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An Appraisal of Geomorphic Characteristics and Flood Susceptibility Zone using Remote Sensing and GIS: A Case Study in Bongaon Subdivision, North 24 Parganas (West Bengal), India

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Abstract: *Flood hazard is one of the most severe natural hazards in Bongaon sub-division, North 24 Parganas. In this study using multi-temporal satellite data and Geographic Information System geomorpho logical features were identified to define the flood susceptibility. Different landforms (river channel, channel bar, back swamp, natural depression, meander scar, alluvial plain, ox-bow lake, and paleochannel) observed in the sub-division are the outcome of the practice of erosion and deposition that functioned in the ancient and are still enduring. The areas of abandoned river channel, paleochannel, Ox-Bow Lake, back swamp and deep depression were created due to the location adjacent to very high susceptibility zone. Very high susceptibility zones were identified in the south-east, north east and small pockets of central and northern part. Very low flood susceptibility zones were located/marked in the west of the sub-division. Results derived in this study provide baseline information about the flood prone zones for determining and planning for disaster management of the flood situation.*

Keyword: *Multi-temporal satellite data, Geomorphology, Flood Susceptibility zone, Flood management and control, Geospatial technology*

1. INTRODUCTION

Floods are among the most frequent and savage of natural disaster, caused by overflowing of water of the normal confines of a stream or other body of water or accumulation of water by drainage over areas [1]. These flooding have caused considerable damage to highways, settlement, agriculture and livelihood [2]. The questions concomitant to flooding have largely augmented and there is a demand for an efficacious modeling to interpret the difficulty and extenuate its calamitous effects. There are several factors contributing to the flooding ranging from topography, geomorphology, drainage and climate [3]. Consequently, human action such as unexpected rapid growth of human habitation, anarchical structure of buildings and major changes of land use characteristics can influence the spatial and temporal forms of risks.

Problems associated to flooding have greatly increased, ranging from topography, geomorphology, drainage, engineering structures and climate. In Bongaon sub-division, floods are caused by the combination of natural and human factors [4]. However, paleogeographic studies of Ganga delta indicated that the Bhagirathi and Hooghly river has changed their course towards east through space and time with the evolution of the deltas of the peninsular river [5]. The river Ichhamati accumulate discharge from several rivers, e.g., Naobhanga, Jamuna, Padma, Sonai, Ko Hakar, Sonai, Saratkhal and Datvanga and also flood spills from many other channels connecting the adjoining baors and beels. Due to lack of navigation, water logging during rainy season, the ecological balance of the river is very much affected. Common people use the river as a large sector of garbage dumping station and bathing pool of domestic animals. Garbage dumping is frequently allowing toxic wastes to adulterate adjacent soils and water bodies deforming the ground surface as well as channel bed of the river [6]. Use of fish traps, illegal lifting of water also contributes to the cause of threat to the river water. Coupled with the natural aspects such as heavy monsoon rainfall, poor drainage, strong convection rain storms and other indigenous factors, floods have become a common feature in Bongaon sub-division.

The geospatial technology has made significant contribution in natural hazard analysis [7]. Earlier studies have made several efforts in flood mapping and monitoring using remote sensing and GIS [8-10], probabilistic methods [11], hydrological and stochastic rainfall method [12], neural network methods [13, 14]. Present paper focuses on the delineation the flood susceptibility zone of Bongaon subdivision using remote sensing data along with other tabular and metadata.

2. DESCRIPTION OF THE STUDY AREA

Bangaon is a subdivision of the North 24 Parganas district in the state of West Bengal (India), extended between 23˚15′43.22″ N 22˚51′36.52″ N latitude and 88˚40′49.51″ E 88˚58′14.40″ E longitude, its eastern side has international border with Indo-Bangladesh, Nadia district situated in the west, northern side has Bagdah block and southern side bounded by Gaighata block (Figure 1).

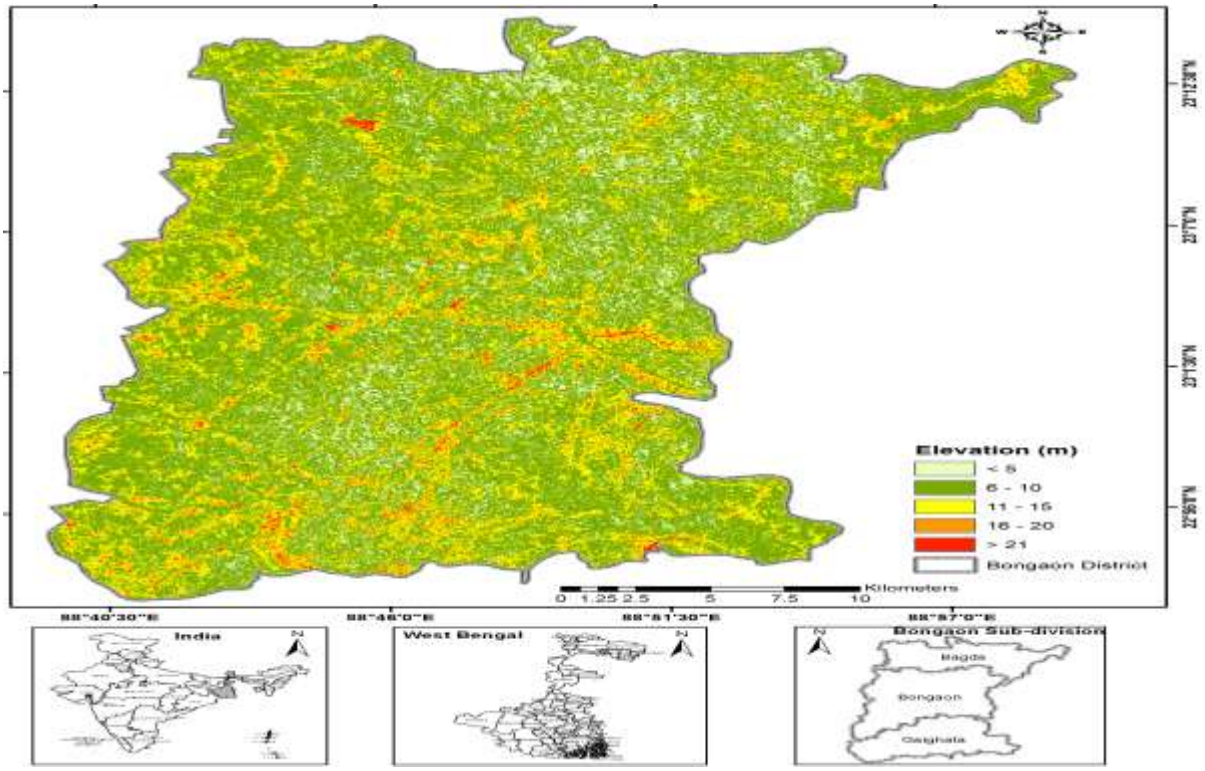

Figure1. *Location map of the study area*

The sub-division contains Bongaon Municipality, two census towns and 38 gram panchayats. The rainy season begins about the middle of June and lasts till October. The average annual rainfall of the sub-division is 142 cm (Figure 2).

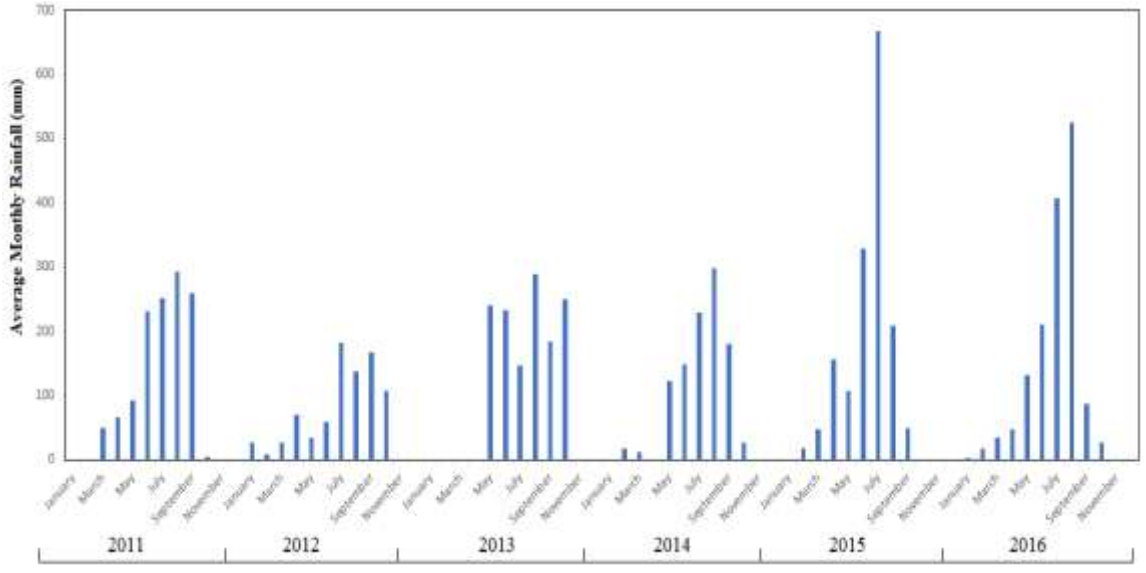

Figure2. *Average monthly rainfall of Bongaon sub-division*

The sub-division is a part of the lower Gangetic delta and is also remarkable on the vast gradational surface [4]. Bhagirathi and Hooghly River flow over the western side of the sub-division [15]. Ichhamati river flows through the center and the lifeline of Bongaon sub-division. The river water is used extensively in pisciculture, irrigation, religious works, brickfield etc. The soil of the subdivision belongs to the category of clayey, loamy, sandy and saline soil. Surface expression of normal fault is running through the Burdwan-Debagram-Jalangi area [16]. The dwindling of this Ichhamati River can be accredited to extreme sedimentation load, lessening headwater supply, tidal interference, growth of cultivated land and numerous instinctive interferences into the river regime like creation of bridges, road on the river bed by intruding its natural flow [4].

3. DATA USED

The administrative boundary layer of the sub-division was prepared from the survey of India topographical sheet at a scale of 1:50000. Field survey was conducted during the period between June 2016 and December 2016. The historical data of flood affected villages were recorded from the respective village and Block Development office. The topographical sheet map was collected from the Survey of India office, Kolkata. The Survey of India (SOI) topographical sheets were geo-referenced in Universal Transverse Mercator (UTM) projection system and World Geodetic System (WGS) 84 datum in ERDAS Imagine version 9.0 software. A personal geodatabase was generated in Arc Catalog and dataset was prepared for the study area with spatial reference of GCS WGS – 1984. Mapping of flood plain landscape element and dynamics is now possible using the medium resolution satellite data. Advanced Space Thermal Emission Radiometer (ASTER) Global Digital Elevation Model (GDEM) data (2010) with a spatial resolution of 30m was used for the topographical analysis, collected through the Earth Remote Sensing Data Analysis Center (ERSDAC) and the NASA Land Processes Distributed Active Archive Center (LP DAAC).

4. METHODS

4.1. Data Processing and Interpretation

Landsat8 Operational Land Imager (OLI) data of two different time period (Month of October and February) were acquired from the United State of Geological Survey (USGS) Earth Explorer community. The satellite data was radiometrically and geometrically corrected using ERDAS Imagine software version 9.0. By combination of spectral band7 (SWIR 1.55 – 1.75µm), band10 (TIR 10.40 – 12.50 µm) and band6 (NIR 0.77 – 0.90 µm), image analysis was performed to identify the geomorphic characteristics, like river/stream, abandoned channel, old and new alluvial plain, ox-bow lake, paleochannel, natural depressions, back swamps and meander scar. The geomorphological map was prepared with the evidence used by Chaturvedi and Mishra [3] and Mukherjee [17]. After that the selective field checks were performed to assess the validity of the pre-field image interpretation.

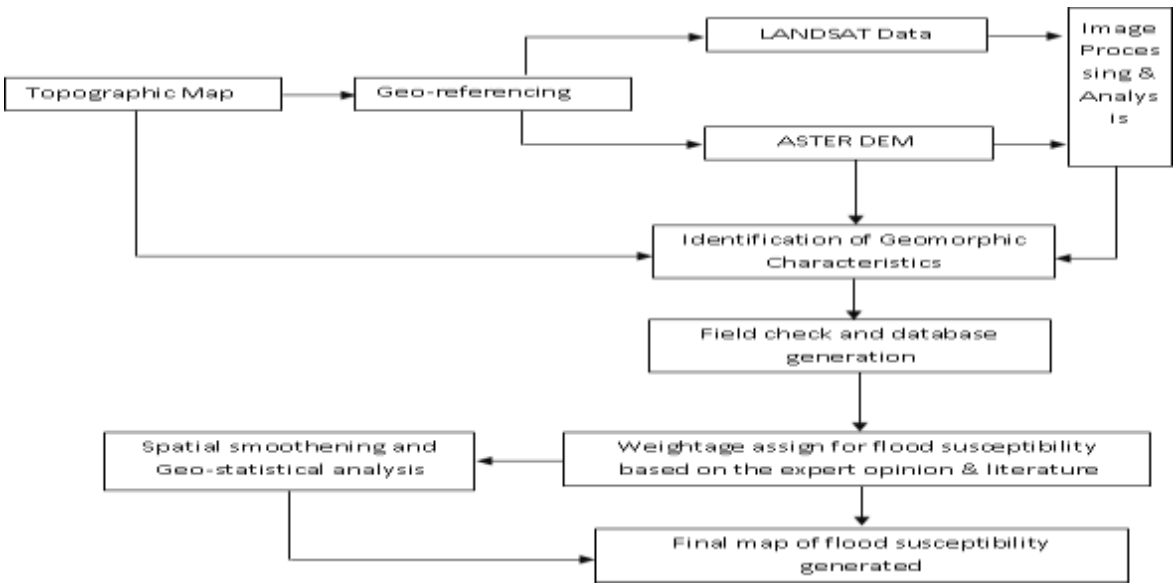

Figure3. *Flow chart map of study methodology*

The principal component analysis (PCA) images of Bongaon sub-division were created using multi-spectral band. A composite of PCA-images were generated by conveying the PC – 1, PC – 2 and PC – 3 on blue, green and red spectral band correspondingly. This PCA color combination delivers a better visualization of drainage network, abandoned channels and natural depression. The alluvial plain of Ganges delta had very low relief and gentle slope. Therefore, the topographic contours were not available topographical sheets of this region. A Digital Elevation Model (DEM) was prepared for the Ichhamati river using ASTER-DEM. The overlaying of the PCA data of Bongaon sub-division on the DEM indicates relationship between topographical characteristics channel morphology. The heads up digitizing method was used to demarcate the geomorphological features. Finally incorporating the necessary corrections, image based maps was completed by using QGIS software version 2.4. Table 1 showed the image physiognomies of geomorphic features in Bongaon sub-division.

Table1. *Image characteristics of geomorphic features in Bongaon sub-division based on Landsat8 OLI data*

Geomorphic features	Tone	Texture	Shape	Size
Active River Channel	Uniform tone of dark blue	Smooth	Elongated	Large
Abandoned channel	Light blue	Coarse	Elongated	Small
New alluvial plain	Dark Red	Smooth	Irregular	Large
Old alluvial plain	Light to dark red	Coarse	Irregular	Large
Old alluvial plain – Type II	Light red mixed with white	Coarse	Irregular	Large
Paleochannel	Dark red	Smooth	Sinusoidal	Small
Deep depressions	Dark blue	Smooth	Irregular	Large to small
Shallow Depressions	Light blue to dark blue	Coarse	Irregular	Large
Meander scar	Fossil meander surrounded with vegetation	Coarse	Irregular	Varying size
Back swamp	Light blue and red	Coarse	Irregular	Small to large

4.2. Flood Susceptibility Zone Identification

The fluvial process is the principal geomorphic cognition in the Gangetic plain. Landform of the Gangetic flood plain give a cue for mapping the level of past floods that are preponderantly deduced from the high soil moisture content, water logging and marshy land in the flood affected areas. The geomorphological characteristics were ranked in order to their susceptibility for causing flooding. The inverse ranking was applied to these factors i.e., '1' is the least important and '4' is the most important factor. The weightage of the geomorphic characteristics were given based on the literature review and expert evidences [3, 17, 18]. Voronoi statistics was chosen to evaluate the local smoothing and variation [19]. Local smoothing technique was opted which comprises the possessions of spatial changeability by spending information from contiguous geographic area of each geomorphic unit. Finally, the radial basic function (RBF) interpolation was performed for susceptibility mapping and analyzing using geographic information system (GIS). RBF method approximates values that can fluctuate above or below the maximum or minimum level of the appraised values. It also shields all the surface values of the direction and it was interposed surface will reside inside the bias [20].

5. RESULTS AND DISCUSSION

The subdivision seems to be the outcome of complex geologic and geomorphic procedures. In the northern alluvial plain the river Ganga, Ichamati have been performing an ascendant role in shaping and regulating the landforms with their predominant modifications in course. The geomorphic features of the study area are largely governed by the geomorphic processes and geologic structures and stages of the development.

4.3. Geomorphological Features Identification and Analysis

The floodplain region composed primarily of unconsolidated depositional materials derived from sediment being transported by the related stream [17]. The flood plain properties of Bongaon subdivision are generated by sedimentation of alluvial materials brought down by the Ganga and Ichamati river. There are twelve geomorphological parameters which have been identified in the Bongaon sub-division, such as active river channel, abandoned river channel, channel bar, back swamp, deep depression, meander scar, newer alluvial plain, older alluvial plain, older alluvial plain-type II, ox-bow lake, paleochannel and shallow depression (Table 2 and Figure 4).

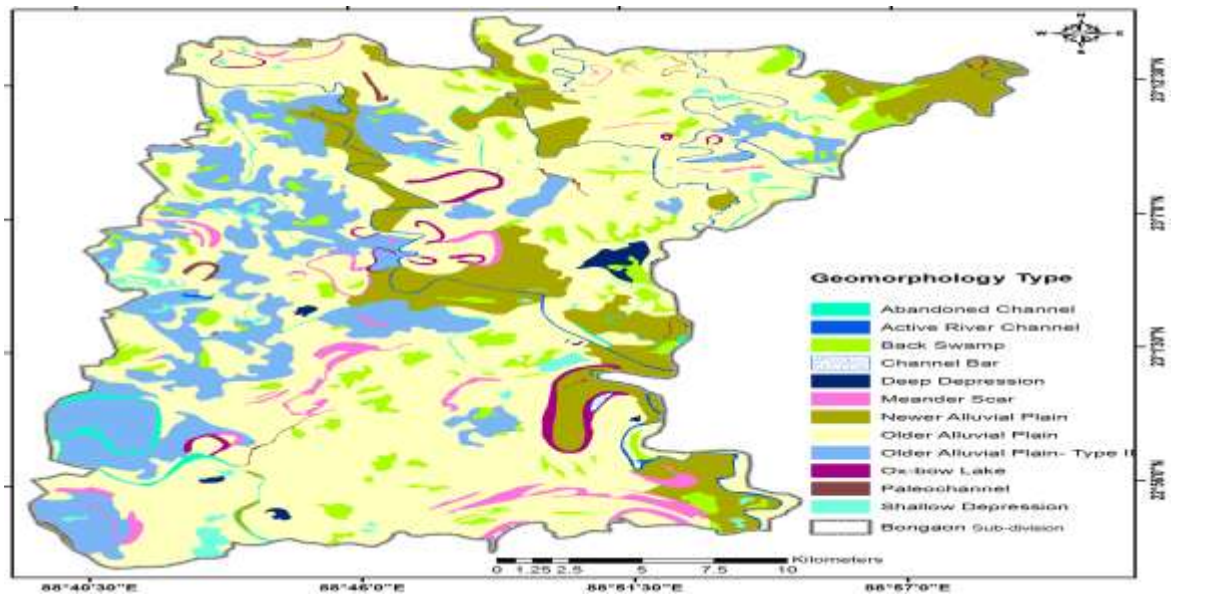

Figure4. *Geomorphological characteristics of Bongaon Subdivision*

Table2. *Areal extent of geomorphological characteristics and its association with the flood susceptibility of Bongaon sub-division*

Geomorphological Type	Area in km^2	%	Ranking for flood susceptibility
Abondoned Channel	23.57	2.83	Medium
Active River Channel	486.31	58.31	Very high
Back Swamp	13.08	1.57	Medium
Channel Bar	49.04	5.88	Very high
Deep Depression	5.26	0.63	High risk
Meander Scar	2.99	0.36	Very high
Newer Alluvial Plain	13.77	1.65	High risk
Older Alluvial Plain	9.71	1.16	Low
Older Alluvial Plain- Type II	11.64	1.40	Very low
Ox-bow Lake	124.39	14.91	High risk
Paleochannel	93.85	11.25	High risk
Shallow Depression	0.44	0.05	Low

5.1.1. Active and Abandoned River Channel

In the study area, the river channel was classified into active channel and abandoned channel. The active channel network gets periodic scour and/or fill during sediment transport events. The river valleys are shallow with a low gradient. The channel is certainly discernible by its regular shape with a light uniform tone. Active river channel is extended with an area of 23.57 km^2 (58.31%) and is cogitated as very high decisive factor for flood susceptibility. The abandoned stream channels was the part of the fossil meanders still carrying water, detach from the recreation of the river and normally absences year long standing water, and are filled with coarser material. These are eminent on satellite data from their identical surface configuration and light to medium tones.

5.1.2. Newer Alluvial Plain

The newer alluvial plain is concealed by 1.65% (13.77 km^2) of the Bongaon sub-division. This region epitomizes the tracts of newer flood plain designed by the flood streams, also locally recognized as Khadar. It is generally considered as an integral part of the streams where deposition of sediments occurs during each flood. The soil of this zone is extremely fertile, appeared in dark red tone, smooth texture and irregular shape in the standard False Colour Composite (SFCC) data. The new floodplain zones are more prominent along the banks of the river.

5.1.3. Older Alluvial Plain

The older alluvial plain is concealed by 2.56% (21.35 km^2) in the study area. Old alluvial plain (OAP) also known as Bangar, represents the older alluvium of higher ground located far from the channels. The OAP appeared as light to dark red tones on SFCC satellite imagery.

5.1.4. Meander Scar

When the channel roams crossways down the valley on the way to the concave bank, the depression and growths which are designed on the convex side of the bank are called meander scar. These are formed by the remnants of a meandering water channel caused by the varying velocities of current within the river channel. Formation of meander scar observed adjacent to the active river channel and appeared as very light tone on satellite imagery. If enough water is stored into the scar or fills with sediment, these areas may become marshes or wetlands [21]. Meander scar is covered with an area of 2.99 km^2 (0.36%) area and is considered as very high determining factor for flood susceptibility.

5.1.5. Back Swamp

Back swamp are the common features in the study reach. This is an area of low, poor drained, slightly depressed relief area on a flood plain far from the main channel, shows a dark tonal anomaly on image [22]. It stands marginally lesser than contiguous alluvial plain, comprises with the accretion of silts, clays, usually inhabitant by marsh plants.

5.1.6. Ox-Bow Lake and Paleochannels

A meandering stream may erode the convex shores of its wide bends. These resulting shallow crescent shaped water bodies are called ox-bow lakes. The paleochannels may be preserved as abandoned surface channels on flood plains or might have been unfilled by fluvial or other sediments and are exposed as isolated sediment section. The common geographies of paleochannels were brought into the fame by Schumm [23]. The paleochannels are typically of a sinusoidal pattern on nearly dry ground with high reflection which is characterized by disjoints parts of channels like meanders. The existence of vegetation along channels can be recognized in images due to higher reflectance in the NIR bands. Consequently, the ox-bow lake and paleochannel are covered by 14.91% (124.39 km^2) and 11.25% (93.85 km^2) respectively in the study area and also cogitated as high susceptible for flood.

5.2. Identification of Flood Susceptibility Zone

Floods are the short term geomorphic risks that may bear upon geomorphic stability of a landform to hardship of living things [24]. Recently, the employment of satellite based geospatial techniques has importantly built the quality and coverage of flood vulnerability mapping. In our study, the mapping of flood vulnerability zones of Bongaon sub-division was attempted by using Landsat8 OLI imagery and selective field visits (Figure 5). Landforms of the Gangetic plain provide a clue for mapping the extent of past floods that are prominently inferred from the high soil moisture content, water logging and marshy land in the flood affected areas. The mean value of the RBF interpolation technique is 0.0023 with a root mean square error (RMSE) of 0.19. The kernel parameter of the RBF function is 0.003 and the estimation is based on the completely regularized spline. Based on the local geomorphological characteristics, the Bongaon sub-division was categorized into very high, high, moderate, very low and flood free zone (Figure 5).

5.2.1. Very High Flood Susceptibility Zone

This zone is covered by approximately 13.71% (114.35 km^2) and this zone is extended in the south-east and northern part of the sub-division. The area is marked adjacent to the rivers where water of the river casually compasses in the form of flood. Geomorphologically, such regions are confining under new alluvial plain zones, channel bar, and meander scar. The average height of this zone is 5.0m above mean sea level. These zones are extended in the south-east, north east and small pockets of central and northern part of the Bongaon subdivision. During the field visit, the local people recommended that Manigram, Madhabpur of Bongaon block, Rajapur and Raghunathpur of Gaighata block and Ranaghat, Kulia, Rajkol of Bagda areas get inundated during the monsoon season when heavy rainfall occurs (Figure5). The principal reason of the flood in this zone is gentle terrain and the poor transferring capability of river Ichhamati during massive rains. Consequently, the spatial arrangement pattern of gravel, sand, silt, and clay accumulation resulted from fluvial activity in the past may be reported as accountable for future day floods.

5.2.2. High Flood Susceptibility Zone

High flood susceptibility zone is shielded by 25.98% (216.68 km^2). The average height of this region is ranges between 6m and 10m above MSL. The areas of abandoned river channel, paleochannel, ox bow lake, back swamp and deep depression due to the location adjacent to very high susceptibility zone.

The small pockets of the region are extending in the eastern, southern, northern and small pockets of central part of the sub-division. This zone is extended in Tankshali, Parmadan, Andulpota of bagda block, Nakful, Molahatti, Khalitpur chak of Bongaon block and Tentulabari, Simulpur, Dharampur, Shyampur of Gaighata block (Figure 5).

5.2.3. Moderate Flood Susceptibility Zone

The moderate flood susceptibility zone is extended with an area of 146.28 km^2 (17.54%). Such areas are confined as older alluvial plain and shallow depression. The altitude of the region is extended between 11m and 20m above MSL. This zone is extended between high and low susceptibility zone, distributed in the central and southern part of the sub-division. The very small part of this category was also observed in the eastern and north-east corner of the sub-division. Karola, Gutri, Chikanpara of Gaighata block, Byaspur, dharampur, Belta of Bongaon block and Beara, Makra and Kulandarpur of Bagda block situated under this category (Figure 5). During field check, villagers also reported that the regions get inundated during rainy season.

5.2.4. Low Flood Susceptibility Zone

The average height is noticed as more than 20m above MSL. The low susceptibility zone is covered with an area of 235.73 km^2 (28.26%). This zone is mainly stretched in the west, upper central and north-east part of the subdivision. These areas are identified as older alluvial plain, shallow depression.

5.2.5. Very Low Flood Susceptibility Zone

These areas are identified as older alluvial plain- Type II. This zone is enclosed with an area of 121.03 km^2 (14.51%). The areas are extended in the west of the sub-division. Some small patches of are also observed in the central and northern part of the sub-division. This zone generally extended in the Hingli, Chauberia, Garjala of Gaighata block and Malida, Mustafapur, Kathalia of Bagda block are comes in this category (Figure 5). Geomorphologically, these areas are characterized by sparse vegetation and mostly accounted as open land where flood may occur during heavy rainfall.

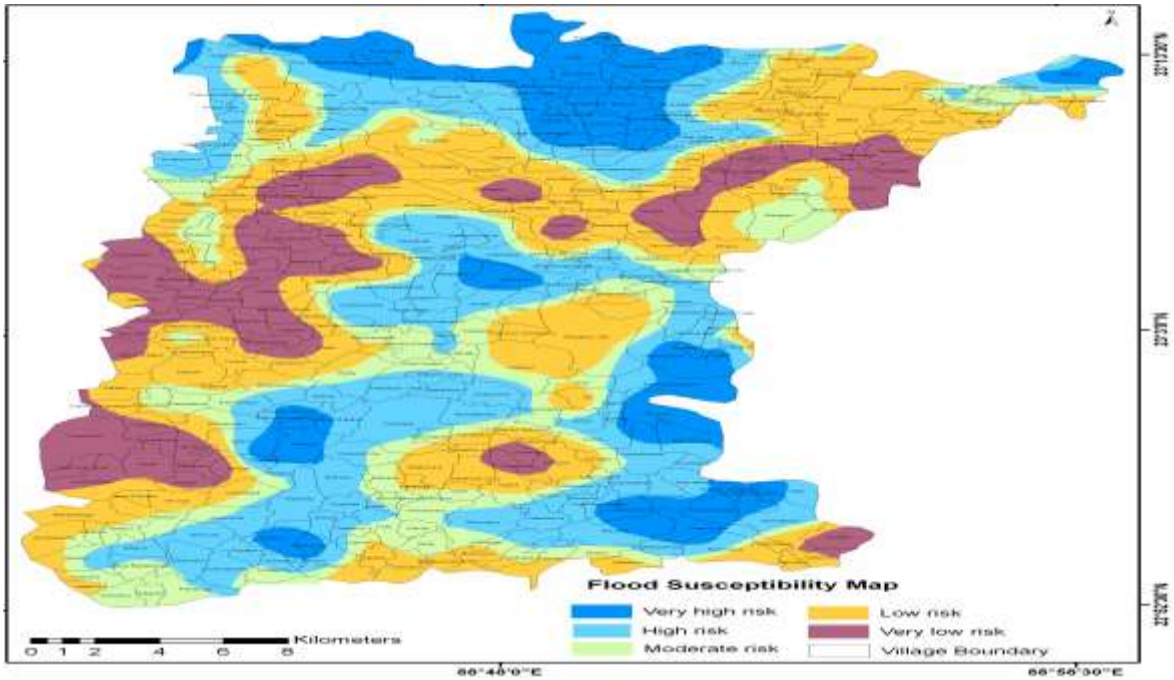

Figure5. *Flood hazard susceptibility map of Bongaon Sub-division*

6. CONCLUSION

However, the final susceptibility map was generated based on the relative importance of gemorpohological aspect within the study region. Bongaon sub-division located on the Indo Gangetic plain and river Ichhamati passes through the sub-division. Present study indicated that geospatial technology is very appropriate tool for diagramming geomorphic features and flood susceptibility areas. Landsat8 OLI data with 30m spatial resolution aids to delineate the spatial extent of regional

geomorphic features like, new and old alluvial plain, meander scar, paleochannel, ox-bow lake, active river channel, abandoned river channel, natural depression etc. These landform features are largely helpful in delineating flood susceptibility zone. However, the population density is very high in the sub-division due to its fertile alluvial plain [25, 26]. A huge chunk of settlements are observed in the sub-division and make some barriers [4]. Local residents are using the river bed as agricultural land since many decades. So, the increase of sedimentation in river water caused loss of navigation which is also a great threat of ecological balance of the river basin [27]. Consequently, by the construction of railway bridge at Majdia (Nadia District, West Bengal), water barrier has been developed. Some of the villages like Alakalippur, Janipur Sadarpara, Taranipur and Damdama were marked as low flood susceptibility zone in flood susceptibility map whereas, these are demarcated as high flood susceptibility zone by the locality. However, flood is occurred due to multiple factors like rainfall, slope, proximity to the river, soil texture, land use etc. Integration of all these parameters may provide the better accuracy. Therefore, a comprehensive investigation on vulnerability necessitates the evidence about the susceptibility of dissimilar features at risk. This is preliminary analysis of flood susceptibility of Bongaon sub-division and the present study could be helpful for providing the base line information for determining and planning about the flood prone zone for disaster management of flooding.

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