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Application of Remote Sensing and GIS for Flood Hazard Mapping: A Case Study at Baralia-Nona River Basin, Assam, India

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ABSTRACT: *Floods are the most common natural hazards which lead to the loss of lives, properties and resources. Floods in the Indo-Gangetic-Brahmaputra Plains are an annual feature. Flood, bank erosion and sedimentation are a major problem in the plains of the Baralia-Nona basin. Heavy rainfall in the Bhutan Himalayas as well as in the flood plains of Brahmaputra Valley, lack of adequate gradient to drain out the high discharge of the rivers, increasing sedimentation due to deforestation and landslide in the upper catchment, breaching of embankments are the main causes of flood in this part of the basin. Flood history indicate that regular large floods have breached the embankments, created areas of bar development and caused bank erosion and aggradations and channel migration in the study area. This study area needs an efficient and cost-effective methodology for preparing flood hazard map for Baralia-Nona Basin, where flood pose a recurrent danger. An additive model was utilized to create a composite flood hazard index of the study area. A composite flood hazard index was developed incorporating variables like elevation, population density, proximity to the rivers, number of household and cropland. The study demonstrated the potentials of GIS applications in flood hazard mapping which will also be helpful in studying the problems of agricultural land use, cropping characteristics in the area.*

KEYWORDS: *GIS Modeling, Land Cover/Use Classification, Hazard Rank, Hazard Map.*

I. INTRODUCTION

India is one of the most vulnerable developing countries to suffer very often from various natural hazards, namely drought, flood, cyclone, earthquake, landslide, and forest fire, hail storm etc. These hazards are causing a dreadful impact on the human life, economy and environment. Due to its geographical position, climate and geological setting coupled with deforestation, unplanned growth explosion non-engineered constructions which make the disaster –prone areas more vulnerable. About 60% of the total country is vulnerable to earthquake, 8percent area prone to cyclones and 12 percent vulnerable to floods **(Kumar, 2009).**

Among all kinds of natural hazards of the world flood is probably most devastating, wide spread and frequent. In the humid tropics and subtropical climates, especially in the realms of monsoon, river flooding is a recurrent natural phenomenon **(Bardaloi, 1986).** In spite of the great loss and suffering people are attracted more and more to the floodplain. It is due to the fact that floodplain provides fertile land for growing crops, adequate quantities of water for irrigation, domestic and industrial use, easy access for transport and communication, level land for construction of homes and factories etc **(Brahma, 1995)**. India is one of the worst flood affected countries, being second in the world and accounts for one fifth of global death count due to floods. India receives 75% of rains during the monsoon season (June to September). As a result almost all the rivers are flooded during this time resulting in sediment deposition, drainage congestion, invading into the main land. More than 8 million hectares of land in India are annually affected by floods **(Valdiya, 2004).** The flood prone area in India constitutes about 40 million hectares, about 25 percent of the cultivable land. Average damage caused by flood fury to house properties, public utilities and standing crops evaluated in terms of money of about Rs.13470 million **(Talwar *et al*.,2010).**

Floods are a recurring annual feature of Assam when Brahmaputra and its tributaries, with very large catchments, are flooded exceeding the limit of bankful discharge and submerge a substantial part of Brahmaputra plain. In very severe floods, three to four million hectares of land are affected. These floods occur between May and September, the period of summer monsoon. The floods affect the crops, cause erosion, breach embankments, wash away cattle, destroy houses, uproot trees and even affect the wildlife sanctuaries (Dikshit *et.al*.,2014). The Baralia-Nona Basin is frequently affected by floods of the Baralia and Nona rivers and some other small courses coming from the mountains located to the north of the basin. The lower part of the basin is severely affected by flood every year.

II. STUDY AREA

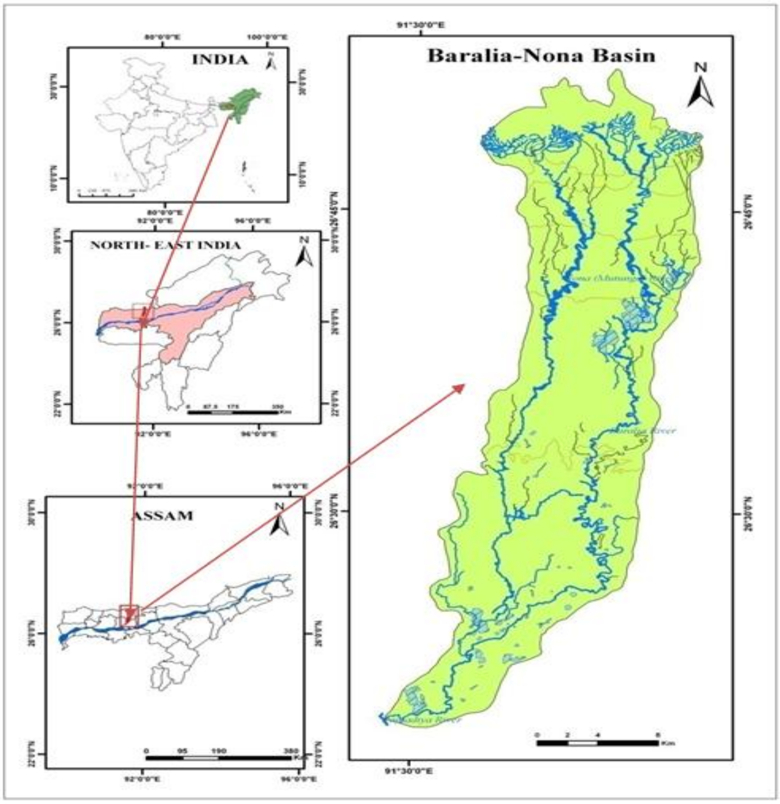
The study area i.e., the Baralia-Nona river basin **(Fig.1)** extending from 26^{o} 19'N to 26^{o} 50'N latitude and from 91^{o} 28' to 91^{o} 41'E longitude has a catchment area of about 558.71 km^{2} .The river Baralia originates from Bherberi Bhumuk near Nagrijuli tea estate where some small channels from Bhutan hills find their ways as underground flow into low lying area there. This river covers a length of 75 Km before it joins Pagladiya near Dusutimukh on its left bank.The river in its entire length drains an area of 270 Sq. Km. The river has formed meanders in its entire length. The river Baralia flows to the west of river Puthimari and runs almost parallel to it up to R.G. Railway line and finally falls in the river pagladiya near Dusutimikh. The river runs dividing the Sub-Division Head Quarter Rangia. The river is bounded by Puthimari in the east and Nona and Mutunga in the west. In the upper reach spill from river Balti joins it on the right bank just about 2.4 Km below Nagrijuli tea garden.The nature of river Baralia is heavily silt loaded discharge during the monsoon period. The Baralia river is meandering in nature with attitude to charge its course frequently due to silt deposition in the river bed. The length of river approximately 20 Km under Rangia Sub-division from Dwarkuchi to Chamukha Bathan and length of embkt. is 21 Km in both banks (9Km on R/B & 12 Km L/B from N.T. Road to Nona Outfill).The danger level of Baralia river at N.H.-31 crossing is 51.98 **(Flood Management Plan-2013).**

The Nona River originates from the Bhutan hills where two small rivulets namely Bogajuli and Dimabari join to form one stream known as Mutunga at Dewabari and is subsequently known as Nona. The total length of the river from the Bhutan foot hills to its outfall into Baralia is 63 Km. This river has all the characteristics of a flashy river like pagladiya. It also meanders freely and has many loops, the slope being somewhat flatter in the lower reaches. In the upper reach the Nona (Mutunga) river bed is built up of boulders, shingle and sand with steep slope, while lower down it is in the alluvial stage. The Nona river has 21 loops on the right bank and 20 loops on the left bank in its embanked reach of 29.4 Km. The meander lengths of the river loops vary from 150m to 520m., while the meander belts vary from 80 to 290m.**(Master Plan, 1996).** Together both the rivers form the Baralia-Nona basin.

III. OBJECTIVES

The principal objectives of the study have been outlined as follows

1) To study the meteorological characteristics of the basin.
2) To identify the vulnerability of flood hazard within the basin.
3) To design a flood hazard zonation map by using composite flood hazard index.
4) To suggest steps for hazard mitigation & planning in the study area.



FFigure 1: Location of the study area

IV. MATERIAL AND METHODS

The Survey of India topographic sheets (1:50,000) No.78 N/7, 8, 10, 11 used in the study was registered to UTM projection (WGS 84 North, Zone 46). The drainage network of Baralia-Nona basin was delineated by digitizing drainage line in GIS environment from the topographic map. Rainfall data were collected from secondary sources and represent through graphs to show the relationships. Land use map of the sub-basin has been classified into 10 categories viz. settlement, dense forest, degraded forest, water logged area, wetlands, rivers, ox-bow lake, plantation crops, fallow land and cropland and others. The area under each Category has prepared from SOI, Toposheets of 1971. The topographic maps and SRTM image has been used to extract the contours at different interval. For preparing village wise density map village boundary were extracted from Assam Administrative Atlas. Village wise population data were taken from Census from India, 2011 and with the help GIS village wise area is calculated and density of population village were calculated. Proximity of villages from Baralia and Nona river were taken by taking buffer of 0.5,1 km and 1.5km. Village wise household were calculated from census data. The information collected from the primary and secondary sources are tabulated, summarized and analyzed using quantitative and computer aided techniques and prepared with thematic maps, charts, tables, graphs using appropriate cartographic methods.

A total of 280 villages within the basin have been analyzed. Five factors have been taken into consideration for developing the composite flood hazard index. Each of the factors has been assigned different weightage to quantify the severity of hazard. The final flood hazard map is represented in a colour map. It was classified into 5 hazard categories by natural breaks. The flood hazard map exhibits that there is no defined pattern in the disposition of flood hazard zones. Contrary to the overall topographic configuration high hazard zones are not necessarily located very near to River. In the southern side of the basin there depict very high hazard situation. This high hazard potential might be as a result of their higher population density. The upper part of the basin is closer to river but due to elevation factor less prone to flood hazard. The effect of flood in the middle portion of the basin is medium and in few patches near the river high hazard zones were seen.

V. DISCUSSION AND ANALYSIS

5.1. Meteorological Aspects

Rainfall- The climate of the Baralia-Nona-Mutunga basin lies in tropical monsoon climate. As it is part of Assam and the North-east India. Owing the rapid changes in topographic and altitudinal levels, the climatic condition is different types in various seasons. There are four climatic seasons are experienced by the region as given below:

a) ***Summer Season***- After middle of May, June, July, August, September and first half of the October. The total rainfall during this season is 180cm.
b) ***Retreating Monsoon***- From middle Oct to November.
c) ***Winter Monsoon***- Dec, Jan, Feb and first half of March. Total rainfall in this season hardly exceeds 11.5 cm.
d) ***Pre Monsoon***- From last part of March to May.

During the summer season the temperature is extremely high ranges between 20° to 30° C. Heavy rain falls occurred in summer. Maximum rainfall occurred which ranges from 2500 to 2600 mm. The months of winter temperature fall and it varies between 8° to 15° C and rainfall varies from 40 mm to 60 mm. The winter is dry and sometimes rainfall occurred but it is little which occurred by retreating monsoon. But summer season is very wet. Mean annual rainfall is 1095 mm and temperature is 24.6 ^{0}C. The study area is fall under the humid climatic region.

There are four meteorological situations for causing of heavy rainfall, such as-

(i) Movement of North-westerly to northerly monsoon depression from the Bay of Bengal to the sub-basin.
(ii) Shifts of the axis of the seasonal through to the north from its normal position.
(iii) Formation and movement of land laws or land depression over North-East India.
(iv) Circulation of cyclonic upper air over North-East India.

The air is highly humid throughout the year. During the months January to April, the relative humidity is comparatively less specially in the afternoons when they are between 52p.c. respectively. (Baruah, 2008).

Details of Mean Monthly total Rainfall and seasonal rainfall of Nagrijuli T.E. and Rangia Station within the Baralia-Nona Basin are shown in **Table 1, 2, 3 & 4.**

Table 1 & 2,. Mean Monthly total rainfall (mm) and average Seasonal rainfall from 2004-2013 of Nagrijuli T.E.

Mean Monthly Total Rainfall (2004-2013) Station- Nagrijuli Tea Estate	
Month	**Rainfall(mm)**
Jan	5.22
Feb	28.28
Mar	95.78
April	302.48
May	312.33
Jun	553.88
Jul	522.2
Aug	316.57
Sept	314.64
Oct	136.55
Nov	7.16
Dec	5.91

Year/Month	**Average Monsoonal Rainfall**	**Average Non-Monsoonal Rainfall**
2004	591.60	111.57
2005	415.48	136.80
2006	277.92	53.60
2007	332.80	91.99
2008	347.27	103.10
2009	308.63	32.93
2010	367.27	89.29
2011	287.10	34.34
2012	379.83	65.80
2013	279.60	66.59

Source: Nagrijuli Tea Estate

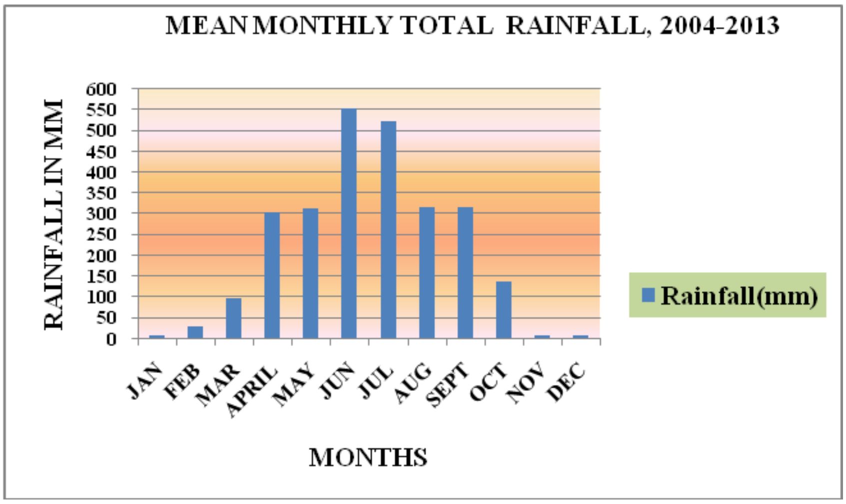


Figure 2: Bar graph showing the trend of mean monthly rainfall from 2004-2013 of Nagrijuli T.E.

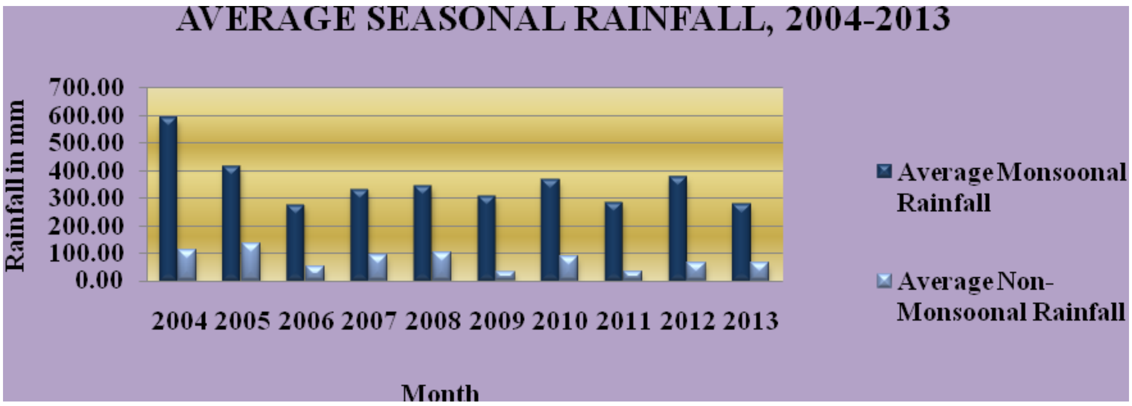


Figure 3: Bar graph showing the trend of Average seasonal rainfall from 2004-2013 of Nagrijuli T.E.

Table 3. Mean Monthly total rainfall of Rangia (mm) from January, 2004 to December, 2013

Month	Rainfall(mm)	Month	Rainfall (mm)
Jan	7.96	Jul	295.5
Feb	20.58	Aug	200.41
Mar	70.32	Sept	147.18
Apr	271.14	Oct	93.36
May	207.67	Nov	66.9
Jun	308.17	Dec	2.19

Source: *RMC, Borjhar, Guwahati-17*

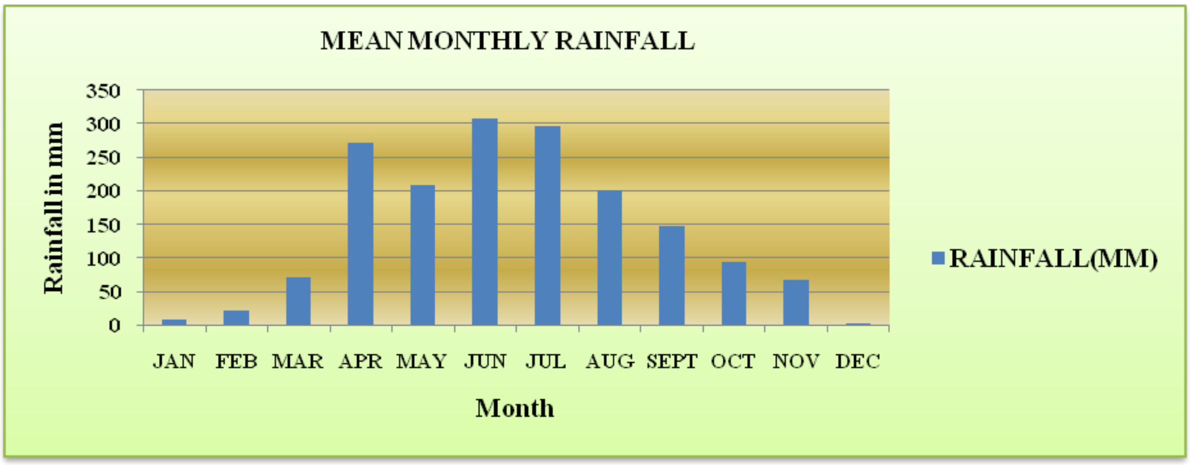


Figure 4. Bar graph showing the trend of mean monthly total rainfall from 2004-2011 of Rangia station.

Table 4. Average Seasonal rainfall from 2004-2013 of Rangia Station

Years	Mean monsoonal rainfall	Mean Non-monsoonal rainfall	Years	Mean monsoonal rainfall	Mean Non-Monsoonal rainfall
2004	186.28	13.95	**2009**	184.70	1.85
2005	157.43	7.80	**2010**	269.91	3.375
2006	139.73	10.52	**2011**	208.90	8.30
2007	276.66	27.40	**2012**	257.90	5.70
2008	212.01	10.45	**2013**	193.60	4.20

Table 5. Average Annual rainfall of Rangia and Nagrijuli T.E.

Year/Month	Average Annual Rainfall (mm)		Year/Month	Average Annual Rainfall (mm)	
	Rangia	Nagrijuli T.E		Rangia	Nagrijuli T.E
2004	139.99	344.68	2009	108.43	174.67
2005	119.24	269.16	2010	191.85	230.58
2006	91.43	165.98	2011	127.62	162.42
2007	174.45	202.93	2012	160.50	219.08
2008	133.66	221.09	2013	112.14	159.71

Source: RMC, Guwahati & Nagrijuli T.E.

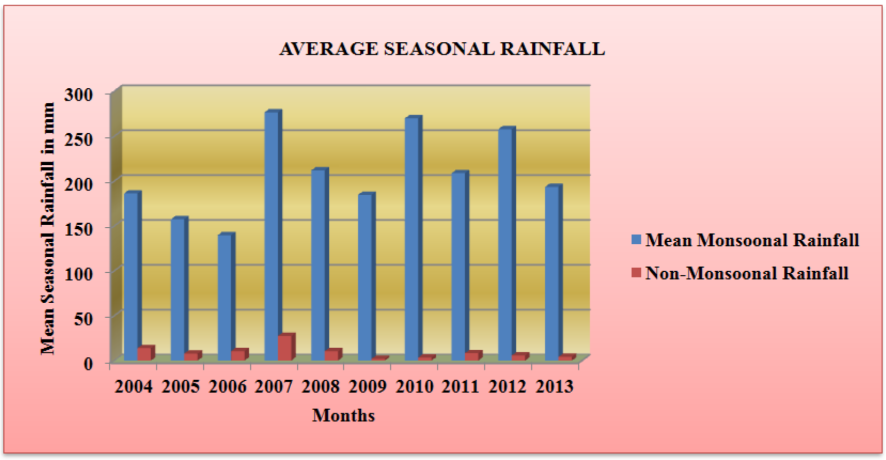


Figure 5. Bar graph showing the trend of Average seasonal rainfall from 2004-2013 of Rangia Station.

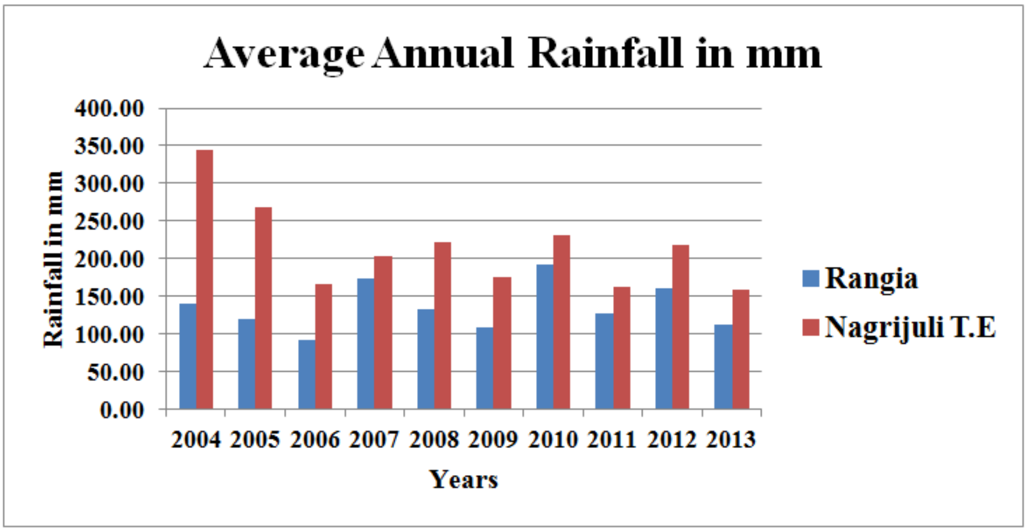


Figure 6. Bar diagram showing the comparison between Average Annual rainfall of Rangia and Nagrijuli T.E

5.2. Temperature

The data of temperature and other meteorological elements may be takes as representative condition in the basin in general; from about the end of February temperatures begins to increase .In April , the main daily temperature is 30°C. Although the temperature during the period March to May is seldom excessive weather is rather unpleasant on account of the excessive dampness in the air.Even in the South- West monsoon period, the day temperatures continue to be nearly the same as in April and May. So, the weather in the monsoon is also sometimes trying particularly when not raining .Temperature decrease progressively after end of the South West monsoon season. From later half of November, the temperature ranges between 20 to 30°C and during winter season temperature ranges between 8 to 15°C. The mean annual temperature is 24.6^{o}C. In present time due to the global warming temperature of globe is increasing day by day.

5.3. History of Flood in the study area

Flood, bank erosion and sedimentation are a major problem in the plains of the Baralia-Nona basin. Heavy rainfall in the hilly reach as well as in the plains, lack of adequate gradient to drain out the high discharge of the rivers, increasing silt load due to increased deforestation and landslide in the upper catchment, breaching of embankments are the main causes of flood in this part of the basin. Geotectonically fragile and seismically sensitive segment of the basin further accentuates the flood and erosion scenario. Flood history indicate that regular large floods have breached the embankments, created areas of bar development and caused bank erosion and aggradations and channel migration in the study area. The river has changed its course several times since the past. **Table-6** shows the damage statistics due to flood and erosion in the basin from 1987 to 2013.

Table 6. Damage statistics due to flood from 1987-2013

Year of flood	Area affected by flood (sq km.)	No.of villages affected by flood	No.of people affected by flood	Crop area affected by flood (sq. km.)	Area affected by erosion (sq km)	No. of villages affected by erosion
1987	513	256	1,20,123	345	NA	NA
1988	524	214	1,11,897	423	NA	NA
1989	435	267	1,32,000	321	NA	NA
1990	476	211	1,11,132	378	NA	NA
1991	482	234	1,43,000	411	5.01	12
1992	415	118	1,56,000	390	7.08	5
1993	325	198	1,71,000	311	3.14	3
1994	321	213	2,11,200	278	NA	NA
1995	311	256	1,81,000	231	NA	NA
1996	285	198	2,13,214	187	8.09	17
1997	345	176	2,11,198	324	NA	NA
1998	467	134	2,41,000	432	NA	NA
1999	237	234	1,89,000	176	NA	NA
2000	327	198	1,71,012	276	NA	NA
2001	457	176	1,90,567	378	NA	NA
2002	345	154	2,16,345	278	17.02	7
2003	456	123	2,78,916	321	NA	NA
2004	590	264	2,81,987	416	22.01	9
2005	455	243	2,32,456	378	15.01	5

2006	434	233	1,89,985	398	NA	NA
2007	342	256	1,23,456	294	NA	NA
2008	415	213	2,78,932	369	NA	NA
2009	432	222	2,67,189	318	NA	NA
2010	324	153	2,13,322	321	14.31	8
2011	345	213	1,81,987	314	NA	NA
2012	546	256	2,13,221	467	NA	NA
2013	217	200	1,87,900	189	NA	NA

NA means data not available

(Source: Water Resource Department, Govt. of Assam, Guwahati)

5.4. Preparation of Land Use Map

Land use pattern of the sub-basin has been classified into 10 categories viz. settlement, dense forest, degraded forest, water logged area, wetlands, rivers, ox-bow lake, plantation crops, fallow land and cropland and others. The area under each Category is shown in the **Table-7** Which has prepared from SOI, Toposheets of 1971 .The table shows that cropland and others activities like roads, railways etc occupies most of the area in the basin in plains. About 68 % of area is covered by cropland and other activities. In the hilly region, the basin is mainly covered with forests. The upper part of the basin mainly consists of dense forest covers 4.4% of the basin area. Below this degraded Darranga R.F. covers 4.3% of the basin area. By observing land use map it is seen that land use pattern in the whole basin is not evenly distributed, concentrated of population were also more in upper part due to tea estate and other reasons. But lower part is severely affected by natural hazard like flood and bank erosion due to less gradient and confluence of Baralia and Nona river along with many small nalas. The land use pattern of the Baralia-Nona basin is shown in the following table:

Table 7. Land Use pattern of Baralia-Nona Basin

Sl.No.	Categories	Area(sq km)	Percentage	Sl. No.	Categories	Area(sq km)	Percentage
1	Water logged area	2.660	0.476	6	Rivers	13.699	2.452
2	Fallow land	13.214	2.365	7	Wetland	11.771	2.107
3	Plantation crop	25.801	4.618	8	Degraded forest	24.570	4.398
4	Settlements	56.552	10.122	9	Dense Forest	27.722	4.962
5	Ox-Bow lake	2.590	0.464	10	Cropland and others	380.126	68.037
					Basin Area	**558.706**	**100.00**

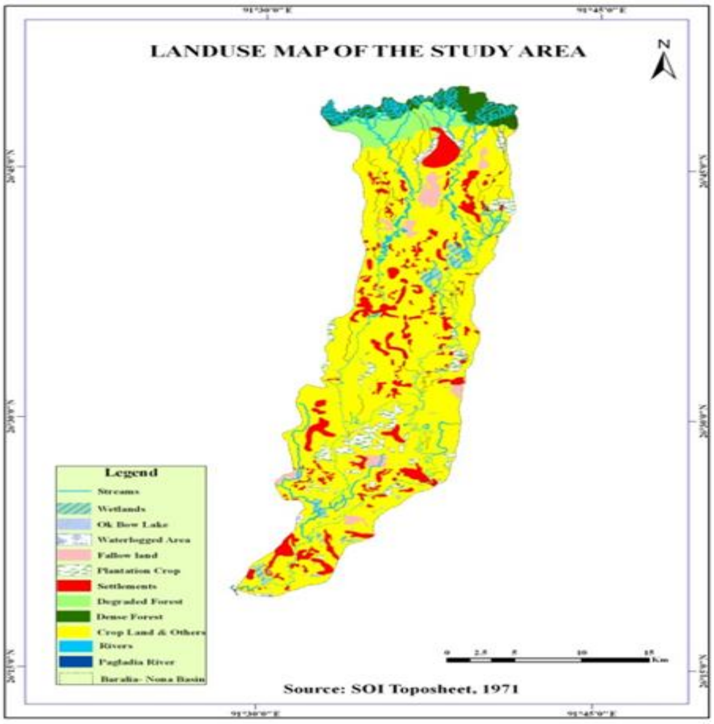


Figure 7. Land Use map of Baralia-Nona Basin under different categories

5.5. Flood Vulnerability Mapping

Flood hazard mapping is a vital component for appropriate land use in flood areas. It creates easily read, rapidly accessible charts and maps (Bapalu and Sinha, 2005) which facilitates the identification of risk areas and prioritize their mitigation effects. Flood hazard mapping is not a new endeavor in the developed countries of the world. One of the most active and well known in this sphere is Federal Emergency Management Agency (FEMA, 2006). Floods are of many types including flash flooding (Gruntfest and Handmer, 2001), flooding due to rising of ground water (Burt et al, 2002), coastal flooding (Doornkamp, 1998, Nicholls, 2002) and flooding due to the opening of a dam or reservoir. The purpose of flood risk assessment is to identify the areas within a development plan that are at risk of flooding base on factors that are relevant to flood risks.

5.5.1. Elevation Map: An elevation map is a representation of the Earth's relief that consists of an ordered array of elevations relative to a datum, and referenced to a geographic coordinate system (Forkuo, 2010). It provides elevation information that is useful for many environmental applications including hydrologic modeling and flood management planning (McDougall et al, 2008). They provide the opportunity to model, analyze and display phenomenon. The topographic maps and SRTM image has been used to extract the contours at different interval. The village boundary layer has been overlaid and elevation for each village polygon has been extracted using ArcGIS. Each polygon has been assigned a unique identity number (i.e., ID) in the attribute table that represents a village so that composite hazard index can be joined to the GIS data base using the common unique ID. Elevation plays an important role in determining the severity of flood and bank erosion hazard. The raster map in **Figure-10** indicates the elevation map obtained for each village.

5.5.2. Population Density Map: Recent floods within the basin has left a trail of devastation everywhere. The population density of the entire catchement is not uniform. The upper most catchment is thinly populated where as the middle and lower part of the catchment which come under Nalbari and Kamrup districts were of Assam were thickly populated. The total population has been estimated as 3,10,402 persons. The average density of population within the basin is about 733 persons per Sq.Km.

5.5.3. Proximity to Baralia and Nona River: Proximity to river and streams is an important factor while determining flood hazard. For the analysis, various village distances from the Baralia and Nona river were determined by taking buffer of 0.5 km, 1km and 1.5 km along the both rivers. The midpoints of the villages were considered. The distances of the various villages in Kilometers were then extracted. The villages near to the river were highly prone to flood hazard.

5.5.4. Number of household: Flood affected severely the economic condition of the people. Loss of property, houses is a common thing. There is about 70,390 household within the basin comprising 280 villages. Calculation of household within each villages in the basin helps in determining the losses and which further helps in flood plain zoning.

5.5.5. Agriculture: Agriculture is the major occupation of the people in the Baralia-Nona basin and the entire economy of the basin is dependent on agriculture. Every year due to heavy flood agricultural crops were severely affected. Secondary data collected from various sources were used to represent the distribution of cropland in the basin. An additive model has been adopted for creating a composite flood hazard map. It is recognized that the principle of assigning weightage to the variables is very crucial in this entire process of hazard mapping. The process of assigning weightage to the flood hazard indicators is primarily knowledge based. The variable proximity to the river has been attached high importance because where the risk of inundation is very low other variables do not contribute anything to the element of flood hazard. Villages have been assigned weightage for each of the 4 hazard indicators. The weightage scheme for proximity to river clearly displays that very low or 0 weightageing have been applied to far away villages and high weightage value were assigned to nearby villages. weightage have been increased at rate with higher risk of flood occurrence. The weightage scheme for proximity to river is presented in **Table-8 & Fig-8.**

Table 8. Proximity Catchments areas with weightage

Distance(km) from catchments Area (Near_Village)	Weightage (D_W)
< 0.5 Km	4
0.5-1 Km	3
1Km – 1.5 Km	2
>1.5Km	1

Similarly the weightage scheme for elevation clearly displays that very low or 0 weightage has been applied to high elevation areas and high weightage were assigned to low elevation areas. Weightage have been increased at rate with higher risk of flood occurrence. The weightage scheme for elevation of villages within basin is presented in **Table 9 & Fig-9.**

Table 9. Elevation classes with weightage

Elevation (m)	Weightage (W_E)	Elevation (m)	Weightage (W_E)
< 50	15	180-200	8
50-55	14	200-240	7
55-100	13	240-280	6
100-110	12	280-340	5
110-130	11	340-380	4
130-160	10	380-400	3
160-180	9	400-440	2
		>440	1

Similarly density of population within the villages, cropland per sq km and No.of Household in a village were weightage by assigning high weightage to high values and low weightage to low value in all the three cases. Thickly populated were more prone to natural hazards, more production of crops means more losses to crops during flood. Losses from flood were less where No. of household were less. Weightage for all the three parameters were shown in **Table 10 and Fig-10,11 &12.**

Table 10. Population density , Cropland & Household classes with weightage

Density of Population	Weightage (W_D_p)	Cropland (Sq Km)	Weightage (W_C)	Household	Weightage (W_HH)
< 428	1	< 0.23	1	< 174	1
428-834	2	0.23-0.78	2	174-356	2
834-1537	3	0.78-1.71	3	356-683	3
1537-3041	4	1.71-4.78	4	683-1337	4
>3041	5	4.78-21.0	5	>1337	5

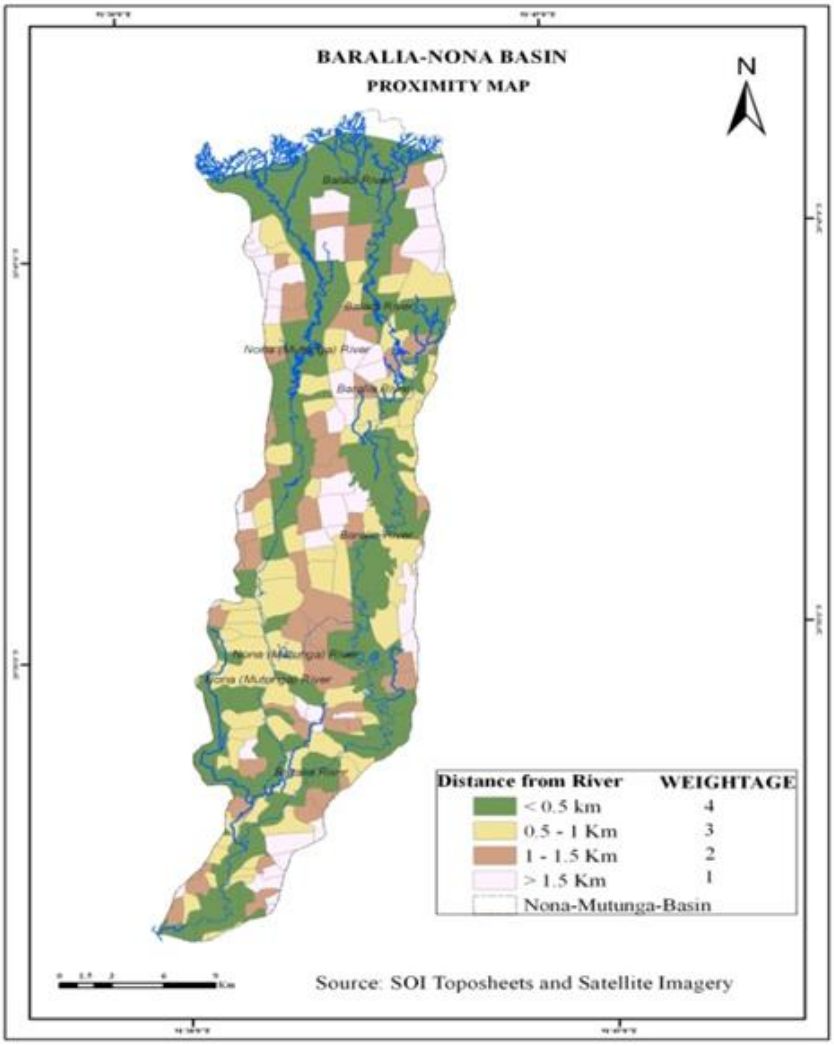
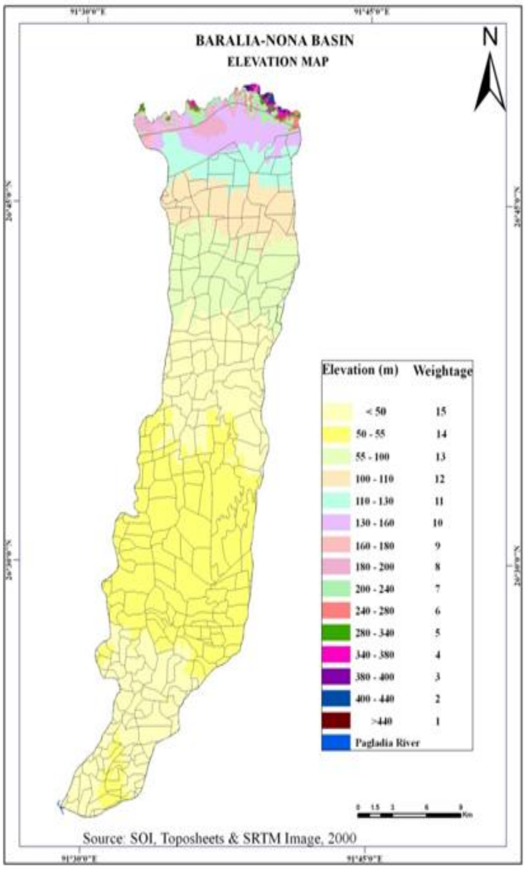


Figure 8. Proximity map of Baralia-Nona river basin



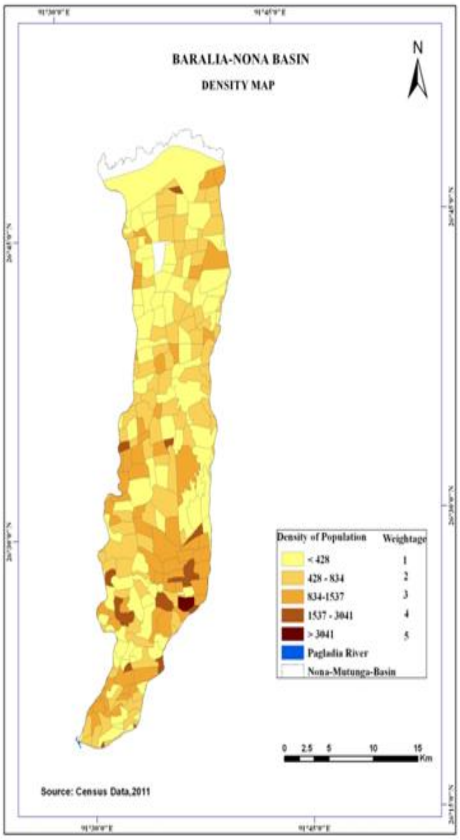
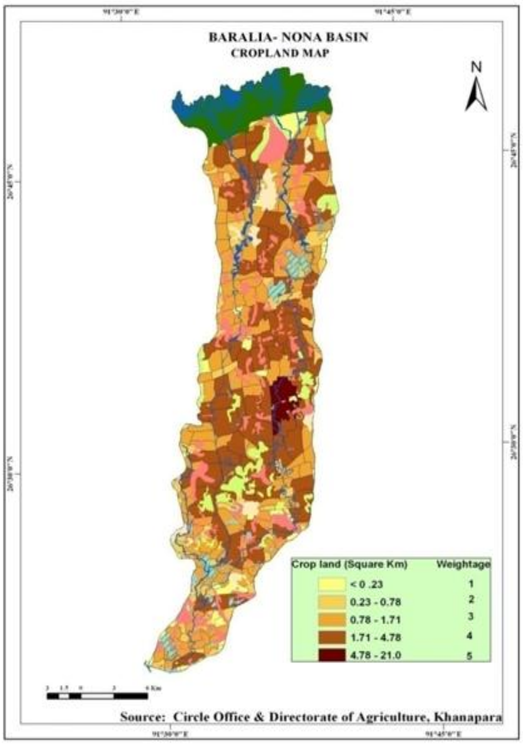


Figure 9 & 10. Elevation and Density map of Baralia-Nona basin



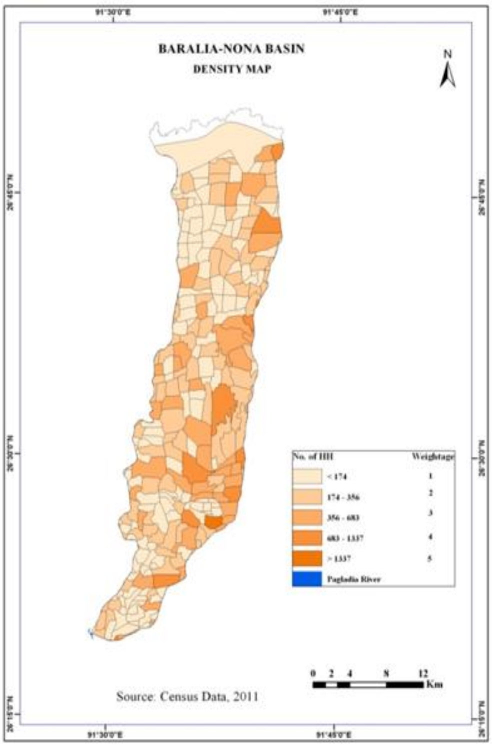


Figure 11 & 12. Cropland area & household map of Baralia-Nona basin

5.6. Flood hazard Index model:

For preparing a composite index, a model is normally adopted. The variables and the principle of assigning weightage to the variables are very crucial in arriving at a flood composite index in process of hazard mapping. Mostly, the process of assigning weightageing to flood hazard indicators is knowledge based. Final flood hazard index (FHI) for village level is created from an additive model which was adapted by Sanyal and Lu in his study in 2003.

$$FHI = (D\_W+W\_E+W\_D_p +W\_C+W\_HH$$

Where D_W is weightage for the villages proximity to the river, W__E is weightage for Elevation, W_D_p weightage for village population density, W_C is weightage for cropland in each village and W_HH for household within the village.

The attribute tables bearing the various indicators weightage, were join and field calculations performed to obtain the index for the villages.

5.6.1. Hazard Categories:

After the final flood hazard index was devised it has been represented in a colour map using ArcMap. It has been classified into 5 hazard categories by natural breaks (Jenks) scheme since the data ranges are not very familiar. In this process ArcMap identifies break points by identifying inherent clustering pattern of the data. Hazard values have been divided into 5 classes on the basis of 4 quartiles measurements. The first, second, third and fourth quartiles of the hazard index values are 5, 9, 12 and 15 respectively. The classification scheme is summarized in **Table 11** and the final flood hazard map produced is shown in **Fig -13**.

Table 11. Classification of composite hazard weightage into qualitative hazard intensity classes

Index Value Range	Number of Villages	Hazard Category
< 5	20	Very Low
6-9	46	Low
10-12	60	Medium
13-15	60	High
>15	93	Very High

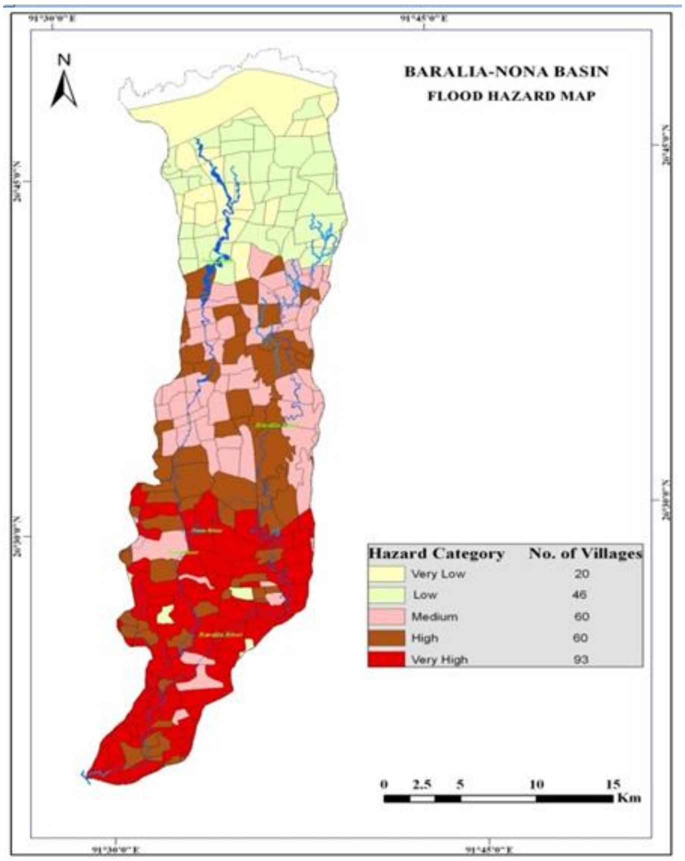


Figure 13. Flood hazard zonation based on composite hazard weightage

VI. CONCLUSION

Every year due to heavy rainfall in the hilly terrain of Bhutan Himalaya as well as in the plains, three to four waves of flood pass over the Baralia-Nona basin in Assam. Structural flood protection measures like earthen embankments, spurs, porcupines etc. are used to protect the area from flood. Embankments provide protection to the flood affected areas of the basin for a limited period. But, their effectiveness decreases due to rising of the river bed gradually. Breaching of embankments occurs mainly due to overtopping, seepage and erosion. The materials used for construction of embankments are mostly sand and silt which are susceptible to erosion. Due to lack of proper maintenance of the existing embankments and meandering nature of the river, the erosion problem leading to breach of embankments is increasing year by year causing heavy flood in this portion. For flood vulnerability mapping and proper management of the basin in order to mitigate the flood problem, a detailed analysis of the area on the basis of probable flood zones, villages and land use affected by flood, and socio-economic condition of the people living in the basin, is highly essential. The present study is an efforts to identify the flood risk zones which will be useful for future planning of the area. The main objectives of producing these kinds of maps is for public dissemination of flood related information and knowledge which will serve to improve general awareness and aid the process of planning and management of flood risks and hazards. This paper is also an attempt to help individuals and officials to take appropriate scientific measures and to take rational decisions in regard to use, layout and design of an area of land exposed to the hazard of flood. The various measures urgently needed in the study area for reducing flood damages and increasing food, health as well as ecological security, mention may be made of an effective flood forecasting and warning system, evacuation of probable flood affected people before they are affected by flood, use of eco-friendly materials and techniques such as Geotextile bags (or Geobags) for construction of embankments to protect river banks from severe scouring and erosion, and most importantly, selection of variety of crops that are best suited to soil and water conditions for cultivation in the non-flood period, raising of plinths of houses especially the granaries, and deployment of life saving emergency actions.

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