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Flood Susceptibility Assessment and its Management in Malda District of West Bengal through Geospatial Technique

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ABSTRACT

Flood is one of the most popular natural hazards that create havoc in the society. Flood involves inundation of a huge tract of area under water owing to heavy rainfall. Occurrence of flood lays a severe impact upon the agricultural sector. Flood not only brings about destruction of crops but also brings down the productivity of the soil. Malda district of West Bengal is not an exception in this regard. The district is one of the most flood prone districts and involves a lot of loss in crop production. The present study aims to identify the flood susceptible zones of the district through the application of Analytical Hierarchy Process and geospatial techniques and also makes an attempt to detect how much cropland falls within the very high susceptible flood prone area so that proper precautionary measures can be taken to minimize the maximum damage. The study results reveal that the western part of the district is more flood prone and about 55.27% of very high flood prone area is dominated by croplands. Hence, proper flood management techniques have to be adopted in this area to reduce the loss of production of crops owing to floods.

Keywords Flood susceptible zone, Analytical hierarchy process, Geospatial technique, Flood management.

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INTRODUCTION

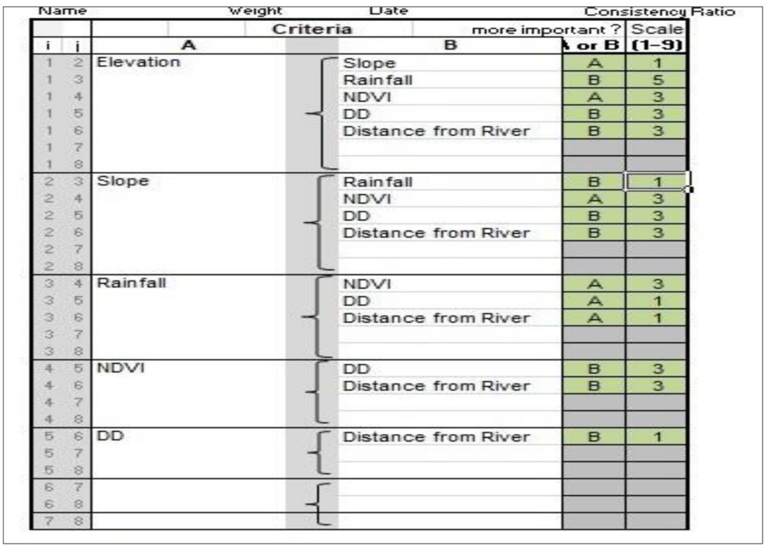
Natural hazards and disasters are inevitable and they can take place anytime and anywhere. When a disaster takes place, it creates large scale loss of life and human property. Disasters can be mainly categorized into two classes namely natural and man-made. Among the domain of natural disasters, meteorological hazards derive special mention. Flood is one of the most important meteorological hazards which involve inundation of vast area under water due to heavy rainfall. Since time immemorial, floods have highly shaped human society and have also become a part of their culture. Flood myths of different nations have become very well known all over the world. Indian flood myth, Chinese flood myth, Roman flood myth, Babylonian flood myth and Noah's Deluge are some significant flood myths which prove the event of occurrence of major floods in the historic past. The landscape of Uzengili Village reveals the existence of Noah's ark which in turn acts as a major evidence of occurrence of a major flood event. Floods cause great damage to human society and severely affect the pace of human development. Agriculture is the sector which gets highly affected by the flood events. Crops are washed out and thus there is total loss of production which in turn creates a lot of problem for the poor farmer. In Sundarban region of West Bengal, floods mainly take place owing to outbreak of tropical cyclones during the pre-monsoon cyclone season and post monsoon cyclone season as a result of which salt-water enters the agricultural fields which not only affects crop production but also destroys soil fertility. Besides, farmers in India have the tendency to have their agricultural fields near rivers as it is a major source of water for irrigation. When flood takes place, flood water gushes into those fields damaging the crops. These problems have triggered the necessity to plan agricultural activities keeping in mind the areas that are highly vulnerable to flood. Malda district in West Bengal is one of the major flood prone districts. The district gets flooded owing to heavy rainfall. According to a newspaper report, about 30 villages in Malda were flooded owing to heavy rainfall and breaching of the dyke of the Ganga. Thus, delineation of flood susceptible zones is highly needed to minimize the impact of flood on agricultural sector of the district. With the advent of GIS and remote sensing, delineation of flood susceptible zones have become very easy and less time consuming task. Mapping of several factors responsible for the occurrence of flood in the district can be easily done using geospatial techniques. The present study has used eight factors that affect the occurrence of floods. Weights were assigned to those factors using Analytical Hierarchy process and then the flood susceptible map was prepared and the susceptibility map was categorized into five classes. This flood susceptibility map will act as an indispensible tool in the hands of the planners to adopt flood control strategies and will also guide the farmers to select their agricultural plots accordingly which will reduce crop damage owing to flood and strengthen the backbone of the agricultural sector of the district. Flood is a very common meteorological hazard that disrupts the lifestyle of the area where it takes place. It involves colossal loss of human lives and property. Islam *et al.* (2021) attempted to prepare a flood susceptibility model using advanced ensemble machine learning techniques. The study area was Teesta River basin in Bangladesh and it used twelve conditioning factors (Islam *et al.* 2021). Swain *et al*. (2020) prepared flood susceptibility analysis of flood prone area of Bihar using GIS and analytical hierarchy process and the study revealed that about 40.36% of the study area lies within high to very high flood susceptible zone whereas about 12% of the study area lies in low flood prone zone (Swain *et al.* 2020). Samanta *et al.* (2018) applied frequency ratio and geospatial technique for making a flood susceptibility model of Markham River Basin in Papua New Guniea and used 143 flood events as data inventory and the study revealed that about 19.4% area is located in very high susceptible area and 35.8% area is in high susceptible zone (Samanta *et al*. 2018). Yariyan *et al.* (2020) aimed to prepare a flood susceptible map of Saqqez city in Kurdistan Province in Iran using improved Analytic Network process with statistical models (Yariyan *et al.* 2020). The study revealed about 95.1% efficiency in ANP-EBF hybrid model, 91% efficiency in ANP-FR hybrid model and 89.6% efficiency in ANP-OWA hybrid model (Yariyan *et al.* 2020). El-Haddad *et al.* (2021) compared flood susceptibility models of Wadi Qena basin in Egypt which were prepared using four machine learning techniques namely Boosted Regression Tree (BRT), Functional Data Analysis (FDA), General Linear Model (GLM) and Multivariate Discriminant Analysis (MDA)(El-Haddad *et al.* 2021). The results revealed that AUC for success and prediction rates are 0.783, 0.958, 0.816, 0.821 and 0.812, 0.856, 0.862, 0.769 for BRT, FDA, GLM and MDA models, respectively (El-Haddad *et al.* 2021). Goyari (2005) stated that floods are hampering the agricultural sector of Assam since time immemorial and thus there is an urgent need to implement long term policies both from the ground of the state and the central Government. Besides, cooperation is also needed from the neighbouring countries to bring about a solution of this long term problem (Goyari 2005). Rahman and Barman (2019) performed a perception study on the impact of flood among the farmers of two districts namely Majuli and Jorhat in Upper Brahmaputra Valley in Assam (Rahman and Barman 2019). The study revealed that increase in dependency on mechanical draught power, scarcity of fodder for livestock and introduction of new breeds of livestock were some of the major impacts of floods perceived by the farmers (Rahman and Barman 2019). Heavy rainfall in September 2014 led to massive floods in the catchment areas of India's eastern rivers namely Chenab, Jhelum, Ravi and Sutlej and these floods severely affected the Azad Jammu and Kashmir, Gilgit Baltistan and Punjab (Rehman *et al.* 2015). About 250,000 farmers were affected and more than 1 million acre of agricultural land was damaged and lots of fodder and cash crops were damaged (Rehman *et al.* 2015). Fu *et al.* (2018)in their work stated that Heliongjiang Province in China is more affected by floods than droughts and floods highly affect the development of agriculture of the area (Fu *et al.* 2018).

MATERIALS AND METHODS

The main objective of the study was to prepare the flood susceptible map of Malda district and also to assess how much agricultural land falls within the very high flood susceptible zone. In order to accomplish the work, it was first necessary to identify the factors which affect the occurrence of flood in any area. These factors were known as 'Conditioning factors'. The present study has used six conditioning factors namely elevation, slope, rainfall, NDVI, distance from river and drainage density. SRTM Dem down -loaded from USGS Earth Explorer was used to prepare elevation, slope, drainage and drainage density maps. Rainfall map was prepared using the rainfall data downloaded from IMD website of Pune in Net -CDF format. The rainfall data was then converted into point data and the point data was then spatially interpolated to obtain the rainfall map. NDVI map was prepared for the year of 2022 using Landsat 9 satellite image downloaded from USGS Earth Explorer. Landuse map was prepared from the ESRI L and Cover website that provides land use maps prepared using Sentinel -2 satellite with 10 m resolution. Each conditioning factor was assigned weights using the Analytical Hierarchy process.

Analytical hierarchy process

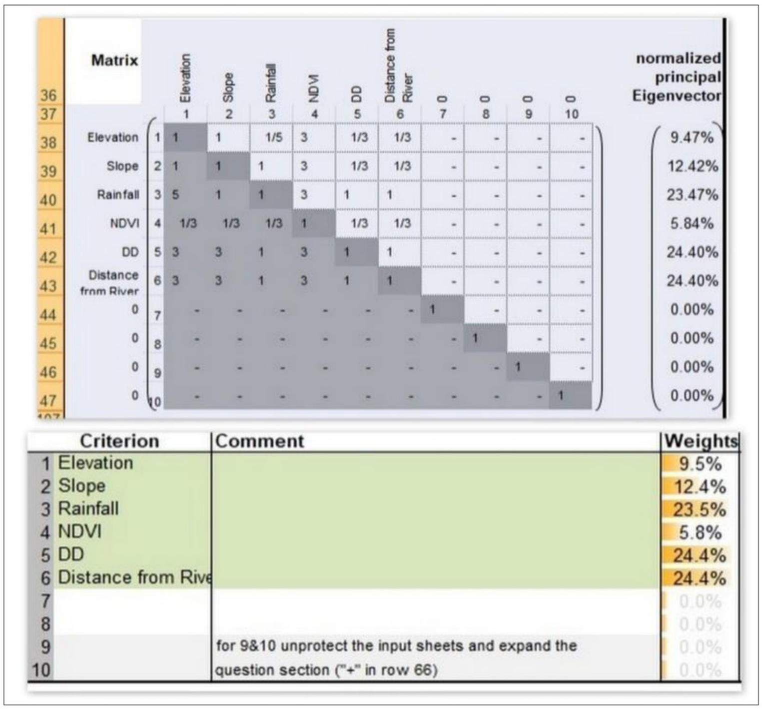
Analytical Hierarchy Process, abbreviated as AHP



Name Weight Date Consistency Ratio

i	j	Criteria A	B	more important ? A or B	Scale (1-9)
1	2	Elevation	Slope	A	1
1	3		Rainfall	B	5
1	4		NDVI	A	3
1	5		DD	B	3
1	6		Distance from River	B	3
1	7				
1	8				
2	3	Slope	Rainfall	B	1
2	4		NDVI	A	3
2	5		DD	B	3
2	6		Distance from River	B	3
2	7				
2	8				
3	4	Rainfall	NDVI	A	3
3	5		DD	A	1
3	6		Distance from River	A	1
3	7				
3	8				
4	5	NDVI	DD	B	3
4	6		Distance from River	B	3
4	7				
4	8				
5	6	DD	Distance from River	B	1
5	7				
5	8				
6	7				
6	8				
7	8				

Fig. 1. Assigning intensity values to conditioning factors.



Matrix		Elevation	Slope	Rainfall	NDVI	DD	Distance from River	0	0	0	0	normalized principal Eigenvector
		1	2	3	4	5	6	7	8	9	10	
Elevation	1	1	1	1/5	3	1/3	1/3	-	-	-	-	9.47%
Slope	2	1	1	1	3	1/3	1/3	-	-	-	-	12.42%
Rainfall	3	5	1	1	3	1	1	-	-	-	-	23.47%
NDVI	4	1/3	1/3	1/3	1	1/3	1/3	-	-	-	-	5.84%
DD	5	3	3	1	3	1	1	-	-	-	-	24.40%
Distance from River	6	3	3	1	3	1	1	-	-	-	-	24.40%
0	7	-	-	-	-	-	-	1	-	-	-	0.00%
0	8	-	-	-	-	-	-	-	1	-	-	0.00%
0	9	-	-	-	-	-	-	-	-	1	-	0.00%
0	10	-	-	-	-	-	-	-	-	-	1	0.00%

	Criterion	Comment	Weights
1	Elevation		9.5%
2	Slope		12.4%
3	Rainfall		23.5%
4	NDVI		5.8%
5	DD		24.4%
6	Distance from Rive		24.4%
7			0.0%
8			0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%
10		question section ("+" in row 66)	0.0%

Fig. 2. Matrix and weights.

is an important multi-criteria decision making tool used for the analysis of complex decisions. It was developed by Thomas L Saaty in 1970 (Saaty 2008, Saaty and Özdemir 2014, Saaty and Vargas 2012). It has 9 intensity scales and it analyzes out of two elements or conditioning factors, which one is more important and at what scale. The present study used six conditioning factors and while assigning weights to them, the following considerations were taken into account. Out of slope and elevation, both were given equal importance and were assigned the intensity value 1. Areas with lower elevation and gentle slope have high chances of getting affected by flood as water can easily inundate low elevation areas. Areas which have low elevation but steep slope are less susceptible to flood as water will get less chance to remain stagnant and will undergo run-off. Areas with gentle slope and higher elevation will not get affected by flood as water cannot inundate higher altitudes. Out of elevation and rainfall, rainfall was given strong importance and was assigned intensity value 5. Rainfall is the most important factor that affects flood. Extreme heavy rainfall leads to heavy floods. Out of elevation and NDVI, elevation was given moderate importance and was assigned the intensity value of 3. Out of elevation and drainage density, drainage density was given moderate importance and was assigned the intensity value of 3. Areas with higher drainage density have more chances to experience flood. Out of elevation and distance from river, distance from river was given moderate importance and was assigned the intensity value of 3. Areas located to close to river have more chances to get affected by flood. Out of slope and rainfall, both were assigned the same importance and were assigned the intensity value 1. Even if the rainfall is high, chances of flood are more in areas with gentle slope rather than steep slope as in water will remain stagnant for a longer time in former and will undergo run-off in case of the later. Out of slope and NDVI, slope was given moderate importance than NDVI and was assigned intensity value 3. Out of slope and drainage density, drainage density was given moderate importance and was assigned intensity value 3. However, both drainage density and distance from river were assigned equal importance with rainfall and were assigned intensity value 1.

Irrespective of rainfall, areas located close to rivers and having high drainage density always have high chances to get affected by flood. Areas located close to rivers and having high drainage density always have high chances to get affected by flood. But proper afforestation programs can reduce the severity of floods. Out of drainage density and distance from river, both were given equal importance and were assigned the intensity value 1 (Fig. 1). Based on above decisions, elevation was given the weight of 9.5%, slope 12.4%, rainfall 23.5%, NDVI 5.8%, drainage density 24.4% and finally distance from river 24.4% (Fig. 2).

Based on these weights, the flood susceptibility analysis of Malda was done. Then, areas which are cropland as well as falls in very high flood susceptible zone were extracted. All mapping were done using ArcGIS 10.3 and QGIS 3.16 software. Finally, the maps prepared were analyzed and interpreted to arrive at the results.

RESULTS AND DISCUSSION

A brief idea about the study area

Malda is one of the most important districts of West Bengal. It is considered to be the transitional zone between North Bengal and South Bengal (Fig. 3). The district has a total area of about 3671.23 square kilometer. The district has latitudinal extension from 24.66 degrees north to 25.545 degrees north and longitudinal extension from 87.774 degrees east to 88.466 degrees east. The district is bounded by Bihar and North Dinajpur in the north, Murshidabad in the south, Bangladesh in the east and Jharkhand and Bihar in the west. The district shares about 165.5 km international border with Bangladesh and is located at a distance of 347 km from Kolkata. English Bazar also known as Malda is the district headquarter. According to 2011 census, the total population of the district was 3988845 and the population density of the district was 1071 persons per square kilometer. Population growth of the district for the time period 2001-2011 was 21.5%. Being a low lying area, the district is one of the flood prone districts of the state.

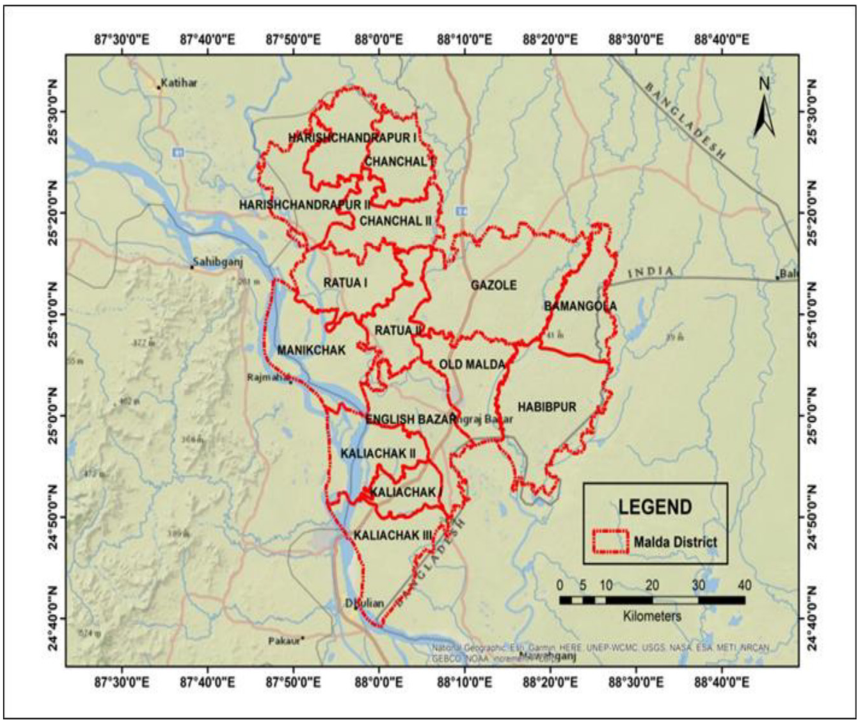


Fig. 3. Location map.

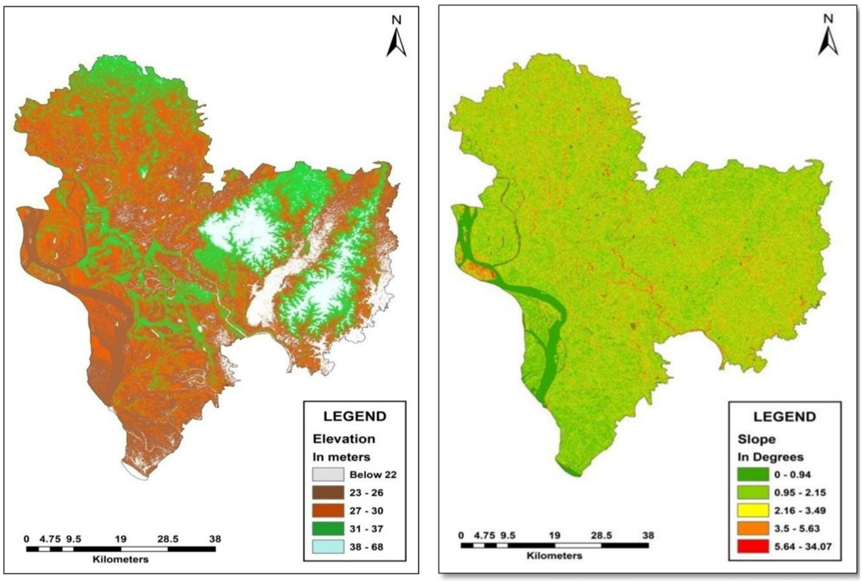


Fig. 4. Elevation map and slope map.

Appraisal of conditioning factors affecting floods

Occurrence of flood in an area gets affected by several factors and they are known as conditioning factors. In order to prepare a flood susceptibility zone, it is very much necessary to have idea about the conditioning factors which influence the landslide of an area. The present study has used six condition factors.

Elevation and slope

The district of Malda is an area of low elevation.

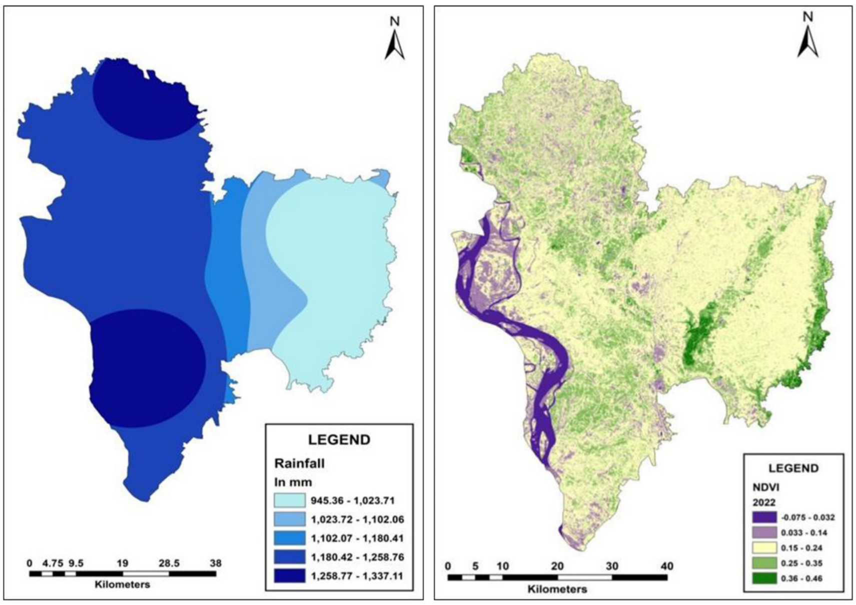


Fig. 5. Rainfall map and NDVI map of the study area.

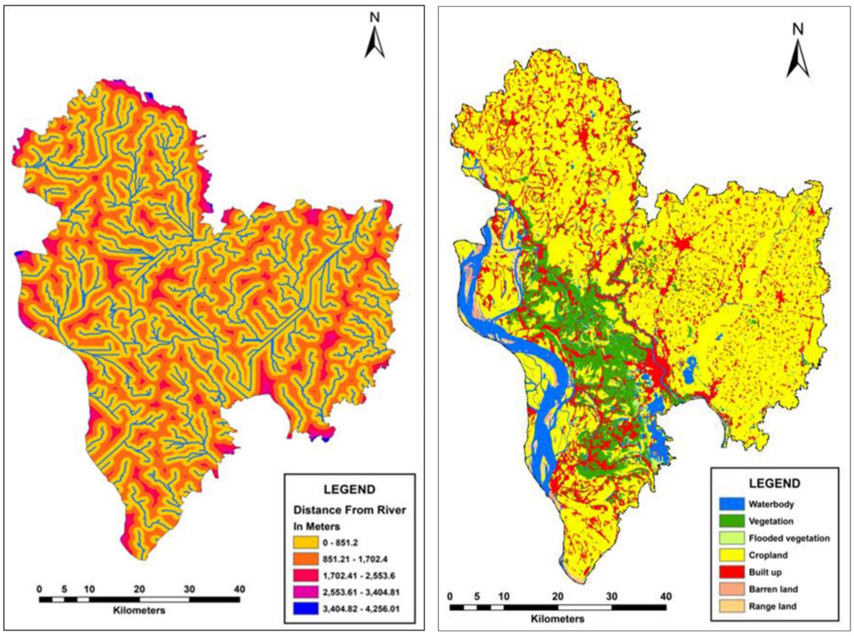


Fig. 6. Distance from river and land use map of the district.

The highest and the lowest altitudes of the district are 22 meters and 68 meters respectively. Very low lying areas are found near the rivers. Most part of the district lies within the elevation zone ranging from 23 meter to 26 meter and from 27 meters to 30 meters (Fig. 4). The district is a region of gentle slope. The highest slope of the study area is 34.07 degrees. Relatively gentle slope is seen near the rivers. About 52.76 square kilometer is having slope values ranging from 0 to 0.94 degrees and is seen mainly along rivers. About 690.52 square kilometers is located within the slope zone having values from 5.64 degrees to 34.07 degrees. Slope gradually declines from east to west (Fig. 4).

Rainfall and NDVI

Rainfall is considered to be the most important factor which triggers flood. When heavy rainfall takes place, rivers get filled up with water and gradually exceed its water holding capacity. Then, it inundates its two banks causing flood. Sometimes, floods also take place owing to breach of embankments due extreme pressure of gushing water due to torrential downpour. Malda district gets an annual average rainfall of about 1501 mm to 2500 mm. Rainfall exhibits an increasing trend from the east to the west (Fig. 5). Two pockets in the northern and south-western part of the district get the heaviest rainfall. The district receives about 80% of its rainfall during the south-west monsoon season. Normalized Difference Vegetation Index or NDVI is also an important parameter that controls flood.

Dense vegetation cover allows a huge part of the rainwater to get intercepted and thus prevents it from reaching the surface of the earth. Besides, it also reduces the velocity of running water and allows a huge volume of rainwater to get infiltrated. Thus, it imposes a check on the volume of water flowing

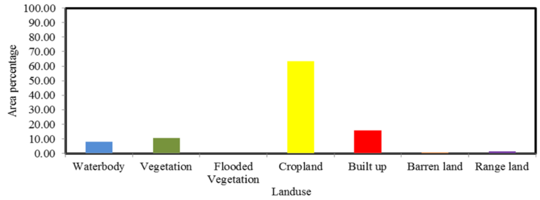


Fig. 7. Graphical representation of land use of Malda.

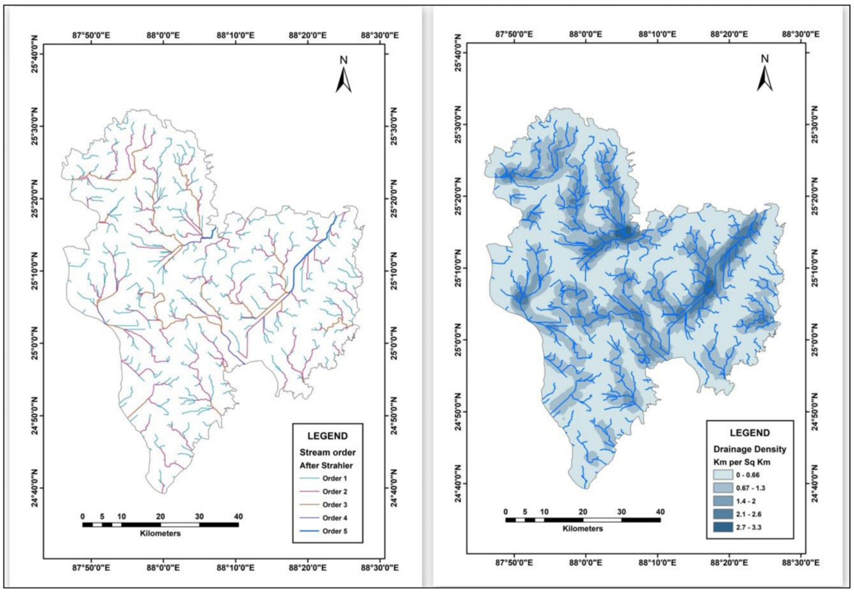


Fig. 8. Drainage pattern and drainage density map of Malda.

into the rivers and channels and prevents them from exceeding their carrying capacity. The highest NDVI value of 0.46 can be seen in the central and extreme eastern part of the district (Fig. 5). Since the highest NDVI value 0.46 lies between 0.3 and 0.6, the vegetation is considered to be under stress. Lack of dense and good quality vegetation cover can be considered to be one of the important reasons for high flood susceptibility of the district.

Distance from river and landuse map

Distance from river is an important factor that determines the susceptibility of flood. Areas located near the river channels have the maximum chances of getting severely affected by flood (Fig. 6). On the contrary, areas that are located at a distance from the river have less chances of getting affected by flood. In Malda, many villages get submerged owing to their location in close proximity to the rivers. As per a newspaper report published on 16th August 2021, three rivers namely Ganga, Mahananda and Fulhar flooded a large number of villages due to heavy rainfall. The Bhutni Island located in the Ganga was severely flooded and most areas in all three panchayats were under water. Malda district exhibits multiple varieties of land use patterns (Fig. 7). Out of 3671.23 square kilometer, about 2321.30 square kilometer is dominated by croplands and it accounts for about 63.23% of the total area. Vegetation and flooded vegetation covers about 10.64% (390.78 square kilometer) and 0.24% (8.91 square kilometer) of the total area respectively. Built up area occupies about 15.70% (576.54 square kilometer) of the total area. About 1.41% (51.75 square kilometer) and 0.61% (22.39 square kilometer) are dominated by range land and barren land respectively. Water body occupies about 299.56 square kilometer and it accounts for about 8.16% of the study area (Fig. 7).

Drainage density

Drainage density is also an important parameter that controls flood. Drainage density is defined as sum of channel lengths per unit area. Areas with high drainage density will have more tendencies to get flooded while areas with low drainage density will have lower tendencies to get flooded (Fig. 8).

Flood susceptibility analysis of Malda

Through the analysis of the six conditioning factors,

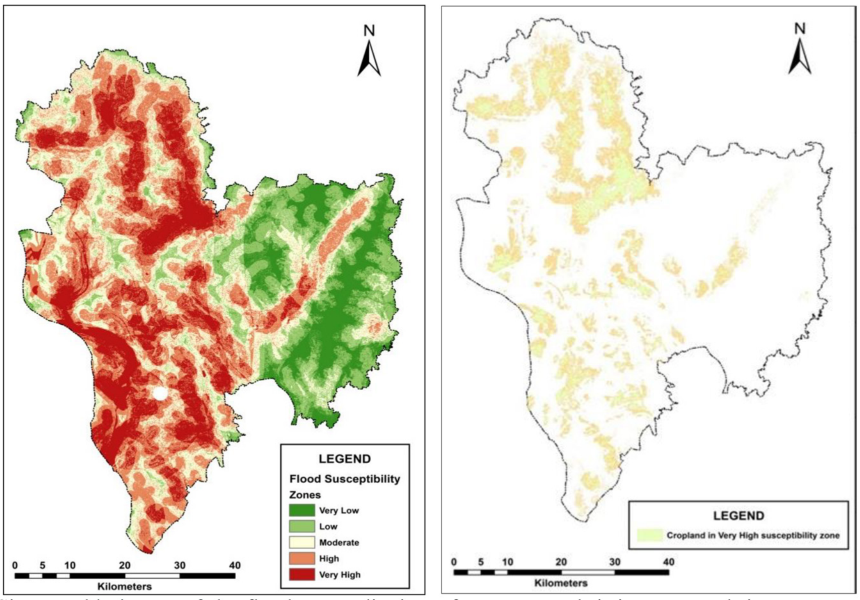


Fig. 9. Flood susceptibility zone of Malda.

weights were assigned to the factors using AHP technique and the flood susceptibility map was prepared. Out of 3671.23 square kilometer area, most of the area of about 1056.06 square kilometer is falling in high susceptibility zone. About 704.37 square kilometer area falls in very high susceptibility zone. Moderate susceptibility zone covers about 916.85 square kilometer area. About 368.12 square kilometer and 625.83 square kilometer area is falling in very low and low flood susceptible area (Fig. 9). Concentration of very low and low flood susceptible areas can be seen in the eastern part of the district while high and very high flood susceptible zones can be seen in the western part of the district. Moderate flood susceptible zones can be seen as pockets and bands scattered all over the map. Pockets of low and very low susceptible areas can also be seen in the western part of the district.

Since Malda is one of the flood prone districts of West Bengal, it is very much important identify the areas which are agricultural land as well as falls in very high flood susceptible zone. It was seen that about 704.37 square kilometer area falls in very high flood susceptibility zone and out of this 704.37 square kilometer, about 389.29 square kilometer is occupied by croplands or agricultural lands and this accounts for about 55.27% of total very high flood susceptible area (Fig. 9). This analysis clearly manifests the reason for which there is large scale loss of crop due to flood in Malda. Thus, it is necessary to adopt proper site selection strategies for agriculture keeping in mind the flood susceptible zone.

CONCLUSION

There is no doubt of the fact that flood is a major handicap in the development of agriculture. However, natural disasters are inevitable and can take place any moment. Since India is an agricultural country, proper management of flood is needed to bring about a solution of the problem. It is a true fact that man does not have any control on rainfall. But proper water-management techniques in agricultural fields can turn to be a way adopting which crop losses due to flood can be minimized. At present, geospatial science is making a rapid advancement. Full utilization of geospatial technique can help in preparation of flood susceptibility maps which can act as indispensible tool in management of floods. Besides, continuous monitoring of land use can be performed using multi-temporal satellite images. Weather forecast information must be dissipated among farmers so that they can take proper steps for protecting their crops against floods. Crop calendars must be prepared keeping in mind the agricultural areas that are vulnerable to flood. Crop insurances must be given to the farmers residing in flood susceptibility zones and credits at lower rate of interest should be given to the farmer in case he suffers huge loss owing to flood. Besides, awareness from the side of the farmer is also needed and both the state and the central governments should come forward to undertake these tasks. Local NGO's and clubs can also extend their cooperation in this regard. Problems of farmers due to flood can be solved by conducting Focus Group Discussions (FGD) where district administrators and planners will also be present. Since India is an agricultural country, proper strengthening of the agricultural sector is very much needed for the overall development of the country.

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