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Morphometric Analysis of Diyung Watershed in Northeast India using GIS Technique for Flood Management

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Abstract: The North eastern region is characterized by undulating terrain and high rainfall. Such condition creates a situation of floods in the downstream plain areas of Assam. Difficulties in monitoring the data collection of hydrological events (runoff and sediment yield) in the rugged terrain hinders the planning of suitable control measures. To overcome such constraints alternate measures need to be explored and the study of terrain is one such approach. The study of terrain (morphometry) can help in diagnosing the hydrological behavior of any watershed. In the present study morphometric analysis was done to determine the drainage characteristics of Diyung watershed in Kopili river basin using topographic maps and GIS tools. The morphometric analysis indicates high values of stream density (15464), stream length ratio (1.81); Bifurcation ratio (3.66), RHO coefficient (0.49), Stream frequency (5.26 km^{-2}), Drainage density (3.24), indicative of high runoff generation capabilities of the watershed. This high runoff from the watershed is the main reason for floods in the downstream areas. Based on the results, structural and non-structural measures are proposed to mitigate the impacts of flood events.

Keywords: Morphometric analysis, GIS, Diyung watershed, Flood managment, Kopili river basin

INTRODUCTION

The northeastern region of India is one of the unique regions in the world in terms of its bio diversity and vast natural resources viz., water and land. The region is characterized by widely varying undulating terrain and is endowed with very high rainfall ranging 2000-10000 mm (average annual). The high rainfall characteristics of the region coupled with undulating terrain makes its vulnerable to natural calamities particularly floods, erosion and landslides. Planning suitable mitigation measures for calamities have been constrained owing to non availability of long term reliable data of hydrological events. Setting up data monitoring stations for generation of hydrological data has been a matter of concern due to inaccessible terrain conditions. This necessitate alternate endeavor to generate information on hydrological characteristics of any watershed that can provide basic minimum information for planning and implementing suitable conservation measures. Morphometric analysis (study of terrain) is one such approach to describe the hydrological characteristics of any watershed (Esper, 2008). Morphometric analysis represents the topographical expression of the basin geometry to understand its slope, area, shape, length or inequalities in the rock hardness, structural controls, recent diastrophism, geological and geomorphic history of drainage basin (Strahler, 1964). The generation of morphometric parameters through conventional method such as field observations and topographic maps is a tedious activity. However, in the recent years the analysis of morphometric parameters have gained increasing attention after the advent of tools such as remote sensing and geographical information system (GIS) (Maidment 2002; Singh et al. 2012). These tools can be effectively used to generate the digital elevation model (DEM) and then create information on geometric characteristics including the topology of the stream networks, and quantitative description of drainage texture, pattern, shape, and relief characteristics. These geometric characteristics of drainage basins are the fundamental units of the fluvial landscape and a great amount of research has focused on it (Abrahams, 1984). The application of morphometric analysis using remote sensing and GIS techniques for studying floods and flood hazard management have been reported by number of researchers (Ozdemier and Bird, 2009; Subyani et al. 2012; Dawood et al. 2013).

In the present study the morphometric characteristics were analyzed using GIS technique in one of the watershed of Kopili River in Assam for understanding the runoff generating capabilities and its flood characteristics. Based on the interpretation of the hydrological response characteristics suitable measures have been proposed for management of water resources for mitigating the adverse impact in downstream areas.

STUDY AREA

The Diyung watershed is a part of Kopili river basin that forms part of Brahmaputra river system. The Brahmaputra is the major drainage line almost bisecting the entire NE region of India. The Brahmaputra is an international river and it has a catchment area of 2,93,000 sq km in Tibet (China), 1,95,000 sq km in India, 45,000 sq km in Bhutan and 47,000 sq km in Bangladesh. The length of the river in the respective countries are 1625 km in Tibet (China), 918 km in India and 337 km in Bangladesh before joining river Ganga in Bangladesh. The river originates in Tibet and then it enters into India and finally drains into Bay of Bengal after traversing through Bangladesh. The entire NE region of India drains into Brahmaputra. It has 33 major tributaries joining in the entire Indian stretch on the north bank (20 nos) and south bank (13 nos). Kopili river basin is one of the largest tributaries of the Brahmaputra system. The total catchment area of the basin till its confluence with Brahmaputra is about 12,000 sq km. The river originates in Meghalaya at an altitude of 1800 m and drains into flat plains of Assam. The upper catchment of the river basin is mostly forested and comprised of inaccessible undulating terrain. The Kopili river basin comprises of five major watershed viz., Diyung, Kopili, Borpani, Jamuna and Umiam. (Fig 1).

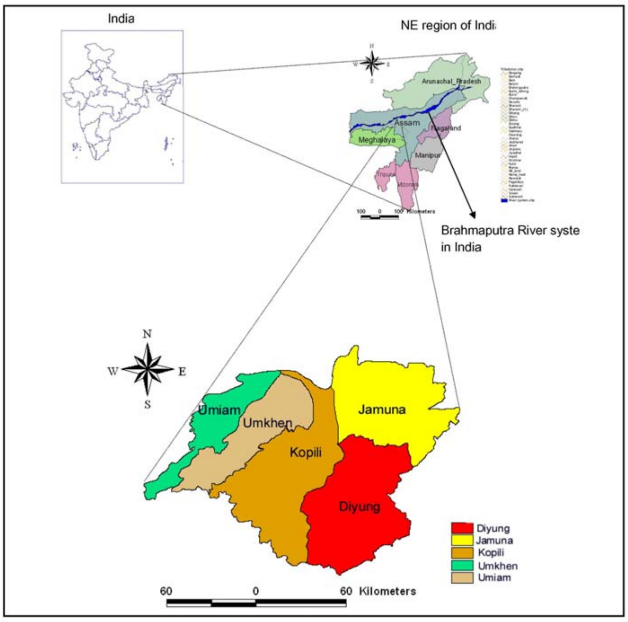


Fig.1. Location map of Kopili river basin.

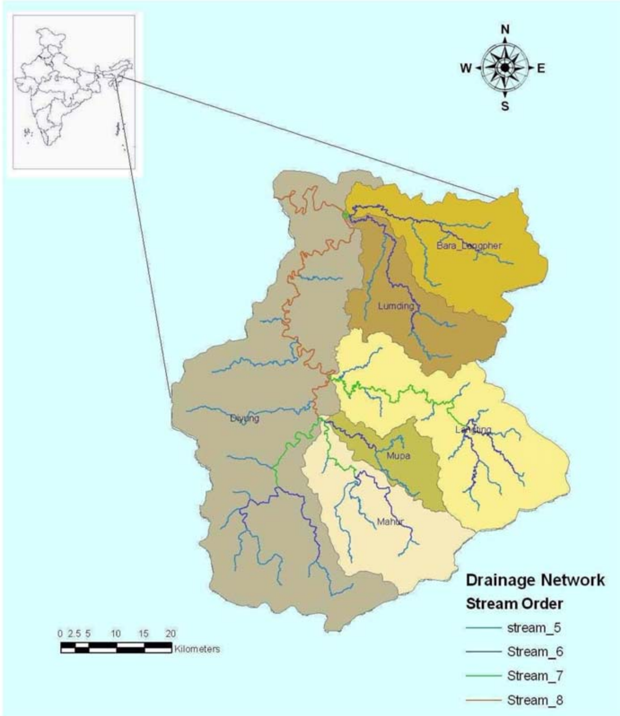


Fig.2. Diyung watershed, its major sub-bain and major drainage network.

The Diyung river originates from the Barail range at an altitude of 1800 m near Haflong in NC hills district of Assam. The catchment lies between 25°06´N and 25°53´N latitudes and 92°44´ E and 92°26´E longitudes. The total area of the Diyung watershed till its confluence in Kopili river is 3839.29 km^2. The Diyung watershed consists of six major sub-basins viz., Diyung, Langting, Baralangphar, Lumding, Mupa and Mahur (Fig 2).

The longitudinal profile of the river depicts concave profile which reveals normal degradation of landscape. The flow direction of the river is south-north course in upper catchment and southeast –northwest in the plain tracts.

The climate of the basin is extremely variable with reference to distribution of rainfall, temperature and humidity. Average annual rainfall in the area is ranging from around 2000 mm in the lower parts of the basin to 3000 mm, in the upper parts of the basin. More than 80% of rainfall occurs during the monsoon months (June to September). Daily mean temperature ranges from a maximum of 44^{o}C (May) to a minimum of 4^{o}C (January). The daily mean relative humidity varies from a minimum of 40% (April) to a maximum of 95% (July).

MATERIALS AND METHODS

The study was performed in two stages (a) field visit and (b) laboratory work. Field visits were made to gather additional information such as socio-economic and traditional agricultural practices in the upper catchments and extent of damage due to extreme hydrologic phenomenon (i.e. floods) in the downstream areas. Geomorphological and drainage map of the area was prepared using Survey of India topographical sheets (1:50,000 scale).

Generation of Digital Elevation Model (DEM)

The contour information extracted from Survey of India (SOI) at 1: 50,000 scale and 20 m contour interval was used to generate the DEM. SOI toposheets are prepared following standard procedure and is universally recognized document. The uses of SOI toposheets for hydrological studies in northeast India have been reported by some earlier workers (Gossain and Rao 2005, Dabral et al. 2008). The toposheets were registered in Arc GIS platform in UTM projection (Zone 46 N). The contour map was converted to raster, using a geo-reference in which the pixel size, the number of lines and columns, and the minimum and maximum X and Y coordinates of the map are defined in Arc GIS environment. The raster map resulting from the segment to raster conversion contained values for those pixels covered by a contour line. At this stage all other pixels in the map remain undefined. The DEM was generated by linear interpolation made between the pixels with altitude values, to obtain the elevations of the undefined values in between the rasterized contour lines. The output of the contour interpolation is a raster map in which every pixel has a value.

Stream Network

The stream information of Diyung watershed was extracted from the Survey of India toposheet at 1: 50000 scale using Arc GIS software. The stream networks were digitized and geo-referenced using the capabilities of ArcGIS tools. The digitized streams were ordered on the basis of Strahlers stream ordering method.

Table 1. Morphometric parameters and their mathematical representation

Sl. No.	Morphometric parameters	Formula	Description	Reference
1	Total order number (N)	ΣN_u	Total order number in the basin	Strahler (1964)
2	Cumulative length of stream (L)	ΣL	Total length of each order was computed at sub-basin level	
3	Bifurcation ratio (R_b)	$R_b = (N_u / N_{u+1})$	It expresses the ratio of the number of streams of any given order (N_u) to the number in the next lower orders (Nu+1)	Horton (1945) Ozdemir and Bird (2009)
4	Stream length ratio (R_l)	$R_l = Lu / L(u-1)$	It is ratio of stream order to the next lower stream order	Sreedevi et al. (2004)
5	RHO coefficient (RHO)	$RHO = R_l / R_b$	It is ratio between the stream length ratio (R_l) and the bifurcation ratio (R_b)	Horton (1945)
6	Stream frequency (F_s)	$F_s = \Sigma N_u / A$	It is the ratio between the total number of stream segments of all orders in a basin and the basin area	Horton (1945)
7	Drainage density (D_d)	$D_d = \Sigma Lt / A$	It is defined as the total length of streams per unit area divided by the area of drainage basin.	Horton (1945)
8	Time of concentration (T_c)	$T_c = 6.95\ (L^{1.15}/B_h^{0.385})$	It is time taken by water to travel from most distant point of a sub basin to its outlets	Reddy et al. (2004)
9	Basin relief (R)	$R = H - h$	It is the difference in elevation between the highest and the lowest point of the basin	Hadley and Schumm (1961)
10	Relief ratio (R_r)	$R_r = R / L$	It is ratio between the basin relief (R) and the basin length (L)	Schumm (1963)
11	Circularity index (R_c)	$R_c = 4\pi A / P_2$	It is expressed as the ratio of the basin area (A) and the area of a circle with the same perimeter as that of the basin.	Miller (1953) Strahler (1964)
12	Elongation ratio (R_e)	$R_e = (D / L) = 1.128\ (\sqrt{A} / L)$	It is expressed as ratio between the diameter of a circle of the same area as the basin (D) and basin length (L)	Schumm (1956)
13	Form factor (F_f)	$F_f = (A / L^2)$	It is expressed as the ratio between the area of the basin (A) and the squared of the basin length (L^2)	Horton (1945)

Derivation of Morphometric Parameters

Delineation and derivation of various basin parameters such as watershed boundary, perimeter, basin length, and water divide were performed in Arc GIS platform. The stage of landscape evolution, tilting of the basin, shape parameters and time of concentration of the Diyung river basin were determined by analyzing the basin parameters. Drainage network and stream orders were defined using standard methodologies (Horton, 1945; Strahler, 1964). The methodologies for estimating each parameter are described in Table 1.

RESULTS AND DISCUSSION

The morphometric parameters of any watershed are resultant of climate, geological formation and the underlying rocks. These parameters provide the information regarding watershed hydrological characteristics and are classified under three different categories: (i) basic parameters, (ii) derived parameters, and (iii) shape parameters. The quantitative values of parameters under each category are shown in Table 2.

Basic Parameters

The basic parameters included the drainage area, basin perimeter, length of the longest stream from the origin, basin relief, stream order and stream length. The total drainage area of Diyung watershed is 3839 km^2, and the perimeter is 322 km. The length of the longest stream from the origin to the point of confluence with the main stream Kopili is 164 km. Other basic parameters included are stream order (Nu), stream length (Lu) and basin relief (R).

Stream Order (Nu)

Stream order, or classification of streams based on the number and type of tributary junctions, has proven to be a useful indicator of stream size, discharge and drainage area (Strahler, 1957). The number of streams (N) of each order (u) is presented in Table 2. Diyung is an eight order watershed with dominance of first order (15464) streams. The dominance of first order stream is indicative of high runoff generation characteristics. The details of stream characteristics confirm Horton's first law (1945) "law of stream numbers" which state that the number of streams of different orders in a given drainage basin tends closely to approximate an inverse geometric ratio. This inverse geometric relationship is shown graphically in the form of a straight line when log values Nu are plotted on an ordinary graph (Fig 3).

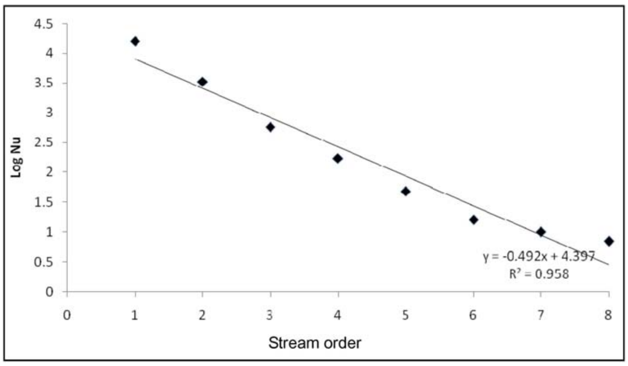


Fig.3. Stream number vs stream order for Diyung watershed.

Table 2. Morphometric parameters of Diyung watershed

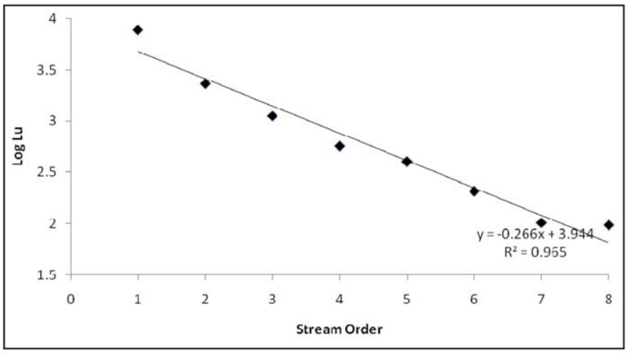
Basic Parameters		Derived Parameters		Shape Parameters	
A (sq km)	3839.29	R_b	3.66	R_e	0.43
P (Km)	321.52	R_l	1.81	R_c	0.47
H (m)	1800	RHO	0.49	F_f	0.14
h (m)	80	F_s	5.26	A_f	70.72
N1	15464	D_d	3.24		
N2	3126	T_C	139.0		
N3	551	R_r	10.49		
N4	166				
N5	44				
N6	15				
N7	10				
N8	7				
L1	7349.94				
L2	2141.59				
L3	1091.70				
L4	553.14				
L5	380.16				
L6	190.25				
L7	102.68				
L8	97.07				
Lt	11906.54				

Stream Length (L_u)

It is the total length of streams of a particular order. It reflects the hydrological characteristics of the underlying rock surfaces of any watershed. Generally, the total length of stream segments decrease with each stream order. Deviation from its general behavior indicate that the terrain is characterized by high relief and/or moderately steep slopes, underlain by varying lithology and probable uplift across the basin (Singh and Singh, 1997).

The numbers of streams of various orders in the watershed were counted and their lengths measured. The total stream length of Diyung watershed is 11907 km. The values of length (L_u) and total stream length (L_t) are shown in Table 2.

Analysis of stream length characteristics of Diyung watershed confirm Horton's second law (1945) "laws of



stream length,'' which states that the average length of streams of each of the different orders in a drainage basin tends closely to approximate a direct geometric ratio. This geometric linear relationship is shown graphically when log values of these variables are plotted on an ordinary graph (Fig 4). Most drainage networks show a linear relationship with a small deviation from a straight line (Chow 1964).

Basin Relief (R)

The R controls the stream gradient and therefore influences floods patterns and the amount of sediment that can be transported (Hadley and Schumm 1961). The Diyung watershed has high values of R (1800 m above mean sea level) due to physiographic mountainous structure of the area. The difference between maximum (1800 m) and the minimum (80 m) is also significant resulting in faster runoff response.

Derived Parameters

Derived parameters considered in the present study are relief-ratio (Rr), bifurcation ratio (Rb), stream-length ratio (Rl), RHO coefficient (RHO), stream frequency (Fs), drainage density (Dd), and time of concentration (T_c).

Relief Ratio (R_r)

Relief-ratio (*Rr*) is a dimensionless parameter. It is the ratio between basin relief (*R*) and basin length (*L*) (Schumm, 1963) and is directly proportional to the surface run-off and intensity of erosion. In Diyung watershed the R_r was found to be 10.49 m/km indicating high surface runoff. The high value of R_r of the basin is high due to the presence of resistant rocks in the area.

Bifurcation Ratio (R_b)

This is a very important parameter that expresses the degree of ramification of the drainage network. It indicates the proneness of watershed to flooding. Higher value of bifurcation ratio indicates greater proneness to flooding. The lower values of bifurcation ratio are characteristics of watersheds where the drainage has not been affected by structural disturbances. Verstappen (1983) stated that R_b characteristically range from 3 to 5 for watersheds when the influence of geological structures on the drainage network is negligible.

In the present study the value of R_b was estimated at 3.66 (Table 2). This indicates that, overland flow is dominating process in the Diyung watershed.

Stream Length Ratio (R_l)

R_l between successive streams orders varies due to differences in slope and topographic conditions, and has an important relationship with the surface flow discharge and erosional stage of the basin (Sreedevi et al. 2004). Diyung watershed has high values of R_l (1.81) indicating high runoff generation capabilities.

RHO Coefficient (RHO)

It is an important parameter that determines the relationship between the drainage density and the physiographic development of the basin, and allows the evaluation of the storage capacity of the drainage network (Horton 1945). It is influenced by climatic, geologic, biologic, geomorphologic and anthropogenic factors. The *RHO* of Diyung watershed is 0.49 which indicates that it will have higher storage during flood periods and it attenuates the erosion during elevated discharge.

Stream Frequency (F_s)

Stream frequency (*Fs*) is defined as the ratio between total number of stream segment of all orders in a basin and the basin area. It is measure of the permeability of surface lithology, vegetation, and relief. The F_s of the whole basin is high (5.26 km^{-2}). The higher value indicates impermeable sub-surface materials, sparse vegetation, high relief conditions and low infiltration capacity (Ozdemir and Bird, 2009). Such watersheds contribute to higher runoff.

Drainage Density (D_d)

D_d is a measure of the degree of fluvial dissection and is influenced by numerous factors, among which resistance to erosion of rocks, infiltration capacity of the land and climatic conditions rank high (Verstappen 1983).The D_d of Diyung is 3.24 indicating high runoff generation capabilities. The drainage density ranging from less than 1 to nearly 10 are associated with discharges ranging from 0.02 to 2.19 lps per hectare (Greogery and Walling 1968). The drainage density D_d is directly proportional to discharge Q. In these watersheds the runoff is higher due to impermeable sub surface leading to reduced infiltration.

Time of Concentration (Tc)

The T_c value represents the time taken by the water to flow from the remotest point to the outlet. The watershed with lowest T_c values should be considered appropriate for treatment of flood moderation. The T_c value is indicative of proneness of areas subjected to floods and flash floods. It also gives an idea of response time to mitigate the adverse impacts. The T_c value for Diyung watershed is 139 min.

Shape Parameters

Shape parameters such as elongation ratio (*Re*), circularity index (R_c), form factor (F_f) and drainage basin asymmetry (A_f) indicate shape characteristics of the basin (Table 1).

Circularity Index (R_c)

The circulatory index can be interpreted as the capacity of watershed to drain out the water. The watersheds approaching circular shape tend to be slow flowing, have depositional layer whereas linear catchments tend to have faster channel drainage (Dowling et al. 1998). The R_c of Diyung is 0.47 which indicates lack of circularity.

Elongation Ratio (R_e)

The R_e of Diyung is 0.43, is indicative of elongated shapes. The value of R_e approaches 1 as the shape nearly becomes circle.

Form Factor (F_f)

Horton (1945) proposed the parameter form factor. The parameter indicates the flow intensity pattern and runoff disposal response to any rainfall for any watershed. The index F_f shows the inverse relationship with the square of the axial length and has a direct relationship with peak discharge (Gregory and Walling 1973).The F_f of Diyung is high (0.14) indicating slow infiltration rate and high runoff. The value of circular watershed is less than 0.745 and it reduces as the watershed becomes elongated resulting in flow for longer duration.

Drainage Basin Asymmetry (Af)

The drainage basin asymmetry (*Af*) is a factor developed to detect tectonic tilting transverse to flow at drainage-basin or larger scales (Hare and Gardner 1985, Keller and Pinter 2002).The value of *Af* greater or lower than 50 indicates tilting. The *Af* value for Diyung watershed 70.72 indicating a tilt on left side (western flank of the watershed).

Hydrological Response

Hydrological response of a drainage basin can be described as the conversion capability of rainfall to runoff. Hydrological response is mainly governed by the basin morphometric properties, soil characteristics and land use pattern. The soil characteristics and land use pattern has an effect on interception where as morphometry decides the distribution of runoff excess (Ajibade et al. 2010). Such analysis is found to be of immense utility in watershed evaluation, soil and water conservation and natural resources management.

The analysis of morphometric parameters indicates that the basin is mature and is characterized by high rainfall resulting in high surface runoff. Such runoff generating mechanism leads to a situation of floods in the downstream areas due to spilling of excess water from the drainage channel. The hydrological behavior of the watershed is explained in details in the following paragraph.

The analysis revealed that higher number of first order stream (15464), high relief (1720 m) and slope gradient (10.49 m km-1) are the significant aspects of the watershed. These characteristics reflect the mature stage of topography whose behavior can be explained in terms of low infiltration rate, high surface runoff and low sediment production. Such watersheds are outcome of high rainfall and have flash flood profiles.

The high values of derived parameters viz., the stream length ratio (1.81); bifurcation ratio (3.66), RHO coefficient (0.49), stream frequency (5.26), drainage density (3.24) are indicative of high runoff generation capabilities of the watershed. The watershed confirms to dendritic drainage pattern. Such patterns are resultant of steep slope, impervious and non-porous homogenous rock types.

The shape parameters also reveal the elongation nature of the basin. The geological processes i.e. thrusting and faulting are the guiding forces for the elongation of the watershed. Due to this characteristic, the watershed will tend to have smaller flood peaks but longer lasting flood flows compared to a circular basin (Gregory and Walling, 1968). The significance of shape parameters lies in considering the management objective in any watershed projects and assessment of flood hazard (Singh 2006). The Drainage basin asymmetry (*Af*) also reveals the watershed is tilted towards left which can be assumed to be the effect of tectonic activity. The study also reveals that the watershed is relatively matured, rainfall is the guiding forces for the formation of streams and lower order stream dominates the watershed.

Floods and Flash Flood Mitigation Measures

High runoff generation property of the watershed is reflected in the lower part of the Kopili river basin in the form of chronic floods. As per the estimate available, the loss in life and property in this part has been reported to the tune of $ 6000 million (GoA 2004). The morphometric parameters also reveal the surface runoff as the dominating process in the Diyung watershed. Retention of surface runoff in the upper catchment and channelizing the water through natural drainage pathways can provide certain answer. Further educating people and creating social awareness is also important. To attain the objectives both structural and non-structural measures have to be adopted.

Number of structural measures has been used for mitigating the impact of floods and flash floods worldwide. These include flood control reservoirs, diversions, flood ways and improvements in channel capacity, levees and spillways (Kundzewicz and Takeuchi, 1999; Berning, 2001). Each structure has its own function for example dams and flood control reservoir dissipates the flood waves and increases storage, diversions reduces the erosive nature of flowing water. Similarly levees are used to prevent the inundation caused by the overflow of the banks into agricultural or habitat land. Flood ways and improvement in channel capacity increase the water retention within the drainage line. Spurs retards the erosive velocity of the flowing water and thereby aids in controlling the stream bank erosion.

In the present case a combination of storage reservoir and series of rock filled spurs could be used. The reservoirs will absorb the flood wave shocks and spurs will provide zigzag flow pattern reducing the destructive velocity. The Diyung river at the outlet confluences with another major stream Kopili and enters the flat terrain with mild slope. These are the areas affected by recurring floods. Construction of levees/ dykes on both sides of the river can prevent inundation of the agricultural fields. Locating and sizing of these structures is also an important aspect. Flood risk maps can be generated by performing morphometric analysis on sub-watershed basis for locating these structures. The preliminary results reflect the need to conduct a comprehensive study for planning a structure, which would take other factors such as precipitation, infiltration and evaporation into consideration. However, planning structural measures involve huge finances therefore details study on vulnerable areas contributing higher runoff could be identified.

The structural measures apart from involvement of finances does not provide absolute guarantee against extreme flood events (Takeuchi et. al, 1998). Therefore structural and non structural measures should be used in conjunction (Hossain 2003). Montz and Gruntfest (2002) recommended (1) greater emphasis on increasing understanding of the social processes involved in flash flood warning, particularly in the response phases, and (2) the need to reduce vulnerability in sustainable ways compatible with long-term economic and social goals. They highlighted the importance of relationship between hydrometeorology and social science for advancing our abilities to cope with flash floods.

The non structural measures may include flood forecasting systems and capacity building of the community living on the banks of river. Flood forecasting may incorporate collecting flood causing information such as precipitation and river stage. Kobiyama and Goerl (2007) proposed Operation Efficiency Index (OEI) for tackling the incidences of floods and flash floods. In their review they referred flash floods as those events where the response time was less for the community to evacuate. They suggested converting the flash floods into floods using Operational efficiency index (OEI). The OEI index proposed is defined as

$$\mathrm{OEI} = \frac{T_c}{T_o}$$

where T_c is the time of concentration and T_o is the operation time that is defined as

$$T_0 = -T_a + T_t + T_{al} + T_e$$

where T_a is the antecedent time of weather forecasting, with high precision; T_t is the transmission time of the forecasting from the forecasting center to the disaster management centre, T_{al} is the time necessary for the civil defence to alert the community; and T_e is the time necessary for the communities to move to safe places. The OEI values greater than 1 indicates normal floods whereas less than 1 is flash floods.

In the present day context the T_a and T_1 can be achieved on real time basis. The authors' observation during some floods events found that 30 minutes time is required for evacuation after carrying bare minimum valuables and livestock resources. In case of Diyung approximately 100 minutes are available for alerting the community for taking necessary precaution in case of flash floods. For alerting, the local bodies can be trained to disseminate the information at the earliest.

DISCUSSION AND CONCLUSION

The novelty of quantitative analysis of morphometric parameters in Diyung watershed lies in the interpretation of its hydrological response resulting in recurring floods in the downstream low lying areas in data scarce NE region.

It is observed that the outcome of the morphometric analysis is comparable with the geological characteristics of the watershed. The geological characteristics indicates that it forms the part of Barail range comprising of post Oligocene sedimentary rocks which extends to Naga hills towards south east (GSI 2009). These formations are older in age thereby less susceptible to erosion and generates higher water yield and low infiltration rate. The southwestern part which extends upto Surma valley is characterized by steep gradients and twisting channels which was evident in the analysis. Similar features were also observed in the north eastern part. The NE part also belongs to Barail Group of rocks (upper Eocene and Oligocene) continues with a reduced thickness in the sub thrust block. The region is covered by a granite wash with a thin conglomerate. (GSI 2011).

Findings similar to the present study have been reported earlier by many researchers in various parts of the world. They have reported the importance of morphometric analysis for assessing the incidences of floods hazards and derived suggestion to mitigate its impact. For example Ozdemir and Bird (2009) in their study in Havran river basin in Turkey reported that morphometric analysis is essential component in hydrologic studies for better understanding of flood hazards and planning mitigation measures. Similarly Youssef et al. (2011) performed morphometric analysis of sub-watersheds within the Wadi Feiran basin in Southern Sinai, Egypt to estimate the flash flood risk levels. The use of morphometric analysis for predicting behaviours of sub watersheds for different types of rainfall events have also been reported (Singh and Awasthi, 2011; Angillieiri 2012). The parameters generated during the analysis could aid as guiding factor for adopting suitable measures for water resources management and developmental planning.

With the easy access to digital elevation model (from satellite source) and GIS technology performing morphometric analysis has become easy. Such analysis can provide insight to hydrological response of many inaccessible watersheds of north eastern region which contributes to erosion and flood hazards in the downstream plain areas. Further, integration of morphometric parameters with land use and soil cover information in GIS domain can aid in siting and sizing of suitable soil and water conservation measures for flood management. It could be observed that application of GIS technique can yield better and efficient results as compared to traditional approach.

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