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FEW MORPHOMETRIC CHARACTERISTICS AND THEIR IMPACT ON FLOODS USING REMOTE SENSING AND GIS TECHNIQUE IN THE GABHARU RIVER BASIN, ASSAM, INDIA

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Abstract: Every river basin has its unique morphometric characteristics naturally designed by the basin's relief and slope, profile and drainage net, etc. These characteristics act as the determinants of understanding and evaluation of overall topographic pattern constituting differential landforms and their associated activities and the nature and dimension of drainage flow as well. The Gabharu river is no exception to all these morphometric and drainage determinants and behavior. The river being originated at the high hill of the Arunachal Himalaya has been fed by melting snow and rain waters. It has its perennial water sources causing heavy downflow of water during rainy season almost every year. Floods have,therefore, been common phenomena which at a certain interval of time highly devastateland and topographic features in the basin. The present paper in the title aims to investigate the morphometric characteristics on the consideration of relief, slope, profile and drainage network pattern and their influence on the genesis and enhancement of floods. Landuse and land cover have also been considered in the purview of this paper in order to find soil erosion sensitivity in the Gabharu river basin area. For the purpose of data generation and analysis relevant techniques of Remote Sensing and Geographical Information System (GIS) as the effective tool have been used. The paper eventually reveals that the differential pattern of relief, slope, profile, and drainage network have variously influenced the occurrence and enhancement of floods and their associated problems like water congestion, river bank erosion, channel shifting and sedimentation on river bed and banks and flood hazards, etc. The paper finally spells out some of the measures and strategies for mitigation of floods in the basin.

Keywords: Morphometry, Floodplain, Flood hazards, Land-use, Sustainable development.

1. INTRODUCTION

Ever since the inception of drainage over the surface of the earth, rivers have been recognized as the exciting entities causing geomorphic changes of land and hydrological regimes. A drainage basin being the best unit for hydro-physical studies among many (Horton, 1945; Chorley, 1969), bears a great significance in today's fluvial-geomorphic investigation of channel network and drainage morphology along with flood events and their relationship with land, water and man (Chorley, 1969b). The people have been facing remorseful and disastrous flood damages since time immemorial, but the frequency and intensity of floods have increased over the years (Sinha, 2012). Floods in some riverine areas, mostly in the areas of hot and humid climatic conditions have been gradually increasing their exercising roles in different ways. It is observed that morphometric characteristics of a drainage basin have their far reaching impact on the occurrences and enhancement of floods and their associated problems. It is also seen that land use and land cover, rainfall pattern and human interference have been adding an additional dimension in the floods and flood problems of the basin. The morphometry of the Gabharu river basin has, like other river basins in the Brahmaputra valley, now become so complex and dynamic that it affects badly the normal flow of water along and across the river channel. As such flood and water flow above the normal level have rendered hazardous to disastrous situations within the basin. The data sources of such an area have become very large and complex which at present cannot be handled by the traditional techniques. The Remote Sensing and GIS as the new and advanced technique can be appropriately useful in collecting, generating and processing of data base and mapping thereof in order to yield a better and comprehensive result of the basin realities.

The Gabharu river basin being a Himalayan tributary basin of the Brahmaputra has been found to have complex geomorphometric pattern and process bearing far-reaching impact on flood and associated problems.The basin has, of late, witnessed increasing floods resulting in different types of hazards. The river basin has been very thickly populated, because of which the basin area has become geo-environmentally a very sensitive in the Brahmaputra valley. Such a disturbing situation with streams and floods has caused serious geomorphic, hydrologic and environmental abnormalities and implications to be investigated intricately. It is realized that mere adoption of structural measures,especiallyconstruction of earthen embankments can never solve the flood and associated problems in the basin; rather it has created,it is observed, many other associated problems (Goswami, 1985).

2. STUDY AREA

The present study area belongs to the Gabharu river basin representing a tributary system area of the Brahmaputra river system in the western part of the middle portion of the Brahmaputra valley below the high standing Himalaya. The river basin having its evolution and development in the Himalayan foreland (Krishnan, 1982) now covered by the Brahmaputra in this part has been marked by characteristic geologic, topographic, climatic and human dynamics of their own. The river basin covers an area of 382.36 sq km. bounded latitudinally by 26^{0}03$'$N and 26^{0}39$'$N, and longitudinally by 92^{0}25$'$E and 92^0 40$'$E. The river has its origin in the lesser Himalayan range of Arunachal Pradesh and passes through the hills and plains to meet the river Brahmaputra near the village called Nabil in the Sonitpur district of Assam (Fig. 1). This river having a length of 78 km. from the source to the mouth carries huge amount of water with discharges of 8450 m^3s-1 and 0.86 m^3s-1 asthe averages of the monthly maxima and minima respectively of the year 2008. The basin area receives an average annual rainfall amounting to around 210 cm. Of the total annual rainfall of the basin as large as 79 per cent occurs during the months of June to September. Even as the rainfall has a great role in feeding the river Gabharu, snow melt and spring water also contribute a substantial amount to the totality of the water supply in the channel causing flow of excess water in the form of flood.

3. OBJECTIVES

The main objectives of the study are

i) to investigate the morphometric characteristics of the Gabharu river and its basin

ii) to examine the locational pattern of floods and flood hazard

iii) to examine the impact of basin morphometry on flood and flood hazard

iv) to formulate strategies to understand and mitigate the flood problems

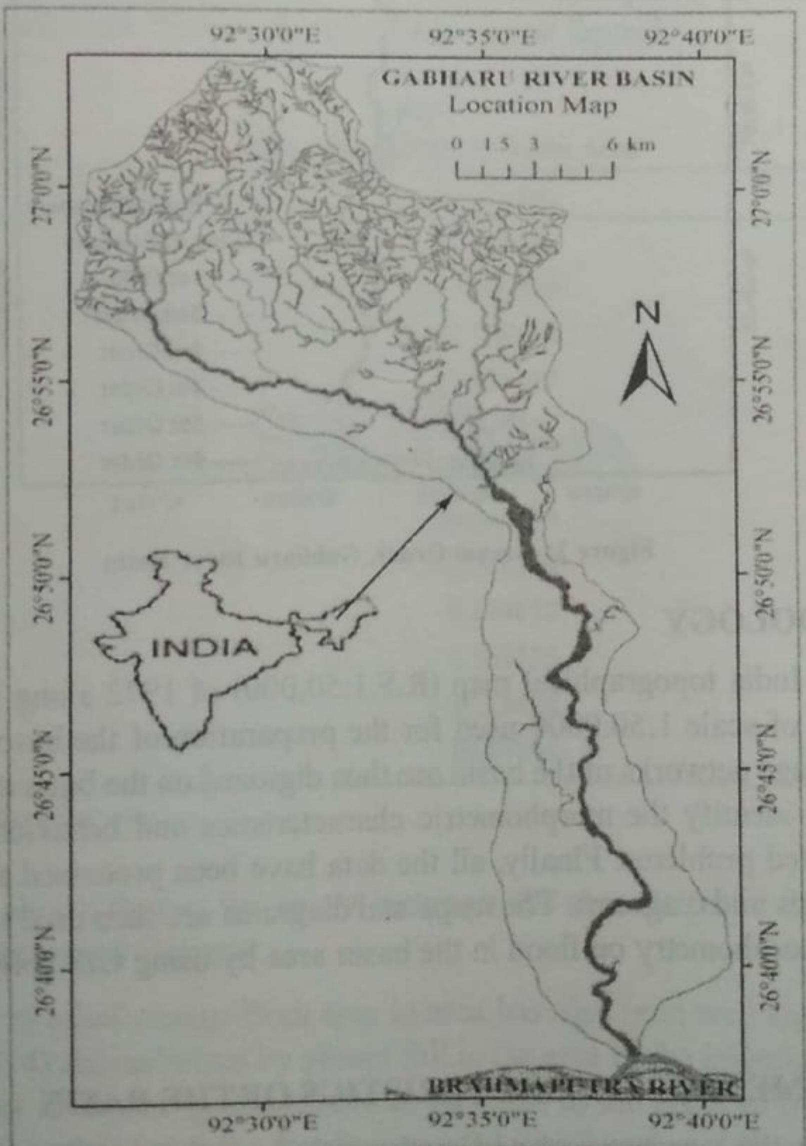

Figure 1: Location of Study Area

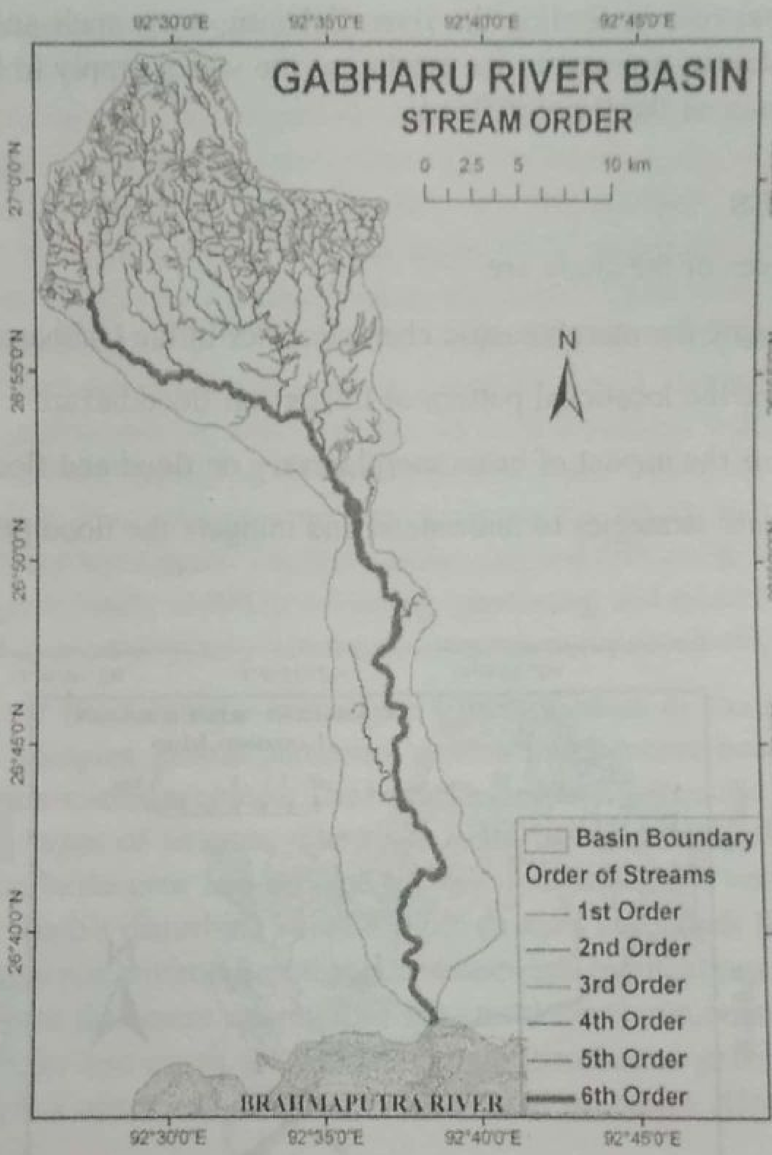

Figure 2: Stream Order, Gabharu River Basin

4. METHODOLOGY

The Survey of India topographical map (R.F.1:50,000) of 1972 along with IRS LISS-III image of 2008 of scale 1:50.0000 used for the preparation of the base map of the study area. The drainage networks of the basin are then digitized on the basis of the basin map so that it helps to identify the morphometric characteristics and behavior along with areas offlood associated problems. Finally, all the data have been processed and represented by appropriate maps and diagrams. The maps and diagrams are then used to analyze and find the impact of morphometry on flood in the basin area by using GIS software like Arc Info and Erdas.

5. MORPHOMETRIC CHARACTERISTICS OF THE BASIN

Morphometry is the measurement and mathematical analysis of the configuration of the earth surface, shape and dimension of its landforms (Clarke,1966) which can be well extended in case of a drainage basin to cover up its linear, areal, and relief aspects including slopes (Nag and Chakrabarty, 2003). The Gabharu river basin being located partly in the high hills of the Arunachal Himalaya in the north and partly in the Brahmaputra valley in the southhas its riverine plain areas and sloping hilly terrain of abruptly falling nature. The plain right from the foothills up to the boundary of the lower plain consists of moderate slopes,while the lower plains have low to very low slopes. A number of factors ranging from the geologic basement to fluvial geomorphic have been found to be responsible for such a characteristic landform set-up. The geological basement of this fluvio-geomorphologically significant basin is such that in the Arunachal Himalayan part it is composed of tertiary sediments by layers. The foothills are composed of boulders, gravels, pebbles, cobles, grit and sand, while the plain part is composed of thick layers of river borne alluvial deposits.

The basin has its elevation ranging from more than 1959 meter in the northern tip to about 60 meter in the neighborhood of the river Brahmaputra covering differentially distributed shares of basin area as shown in table 1 and figure3.

Table 1
Elevation of the Drainage Basin Area

Elevation in Meter	*Area in Sq.km.*	*Percentage*
60-80	87.250332	22.58
80.01-120	87.809849	22.72
120.01-150	32.778180	8.48
150.01-250	53.803477	13.92
250.01-500	53.837111	13.93
500.01-750	25.894229	6.70
750.01-1000	20.644169	5.34
1000.01-1250	7.901340	2.04
1250.01-1500	6.274832	1.62
1500.01-1959	6.169275	1.6
Mean	38.23628	9.893
STDEV	29.67705	7.679932

Source: Generated from the map

Table 1 has shown that as the height increases the area shares in different groups of elevation have decreased abruptly.

Such a state of relief change from area to area has also been well substantiated by the river profile (Fig. 4) characterizes by abrupt fall in the area of the inflexion in the hill-plain margin. The relief as shown by the profile is very less in the areas of built up plains and floodplains. On the other hand, the distribution of slopes based on GIS software useranges from less than 1^{0} to about 80^{0} (Table 2).

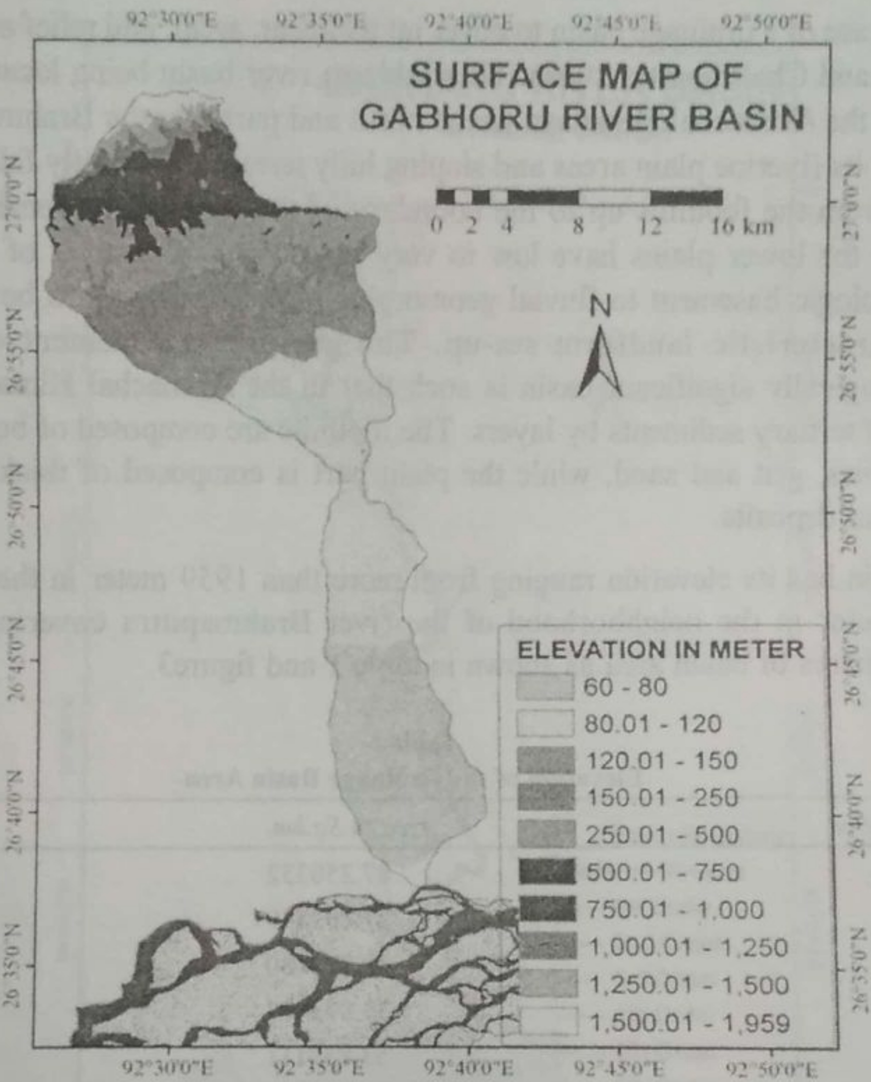

Figure 3: Surface Map

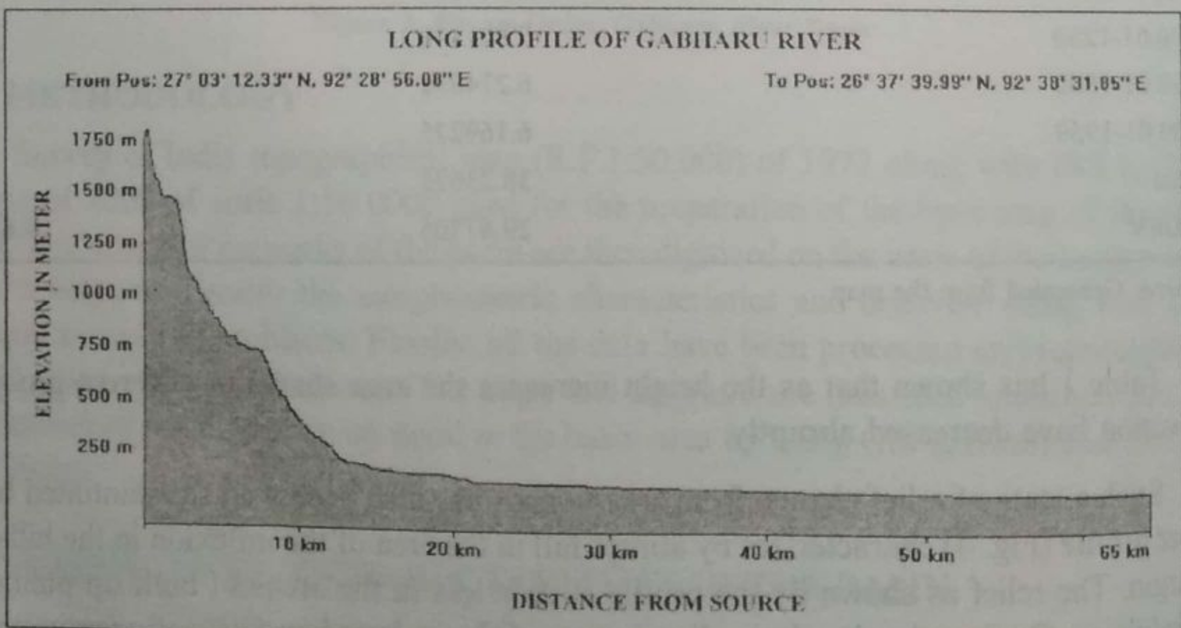

Figure 4: Longitudinal profile of the Gabharu River

Table 2
Gabharu River Basin:Slope Distribution

Slope in Degree	*Area in Km²*	*Percentage of area*
0 – 1	245.65339	63.58
1 – 3	13.3996	3.47
3 – 5	7.4932	1.94
5 – 10	18.1108	4.69
10 – 15	21.9964	5.70
15 – 25	39.3336	10.18
25 – 35	25.0308	6.47
35 – 45	9.1852	2.30
45 – 60	1.95	0.50
60 – 80	0.2168	0.05
Mean	38.23698	9.888
STDEV	73.81234	19.10793

Source: Generated from the map using GIS

The slope areas as per table 2 are never uniform; rather they are exponential in nature. It is found that below the level of 5^0slope,the basin covers as large as 68.99 per cent of the total area of the basin. The percentage share of 10.39 goes to the slope group of 5^0 to 15^0. Beyond 15^0 slope up to about 80^0,the basin covers the percentage share of 17.50. The mean of the distributional pattern of slope is 38.23 degrees, while the standard deviation is 73.81(Fig.5). Such a state of slope distribution pattern in the basin clearly indicates that there is abruptly changing slope distribution from mountainous areas to the mouth of the Gabharu river in the neighborhood of the Brahmaputra. While the average bifurcation ratio of the 6th order Gabharu river is 3.18, there are perceptible deviations of the bifurcation ratios of the successive stream orders bifurcation ratio. The widely varying bifurcation ratios with the orders of streams reveal that the whole of the basin is hydrologically unstable. The lower reaches of the basin reveals the frequently occurring flash floods as well as the strong hydraulic action as compared to that in the topographically controlled up stream areas.

Table 3
Gabharu River Basin: Drainage Network Distribution

Order of Streams	*Number of Streams*	*Bifurcation Ratio*	*Length of Streams (Km)*	*Stream Frequency (Fs)*	*Drainage Density (DD) km/km2*	*Length Ratio*
1st	529	-	295.388	1.38	1.54	0.33
2nd	107	4.94	97.583	0.27		0.762
3rd	35	3.05	74.394	0.09		0.601
4th	9	3.88	44.736	0.023		0.501
5th	4	2.25	22.420	0.01		2.43
6th	1	4	54.570	0.0026		

Source: Calculated from the toposheet, 1972 and Satellite Image, 2008

The streams in the basin have been marked by differential length as per topographic, hydrologic, and hydraulic controls. The length of the stream of different orders ranges as shown in Table 3 wherein length ratios varies from 2.43 to 0.762 with an average of 0.92.

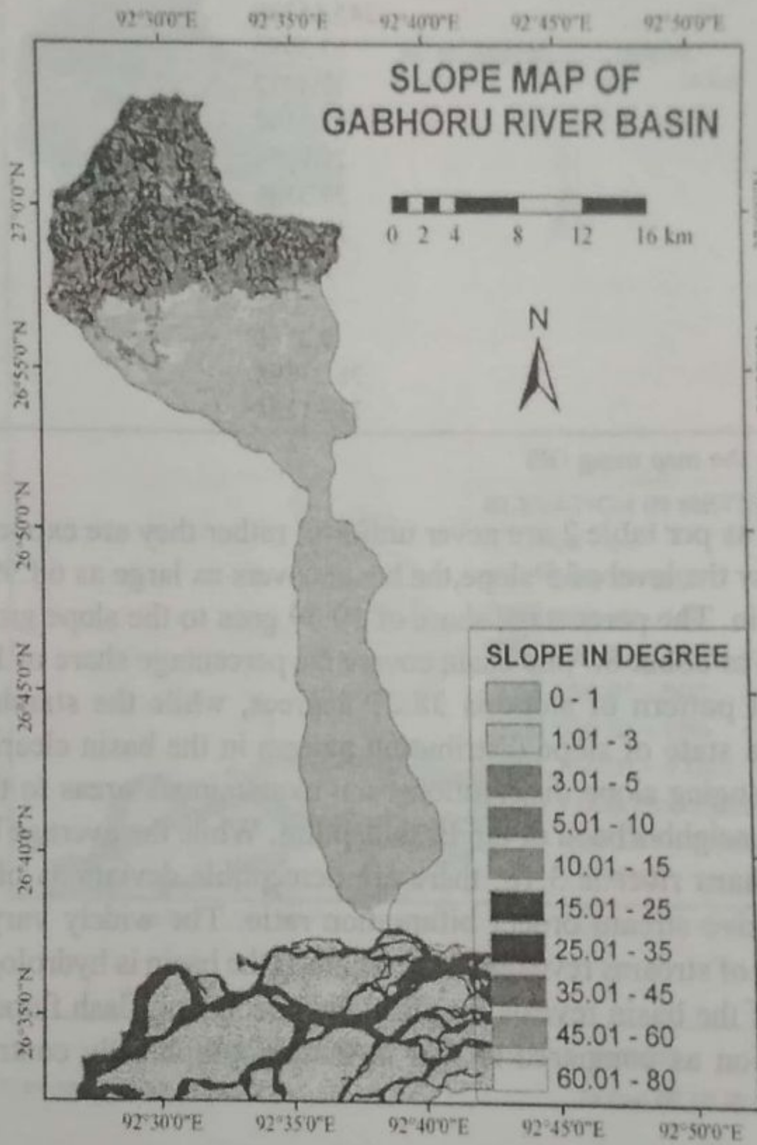

Figure 5: Slope Map of Gabharu River Basin

The entire basin has stream frequency (Fig. 6) in the tune of 1.79 numbers per sq.km. However in the hilly areas including the foothills the stream frequency ranges from 0.002 to 1.38 per sq km. The drainage density in the basin like other basins in the Brahmaputra valley has a good positive relation with the stream frequency.The Lgvalue of the basin area is 0.42.Such a value of Lg indicates high relief in the hilly part of the basin. The circularity ratioof the basin is mainly concerned with the length and frequency of stream. Miller's formula based circularity ratio of 0.48 (Miller, 1953) 0.48 substantiates that the basin is an elongated one. It implies that the basin is mostly controlled by the topography. The elongation ratio of the stream is defined as the ratio of the diameter of the circle of the same area as of the drainage basin and the maximum length of the basin (Schumm, 1956). It is calculated to be 3.18. The drainage texture which according to Horton (1945) is the total number of stream segments of all orders per unit length of the perimeter of the basin. The value of drainage texture in the Gabharu river basin area being 7.13 indicates that the drainage texture is comparatively fine.

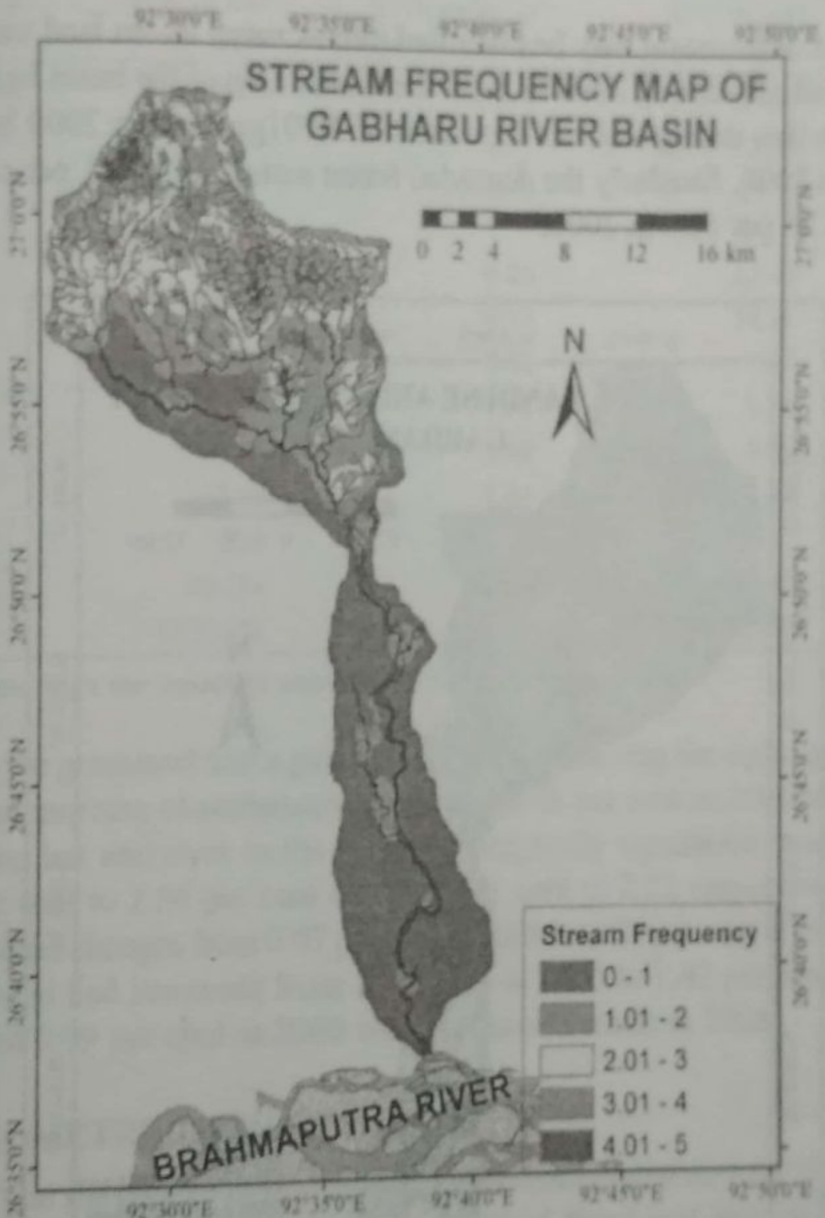

Figure 6: Stream Frequency Map

The overall morphometric character of the drainage basin shows the dendritic to semi dendritic pattern of the streams with moderate texture. The bifurcation ratio of the streams in the basin indicates that there is slight deviation of it from being a normal basin. The low drainage density in the plain areas shows that this part of the basin has highly permeable soil with coarse texture. The values of form and circularity ratios indicate that the basin is elongated over low to high relief areas having moderate to low slope.

6. LAND USE PATTERN IN THE BASIN

The availability and pattern of surficial water have their strong bearing on the pattern of land use of different categories in the basin. The Gabharu river basin having landform types from hills to flat plain have been signified by various land capability conditions (NATMO, 2001).

The land area of the basin may be classified into as many as ten land use classes (table 4). It was observed that during 2000 to 2008 these land uses of the basin have changed fast (Fig.7). It is seen that the agricultural land area of 20.01per cent in 2000 has increased to 19.14 per cent in 2008. Similarly the degraded forest estimated at 9.1 per cent as on 2000 has reduced to 6.25 per cent in 2008.

Figure 7: Land use and Land Cover Map

The forest cover has a marginal loss of 1.34 per cent in 2008 over 49.07 per cent as on 2000.

Table 4
Category of land use and land cover, 2000 and 2008

Category of Land Use and Cover	*Area in km² in 2000*	*Percentage of area*	*Area in km² in 2008*	*Percentage of area*
Agricultural Land	76.86	20.10	73.22	19.15
Degraded Forest	34.48	9.01	23.93	6.25
Forest Cover		187.78	49.11	182.63
47.76				
Grasslands	23.94	6.26	33.93	8.87
Settlement	35.11	9.18	38.80	10.14
Sand Bar	8.52	2.22	9.82	2.56
River	6.33	1.65	8.70	2.27
Tea Garden	3.81	1.00	3.79	0.99
Wasteland	3.90	1.01	5.43	1.42
Wetland	0.28	.07	0.17	0.04
Mean	38.101		38.042	
STDEV	57.53173		55.46598	

Source: Calculated from the toposheet and Satellite Image, 1972 and 2008

Similarly the grassland had a gain of 2.25 per cent during the eight years of time. There was a marginal increase of settlement areas from 9.18 per cent in 2000 to 10.14 per cent in 2008. The sand bar and river as the geomorphologically significant landform entities rose from 2.22 per cent to 2.56 per cent and 1.60 per cent to 2.22 respectively during 2000 to 2008. The wetland changes from 0.07 per cent in 2000 to 0.04 per cent in 2008. The wasteland on the other hand had increased from 1 per cent in 2000 to 1.42 per cent in 2008. The tea garden covered 0.99 per cent in 2000 which remained static in 2008.

7. MORPHOMETRIC IMPACT ON FLOOD

It is observed that the pattern of drainage net, differential relief and the slope characteristics as well have their roles on the enhancing effect of flood and associated problems. The abruptly rising hills in the areas of elevation ranging from 250 to 1959 meter with rugged relief and high slope of 15 to 80 degrees in the northern part of the basin have given rich forest cover now highly degraded due to human interference. The high drainage density of more than 4 km per square km, drainage frequency of more than 10 numbers per square km along with efficiently developed drainage net have all rendered congenial condition for retaining soil moisture in the area for luxuriant growth of forest cover. In spite of congenial conditions for natural growth of forest, the area has undergone human aggression. As a result, there have been the changes in the quality and quantity of forest cover during 2000 to 2008.

Table 5
Bank Erosion and Deposition, Gabharu River Basin

Year	*Bank*	*Erosion in km²*	*Deposition in km²*
1962 - 2000	Right Bank	4.58	3.18
	Left Bank	4.51	4.40
2000 - 2008	Right Bank	4.71	2.38
	Left Bank	3.56	2.25

Source: Base on Toposheet, 1972 and Satellite Imagery 1972 and 2008

Thus the basin hassuffered from severe soil erosion problem ((Fig. 8) mainly in the upper part of the basin causing sedimentation on the river bed. Even as the agriculture is the mainstay of the majority of the population in the basin, the figures of 2000 and 2008 indicate that the land under agricultural practices in the basin is low. It is about 20 per cent of the total land uses. The Gabharu river basin is highly flood prone and the land in the basin is less suitable as expected. The increasing trend of sand bar covering 2 per cent of the area during 2000 to 2008 in the basin indicates that flash floods occur every year. Such flash floods have their adverse impact on agricultural practices in the basin.The low to very low relative relief, low slope, low drainage density, low drainage frequency and reticulated pattern of drainage network in the plains have jointly developed a condition for uncertainty in the sound growth and production of agricultural crops.

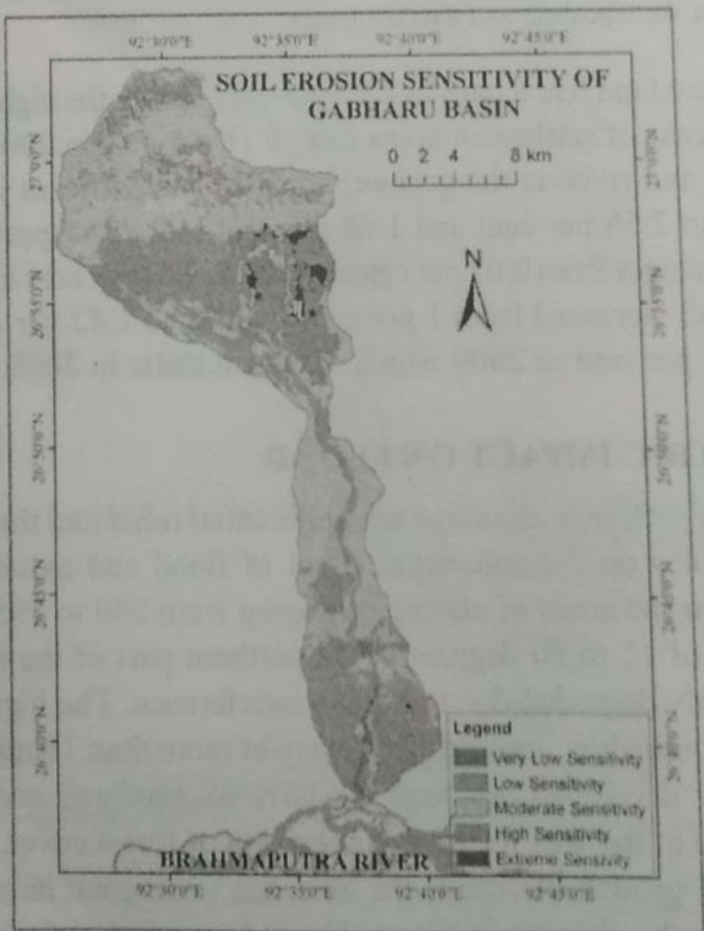

Figure 8: Soil Erosion Sensitivity

The long profile of river Gabharu has also indicated that the downstream part of the river uses to flow over the flat plain causing sheet flood during heavy downpour. The grasslands of riverine origin are mostly scattered along the banks and basins of the river Gabharu and its major tributaries especiallyin the middle and lower parts of the basin. The land areas covered by rivers both in 2000 and 2008 have also clearly shown the impact of climogenetic supply of water flowing over the low slope plain areas of the basin.

The floods in the river Gabharu had intensified since 1950s because of continuous supply of sediment on the river bed due to the impact of 1950 earthquake. Such a phenomenon on the river bed has made the highly occurred and flowing rain waters able to cause intensive erosion on both the banks resulting in shifting of the channel. Table 5 shows the magnitude of erosion on an area of 3.56 to 4.71 $km^2$and deposition causing on 2.25 to 4.40 km^2.

8. STRATEGIES FOR FLOOD MANAGEMENT

Floods are not unmanageable aspect of environment though management is difficult especially in case of rivers and river basins characterized by susceptible to high stage of water flows. For proper management of floodsrelief, slope, river channels including their network and basin characteristics along with the nature of seasonal supply and flow of surface waters as well as ground water levels and the pattern of human interference with the land and streams are to be considered. The analysis of historical fact of topographic disturbance and floods including their intensity, magnitudes and paths are also needed. The following are some of the strategies that may betaken to understand and mitigate the flood problems in the basin of the Gabharu river.

i) Assemblages of spatio-temporal data of distribution of rainfall, morphometric details of varying landforms and hydrologic and hydraulic characteristics of the drainages and the basin will definitely help in understanding, identifying and evaluating the real facts of flood problems leading ultimately to their mitigation and management.

ii) High growth ofpopulation and its increasing pressure in the basin have rendered substantially high risk of flood problems which need adoption of measures and steps for their minimization/amelioration.

iii) Channel characterized by water congestion and increasingly enhancing floods and associated problems are to be trained and regulated in their right directions. The vulnerable points and spots are to be repaired specially in the areas of low slope gradient and water congestion to fulfil long term aim of flood control etc.

iv) Structural measures such as dams, levees, embankments, dykes and appropriately designed and located reservoirs are to be constructed to regulate the excess water flows in order to minimize the effect of flood and flood damage.

v) Appropriately effective measures are to be taken to increase the carrying capacity of water flow of the channels by normalizing the channel slope and basin configuration in some places.

vi) Steps are to be adopted to make the volatile soil drainage system in the basin by the way of balance through ditches and pipes. It will check soil erosion and lead to reduce sediment deposits on river bed.

vii) Embankment cum roads can be constructed along the banks of the big and more vulnerable rivers to floods. At the same time trees can be planted on the embankment site to serve the purposes of flood abatement, reduction soil erosion and creation resource mobilization.

viii) Forestation,especially in the upstream and more flood-vulnerable spots and areas, is to be executed to mitigate force of heavy down-flow of water, slope wash and sedimentation on the channel bed.

ix) As there have developed most up-to-date tools and techniques in the arena of co-existence of man with nature including the flood problems, the flood plain dwellers in the Gabharu basin should follow the same. The use of techniques of Remote sensing, GIS (Geographical Information Systems) and GPS (Global Positioning System) dealing with space and problem realities can highly lead to solve the problem of flood in the basin.

x) While the small wetlands are reclaimed keeping the protection of their ecology and environment, the big ones can be transformed to fulfill the multifaceted objectives of passing of flood water through and development of tourist points, etc. Field management committees formed in the villages can also be helpful for the water management (Roy and Roy, 2012).

9. CONCLUSIONS

The Ghabharu river, though small in areal extent, has its high floods creating environmental, geomorphic and economic problems over time and places. The peculiar landform along with climatic conditions in the basin of the river have rendered substantial impact on the genesis and enhancement of flood and associated problems in the basin. The floods and associated problems have now attained the status of increasing hazards in the area. There have been some measures adopted for the mitigation or amelioration of the flood hazards and problems, but yet to have the right fruit of the measures. The basin is a complex one in its form and fluvial processes. Unless investigation on the geomorphic and climatic basis of water supply and flow is not made, there is no hope of mitigation of the problems. In this case an interdisciplinary approach to landform and water flow processes studies in and around the basin has been needful to arrive at the right point of flood and problem control leading to sound environment, land uses and production in the basin. The use of remote sensing, geographical system and global positioning systems shall definitely help in finding details of the basin, mapping thereof and formulation of ways, means and strategies for favor of basin's balanced health. The strategies formulated shall be right enough to follow the aim and objectives of the mitigation and management of floods, lands and flood problems in the basin. Ultimately it is said that flood problems in the basin are curable even as it is difficult.

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