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Estimation of Erosional Potential Zones of Itagi Sub-watershed: A RS and GIS Approach

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Abstract— Prioritization of watershed, sub-watershed or micro-watershed is an ideal step towards watershed management and also its development. Morphometric analysis of a watershed paves a way to understand its hydrological and geological nature and helps in the prioritization of sub-watersheds or micro-watersheds. RS and GIS are a prime aspect in this study. The morphological parameters are accurately and efficiently found out in the GIS platform. In our study the Itagi sub-watershed is taken for its prioritization. Here based of morphometric analysis the prioritization of the micro-watersheds is carried out on the basis of erosion potentiality. The study area falls under Siddapura taluk of the Uttara Kannada district, Karnataka. It has an aerial extent of the study area is 80.37 sq. km. For our analysis the sub-watershed is divided into ten micro-watersheds. From the results of our study we found that three of the micro-watersheds fall under high priority range and are in need of preventive measures. Whereas other three fall under medium priority range and the remaining four falls under low priority range.

Index Terms—Itagi, Morphometric Analysis, Erosion Potentiality, RS & GIS, Prioritization.

1 Introduction

WATERSHED is an area of land that has a set of streams and rivers that drain into single larger body of water. A watershed becomes ideal for the management of natural resource such as land, forest, soil etc. Watershed is a natural hydrological entity which allow surface run-off to define channel, drain, stream or river at a particular point. It is the basic unit of the water supply which evolves over time. Different workers define water-shed differently. In foreign literature, watershed has been defined as a drainage basin or catchment (Khadri S. F. R. et al. 2013).

Proper planning and management of watershed is very necessary for sustainable development of living being. Geomorphological analysis of a watershed is usually used for evolving the regional hydrological models for resolving different hydrological difficulties of the ungauged watersheds in the absence of data accessibility conditions (Gajbhiye et al. 2014).

The morphometric analysis of drainage basins helps to comprehend aspects of linear, areal, and relief parameters. Geomorphologists have identified that there were clear important relations among runoff features, as well as geographic and geomorphic features for drainage basin networks (Rastogi et al. 1976 and Iyad Ahmed Abboud et al. 2017). Morphometric parameters of a watershed provide a quantitative description of the drainage system which is an important aspect of the characterization of watershed. The influence of drainage morphometry is very significant role to understand the landform process, soil physical properties and erosional characteristics.

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Thus, morphometric analysis is a significant tool for prioritization of sub-watershed development and natural resource management.

RS and GIS are the promising techniques to give accurate and efficient results regarding the basic morphometric parameters. RS and GIS are employed in various diverse fields and its use is usage is increasing rapidly.

Morphometric analysis was conducted to prioritize watersheds for soil conservation purposes, using linear and shape morphometric parameters, which are selected based on their relation to erodibility (Yahaya Farhan et al. 2016). Watershed prioritization is the ranking of different sub-watersheds or micro-watersheds of a watershed according to the order in which they have to be taken for treatment for water and soil conservation measures, etc., (Javed et al. 2011). There has been no prior research work carried out in our study area Itagi sub-watershed. Our attempt is to prioritize the micro-watersheds of the Itagi sub-watershed based on erodibility criteria using RS and GIS.

2 Study Area

The Itagi Sub-watershed is derived from the River Aghanashini basin situated in Siddapura taluk of Uttara Kannada district, Karnataka. The geographical extent of the Itagi sub-watershed stretches from 14^0 15′ 32.3′′ to 14^0 23′ 15.5′′ North latitudes and 74^o 45′ 06′′ to 74^o 51′ 22.4′′ East longitudes and covers an area of 80.37sq. km. The area has a perimeter of 44.86 km. The drainages of sub-watershed connected to the River Aghanashini which flows towards West and joins the Arabian Sea. The mean annual rainfall of the study area is about 3614 mm most of which occurs during the SW monsoon. The average minimum and maximum temperature are 26^0C and 36^0C respectively. The Major land covers in the catchment are forest followed by agriculture. The main food crops grown are paddy, maize, pulses, groundnuts and spices. The commercial crops are sugarcane, cotton, arecanut, coconut. Geographically the study area consists of lateritic soil. The location map is shown in the Figure 1.

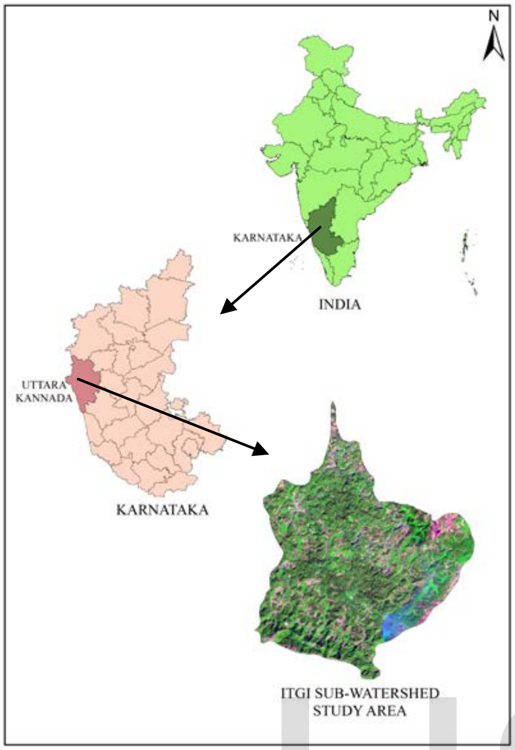

Fig 1: Location Map of the Study Area

3 Methodology

Initially the Survey Of India toposheet 48J15 is scanned and the softcopy is geo-referenced. After this the base map of the sub-watershed under consideration is prepared. Then the drainage map of the sub-watershed is delineated with the help of toposheets of scale 1:50,000 and updated using IRS LISS III satellite imagery data in a GIS platform. For our analysis the micro-watersheds are derived from the third order streams. The stream ordering by carried out based on Strahler (1964) stream ordering technique. The drainage map is shown in the Figure 2. The standard methods and formulae are employed to determine the morphometric parameters of each micro-watershed. The basic parameter such as the area, perimeter, stream length, stream number and basin length are calculated in the GIS platform. The rest of the parameters are determined by using the standard formulae and methods. The study area Itagi sub-watershed was further divided into ten micro-watersheds for our analysis and prioritization. They are designated as MW1, MW2, MW3, MW4, MW5, MW6, MW7, MW8, MW9 and MW10. The standard formulae for the calculation of morphometric parameters are shown in the Table 1. The study area with its micro-watershed is shown in the Figure 3.

TABLE 1
FORMULAE FOR CALCULATING MORPHOMETRIC PARAMETERS

Sl. No.	Morphometric Parameter	Formula	References
1	Stream Order (Nu)	Hierarchical rank	Strahler (1964)
2	Stream Length (Lu)	Length of the stream	Horton (1945)
3	Bifurcation Ratio (Rb)	Rb = Nu/(Nu+1) Nu = Total no. of stream segments of order 'u'	Schumn (1956)
4	Drainage Density (Dd)	Dd = ΣLu/A ΣLu = Total stream length of all orders A = Area of the basin (km^2)	Horton (1932)
5	Stream Frequency (Fs)	Fs = ΣNu/A ΣNu = Total no. Of streams of all orders.	Horton (1932)
6	Texture Ratio (T)	T = ΣNu/P P = Perimeter of the basin	Horton (1945)
7	Circularity Ratio (Rc)	$Rc = 4\pi A/P^2$	Miller (1953)
8	Form Factor (Rf)	$Rf = A/Lb^2$ Lb = Basin length	Horton (1932)
9	Elongation Ratio (Re)	$Re = 2(A/\pi)^{0.5}/Lb$	Schumn (1956)
10	Compactness Coefficient (Cc)	$Cc = 0.2841P/A^{0.5}$	Gravelius (1914)

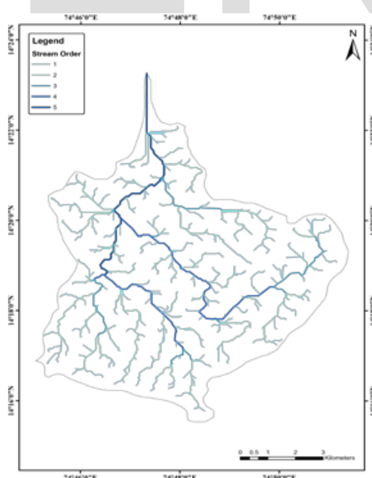

Fig 2: Drainage Map

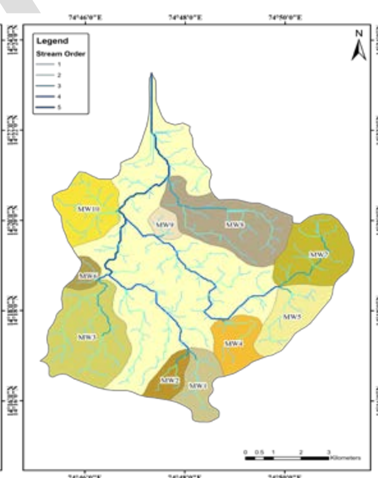

Fig 3: Micro-watersheds Map

Results and Discussions

Basic Morphometric Parameters: The basic morphometric parameters can be accurately and efficiently obtained from the

GIS platform. These are directly computed from the vector data extracted from the topographic maps. The main basic morphometric parameters include maximum order of the streams, number of streams in each order, length, area, perimeter, relief for each of the basins. The values of the basic morphometric parameters are discussed in the Table 2.

Derived Morphometric Parameters: Derived morphometric parameters are also called the applied parameters. These are derived from the basic parameters by using the standard formulae and methods. These parameters help us in giving a brief description about the sub-watershed. It describes the nature and the behaviour of the area under consideration. The derived parameters are shown in the Figure 4. The values of the derived parameters are discussed in the Table 3.

Bifurcation Ratio (Rbm): It is defined as the ratio of the number of the stream segments of given order to the number of the next higher order segments (Schumn 1956). The bifurcation ratio is relief and dissection index (Horton 1945). The smaller values of bifurcation ratio indicate less structural disturbances suffered by the sub-watershed (Strahler 1964). Higher values of bifurcation ratio may denote the indications of potential flooding. The lowest bifurcation ratio value of 2 was obtained in the micro-watershed MW9 and the highest of 7.43 was found in the MW3. Bifurcation ratio characteristically range between 3.0 to 5.0 for basins in which the geological structures do not distort the drainage pattern (Strahler 1964). Eight out of ten micro-watersheds have mean bifurcation ratio less than 5. Therefore, based on the majority of values obtained it indicates that the drainage pattern is not affected by the geological structures of the area (Md. Zakaria et al. 2016). The mean bifurcation ratios of the micro-watersheds are shown in Figure 4-A.

Drainage Density (Dd): It is the ratio of total stream length to the total area of the basin. It is important in indicating the linear scale of land form elements in the stream eroded topography (Horton 1932). The lower values of drainage density for watersheds indicates the presence of permeable subsurface material with good vegetation and also low relief and for the higher values it is vice versa (Nag et al. 1998). Density factor finds relation with the climate, relief, type of rocks, vegetation, surface runoff, infiltration and surface roughness (Rudraiah et al. 2008). The micro-watershed MW1 has the lowest drainage density of 1.83 and MW10 has 2.5 which is the highest. All ten micro-watersheds have drainage density less than 3. From the drainage density values, we can say with reference to Gajul M. D. et al. (2016) that the drainage density is predominantly low and moderate and the area under consideration has permeable subsoil, low relief and is having a rich vegetation cover (Nag S. K. 1998 and Waikar M.L. et al. 2014). Drainage densities of the micro-watersheds are shown in Figure 4-B.

Stream Frequency (Fs): The ratio of the total number of drainages of all orders to the unit area is called stream frequency. The stream frequency and the drainage density have a positive relation between them. Hence an increase in the stream frequency tends to increase the drainage density (Horton 1932). Stream frequency is directly proportional to the relief of watersheds whereas inversely proportional to permeability, infiltration capacity. The MW5 has the lowest stream frequency of 3.13 and MW6 has the highest of 7.92. Based on the study of Gajul M. D. et al. (2016) the stream frequency value below 6 is low and above 6 can be termed high. Eight out of ten micro-watershed have stream frequency lesser than 6. Based on the results, the majority of the stream frequency values of micro-watersheds have lower stream frequency indicates slower runoff and less chances for flood to occur (Charles W Carlston 1963 and Rafiq Ahmad Hajam et al. 2013). The stream frequencies of the micro-watersheds are shown in the Figure 4-C.

Texture Ratio (T): The drainage texture ratio is the total number of drainages of all orders to the perimeter of that watershed (Horton 1945). The drainage texture is dependent on the climate, rainfall, rock type, vegetation, infiltration capacity, soil type, relief and stage of development of basin. The drainage density can be classified into five different categories i.e. very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8) (Smith 1950). The micro-watersheds texture ratios range from 1.25 of MW1 to 2.9 of MW3. Six out of ten micro-watersheds have very coarse texture as their values are below 2 and the remaining four micro-watersheds have coarse texture as their texture ratio value range between 2 to 5. Therefore, the area under consideration has texture predominately of very coarse ranging to coarse texture. The texture ratios of the micro-watersheds are shown in the Figure 4-D.

Circularity Ratio (Rc): The circularity ratio is the ratio of the area of the basins to the area of circle having the same circumference as the perimeter of the basin (Miller 1953). The circularity ratio of 1 will be obtained for the watershed which are a perfect circle. Higher the circularity ratio more circular will the shape of the watershed and the relief tend to be moderate to high and the surface will be permeable (Sadaf et al. 2014). Circularity ratio is mainly dependant on the length and frequency of streams, geological structures, land use / land cover, climate, relief and slope of the basin (Rudraiah et al. 2008). In our study the micro-watershed MW1 has the lowest circularity ratio of 0.52 where the highest of 0.85 is of MW7. Seven out of ten micro-watersheds have circularity ratio lesser than 0.75, this indicates that the majority of the micro-watersheds are elongated in nature and the remaining three micro-watersheds are circular in shape (Nageshwara Rao K et al. 2010). The circularity ratios of the micro-watersheds are shown in the Figure 4-E.

Form Factor (Rf): Form factor is the ratio between basin area and the square of basin length. It is an indicative of the flow intensity of a defined area of a basin (Horton 1945). The smaller value of the form factor indicates that the basin will be more elongated and the higher values of form factors indicates circular shape of watershed. Basins with higher form factor will have larger peak flows of shorter duration as the basins will be circular in shape, whereas lower form factor having elongated watersheds will experiences lower peak flow for longer duration (Waikar M.L. et al. 2014). The lowest form factor observed in our study was 0.39 of the MW8 and the highest being 1.41 of the MW9. Five out of ten micro-watersheds have form factor greater than 0.6 which indicates that these micro-watersheds have high peak flow for shorter durations whereas the remaining five micro-watersheds have a smaller form factor and this indicates that these have lower peak flow for longer durations mainly because they are elongated in shape (Gursewak Singh Brar 2014). The form factors of the micro-watersheds are shown in the Figure 4-F.

Elongation Ratio (Re): It is defined as the ratio of diameter of a circle having the same area as the drainage basin and the maximum length of the basin (Schumn 1956). The basin with elongation ratio of unity corresponds the regions with low relief (Strahler 1964). These values can be grouped into three categories namely circular (>0.9), oval (0.9-0.8) and elongated (<0.7). In the area under consideration the lowest elongation ratio is 0.7 and the highest is 1.34. Based on this range three micro-watersheds fall under the elongated category and two in the oval whereas the remaining in the circular category. Based on the results, it indicates that the micro-watersheds are prominently elongated and oval in nature. The elongation ratios of the micro-watersheds are shown in the Figure 4-G.

Compactness Coefficient (Cc): It is the ratio of perimeter of watershed to circumference of circular area, which equals the area of the watershed (Gravelius 1914). It is also known as the Gravelius Index (GI), which is used to express the relationship of a hydrological basin to that of a circular basin having the same area as the hydrologic basin. A circular basin is the most susceptible from the drainage point of view as it will tend to yield the shortest time of concentration before the peak flow occurs in the basin (Nooka Ratnam et al. 2005). Compactness coefficient has an indirect relation with the elongation nature of the basin area. Lower values of the compactness coefficient indicate more elongation of the basin and also less erosion and vice versa (Waikar M.L. et al. 2014 and Md. Zakaria et al. 2016). The micro-watershed compactness coefficient varies from 1.09 of MW7 to 1.39 of MW1. Here on three micro-watersheds have compactness coefficient below 1.15 whereas seven micro-watersheds have above 1.15. Based on the results the majority of the micro-watersheds are more elongated than circular (Md. Zakaria et al. 2016). The compactness coefficients of the micro-watersheds are shown in the Figure 4-H.

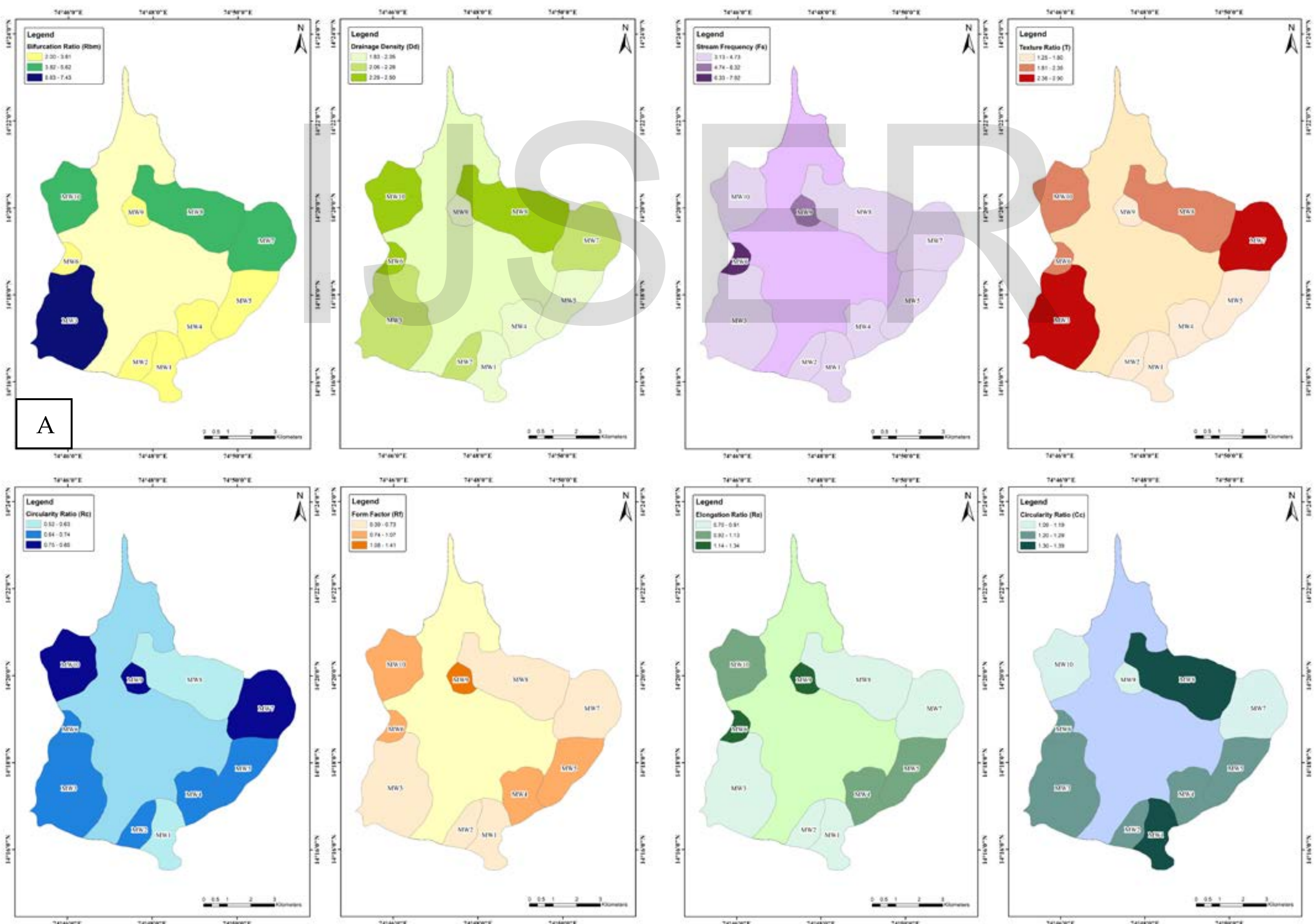

Fig 4: Derived Morphometric Parameters (A, B, C, D, E, F, G, H)

TABLE 2: BASIC MORPHOMETERIC PARAMETERS OF THE STUDY AREA

Micro Watershed	Basin Area (Km^2)	Perimeter (Km)	Basin Length (Km)	Nu			Σ Nu	Lu			ΣLu
				I	II	III		I	II	III	
1	3.25	8.82	2.66	8	2	1	11	3.2	2.17	0.59	5.96
2	1.92	6.01	2.08	5	2	1	8	1.48	1.66	0.95	4.09
3	9.65	13.1	4.02	24	13	1	38	10.44	7.71	3.01	21.16
4	3.27	7.61	1.85	8	2	1	11	3.45	2.92	0.17	6.54
5	4.48	9.24	2.41	11	2	1	14	4.42	3.42	0.52	8.36
6	1.01	4.45	0.99	5	2	1	8	1.91	0.41	0.15	2.47
7	6.4	9.74	3.36	17	5	1	23	7.92	1.88	3.41	13.21
8	9.21	13.9	4.88	26	5	1	32	11.03	6.8	3.21	21.04
9	1.12	4.11	0.89	4	2	1	7	1.39	0.49	0.31	2.19
10	5.09	8.81	2.33	16	3	1	20	7.56	4.99	0.17	12.72

TABLE 3: DERIVED MORPHOMETERIC PARAMETERS OF THE STUDY AREA

Micro Watershed	Rb		Rbm	Dd	Fs	T	Rc	Rf	Re	Cc
	I/II	II/III								
1	4	2	3	1.83	3.38	1.25	0.52	0.46	0.76	1.39
2	2.5	2	2.25	2.13	4.17	1.33	0.67	0.44	0.75	1.23
3	1.85	13	7.43	2.19	3.94	2.9	0.71	0.6	0.87	1.2
4	4	2	3	2	3.36	1.45	0.71	0.96	1.1	1.2
5	5.5	2	3.75	1.87	3.13	1.52	0.66	0.77	0.99	1.24
6	2.5	2	2.25	2.45	7.92	1.8	0.64	1.03	1.15	1.26
7	3.4	5	4.2	2.06	3.59	2.36	0.85	0.57	0.85	1.09
8	5.2	5	5.1	2.28	3.47	2.3	0.6	0.39	0.7	1.3
9	2	2	2	1.84	6.25	1.7	0.83	1.41	1.34	1.1
10	5.33	3	4.17	2.5	3.93	2.27	0.82	0.94	1.09	1.11

TABLE 4: PRIORITIZATION OF MICRO-WATERSHEDS USING MORPHOLOGICAL PARAMETERS

Micro Watershed	Linear Parameters				Shape Parameters				Compound Rank	Final Priority
	Rbm	Dd	Fs	T	Rc	Rf	Re	Cc		
1	6	10	8	10	1	3	3	10	6.375	Low
2	8	5	3	9	5	2	2	6	5	Medium
3	1	4	4	1	7	5	5	5	4	High
4	7	7	9	8	6	8	8	4	7.125	Low
5	5	8	10	7	4	6	6	7	6.625	Low
6	9	2	1	5	3	9	9	8	5.75	Medium
7	3	6	6	2	10	4	4	1	4.5	High
8	2	3	7	3	2	1	1	9	3.5	High
9	10	9	2	6	9	10	10	2	7.25	Low
10	4	1	5	4	8	7	7	3	4.875	Medium

5 Prioritization of Micro-watersheds

Morphometric analysis is one of the effective ways to prioritize sub-watersheds or micro-watersheds and is been usually employed. There are other ways also to conduct prioritization. In this study prioritization is carried out by morphometric analysis based on erodibility criteria on the basis of compound ranking.

Based on compound ranking, highest rank is given to the greatest value of linear morphometric parameters and a highest rank is given to the lowest value of the shape morphometric parameters. The linear and shape morphometric parameters are usually considered as erosion risk assessment parameters. Linear morphometric parameters such as bifurcation ratio, drainage density, stream frequency, drainage texture, length of overland flow etc. have direct relationship with erodibility, whereas the shape morphometric parameters such as circularity ratio, elongation ratio, form factor, basin shape, compactness coefficient etc. show inverse relationship with erodibility (Nooka Ratnam et al. 2005). Based on the ranks given by the compound ranking the prioritization of the micro-watersheds is carried out.

In this study the micro-watersheds are classified into three priority range of high, medium and low. High priority indicates high erosional activities taking place in those areas and are of major concern whereas the medium priority indicates erosion but in manageable terms and the low priority means the regions which do not have any serious erosional problems. The compound ranking within the range of 3.5 - 4.75 are prioritized as high, 4.75 - 6 are prioritized as medium and 6 – 7.25 are prioritized as low. Based on the results the micro-watersheds MW3, MW7 and MW8 falls under high priority, whereas the micro-watersheds MW2, MW6 and MW10 comes under medium priority and the micro-watersheds MW1, MW4, MW5 and MW9 will be in the low priority range. The prioritization of micro-watersheds based on compound ranking is shown in Table 4. The prioritization map of the micro-watersheds is shown in the Figure 5.

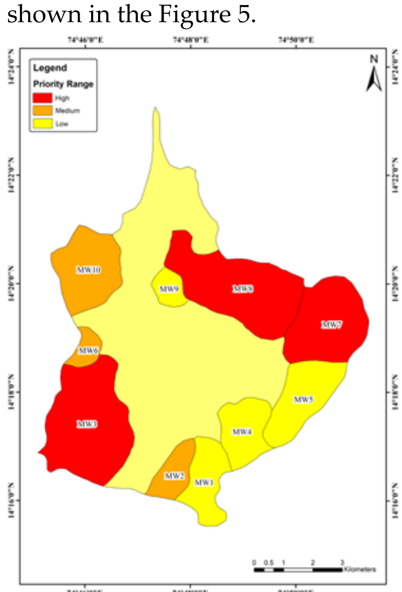

Fig 5: Prioritization of Micro-watersheds of the Study Area

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