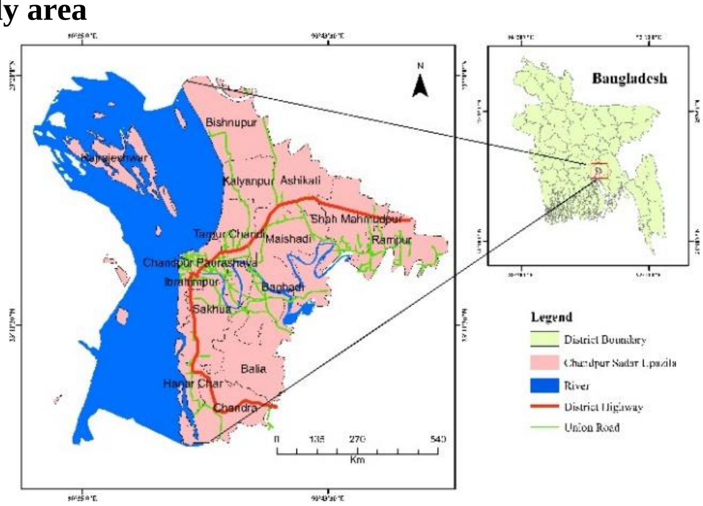

Figure 1: Study Area

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Chandpur Sadar Upazila is situated in the Chandpur District of Bangladesh (Figure 2). This upazila is prone to flooding, particularly during the monsoon season. This area is crisscrossed by numerous rivers and their tributaries, including the Meghna, Dakatia, and Kachua rivers, which often overflow their banks during heavy rains, causing flooding in the surrounding areas. With a 308.78 sq km area, Chandpur Sadar Upazila is situated between 23°07' and 23°20' north latitude and 90°34' and 90°48' east longitude. This upazila broderd by north by the upazilas of Matlab Dakshin and Matlab Uttar, on the south by the upazilas of Haimchar and Faridganj, on the east by the upazilas of Hajiganj and Faridganj, and on the west by the upazilas of Bhedarganj (Shariatpur) and Gosairhat (Banglapedia, 2022). Bangladesh Agro-Meterological Information Service (BAMIS), conducted a study that this Upazila is classified as "Riverine flood-prone" (Figure 1) and this area gets flooding from both river overflow and rainfall during the monsoon season, which can cause harm to crops, residences, and infrastructure. Additionally, Chandpur Sadar Upazila's geography is primarily flat, which intensified it more vulnerable to flooding. Flooding is more likely to happen in low-lying locations, especially those area is close to rivers.

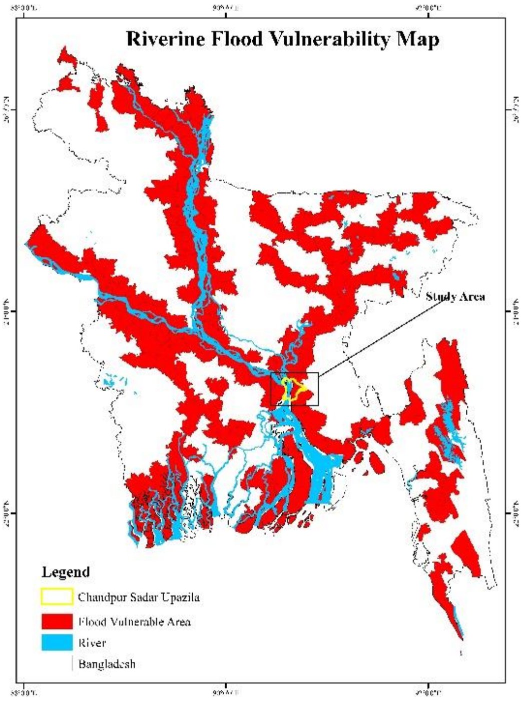


Figure 2: Flood vulnerability Map

Here we see that now a days various models are applied to find out susceptibility hazard in a definite area but in order to analyze flood vulnerability in the Chandpur District, this study applied AHP and FRM model using GIS-based mapping.

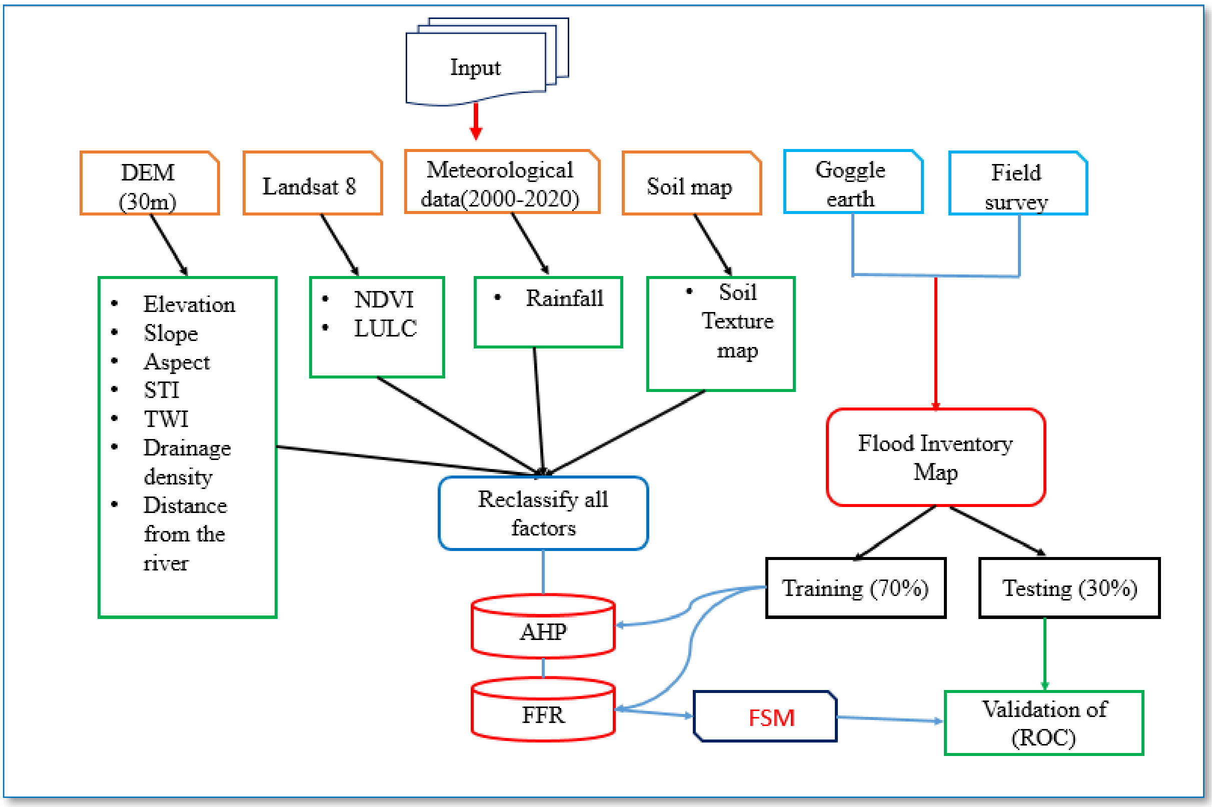
2.2: Data source and Methodology

The persistence of primary data collection, a scientific questionnaire was organized and a field survey is conducted. Secondary were used to realize the flood pattern of the selected area and evaluate the modification process. Secondary data were collected from distributed reports, papers and books along with documents of related organizations. To prepare thematic map of the study area like elevation, Curvature, slope, TWI, STI, drainage density, distance from the river maps were Using DEM data and NDVI, LULC map using Landsat 8 image with 30m resolution. Information about rainfall gathered from the Bangladesh Meteorological Department. All the map layers are integrated in Arc map 10.8. Using AHP and FFR, a flood susceptibility map was produced. Subsequently, examine the map's build-up roc curve.

SL No	Type of Conditioning factors	Description	Source
1	Elevation, Slope, Aspect, Curvature, TWI, STI, Drainage Density, Distance from the River	Raster format	SRTM DEM (30 m), USGS
2	Rainfall (mm/day)	Vector format	BMD (2000-2020)
3	Soil data		USGS (DOMSOI)
4	NDVI, LULC	Raster format	LANDSAT-8 image (30 m), USGS
5	Flood Inventory Mapping		Goggle earth and Field Survey

Table 1: Data source

Figure 3: Workflow of Methodology



2.2.1 Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) provides an organized approach to assess and rank different elements that are essential to understanding and reducing flood hazards in flood analysis. AHP makes it easier to compare several factors in an organized manner, including population density, infrastructure resilience, geographic vulnerability, emergency response capability, and environmental effect. Through the hierarchical leveling of the complex decision-making process, AHP allows stakeholders to weight various elements according to their relative weight. Broader issues like regional infrastructure development and governmental regulations may be considered at a higher level, while elements like land usage patterns, historical flood data, and proximity to water bodies may be evaluated at the local level. AHP helps to quantify subjective assessments and preferences through pairwise comparisons and mathematical calculations. This helps to identify the best flood management techniques and resource allocation to reduce vulnerabilities and increase community resilience against flooding events. The weight vector is determined by averaging each row of the normalized matrix. The weight vector and comparison matrix are multiplied to get the:

[AWi]=[A][Wi] , The maximum eigenvalue(λmax) is:

The weight vector is W, the pairwise comparison matrix is A, and the criteria number is n in these equations. The top right eigenvector system is the name given to this method for figuring out the weight vector of a pairwise comparison matrix (EM). Given that the decision-maker might not provide paired comparisons that are obviously harmonious, it is advised that pairwise comparison matrix A have a reasonable consistency, which is verifiable by the consistency rate (CR). (Aydin & Sevgi Birincioğlu, 2022)

$$CI = \frac{\lambda\,(\max - n)\,(n - 1)}{(\lambda\max - n)(n - 1)} \qquad \text{(Eq: 1)}$$

$$CR = CI/\,RI \qquad \text{(Eq; 2)}$$

The comparisons are considered consistent if the coefficient of consistency (CR) remains within an acceptable range, usually less than 0.10. (Subramanian & Ramakrishnan, 2012)

2.2.2 Flood frequency analysis:

The flood frequency ratio is a crucial statistic in flood analysis that's used to evaluate the probability and frequency of flooding episodes over a specific period of time. The magnitude of one flood occurrence is compared to the magnitude of previous floods that have happened in the past to determine this ratio. Hydrologists and analysts determine the flood frequency ratio by examining past flood data in order to determine how common or uncommon a particular flood occurrence is. The observed flood, for example, has a magnitude 1.5 times larger than the usual or expected magnitude for that particular recurrence interval (e.g., a 100-year flood) when the flood frequency ratio is 1.5. In flood-prone areas, this ratio helps determine the likelihood that a flood of a specific size will occur within a given time frame, which is important information for risk reduction, infrastructure construction, and urban planning. Knowing the flood frequency ratio helps stakeholders and decision-makers make well-informed decisions about managing floodplains, zoning for land use, and designing robust infrastructure to lessen the effects of possible future flood events.

$$FR = \frac{a}{b} = \frac{\frac{Nfopix}{Ntfopix}}{\frac{Ncpix}{Ntcpix}}$$

(Eq: 3)

Where Ncpix is an area of the category inside the study area, Ntcpix is the total pixel area within the complete study area (b), FR is the frequency ratio, and Nfopix is a flood pixel area. Ntfopix is the total area (a). The FR for each causative factor class in the current exploration work was determined using an equation, and the outcomes are summarized. The FR of each factor type or class is added as shown in equation to produce the FSI.

$$FSI = \sum_{i=1}^{n} FRiXi$$

(Eq: 4)

The terms flood susceptibility index (FSI), number of flood factors (n), flood factor (Xi), and frequency ratio (FRi) of each type or class of flood factors are used. Each factor class's frequency rate value is represented by FR. (Wubalem et al., n.d. 2021)

2.3: Flood inventory mapping

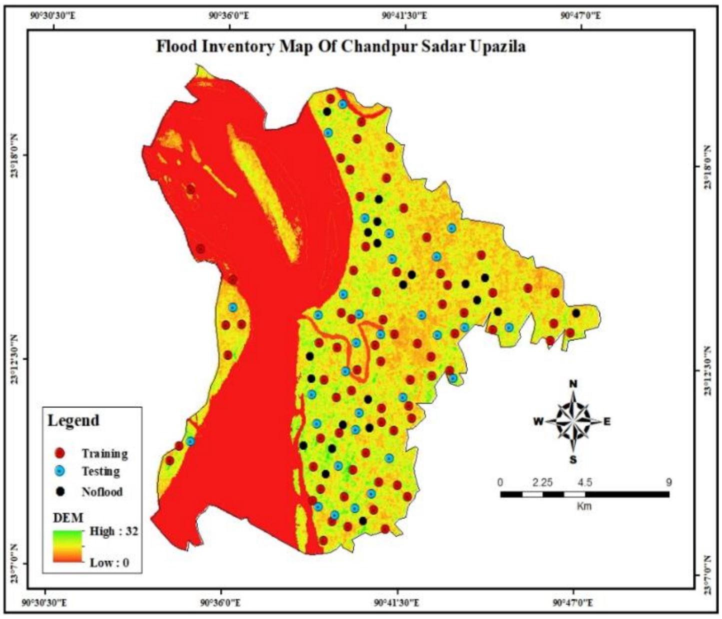


Figure 4: Flood inventory Mapping

The main step in producing a flood susceptibility map is to prepare a flood inventory map for the study area (Abu Reza Md et al., 2020). Analyzing data of previous flood events is crucial for assessing the flood risk in a region (Manandhar, 2010). As a result, an inventory map is thought to be the most important feature for predicting the probability of future disasters; such a map can reflect one or several occurrences in a particular area (Tien Buiet al. 2012). The creation of flood susceptibility models is made possible by training data that is derived from historical flood records and environmental variables. These models, which frequently rely on machine learning or statistical methods, are trained by GIS to understand the complex correlations between environmental parameters and previous flood occurrences. Testing data are essential for assessing the model's accuracy and generalizability because they are different from the training set and represent various time periods or geographical regions. The model's precision in predicting flood-prone places can be evaluated by exposing it to unknown circumstances, confirming that it operates successfully outside the bounds of its training data. 101 flood sites from the Chandpur sadar upazila's 308.78 sq km were gathered for this report's production of the flood inventory plan. As a result, the flood locations were verified using Google Earth, fieldwork, local resident observations, and historical data sources. In order to train and test flood-susceptible models, the 101 acquired flood points were split into 70% (71 points) and 30% (30 points) categories by a geo-statistical analyst using ArcGIS, along with 20 non-flooding points. However, it is well known that flood susceptibility mapping uses a binary classification in which the flood inventory is divided into two sets, for example flood points and non-flood points. The "flood points" were the actual locations where flooding had been seen frequently, whereas the "non-flood points" were the locations where flooding had not been seen recently. (Abu Reza Md et al, 2020)

2.4: Flood conditioning factors

Twelve flood- conditioning features were chosen for analyze the current study area. Factors are elevation, slope, topographic wetness index, Sediment transport index, drainage density, land use and land cover, distance to the river, aspect, soil type, and rainfall. For modeling flood studies, topographic parameters are essential since they both directly and indirectly affect the hydrological characteristics of an area (Abu Reza Md et al., 2020).

Elevation: Elevation is one of the most forceful factors ((Dodangeh et al., 2020). On the other hand, flooding is related to altitude. Higher elevations have a lower probability of flooding, and vice versa (M Amen et al., 2023). Here, I am using SRTM DEM data 30m resolution and highest elevation 32 meter and lowest elevation is 0. Further I am divided three classes from (0 to 15m). After the reclassify count number is highest in (0-3) m which indicate the area is highly vulnerable for flood.

Aspect: The pathways of actual slopes face are determined by aspect. Paths with a unique aspect that are categorized depending on slope angle. Aspect influences the directions how floodwaters flow and maintains soil moisture. Thus, the aspect is indirectly causing the floods. A shaded slope location with high soil humidity and significant runoff will be used as an example.

Slope: The likelihood of water stagnation is reduced, infiltration is reduced, and flow velocity is increased with increasing slope angle. There will be a greater chance of flooding in lower-lying region and flat areas like the Chandpur sadar upazila. Figure: 6 (c), shows that the blue color zone has a lower slope area with upper chance of occur flooding whereas the red color zone has a greater slope area with a lower chance of occur flooding.

Curvature: The dynamics of floods can be significantly and quietly affected by the curvature of the land's surface. During rainstorm events, a landscape's topographic relief or curvature affects the flow and collection of water. Water tends to accumulate and form natural basins in places with concave or bowl-shaped terrain, which can make flooding worse, especially in the lack of sufficient drainage. On the other hand, water is more likely to flow quickly downhill in areas with convex or sloping topography, which could result in flash floods as it builds up in valleys. Additionally, the pace and direction of floodwaters can be impacted by the curvature of riverbanks and channels, affecting where and how flooding occurs.

Topographic Wetness Index: An essential tool for understanding and controlling flood dynamics within a geographic environment is the Topographic Wetness Index (TWI). In order to assess the wetness or water saturation of the land, TWI uses topographic parameters including slope, elevation, and contributing regions as a terrain analysis measure. This methodology is very useful for forecasting and comprehending flood disasters. TWI assists in defining areas prone to flooding by detecting flow channels and places prone to water accumulation during rainfall or high groundwater conditions. The TWI ranges from 4.4643 to 21.346 value in this upazila area.

Sediment Transport Index: River erosion and deposition procedure are characterized by STI. As we know that Chandpur sadar upazila highly vulnerable for Meghna River erosion. The STI rate of the area differs from 0 to 1300.

Land use Land Cover: Flood patterns now certain areas are significantly influenced by land use and land cover. The decisions we make when regulating and developing land have a direct impact on how vulnerable a region is to flooding. The natural equilibrium of water absorption and runoff is disturbed when natural land cover is replaced by impermeable surfaces like roads and buildings. Deforestation lessens the beneficial function of forests in absorbing rainfall and controlling water flow. This process is frequently driven by agricultural expansion or urban growth. Similar to this, the loss of wetlands destroys essential natural buffers that absorb up extra water during torrential rains. Ineffective management of agricultural activities can result in increased runoff and erosion. In the study area the five classes in the LULC map are vegetation, settlement, wetland, agricultural land, and water body.

Distance from the river: A region's susceptibility to floods can be considerably influenced by its proximity of the river. Floods are higher chances to take place in regions close to rivers, known as floodplains, particularly during times of severe rainfall. Such circumstances cause rivers to naturally overflow their banks, and the ensuing floodwaters can submerge surrounding regions. However, the risk of flooding typically decreases as one travels further away from the river.

Soil: In determining flood susceptibility, soil composition is a key factor. The capability of soil to hold and absorb water, sometimes referred to as its permeability or infiltration capacity, can have a big impact on how rain is managed in a specific location. Sand or loamy soils, which have good drainage, can quickly absorb rainwater, lowering surface runoff and the chance of flooding. Clay or areas that are densely populated, on the other hand, have poor drainage or compacted soils that prevent water from soaking into the ground, causing rain to collect on the surface and perhaps producing rapid runoff and flash floods. Additionally, soil characteristics have an impact on groundwater levels. Saturated soils increase the risk of flooding because they reduce the ability of the earth to absorb more water after heavy rains. Figure (13) presents soil map Chandpur sadar upazila mostly area is slit clay loam and it can be the reason for flooding.

NDVI: NDVI is a vital instrument for managing and monitoring floods. Based on satellite or remote sensing data, NDVI gauges the condition and density of a given area's vegetation cover. This index offers important details regarding the state of the land's surface, particularly the quantity and quality of vegetation. When there has been flooding, NDVI can be used to gauge the damage caused and forecast future flooding. Reduced vegetation cover, which may be the result of flooding or waterlogging, is indicated by a lower NDVI value. Identifying flood-prone areas and evaluating the effects of floods on ecosystems and agriculture can both be done by monitoring variations in NDVI over time. NDVI value ranges -1 to +1.

Drainage Density: Flooding and drainage density are directly related. Higher drainage density, which denotes significant surface runoff, is directly related to an increased chance of floods. The SRTM DEM's stream network was recovered, and ArcGIS (10.8) spatial analyzer was used to apply line density to create a drainage density map. A natural breathing pattern was used to divide the drainage density map into five classes. (Ullah & Zhang, 2020)

Rainfall: Rainfall is the catalyst behind many destructive flood events worldwide. When precipitation, whether from heavy rainfall or snowmelt, exceeds the natural capacity of the land and water systems to manage it, floods can occur. The intensity, duration, and spatial distribution of rainfall are key factors influencing flood risk. Sudden, intense downpours can lead to flash floods, particularly in urban areas with impermeable surfaces that encourage rapid runoff. Extended periods of rainfall can saturate the soil and cause riverbanks to overflow, resulting in riverine floods. I have collected rainfall data from BMD for the last 20 years.

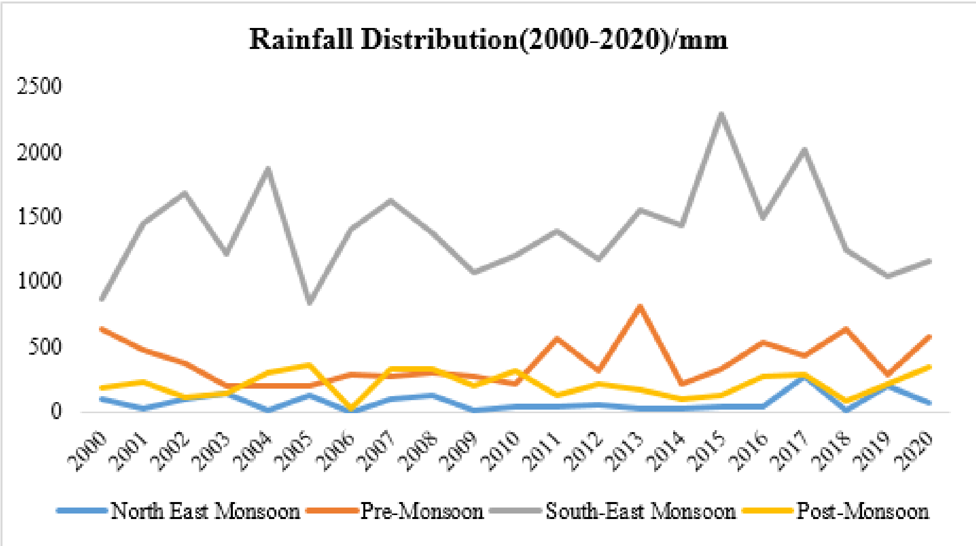
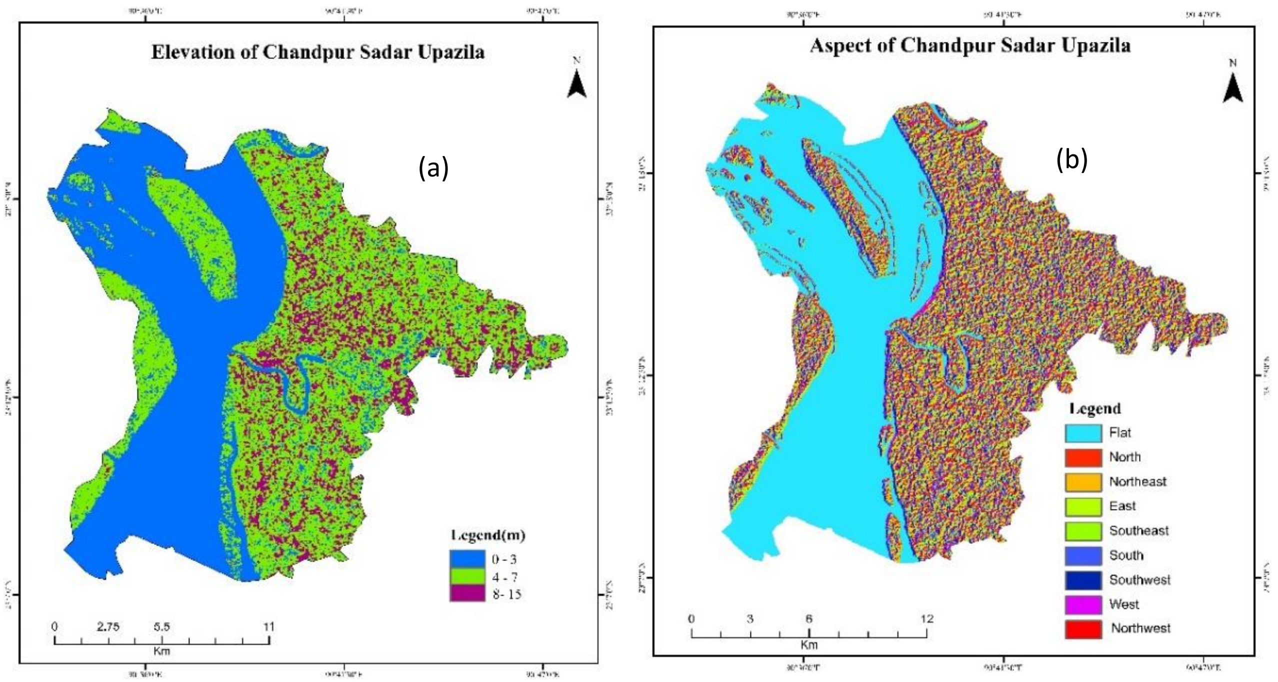
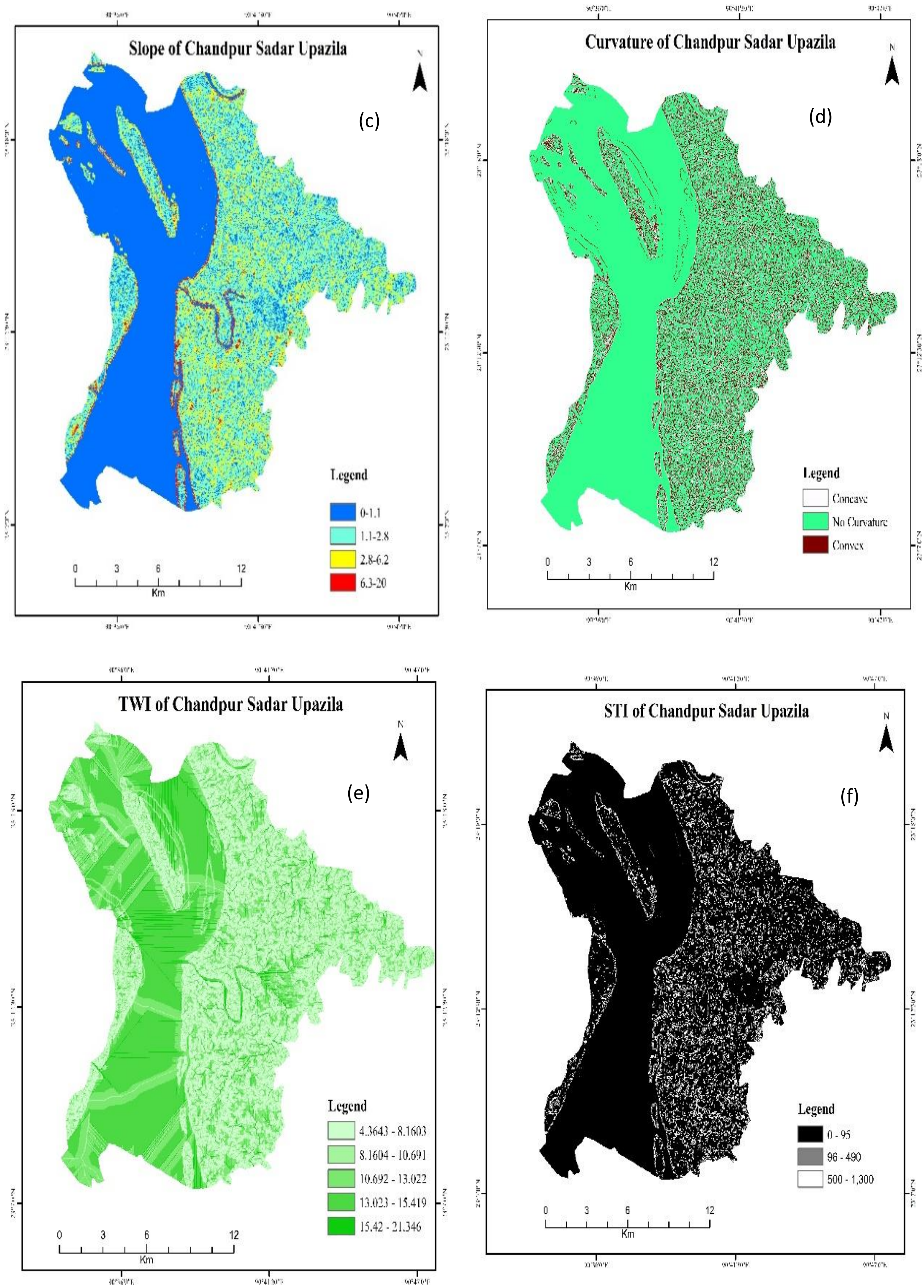


Figure 5: Rainfall Distribution

In this figure 5, we are clearly seeing that rainfall distribution last 20 year, south east monsoon rainfall higher than the others. South-west monsoon rainfall distribution vary between 1000 to more than 2000mm on the contrary the other season rainfall distribution is lower than 700mm. Flood has always relation with rainfall. Excessive rainfall is the direct contributor of creates flooding. In Chandpur sadar upazila highest rainfall occurred in south-west season and most of flooding occurred in these areas during monsoon.




Slope of Chandpur Sadar Upazila
N
(c)
Legend
0-1.1
1.1-2.8
2.8-6.2
6.3-20
0 3 6 12
Km
Curvature of Chandpur Sadar Upazila
N
(d)
Legend
Concave
No Curvature
Convex
0 3 6 12
Km
TWI of Chandpur Sadar Upazila
N
(e)
Legend
4.3643 - 8.1603
8.1604 - 10.691
10.692 - 13.022
13.023 - 15.419
15.42 - 21.346
0 3 6 12
Km
STI of Chandpur Sadar Upazila
N
(f)
Legend
0 - 95
96 - 490
500 - 1,300
0 3 6 12
Km

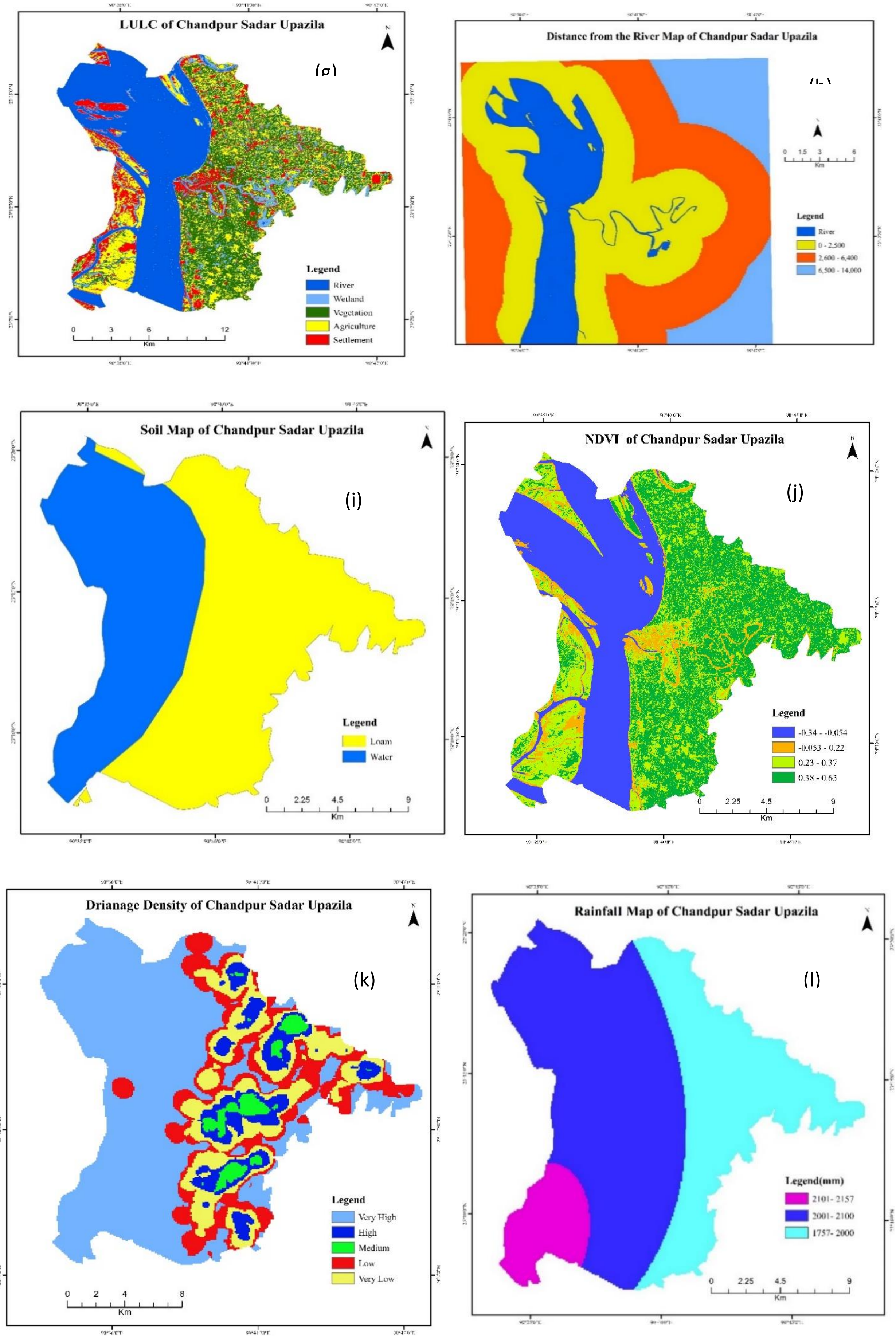

LULC of Chandpur Sadar Upazila
Legend
River
Wetland
Vegetation
Agriculture
Settlement
0 3 6 12
Km
Distance from the River Map of Chandpur Sadar Upazila
0 1.5 3 6
Km
Legend
River
0 - 2,500
2,600 - 6,400
6,500 - 14,000
Soil Map of Chandpur Sadar Upazila
(i)
Legend
Loam
Water
0 2.25 4.5 9
Km
NDVI of Chandpur Sadar Upazila
(j)
Legend
-0.34 - -0.054
-0.053 - 0.22
0.23 - 0.37
0.38 - 0.63
0 2.25 4.5 9
Km
Drianage Density of Chandpur Sadar Upazila
(k)
Legend
Very High
High
Medium
Low
Very Low
0 2 4 8
Km
Rainfall Map of Chandpur Sadar Upazila
(l)
Legend(mm)
2101- 2157
2001- 2100
1757- 2000
0 2.25 4.5 9
Km

Figure 6: Conditioning factors flood (a) elevation, (b) aspect, (c) slope, (d) Curvature, (e) topographic wetness index, (f) sediment transport index, (g) land use and land cover, (h) distance from the river, (i) soil, (j) normalize difference vegetation index, (k) drainage density, (l) rainfall.

3. Result and Discussion

3.1 : Flood analysis using Flood Frequency Model

A Flood Frequency Ratio (FFR) table is a tool used in hydrology and flood frequency analysis to assess the relative rarity or frequency of different flood events based on historical data. Flood frequency ratio table calculated every class flood driving factors.

Table 2: Flood frequency ratio table

Parameter	Classes	Class Pixels	% of Class Pixels	Flood Pixel	% of flood pixels	FR	RF
Slope	0-1.1	156550	51.40	6984	23.28	2.21	0.66
	0.1-2.8	98630	32.38	14959	49.86	0.65	0.19
	2.8-6.2	44087	14.48	8058	26.86	0.54	0.16
	6.3-20	5289	1.74	0	0.00	0.00	0.00
Elevation	0-3	157424	51.20	10001	33.34	1.54	0.74
	4-7	110072	35.80	20000	66.66	0.54	0.26
	7-15	39968	13.00	0	0.00	0.00	0.00
TWI	4.4643-8.1603	72613	23.78	9896	32.99	0.72	0.11
	8.1604-10.691	99267	32.51	9203	30.68	1.06	0.16
	10.692-13.022	105082	34.42	9288	30.96	1.11	0.17
	13.023-15.419	14233	4.66	1018	3.39	1.37	0.21
	15.42-21.346	14119	4.62	596	1.99	2.33	0.35
Curvature	Concave	5387	1.75	200	0.67	2.63	0.69
	Flat zone	301031	97.91	29189	97.29	1.01	0.26
	Convex	1046	0.34	612	2.04	0.17	0.04
Aspect	Flat	126134	41.42	2511	8.37	4.95	0.52
	North	27615	9.07	4235	14.12	0.64	0.07
	Northeast	24139	7.93	3808	12.69	0.62	0.07
	East	24143	7.93	3795	12.65	0.63	0.07
	Southeast	20272	6.66	3141	10.47	0.64	0.07
	South	20746	6.81	2977	9.92	0.69	0.07
	Southwest	20257	6.65	2882	9.61	0.69	0.07
	west	16164	5.31	2616	8.72	0.61	0.06
	Northwest	25086	8.24	4036	13.45	0.61	0.06

Rainfall	2101-2157	261915	85.21	24352	81.17	1.05	0.50
	2001-2100	44397	14.44	5200	17.33	0.83	0.39
	1757-2000	1077	0.35	449	1.50	0.23	0.11
NDVI	(-0.34) -(-0.054)	107086	34.79	8403	28.01	1.24	0.30
	(-0.053)-0.22	67965	22.08	5963	19.88	1.11	0.27
	0.23-0.37	35754	11.62	3484	11.61	1.00	0.24
	0.38-0.63	96980	31.51	12151	40.50	0.78	0.19
LULC	River	116523	37.69	6814	22.71	1.66	0.33
	Wetland	42240	13.66	5566	18.55	0.74	0.15
	vegetation	38697	12.52	4263	14.21	0.88	0.17
	Agriculture	43827	14.18	8128	27.09	0.52	0.10
	Settlement	67837	21.94	5230	17.30	1.27	0.25
Drainage Density	Very Low	202393	65.77	12498	41.66	1.58	0.51
	Low	78172	25.40	10355	34.52	0.74	0.24
	Medium	23774	7.73	4747	15.82	0.49	0.16
	High	1940	0.63	1284	4.28	0.15	0.05
	Very High	1463	0.48	1117	3.72	0.13	0.04
STI	0-95	207661	93.94	16320	53.98	1.74	0.70
	96-490	12871	5.82	13793	45.62	0.13	0.05
	491-1300	536	0.24	119	0.39	0.62	0.25
soil	Loam	226336	73.53	30001	100.00	0.74	0.99
	Water body	81471	26.47	0	0.00	0.00	0.00
Distance from the river	0-2500	261563	51.93	14281	47.60	1.09	0.37
	2600-6400	137072	27.22	7562	25.21	1.08	0.37
	6500-14000	105005	20.85	8158	27.19	0.77	0.26

By analyzing historical data on river discharge or water levels, hydrologists can identify past flood magnitudes and apply statistical methods to estimate the probability distribution of future floods. This analysis allows for the calculation of return periods, which indicate how often floods of specific magnitudes are expected to occur. Table 2, shows a strong association between flood variable class and flood, as well as risk of flood occurrence, the higher the values of FR and RF. High TWI values often likely to become saturated and contribute to surface runoff, thereby increasing the risk of flooding. As we can see that table 2, TWI increased and FR value also increased. Lower elevation locations, which are frequently closer to river, are far more likely to flood, especially during periods of high rainfall. Riverine flooding is generally less occurred in areas with higher altitudes. Table 2, first as well as second class's elevation is lowest specifying higher flood region. The FR value also highest in lower elevation classes. For slope, FR value is highest for the first class is 2.21 indicate that these classes are more chances to flood occurring. In curvature the first and 2nd class get a greater FR value has a strong correlation with flood occurrence. Concave and flat zone are potential to flood occurrence. The first and second classes distance from the river are closer to the river which get high flood pixel and greater FR value. In Land use Land cover Factors River, settlement, wet land has higher FR value, indicating higher flood occurrence probability. NDVI rate of this upazila ranges from -0.34 to 0.63. The low vegetation and water body area get higher FR value. Loam soil mass has received higher value of FR indicating higher flood incidence probability. The intensity of rainfall is a critical factor. Those area get higher intensity rainfall and close to the river are more vulnerable. The first classes get higher FR value which is close to the river. Lower drainage density indicates higher flood occurrences. STI ratio of flood is higher in first class and chances to more flooding occurrence. Aspect is one of the significant factors of flood determination. The class get higher FR ratio that means of high chances of flood occurring. (Table: 2)

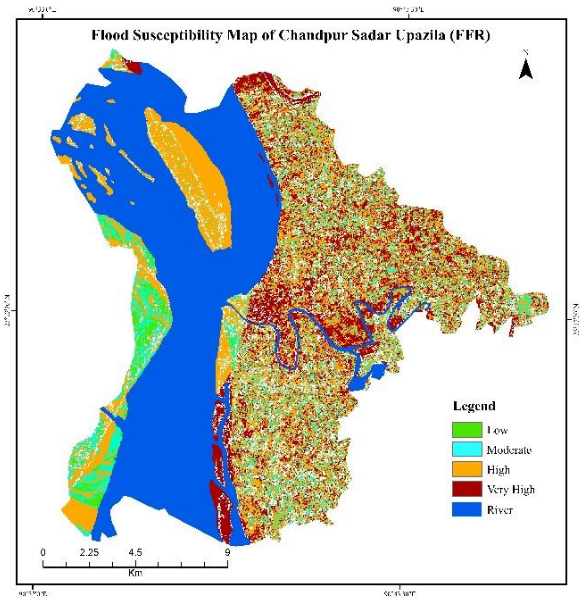


Figure 7: Flood susceptibility Map

Figure (7) represent the flood susceptibility map of Chandpur sadar upazila using FRM. In this map the drak red zone represents very high flood risk zone like chandpur sadar union,sakua union,klayanpur union, brown zone represents high risk zone like Rajshwari, Imbrahimpur, pest and green colour zone represents moderate and low zone. In this map flood free zone are included low susceptible zone of flood. River side area are more vulnerable of flood in chandpur sadar union population density is high which influence the vulnerability of flooding. 27.46% area of the chandpur sadar upazila fall in very high risk region and 33% fall in high risk zone that means total 60% area is high vulnerable flood area.

Table 3: Flood Susceptibile Area Using FRM

Class	Area (hectare)	%
Low	1591.65	9.03
Moderate	5315.58	30.15
High	5879.6	33.35
Very High	4841.01	27.46

3.2: Flood analysis using Analytic Hierarchy Process

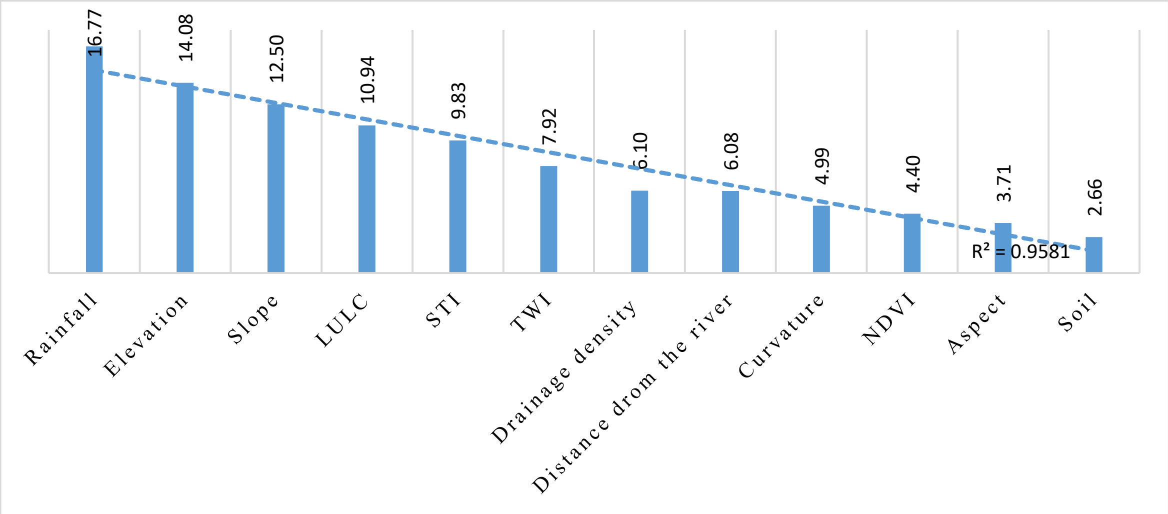
The Analytic Hierarchy Process (AHP) is a dominant decision-making tool that can be applied to flood analysis and risk assessment. AHP helps prioritize and evaluate various factors and criteria involved in flood management.

Table 4: Criteria weights table of study area

Factors	Rainfall	Elevation	Slope	LULC	STI	TWI	Drainage density	Distance from the river	Curvature	NDVI	Aspect	Soil
Rainfall	1	2	2	2	3	3	3	2	3	3	4	4
Elevation	1/2	1	1	3	2	2	3	3	4	1	5	5
Slope	1/2	1	1	2	2	3	4	2	3	2	3	2
LULC	1/2	1/3	1/2	1	3	2	3	2	2	3	4	4
STI	1/3	1/2	1/2	1/3	1	3	3	2	2	3	4	5
TWI	1/3	1/2	1/3	1/2	1/3	1	4	3	3	2	1	3
Drainage density	1/3	1/3	1/4	1/3	1/3	1/4	1	2	2	3	2	4
Distance from the river	1/2	1/3	1/2	1/2	1/2	1/3	1/2	1	3	2	2	3
Curvature	1/3	1/4	1/3	1/2	1/2	1/3	1/2	1/3	1	4	2	2
NDVI	1/3	1	1/2	1/3	1/3	1/2	1/3	1/2	1/4	1	2	1
Aspect	1/4	1/5	1/3	1/4	1/4	1	1/2	1/2	1/2	1/2	1	4
Soil	1/4	1/5	1/2	1/4	1/5	1/3	1/4	1/3	1/2	1	1/4	1

By applying the AHP, the comparative importance of each criterion was estimated after constructing criteria weights for further analyze done by arc map. After functioning the weighting sum of all factors, the map was created with, consistency ratio (CR) is 0.096 (<0.1, validated).

Figure 8: Criteria Weights(%) table using AHP



Criteria weights percentage is more important to analyze risk of flood. The researcher gave the higher weight to the criterion rainfall with 16.77%, elevation 14.08% slope 12.50%. The TWI, STI, distance from the river, LULC weights vary between 10% to 6%. Although all parameters have greater impact on occurrence flooding it is quite difficult to choose.

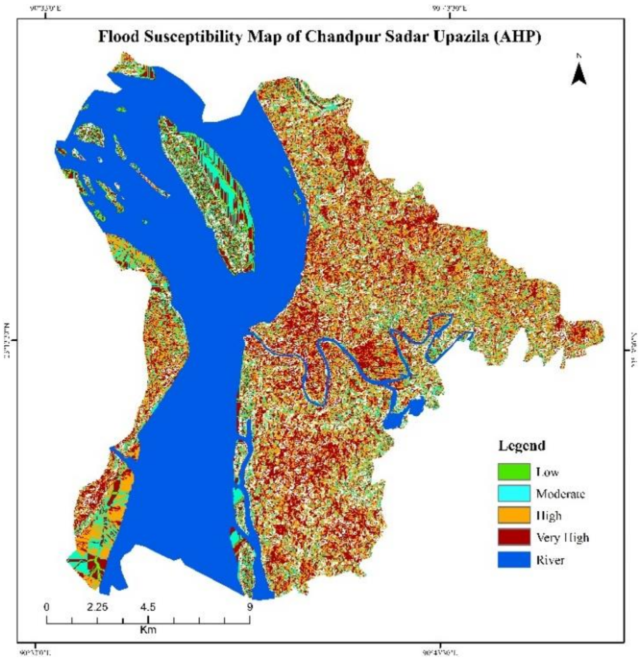


Figure 9: Flood susceptibility Map

Class	Area (hectare)	%
Low	4447.08	16.10
Moderate	9556.65	34.59
High	4587.03	16.60
Very High	9037.08	32.71

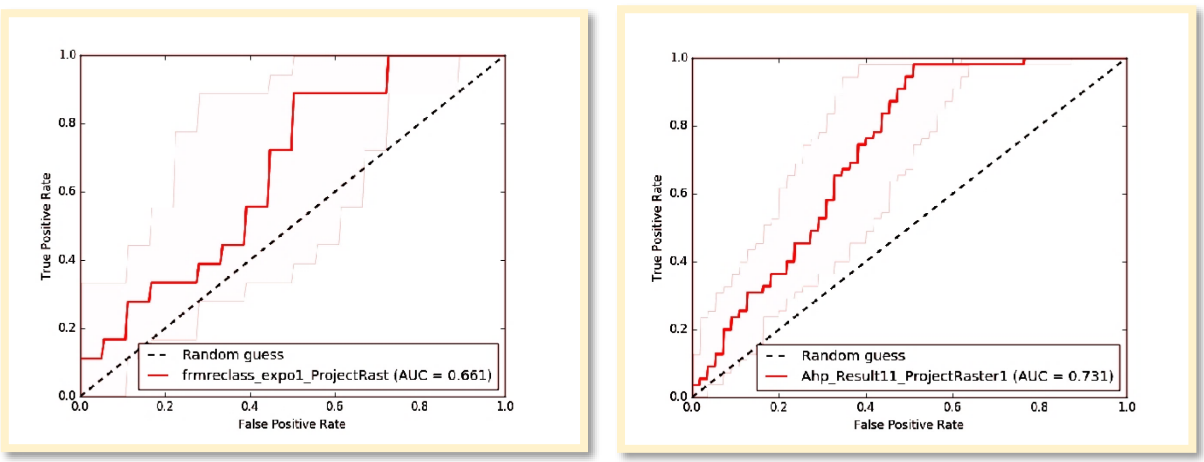
Table 5: Flood Susceptibile Area Using AHP

Figure (9) represent the flood susceptibility map of Chandpur sadar upazila using AHP. In this map the dark red zone represents very high flood risk zone like chandpur sadar union,sakua union,klayanpur union, brown zone represents high risk zone like Rajshwari, Imbrahimpur, pest and green colour zone represents moderate and low zone. In this map flood free zone are included low susceptible zone of flood. River side area are more vulnerable of flood in chandpur sadar union population density is high which influence the vulnerability of flooding. Table (5), 32.71 % area of the Chandpur sadar upazila fall in very high flood risk area and 16.60% fall in high-risk flood area that means total 49% area is high susceptible flood area.

3.3: Validity of models using ROC:

The success rate curve—which is generated by linking the training dataset with the flood susceptibility map—represented the model's fitness to the real flood. The prediction rate curve is generated by comparing the validation dataset with the flood susceptibility map, indicating how effectively the model forecasts future floods. (Addis, 2023)

Figure 10: Roc Curve validation using AHP and FRM



The analysis is deemed good and average based on the AUC values of 0.731 and 0.661. This is quite simple to confirm that the model, which was employed to create the Chandpur Sadar Upazila flood susceptibility mapping, is reliable and appropriate for identifying flood patterns. Finally, it can be believed that the FRM and AHP model is a greatly helpful process for mapping flood susceptibility. (Debabrata and Prolay, 2019)

Conclusion:

In conclusion, two methods are used to identify flood vulnerability area of Chandpur sadar upazila. One is flood frequency ratio and other is analytic hierarchy process. Twelve parameters are selected like TWI, STI, LULC, NDVI, slope, elevation, rainfall, drainage density, distance from the river, aspect, soil, curvature using GIS for further analysis. Using goggle earth and field survey flood inventory map was created. Two flood vulnerability map was created using AHP and FFR method and classified those map low, medium, high, very high flood risk zone. Almost 27% area in AHP method and 32% area in FFR method fall in high-risk zone in this upazila. So, the overall conclusion is that this area fall in is risk zone of flood vulnerability and may help the decision makers and government and nongovernment authorities to mitigate flood vulnerability. As climate change is increasing the risk of flooding Chandpur sadar upazila situated at near the Padma -Meghna Confluences. Flood Measures are need to reduce and control flood risk. Flood management like Levee and dam building, land use planning and zoning to prevent development in flood plains, early warning systems, public awareness, education, and collaboration between governments, communities, and stakeholders is essential.

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