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Meandering Factor" Analysis For The Study of Present Microgeomorphic Status of Runoff Channel Basin

KEYWORDS: Runoff channels, Microgeomorphology, Mathematical Model, MFM Value, MF Index

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ABSTRACT *This study deals with the mathematical testing for analysing microgeomorphic or small area geomorphic status of runoff channels. A field study was conducted on Rangamati Gully Basin of lateric highland of West Medinipur district in India, to generate primary data for mathematical application. True length and shortest linear distances of the runoff channels were measured for the analysis of their microgeomorphic status by mathematical testing. A suitable channel network model was prepared and hardware model testing was done in the laboratory for the contraction of mathematical logic. On the basis those testing "Meandering Factor Model"was developed which stands on two logics, firstly ifany other external factors are absent, the general tendency of water flow is straight by the influence of acceleration due to gravity and secondly the external factors like initial slope condition, structure and vegetation cover along with gravity play vital role for the extension meandering flow path of small runoff channels. By MFM calculation a MF Index was prepared. According to MF Index three categories of runoff channels in the study area were found suchas tramped shaped channels, represents the highest MFM Values, >0.04, narrow elongated channels, having 0.15 to 0.40 MFM Valuesand scour network channels which have the lowest MFM Values from 0.01 to 0.14. Presence of lower MF Index channels in higher number in the study area indicates that this gully basin is still under the stage of development and modifying rapidly.*

1.INTRODUCTION:

Microgeomorphology is a part of landform science, which concentrates on small geomorphic sculptures and designs in the sediment layers and on the surface created by geomorphic agents and their significance in spatial and temporal scales (Dey, 2005). Similar terms were used by Zonn (1986) for the explanation of small or micro-level relief variations within specific geomorphic condition. Bloom (2002) accorded that generally smaller features of landform can be created and destroyed more rapidly that larger ones. It is also well accepted that every geomorphic processes create some specific micro-features which can explains the nature of landform development and sometimes they preserve the history of geomorphic evolution as well. Runoff channels, like rills and gullies are such microgeomorphic features, which not only describe the present geomorphic status but also very useful to predict future landform modification (Garland et al 1994; Pile, 1996; Brinkcate and Hanvey 1996). These narrow watercourses (Plate-4)are developed due to rainfall and causes soil erosion by rapid water flow (Carey et al 2001). Thus a wide range of geomorphic changes occurs across the gully basin areas. It also has some social effects like loss of productivity of soil, spoiling of roads, walls and buildings etc. By this way gully erosion restricts land use and economic activities.

Considering the significance of small runoff channels as microgeomorphic feature, we decided to perform an experimental analysis on microgeomorphic status of gully basin by simple mathematical modelling. Since geomorphologic study using the method of mathematical explanations has been very popular during the last 20-25 years with the increasing use of computer in all scientific research works, mathematical models have become very useful for the expression of geomorphic change and geomorphic status. The mathematical or software models can explain field survey or hardware data more scientifically and logically even in the small or micro-level areas (Dey, 2000; Dey, 2002; Dey, 2005). Hence, for any scientific explanation, perfect data generation from the field is very important. For that purpose we selected a part of Rangamati Gully basin of West Medinipur District of West Bengal, India (Fig-1) to generate field data. This basin covers 37 Km ^{2} along river Kansabati (locally known as Kansai) in Medinipur town in a part of lateritic highland of West Medinipur district. The main objectives of the study were (i) to formulate a simple mathematical model for assessing the present microgeomorphic status of the gully basin and (ii) to assess the range of micro-level landform modification by applying the field data.

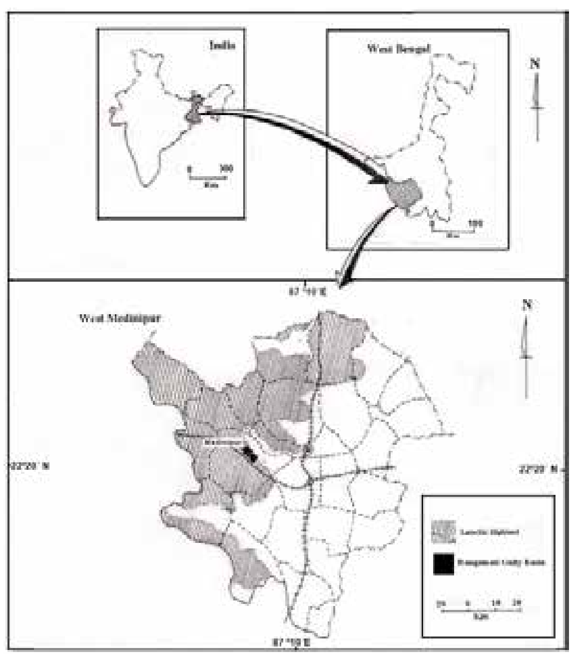

Figure-1: Location of the study area

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2.METHODOLOGY

2.1.Preparation for model building:

2.1.1.Literature survey and fieldwork: Prior to visiting the field area, the present authors surveyed the existing literature such as reports of Geological survey of India, Department of Environment of Government of West Bengal etc and recent research papers published in different journals and presented in different seminars, congresses etc to prepare a complete fieldwork programme.

A fieldwork was conducted to collect hard data which can be used for mathematical testing. Pattern and characters of runoff profiles and associated slopes along with the role of natural vegetation were studied systematically. True or actual length of the run-off channels and shortest distance from the source to mouth of the channels are measured by prismatic compos, dumpy level and tape.

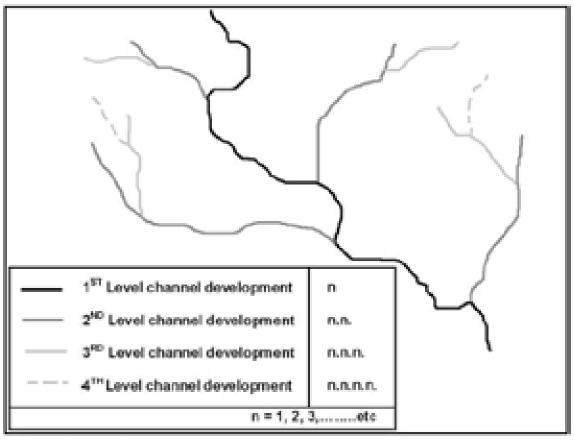

Figure-2: Concept of gully ordering for the application of Meandering Factor model

2.1.2.Gully network model: A model for analysing the network system of the gully basin has been prepared by the present authors for the mathematical application of field data (Fig-2). The main channel of the basin has defined as 1st Level channel. The first level channel has been numbered as 1,2,3, etc in the table. The channels which are directly join 1st level channel are defined as 2nd Level channel. These are numbered as 1.1, 1.3, 1.3 etc. The channels meet the 2nd Level channels are named as 3rd Level channels and numbered as 1.1.1, 1.1.2, etc. By the same way other networking channels are described in the network model (Table-1)

Table-1: True length (L) and shortest distance (S) of the runoff channels of Rangamati Gully Basin

Sl no	Lengths of channels (in metre)							
	1st Level		2nd Level		3rd Level		4th Level	
	L	S	L	S	L	S	L	S
1	272.6	251.0						
1.1.			81.50	71.65				
1.1.1					42.3	38.8		
1.1.2					61.5	51.0		
1.1.2.1							38.3	31.0
1.2.			16.80	13.80				
1.3.			8.50	3.50				
1.4			23.00	22.00				
1.5			49.80	46.00				
1.6.			28.00	27.20				
1.7.			38.00	37.00				
1.8			82.50	76.00				
1.8.1					35.00	31.10		
1.8.2.					33.00	32.00		
1.9			47.00	40.00				
1.9.1					28.00	24.00		
1.9.1.1							24.00	19.00
1.10			22.00	20.50				
1.11			32.00	29.70				
1.12			20.50	17.5				
1.13.			23.70	20.6				
1.14			24.20	20.50				
1.15			84.60	72.20				
1.15.1					25.30	22.00		
1.15.1.1.							21.30	19.00
1.16			72.50	53.00				

(Source: Field investigation)

Table-2: MFM Values of different runoff channels

Sl no	L-S of channels				C_A	MFM value
	1st Level	2nd Level	3rd Level	4th Level		
1	21.6				45.16	0.48
1.1.		9.85			45.16	0.22
1.1.1			3.50		45.16	0.08
1.1.2			10.50		45.16	0.23
1.1.2.1				7.30	45.16	0.16
1.2.		3.00			45.16	0.06
1.3.		5.00			45.16	0.11
1.4		1.00			45.16	0.02
1.5		3.80			45.16	0.08
1.6.		0.80			45.16	0.01
1.7.		1.00			45.16	0.11
1.8		6.50			45.16	0.14
1.8.1			3.90		45.16	0.09
1.8.2.			1.00		45.16	0.02
1.9		7.00			45.16	0.15
1.9.1			4.00		45.16	0.09
1.9.1.1				5.00	45.16	0.11
1.10		1.50			45.16	0.03
1.11		2.30			45.16	0.05
1.12		3.00			45.16	0.06
1.13.		3.10			45.16	0.07
1.14		3.70			45.16	0.08
1.15		10.40			45.16	0.23
1.15.1			3.30		45.16	0.07
1.15.1.1.				2.30	45.16	0.05
1.16		19.50			45.16	0.43

(Source: Field data from Table-1)

2.2.Laboratory testing and model building:

2.2.1.Hardware model testing: During the early 20th century hardware models were very rarely used for geomorphic explanations. Successful experiments of Bagnold (1941) and Schumm (1956) made the hardware models to the geomorphologists. Laboratory experiments of Hub-

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bert (1931), Murphy (1949), Langhaar (1951), Wilson (1952), Duncan (1953) and Strahler (1958) also play vital role for making the hardware models more acceptable to the geo-scientists. In the year 1945, J.F. Friedkin prepared a hardware model for his experiment on river meanders. Presently these models are very popular since they can present some simple visual impression of geomorphic phenomena. We also conducted a simple testing by hardware models in the Environmental Geomorphology and Geo-hazard Analysis Laboratory of the Department of Geography and Disaster Management of Tripura University to construct the logic for mathematical or software model. The basic objective of the experiment is to understand the influences of external factors and acceleration of gravity for the development of runoff channels. For that purpose we prepared 5m x 3m artificial slopes in the laboratory 4 of which are made by plain glasses (having angles of 4°, 8°, 16°, 32°) and other 4 earthen slopes (also having 4°, 8°, 16°, 32° angles). The second category or earthen slopes are very rugged and covered by some artificially made small grasses like natural slopes. By generating continuous water flow at same speed and quantity on the artificial slopes for 2 hours each it has been observed that the water flow on the slopes made by plain glasses are straighter than the earthen slopes (Fig-3). Due to initial ruggedness of the slopes, vegetation cover etc the water flow on the earthen slopes created many small meanders to make their way.

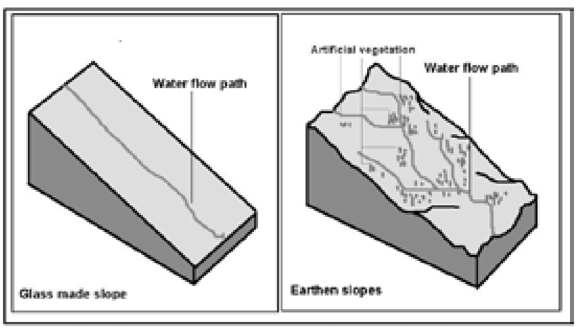

Figure-3: Laboratory testing method-artificial glass made plain slope and earthen rugged slope and general tendency of water flow on those artificial slopes

Although on the lower angled glass made slopes water flow created few meanders, the overall tendency of flowing water on the plain slopes where there are no other external factors is to make a shortcut way. From that experiment three main concepts have been developed by the present authors:

If the supply of water and its velocity is same and the external factors are absent, there will be a general tendency of water to flow straight by the influence of acceleration of gravity.

External factors like initial slope condition, structure and vegetation cover along with gravity play vital role for the development of flow path and meandering of small runoff channels.

Variation water supply due to climatic variation influences the change of runoff channels. Some early writers like Maud (1978), Price-Williams et al (1982), Partridge and Maud (1987), and Partridge (1988) successfully advocated that climatic conditions are also very important factor for gully development. In the tropical area seasonal variation play a vital role for the changing of water supply and geomorphic process (Sen et al, 2004). During the monsoon increase of rainfall creates maximum water energy which causes maximum modification of landform. Thus we also created artificial variation of water supply on the hardware models. The tendency of water flow has been found almost same on the slopes in different water energy conditions.

2.3.Mathematical logic:

From the above experiment it can be explained that the true distance or actual distance of a runoff channel is developed by the influence of external factors since they play important role for the formation of meandering path. The shortest length indicates the probable length of the gully if there is no influence of external factors than gravity. The subtraction between the actual distance and the shortest distance of the runoff channels can be defined as the value of influence of external factors other than gravity. On the other words subtraction between true distance and shortest distance indicates the extension of the length of the run-off channels by the influences of external factors (Figure-4).

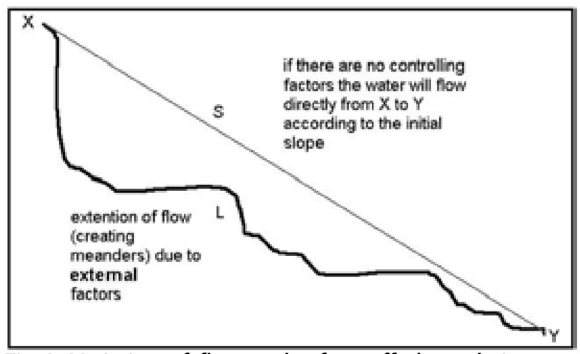

Fig-4: Variation of flow path of runoff channels in presence of external factors and absence of external factors

2.4. Formulation of mathematical model:

On the basis of that, simple mathematical equation, "*Meandering Factor Model*" (MFM) has been proposed by the present authors to assess the level of development of microgeomorphology by field data testing. The model is as follows:

$$MFM = \frac{L-S}{C_A}$$

Where, MFM = Meandering factor model, L = true distance of the runoff channels from its source to end and S = shortest distance of the runoff channels from its source to end and C_A = average flow area of the run-off channels. C_A is calculated by:

$$C_A = \frac{\text{Total flow area of the basin}}{\text{Number of channels}}$$

3.RESULTS AND DISCUSSIONS

3.1.Meandering factor calculation for field data analysis:

Data generation through field study shows the variations of lengths of different order run-off channels. Field observation and the Meandering Factor Model analysis shows that there is a clear relationship between the channel length and meandering factor value. Since development of many meanders indicates the long and turning flow path the difference of true length and shortest distance is greater. Thus there is a general tendency to increase of MFM value with the increase of length of the channels (positive relationship between the channel length and meandering factor value, Fig-5).

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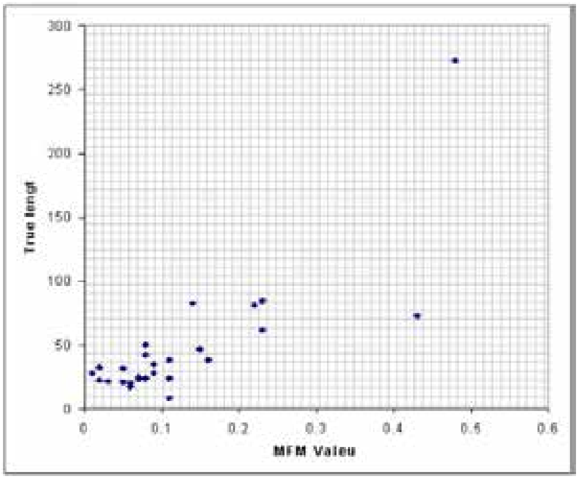

Figure-5: Relationship between MFM value and True length of the gullies

3.2.Meandering Factor Index

3.2.1.Characteristics of MF Index: On the basis of MFM calculation we prepared Meandering Factor Index (MF Index) to categorise the gullies / runoff channels in the present study area. All the categories of MF Index have some microgeomorphic indications like present slope conditions, ruggedness or smoothness of the gully beds and width of the gully beds. The MF Index can detect the following features:

Higher value of MFM indicates lower slopes and wider channel with smooth gully bed.

Lower value of MFM indicates higher slopes and narrower channels with rugged gully bed.

Higher MFM value indicates the older channels, which eroded for long time and modified the slopes. Observation shows that these older channels modify the slope very slowly and as a result soil removal rate has a tendency to decrease.

Lower MFM value indicates relatively younger channels. The rate of slope modification is of those younger channels are higher.

If the MFM rate has a tendency to decrease then it means the slope modification is increasing and if the rate is increasing then the slope modification is increasing.

If in a gully basin MF Index lower MFM values are dominant, then the gully basin must be modifying rapidly by soil removal.

3.2.2.Classification of gullies on the basis of MF Index: Mathematical testing shows that proposed MF Index can be used locally and the user should fix the scale according to his / her field data. In the Rangamati Gully Basin we found four types of gullies with their specific significance (Table-3).

Table-3: Meandering Factor Index measurement of Rangamati Gully Basin

MF Index	MFM Value	Microgeomorphic significance		
		Observed micro-level slope condition	Observed Gully bed condition	Observed width of the gully channels (cross profile)
Tramped shaped gully	> 0.4O	Gentle	Smooth and flat	Very wide, mainly tramped shaped near its mouth
Narrow elongated gully	0.15 – 0.39	Medium to High	Rugged	Narrow
Scour network channels	0.01-0.14	Very high	Very rugged	Very narrow

Tramped shaped gully represents maximum MFM Value (>0.40), which indicates that they are characterised by widest channels with comparatively smooth and flat gully bed in this region. It has also been observed that those gullies are flowing on undulating but comparatively gentle slopes. Field observations show that they are the oldest gully channels and are eroded for long time that modified their slopes very flat. In those channels some sediment loads are found during the dry seasons. Narrow elongated gully represents 0.15 to 0.40 MFM Values. The gullies of this second category are flowing on medium slopes and characterised by wider channels with little rugged gully bed. The last category, scour network channels (MFM Value 0.01-0.14) is representing the narrow gullies, which have very rugged bed and flowing on very high slopes. Field observations show that scour network channels are the youngest in this basin and gully head development is in an initial stage. This initial gully head is the indicator of further gully network development (Drik et al, 1999)

Plate-1: Second level tramped shaped gully with some deposited material on its bed in Rangamati Gully Basin

Plate-2: Depositions on flat bed of a first level tramped shaped gully of Rangamati Gully Basin

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3.2.3MF Index status:

Presently Rangamati gully basin has 26 networking channels among which only 2 are tramped shaped gullies with flat gully bed (Plate-1&2). Other 24 are either narrow elongated or scour networking channels (Table-4, Plate-3, 4&5). So, this basin is characterised by lower meander factor which means most of the gullies are flowing straight and at faster rate. It is also remarkable that the 12 second order and 3rd order channels are scour networking with very low MFM value. This it can be assessed that this gully basin is a younger basin and its landform is modifying rapidly.

Table-4: MF Index status of Rangamati gully Basin

MF Index	Number of runoff channels				
	1st Level	2nd Level	3rd Level	4th Level	Total
Tramped shaped gully	1	1	-	-	2
Narrow elongated gully	-	3	1	1	5
Scour network channels	-	12	5	2	19

Plate-3: A narrow elongated channel of Rangamati Gully Basin at its upper course.

Plate-4: A second level narrow elongated channel at its lower course is flowing on the bed of the first level tramped shaped gully of of Rangamati Gully Basin

Plate-5: Scour network channels are developing on the steep slops of Rangamati Gully Basin

4.CONCLUSION

Though little has been discussed so far in the existing scientific literature, the significance of microgeomorphic features can never be ignored in discipline of geomorphology. The small runoff channels like rills and gullies are such features, which form their catchment-morphology at micro-level. Structure, climate and other environmental factors play vital role on micro-level geomorphic processes and for the development of micro-morphology. The existing microgeomorphology of the present study area is still in degrading condition. During the monsoon season maximum soil erosion is observed which causes the increase of total MFM value of the gully basin. Over the last 20-30 years this process has increased rapidly and now the removal of soil is under serious condition. This rapid soil erosion not only affects the geomorphology of this area but also creates socio-economic and ecological hazard (Stocking's, 1988, 1995). It has been observed that the land users are the worst sufferer by the removal of soil in this area. Under these circumstances scientific study of present geomorphic status of this gully basin would be very important for sustainable development scheme for the future.

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