

## **Prioritization of Balatira Watershed by Morphometric and Landuse Landcover Analysis, Atpadi Taluka, Sangli District, Maharashtra**

Gajul, M.D<sup>1</sup>, Mujawar.K.C<sup>2</sup>, Unhale P.L<sup>1</sup>, Prabhakar.P<sup>1</sup>

<sup>1</sup>Dept of Geology, School of Earth Science, Solapur University, Solapur, Maharashtra.

<sup>2</sup>Dept of Civil Engineering, NBSCOE Sinhgad Campus, Kegaon, Solapur, Maharashtra.

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**Abstract:** Today the world is facing the biggest crisis of water. The available both surface and groundwater resources are not sufficient to the water requirements for all purpose. Remote Sensing and Geographical Information System have emerged to meet ever increasing demand for more precise and timely information. These techniques permit rapid and cost effective natural resource survey and management. The morphometric analysis of the drainage basin and channel network play an important role in understanding the geo-hydrological behaviour of drainage basin and is manifestation of the prevailing climate, geology, geomorphology, hydrology, structure and land cover of the catchment area. In the present study, morphometric analysis and land use / land cover analysis has been carried out using Geographical Information System (GIS) techniques to assess the geo-hydrological characteristic of Balatira drainage basin. Balatira watershed falls in Atpadi taluka, Sangli district, Maharashtra and covers an area of 278 Km<sup>2</sup>. The morphometric analysis of watershed has been carried out using GIS softwares – Arc-GIS 10.0 and Arc View. An attempt has been made to identify the groundwater potential zones through geomorphometric aspects. Drainage analysis based on morphometric parameters is important for watershed planning since it gives an idea about the basin characteristics in terms of slope, topography, soil condition, runoff characteristics, surface water potential etc. The development of landforms and drainage network depends on bed rock lithology and associated geological structures. GIS techniques were used for assessing various morphometric parameters of Balatira drainage basins as it provides a flexible environment and an important tool for the manipulation and analysis of spatial information.

**Keywords:** Morphometry, Priority, Land use/ Land cover, Watershed, Sangli

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### **I. Introduction**

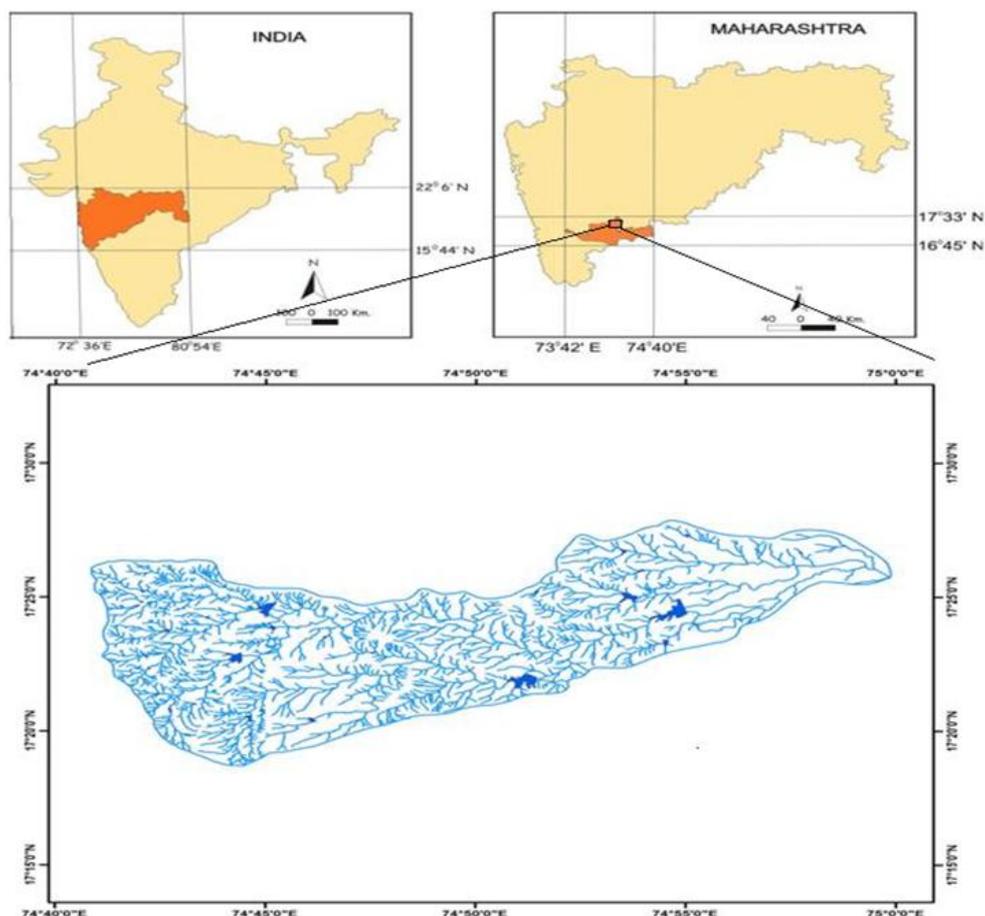
The available surface and groundwater resources are inadequate to meet the growing water demands due to rapid urbanization and increasing population. The geomorphic conditions are essential pre-requisites in understanding the water bearing characteristics of hard rocks. The role of rock types and geological structures in the development of stream networks can be better understood by quantitative morphometric analysis.

GIS techniques are the proven efficient tools in the delineation, updating and morphometric analysis of drainage basin. The drainage basin analysis is carried out quantitatively for Balatira watershed of Atpadi taluka. The analysis of drainage basin is important in any hydrological investigation like assessment of groundwater potential, groundwater management, pedology and environmental assessment. Hydrologists and geomorphologists have recognized that certain relations are most important between runoff characteristics and geomorphic characteristics of drainage basin system. Various important hydrologic phenomena can be correlated with the physiographic characteristics of drainage basins such as size, shape and length of the contributories etc (Rastogi et al. 1976). Drainage patterns refer to spatial relationship among streams or rivers, which may be influenced in their erosion by inequalities of slope, soils, rock resistance, structure and geological history of a region. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms ( Clarke, 1966). This analysis can be achieved through measurement of linear, aerial and relief aspects of the basin and slope contribution (Nag and Chakraborty, 2003).

The term watershed applies to a naturally occurring hydrologic unit defined by natural boundaries and characterized by similar physical, topographic and climatic conditions. It is a natural hydrological entity from which surface runoff flows to a defined drain, channel, stream or river at a particular point. According to the guidelines of AIS and LUS (1990), the mean area of a watershed is less than 500 km<sup>2</sup>. Watershed is further classified as sub-watershed, covering an area of about (30-50 km<sup>2</sup>), mini-watershed (10-30 km<sup>2</sup>) and micro-watershed (5-10 km<sup>2</sup>) (NRSA, 1995). Hence, a watershed becomes an ideal unit for management of natural resources i.e., land, water, forest, soil etc. Watershed management involves proper utilization of land, water, forest and soil resources of a watershed for optimum production with minimum hazard to natural resources (Biswas et al. 1999).

## II. Study Area

The Balatira watershed covers an area of 278 Km<sup>2</sup> in Atpadi taluka. It is towards north eastern part of Sangli district, Maharashtra and is shown in fig 1. It falls between North latitudes 17° 18' and 17° 28' and East longitudes 74° 42' and 75° 0' in the toposheet No. 47 K/11 and 47 K/15 . Climatically, the region falls under the rain shadow region of Sahyadri mountains. The long term average rainfall is about 468 mm. The temperature in summer month goes up to 42°C and the minimum temperature is 7°C during winter. Topographically, the region has large diversified surface with an elevation between 540 m and 840 m above mean sea level. The study area is drained by Balatira river a tributary of Man river and the area comprise of volcanic rock of Deccan traps with alternating layers of compact massive basalt and vesicular amygdoloidal basalts formed during the Cretaceous-Eocene times. 'AA' and 'Pahoehoe' lava flows of varying thickness constitute the lithology of study area.



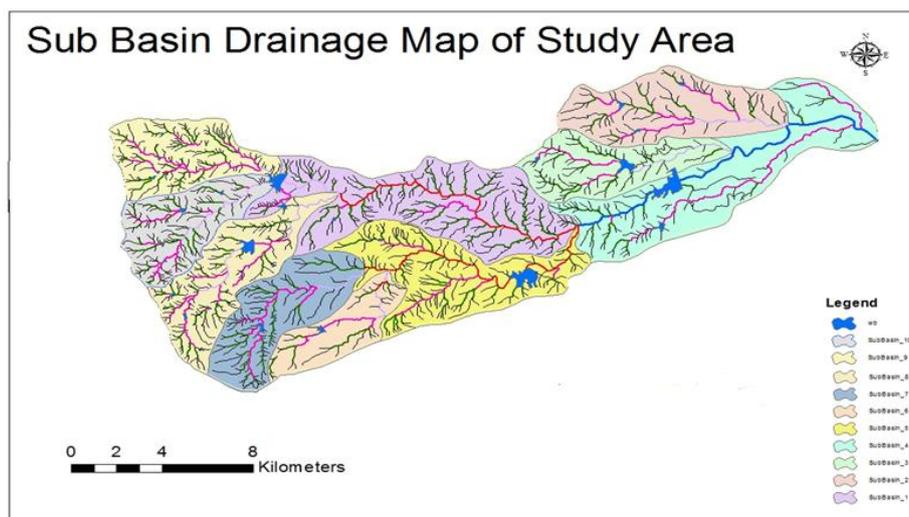
**Fig 1: Location map of study area**

## III. Methodology And Results

Entire study area has been delineated using Survey of India (SOI) topographical maps at 1:50,000 scale. The rectification of base map was followed by digitization of dendritic drainage pattern in Arc-GIS 10.0 software. The digitized map was edited and saved as line coverage in Arc view GIS platform. The Balatira watershed was further subdivided into 10 sub-watershed on the basis of direction of drainage flow, slope, relief, elevation and range in size from 14 Km<sup>2</sup> to 45 Km<sup>2</sup> as shown in fig 2. Based on the drainage order, the drainage channels were classified into different orders (Strahler, 1964). Basin parameters viz area, perimeter, basin length, stream length and stream order were calculated which were later used to calculate other parameter like bifurcation ratio, stream length ratio, stream frequency, drainage density, drainage texture, basin relief, relief ratio, elongation ratio, circularity ratio and form factor. Morphometric parameters under linear aspects, aerial and relief aspects of drainage basin are computed using standard methods and formulae ( Horton 1932, 1945, Smith 1954; Strahler, 1964; Mesa, 2006; Sreedevi et al , 2005). Detail data for the morphometric calculations are depicted in table no.1.

Land use/land cover mapping was carried out at sub-watershed level using IRS 1C LISS III False Colour Composite (FCC) of 2012. Visual interpretation of the IRS data led to the identification and delineation

of land use/land cover categories such as cultivated land, forest area, barren land, water body, built-up land etc. Figure 3 shows land use/land cover map of the study area derived from IRS data and the details of land use/land cover categories are presented in table no 2.



**Fig.2** Drainage Map Of Balatira Watershed with Sub-Watershed Boundaries

#### IV. Discussions

The total drainage area of Balatira watershed is 278 Km<sup>2</sup> and it is divided into 10 sub-basins for the analysis (fig. 2). The drainage pattern of the basin ranges from dendritic to sub-dendritic. Based on the drainage orders it has been classified as 7 sub basins of 4<sup>th</sup> order, 2 sub basins of 5<sup>th</sup> order and 1 sub basins of 6<sup>th</sup> order basin to analyse linear, aerial and relief morphometric parameters as shown in table no.1. The variation in order and size of the sub watersheds is manifestation of topography, lithology and structural condition of the region.

#### V. Linear Aspects

Comparison of the linear aspects such as stream order, stream number for various order, bifurcation ratio, mean stream length and stream length ratio are as follows:

1. Stream order- The Balatira river is sixth order stream covering an area of 278 Km<sup>2</sup>. The sub watershed SW1 and SW5 are having 5<sup>th</sup> order streams covering an area of 45.3 and 33.5 Km<sup>2</sup> respectively. The sub-watershed SW4 is having 6<sup>th</sup> order stream covering an area of 43.6 Km<sup>2</sup>. The sub-watershed SW2, SW3, SW6, SW7, SW8, SW9 and SW10 having 4<sup>th</sup> order streams cover an area of 27.8, 20.5, 14.4, 24.4, 26.5, 21.0 and 20.7 Km<sup>2</sup> respectively.
2. Stream length- The stream length (Lu) has been computed based on the law proposed by Horton (1945) for all the 10 sub-watersheds (table no.1). Normally, the total length of stream segments is maximum in first order streams and decreases as the stream order increases. However, in case of SW1, SW 5 and SW7 sub-watersheds the stream segments of various order show deviation from said condition. This change may indicate flowing of streams from high altitude, lithological variation and moderately steep slopes. Singh and Singh 1997 had similarly noticed in their work elsewhere.
3. Mean stream length (Lsm)- The mean stream length of a channel is a dimensional property and reveals the characteristic size of drainage network components and its contributing basin surfaces (Strahler, 1964). The mean stream length (Lsm) has been calculated by dividing the total stream length of all order by the total number of stream segments of all order. Table1 indicates that Lsm in the sub-watersheds ranges from 0.46 to 0.89 km. It is observed that Lsm values of SW2, SW3, SW5, SW8 and SW9 sub-water sheds indicate that Lsm of the given order is greater than that of the lower order and less than that of the next higher order in half of the sub-watershed except SW1, SW4, SW5, SW8 and SW9. This deviation is due to variation in slope and topography.

**Table 1.** Results of Morphometric Analysis for Balatira Basin.

Sub Watershed	SW 1	SW 2	SW 3	SW 4	SW 5	SW 6	SW 7	SW 8	SW 9	SW 10	Whole basin	
Stream number	1	134	60	64	71	127	31	103	136	128	126	1000
	2	37	14	13	13	31	8	20	31	31	31	229
	3	6	5	2	4	4	3	4	10	8	12	58
	4	1	1	1	1	1	1	1	2	2	1	11
	5	1	-	-	-	2	-	-	-	-	-	3
	6	-	-	-	2	-	-	-	-	-	-	2
Stream length	1	80.63	38.05	33.47	38.39	68.89	15.55	48.74	51.18	47.92	47.83	470.65
	2	35.3	10.55	12.55	10.73	17.9	7.33	15.17	16.74	15.51	14.57	156.55
	3	6.421	7.49	4.69	15.99	8.61	4.46	6	12.59	10.19	7.39	83.831
	4	3.13	7.97	5.16	-	1.15	3.46	8.15	8.21	4.86	7.64	49.73
	5	14.225	-	-	-	11.64	-	-	-	-	-	25.865
	6	-	-	-	15.11	-	-	-	-	-	-	15.11
Stream length ratio	II/I	0.44	0.277	0.375	0.279	0.259	0.471	0.311	0.327	0.323	0.304	0.33
	III/II	0.18	0.71	0.373	1.49	0.48	0.609	0.395	0.752	0.657	0.507	0.54
	IV/III	0.487	1.062	1.1	0.945	0.133	0.774	1.356	0.652	0.477	1.032	0.59
	V/IV	4.545	-	-	-	10.157	-	-	-	-	-	0.52
Bifurcation ratio	II/I	2.271	3.608	2.666	3.578	3.848	2.121	3.21	3.057	3.089	3.281	3.01
	III/II	5.329	1.406	2.676	0.67	2.08	1.641	2.527	1.329	1.521	1.971	1.87
	III/IV	2.051	0.94	0.908	1.058	7.51	1.29	0.737	1.533	2.095	0.968	1.69
	IV/IV	0.22	-	-	-	0.098	-	-	-	-	-	1.92
Area (Km <sup>2</sup> )	45.28	27.79	20.53	43.6	33.47	14.36	24.42	26.45	20.97	20.7	278	
Perimeter (Km)	43.55	24.51	22.51	41.81	36.66	18.39	22.89	28.46	20.65	20.98	91.87	
Mean bifurcation ratio	2.32	1.98	2.08	1.77	3.38	1.68	2.16	1.97	2.24	2.07	3.41	
Mean stream length ratio	0.7	0.8	0.7	0.89	0.66	0.72	0.61	0.5	0.46	0.46	0.62	
Basin Length (Km)	13.49	10.16	9.67	13.75	9.86	7.43	8.71	10.06	7.41	7.6	66.5	
Drainage density Dd (Km/Km <sup>2</sup> )	3.09	2.31	2.72	1.84	3.23	2.15	3.2	3.35	3.74	3.74	2.88	
Drainage texture (Dt)	4.57	3.26	3.55	2.15	4.5	2.34	5.59	6.29	8.18	8.1	14.18	
Stream frequency (Fs)	4.39	2.88	3.9	2.06	4.93	2.99	5.24	6.77	8.06	8.21	4.69	
Form Factor (Rf)	0.25	0.27	0.22	0.23	0.34	0.26	0.32	0.26	0.38	0.36	0.06	
Circulatory ratio (Rc)	0.3	0.58	0.51	0.31	0.31	0.53	0.59	0.41	0.62	0.59	0.41	
Elongation ratio (Re)	0.56	0.67	0.61	0.55	0.61	0.65	0.7	0.61	0.74	0.72	0.43	
Overland flow (Lg)	0.65	0.87	0.73	1.09	0.62	0.93	0.63	0.6	0.53	0.53	0.69	
Infiltration number (If)	13.58	6.64	10.61	3.8	15.94	6.42	16.76	22.7	30.16	30.72	13.52	
Basin relief (r)	200	50	80	70	200	100	100	150	100	150	310.00	
Relief ratio (Rr)	14.83	4.92	8.27	5.09	20.28	13.46	11.48	14.91	13.5	19.74	4.66	
Channel gradient	9.44	3.13	5.27	3.24	12.92	8.57	7.31	9.5	8.6	12.57	2.97	
Basin shape (Bs)	0.30	0.37	0.47	0.32	0.29	0.52	0.36	0.38	0.35	0.37	0.24	

- Stream length ratio (Rl)- Horton's law (1945) of stream length states that mean stream length segments of each of the successive orders of a basin tends to approximate a direct geometric series with stream length increasing towards higher order of streams. The RL between streams of different order in the study area reveals that there is a variation in RL in each sub-watershed (table no 1). This variation is due to changes in slope and topography. Sub-watershed numbered SW2, SW3, SW6, SW7 and SW10 show an increasing trend in the length ratio from lower order to higher order indicating their mature geomorphic stage. However, the sub-watersheds SW1, SW4, SW5, SW8 and SW9 do not confirm the above condition and indicate their late youth stage of geomorphic development (Singh and Singh, 1997).
- Bifurcation ratio (Rb)- The term bifurcation ratio (Rb) is defined as the ratio of the number of the stream segments of given order to the number of segments of the next higher order ( Schumn, 1956). Further, Strahler (1957) demonstrated that bifurcation ratio shows a small range of variation for different regions/ environment except where the powerful geological control dominates. If the bifurcation ratio is not same from one order to its next order, then these irregularities are dependent upon the geological and lithological development of the drainage basin (Strahler, 1964). In the study area mean bifurcation ratio (Rbm) varies from 1.68 to 3.38, lower values in SW6 suggest less structural disturbance, whereas higher value in SW5 indicates that it has structurally controlled drainage pattern.

### VI. Aerial Aspects

Different morphometric parameters such as drainage density, stream frequency, drainage texture, form factor, circulatory ratio, elongation ration and length of overland flow are presented in table no 1 and are discussed as below.

- Drainage density (Dd)- Horton (1932), introduced the drainage density (Dd) which is an important indicator of the linear scale of landform elements in stream eroded topography. It is defined as the total length of streams of all orders per drainage area. Drainage density in all the sub-watersheds of Balatira watershed varies from 1.84 to 3.74 Km/Km<sup>2</sup>. The highest value of drainage density is recorded in SW 9 and SW10, whereas lowest drainage density is found in SW 4. High drainage density is the resultant of weak subsurface material, sparse vegetation and mountainous relief which is found in SW9 and SW10.

Whereas, SW 4 have dense vegetation, low relief, low drainage density with permeable subsoil material. The rest of all the sub-watersheds lie in moderate drainage density category.

2. Stream frequency (Fs)- Stream frequency is expressed as the total number of stream segments of all orders per unit area. Reddy et al. (2004) stated that low values of stream frequency (Fs) indicate presence of a permeable subsurface material and low relief. Stream frequency values of the sub-watersheds vary from 2.06 (SW 4) to 8.21 (SW 10), suggests sub-watersheds having lower Fs values represents low relief and permeable sub surface material whereas, sub-watersheds with higher Fs values show resistant/low conducting subsurface material, sparse vegetation and high relief. It exhibits positive relation with drainage density in all sub watersheds suggesting an increase in stream population with respect to increase in drainage density. High value of drainage frequency in SW 9 and SW 10 produces more runoff in comparison to other.
3. Drainage texture ratio (T): According to Horton(1945) drainage texture is the total number of stream segments of all orders per perimeter of the area. Smith (1954) classified drainage density into five different classes of drainage texture i.e. <2 indicates very coarse, between 2 and 4 is coarse, between 4 and 6 is moderate, between 6 and 8 is fine and greater than 8 is very fine drainage texture. Drainage texture values of the sub-watersheds lie between 2.15 (SW 4 )and 8.18 (SW 9). SW2, SW3, SW4 and SW6 are coarse, SW1, SW5 and SW7 are moderate, SW 8 is fine and SW 9 and SW10 are very fine drainage texture. This indicate fine texture and area is under high relief and steep slopes. (table no 1)
4. Length of overland flow (Lg): This is one of the most important independent variables affecting hydrologic and physiographic development of drainage basins. The length of overland flow is approximately equal to the half of the reciprocal of drainage density ( Horton , 1945). This factor is related inversely to the average slope of the channel and is quiet synonymous with the length of sheet flow. The Lg values of sub-watersheds are varying from 0.53 (SW 9 and SW10) to 1.09 (SW4). The values of Lg are higher in SW4 indicating low relief whereas the values of Lg are low in case of SW9 and SW10 indicating high relief. Overland flow significantly affects the infiltration or percolation through the soil.
5. Form Factor (Rf): According to Horton (1932), form factor may be defined, as the ratio of basin area to square of the basin length. Basins with high form factors experience larger peak flows for shorter duration, whereas elongated watersheds with low form factors experience lower peak flows for longer duration. In the study area Rf values have been found varying from 0.22 (SW 3) to 0.38 (SW9), suggesting that ten sub-watersheds represent elongated shape with lower peak flows for longer duration. Whereas, SW9 and SW10 possess relatively higher Rf values suggesting more or less circular basins, which may generate higher peak flows for shorter duration.
6. Circulatory ratio (Rc)- Circulatory ratio is the ratio of the area of a basin to the area of circle having the same circumference as the perimeter of the basin (Miller, 1953). It is influenced by the length and frequency of streams, geological structures, land use /land cover, climate and slope of the basin. The Rc of sub-watersheds vary from 0.30 (SW1) to 0.62 (SW9). The sub watershed SW1, SW4, SW5 and SW8 with Rc less than 0.5 indicating that it is elongated, whereas the remaining sub watersheds SW2, SW3, SW6, SW7, SW9 and SW10 with greater than 0.5 values suggesting that they are more or less circular in shape and are characterised by the high to moderate relief and the drainage system were structurally controlled.
7. Elongation ratio (Re): Schumm (1956) defined elongation ratio (Re) as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. Values of Re generally vary from 0.6 to 1.0 over a wide variety of climatic and geologic conditions. Re values close to unity correspond typically to regions of low relief, whereas values in the range 0.6 – 0.8 are usually associated with high relief and steep ground slope (Strahler, 1964). These values can be grouped into three categories namely (a) circular (>0.9), (b) oval (0.9-0.8), (c) less elongated (<0.7). The Re values in the study area range from 0.55 to 0.74. Thus all the sub-watersheds of Balatira watershed are less oval to elongated in their shape.
8. Compactness constant: Compactness Coefficient (Cc) is used to express the relationship of a hydrologic basin to that of a circular basin having the same area as the hydrologic basin. A circular basin is the most susceptible from a drainage point of view because it will yield shortest time of concentration before peak flow occurs in the basin (Nooka Ratnam et al. 2005). The values of Cc in the study area vary from 3.13 (SW2) and 12.92 (SW5) showing wide variations across Balatira watersheds.
9. Infiltration Number (If): The infiltration number of a watershed is defined as the product of drainage density and stream frequency and gives an idea about the infiltration characteristics of the watershed. The higher the infiltration number, the lower will be the infiltration and the higher run-off. SW1, SW3, SW5, SW7, SW8, SW9 and SW10 show higher infiltration number. SW2, SW4 and SW 6 show lower infiltration number, higher will be infiltration and lower runoff.

### VII. Relief Aspects

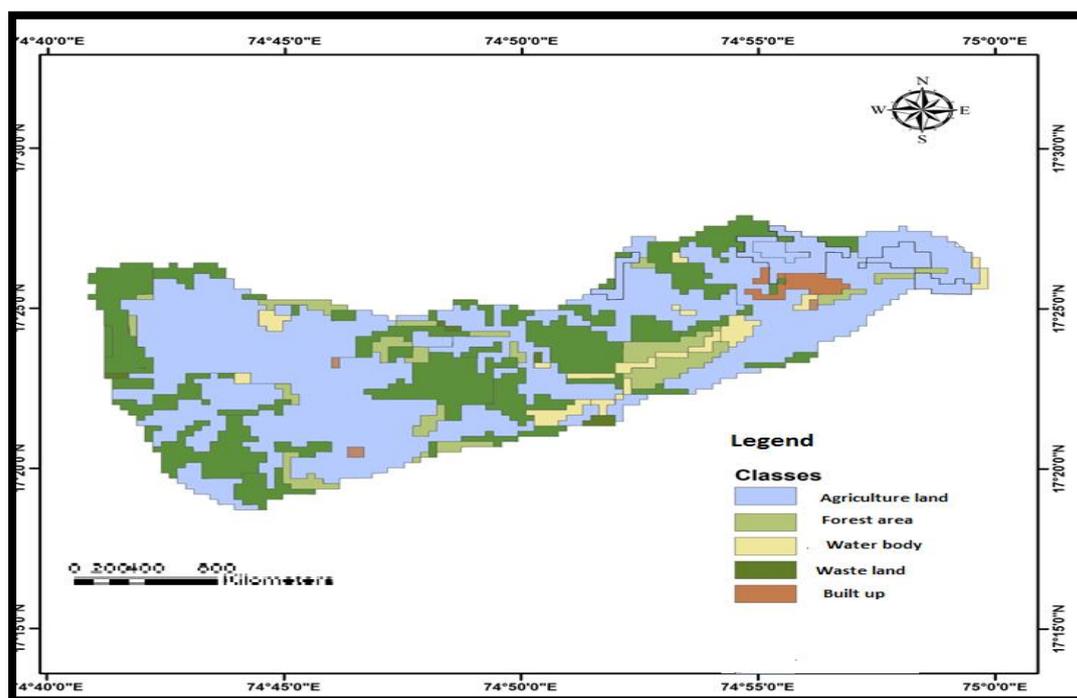
The relief aspects of the drainage basins are significantly linked with the study of three dimensional features involving area, volume and altitude of vertical dimension of landforms to analyze different geohydrological characteristics. The important relief parameters that are related to the study have been analyzed and are shown in table no. 1.

1. Relief ratio (Rr): The elevation difference between the highest and lowest points on the valley floor of a sub-watershed is its total relief, whereas the ratio of maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line is Relief Ratio (Rh) (Schunm, 1956). It measures the overall steepness of a drainage basin and is an indicator of intensity of erosional processes operating on the slopes of the basin. The areas with high relief and steep slope are characterized by high value of relief ratios. Low value of relief ratios are mainly due to the resistant basement rocks of the basin and low degree of slope (Mahadevaswamy et.al 2011). The Rh normally increases with decreasing drainage area and size of a given drainage basin (Gottschalk, 1964). The relief ratio ranges from is 4.92 (SW2) to 20.28 (SW5). Sub-watershed SW1, SW5, SW6, SW8, SW9 and SW10 shows high value of relief ratio and the rest of the sub-watersheds shows low value of relief ratio.
2. Basin shape (Bs): Basin shape is the ratio of the square of basin length (Lb) to the area of the basin (A). The Bs values of sub-watersheds indicates that SW1, SW4 and SW5 have weaker flood discharge periods, whereas SW2, SW3, SW6, SW7, SW8, SW9 and SW10 have sharp peak flood discharge.

### VIII. Land Use/Land Cover Analysis

Land use/land cover mapping was carried out at sub-watershed level using IRS 1C LISS III of 2012. Visual interpretation of the IRS data led to the identification and delineation of land use/land cover categories such as cultivated land, wasteland, water body, built-up land and forest area etc. Figure 3 shows land use/land cover map of the study area derived from IRS data and the details of landuse /land cover categories are presented in table no 2 for the ten sub-watersheds of Balatira watershed.

Various land use/land cover categories exhibit unique spectral image characteristics through their spectral signatures which are subsequently helpful for identification and delineation on the satellite data. The study area comprises land use/land cover categories such as cultivated land, wasteland, water body



**Fig.3.** Land Use/Land Cover Interpreted From IRS 1C LISS III Data Of 2011.

	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW10
Land use and Land cover category	Area/ Area %	Area/ Area %	Area/ Area %	Area / Area %	Area/ Area%	Area/ Area %	Area/ Area%	Area/ Area%	Area / Area%	Area/ Area%
Cultivated land	22.998 (50.62)	16.964 (60.87)	13.508 (65.34)	27.767 (64.3)	13.01 (40.67)	10.34 (75.58)	15.90 (66.26)	18.63 (71.29)	11.32 (54.78)	12.88 (48.79)
Forest area	3.99	0.37	-	7.869	2.246	2.059	0.492	0.369	0.977	-

	(8.79)	(1.32)	-	(18.22)	(7.02)	(15.05)	(2.05)	(1.42)	(4.73)	-
Waste land	17.201 (37.86)	8.905 (31.95)	5.571 (27.0)	2.145 (4.96)	14.379 (44.95)	0.917 (6.69)	7.608 (31.69)	6.762 (25.87)	7.983 (38.63)	12.91 (48.33)
Builtup	0.182 (0.5)	1.342 (4.81)	0.915 (4.42)	1.272 (2.94)	-	0.367 (2.68)	-			-
Water body	1.052 (2.32)	0.287 (1.03)	0.68 (3.3)	4.128 (9.56)	2.354 (7.36)	-	-	0.373 (1.42)	0.383 (1.85)	0.603 (2.88)
Total	45.43 (100.09)	27.868 (99.98)	20.674 (100.06)	43.181 (99.98)	31.989 (100)	13.687 (100)	24.007 (100)	26.135 (100)	20.665 (99.99)	26.396 (100)

**Table 2.** Landuse/Landcover Analysis of the Balatira Watershed.

and built-up area. The land use/land cover categories which were taken into consideration for prioritization of sub-watersheds are described as follows:

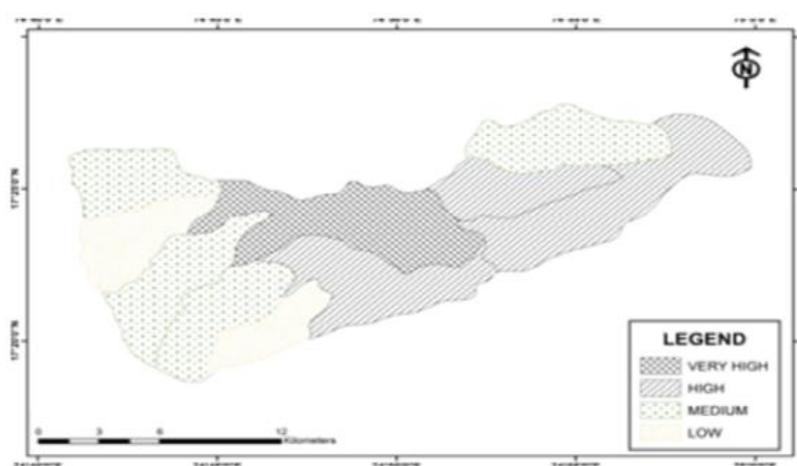
### Cultivated Land

Cultivated land may be defined as the land primarily used for farming and production of food, fibre, horticultural land and other commercial crops. Cultivated land, is the dominant land use category present in the study area and covers an area of 163.31 km<sup>2</sup>, i.e. 40.67% of the watershed area. The maximum area (75.58%) under cultivated land is reported from SW6, whereas minimum (40.67%) is reported from SW5. Higher percentage of cultivated land is reported in sub-watershed SW2, SW3, SW4, SW6, SW7 and SW8. The sub-watershed with lower percentage of cultivated land has been given higher priority, whereas sub-watersheds having higher percentage of cultivated land are assigned lower priority.

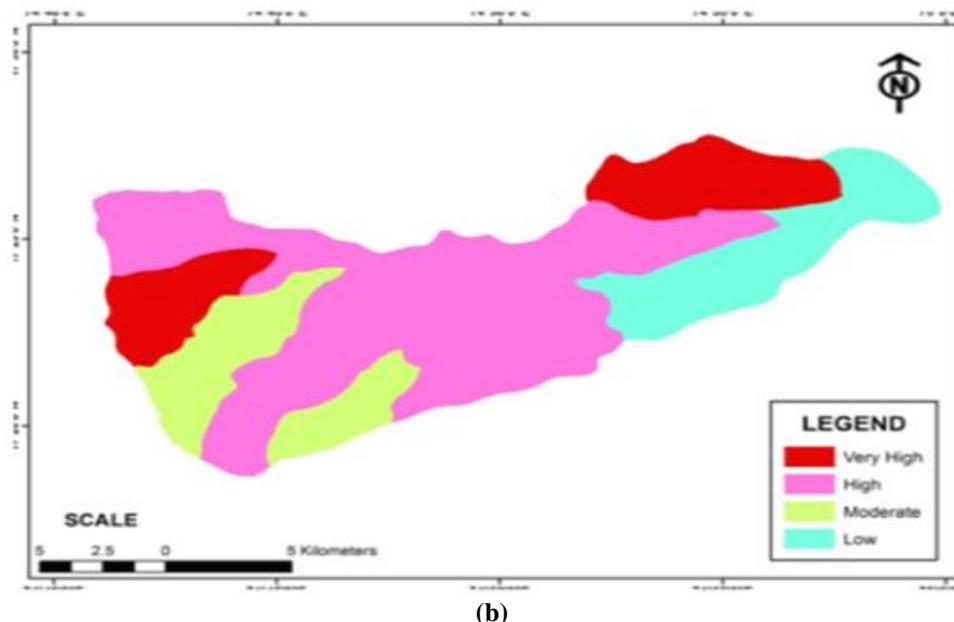
Initially, the SOI topographic maps have been used for delineation of forest boundary. Based on standard visual interpretation, forest cover has been delineated which is the dominant land cover category comprising dense forest, open forest and open scrub. It is mostly confined to hill slopes and distributed in the western and southern parts of study area. The forest cover is reported from all the sub-watersheds and the highest area under forest is reported from SW4 and SW6 with 18.22% and 15.05% respectively, while lowest area is reported from SW2 with 1.32 %. The forest area is nil in sub-watersheds SW3 and SW10. Higher priority has been given to the sub-watersheds having low percentage of forest cover and vice versa.

### Wasteland

Wasteland may be described as degraded land which is currently under unutilized. The land may be deteriorating due to lack of appropriate water and soil management or due to natural causes. It has been reported from the northern and north-western part of the Balatira watershed (Fig 3.). The extent of wasteland in sub-watersheds varies from 0.92 Km<sup>2</sup> to 17.2 Km<sup>2</sup>. The maximum area (48.33%) under wasteland has been reported from SW10, whereas the minimum area is reported from SW4 (4.96 %). SW1, SW2, SW7, SW9 and SW10 shows higher percentage of waste land. Sub-watersheds having higher percentage of wasteland were given higher priority and vice versa.



(a)



(b)  
**Fig.4. Priority of sub-watersheds based on (a) morphometric analysis. (b) land use/land cover analysis.**

**Prioritization of Sub-Watersheds On The Basis Of Morphometric Analysis:**

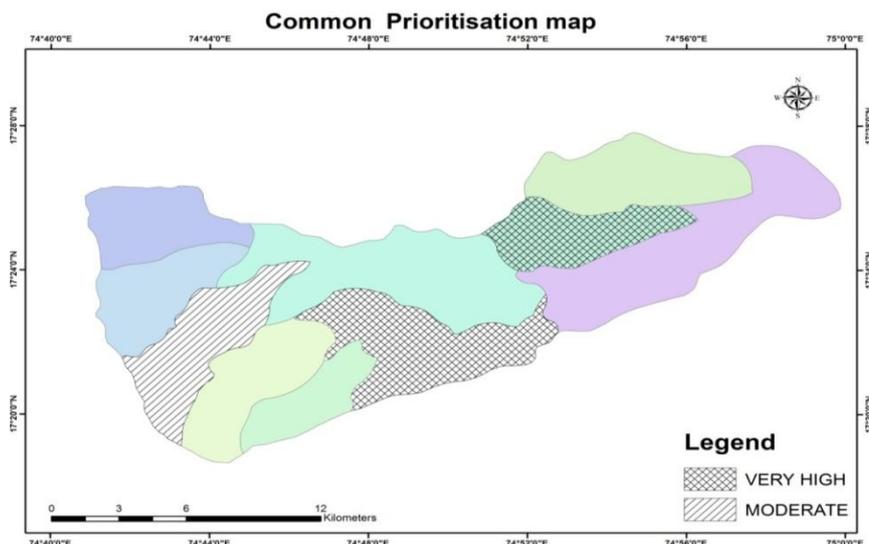
The linear parameters such as drainage density, stream frequency, mean bifurcation ratio, drainage texture and length of overland flow have a direct relationship with erodibility while shape parameters such as elongation ratio, circularity ratio, and form factor and basin shape have an inverse relationship with erodibility. Hence, priority of the watersheds has been carried out for giving highest priority/rank based on highest value in case of linear parameters and lowest value in case of shape parameters.

For prioritization of watersheds, in case of linear parameters, the highest value was given rating 1 and the lowest was given 2. The lowest was rated last in serial numbers. Whereas, for shape parameters, the lowest value was given rating 1 and the highest rating was given 2. After the rating has been assigned based on every single parameter, the rating value for both the watersheds were averaged as to arrive at a compound value (Cp). This compound value of the sub-watersheds was used to prioritize on the basis of their severity to erosion, hence the watershed which has lowest Cp value has been given priority one, next lowest has been allocated second priority (table no 3). The sub-watersheds were categorized as very high (3.6 – 4.2), high (4.3 – 4.9), medium (5.0 – 5.6) and low (5.7 – 6.3) priority on the final compound value. Out of ten sub-watersheds SW1 fall in very high priority, SW3, SW4, and SW5 fall in high priority, SW2, SW7, SW8 and SW9 fall in medium priority, whereas SW6 and SW10 fall in low priority category (table no 3). Figure 4 shows priority of sub-watersheds based on morphometric parameters.

**Prioritization of Sub-Watersheds On The Basis Of Landuse/Land Cover Analysis:**

Since agriculture is the dominant sector which has been used for prioritizing sub-watersheds (Biswas et al. 1999), livelihood of the local people is dependent; hence it was given a high priority. Decrease in natural vegetation is a sign of environmental degradation; hence vegetation is an important parameter for prioritization of watersheds. Wasteland and its reclamation is one of the important activities in watershed treatment, hence its extent needs to be taken into consideration for prioritization of watersheds. For prioritization of sub-watersheds, on the basis of land use/land cover categories viz., cultivated land, forest cover and wasteland were considered. As a general rule, high priority has been assigned to the sub-watersheds having higher percentage of wasteland or lower percentage of cultivated land and forest cover, whereas low priority has given to the sub-watersheds which have higher percentage of cultivated land and forest cover or lower percentage of wasteland. The rankings of individual land use category for each sub-watershed were averaged so as to arrive at compound value based on rankings. The sub-watersheds were categorized into four classes as very high (3.0– 4.1), high (4.2 - 5.3), medium (5.4 –6.5) and low (6.6 – 7.7) priority based on the final compound value. Out of 10 sub-watersheds SW2 and SW10 are falling in very high priority, SW1, SW3, SW5, SW7 and SW9 fall under high priority, SW6 and SW8 sub-watersheds indicate a medium priority, whereas SW4 fall under low priority category (table 2). Figure 4 shows priority of sub-watersheds based on land use/land cover analysis. The results obtained from morphometric and land use/ land cover analysis have been correlated to find out the common sub-watersheds falling under each priority. The correlation shows, only SW3, SW5 and SW8 being the common sub-watershed which falls under high and medium priority respectively based on morphometric as well as land use/cover analysis. The other sub-watersheds exhibit little correlation and differ in their

priority under morphometric and landuse/land cover analysis (table 2). Figure 5 shows correlation of sub-watersheds based on integration of morphometric and land use/land cover parameters after both the themes are superimposed on GIS platform.



**Fig.5.** Priority of sub-watersheds based on superimposition of morphometric and land use/land cover parameters.

### **IX. Conclusion**

In situation of consistent drought, watershed prioritization is considered as one of the most important aspects of planning and development for water conservation measures. The evolution of basin in terms of morphometric aspect and its net effect on land use land cover is beset with complicated scenario. Thus, prioritisation of watershed using GIS platform can help in micro level planning. The present study brings forth the integrated approach for developing a preliminary prioritization of sub-watersheds in Balatira watershed (BM 113).

Low infiltration and higher runoff are reflected in relief ratio of 14.28 and infiltration number of 13.58, drainage density of 3.09, drainage texture of 4.57, drainage frequency of 4.39 and overland flow of 0.65 for SW1. Further, the situation is manifested by more number of flows of massive basalts. These aspects have contributed greatly for morphometric priority in sub-basin SW1 evolution.

The land use land cover for SW2 are dominated by cultivated land of 60.87% and barren land of 31.95% and these classes have direct relationship with priority. While for SW10 the dominant classes are builtup land of 0% and waterbodies of 2.88% have negative relationship with priority. Thereby the compound parameter for the sub-watershed SW2 and SW10 are 3 and 3.2, respectively. All the above statements are reflection of prioritisation on the basis of land use / land cover which reflection of water and soil resources.

In conflicting situation the common priority of morphometric and land use land cover analysis indicate SW3, SW5 and SW8. The SW3 and SW5 sub-watershed have higher prioritisation and sub-watershed 8 with medium prioritisation. Whereas, the rest of sub-watersheds show little or no correlation.

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Sub watersheds	Morphometric analysis													Land use/Land cover analysis									
	Area in Km2	Mean Bifurcation ratio	Drainage density (Dd)	Drainage incisure (Di)	Stream frequency (Fr)	Overland flow (F <sub>o</sub> )	Form factor (Ff)	Circularity ratio (Rc)	Elongation (Re)	Relief ratio (Rr)	Basin slope (Bs)	Infiltration number	Compound parameter (Cp)	Priority	Cultivated land (CL)	Forest cover (FC)	Barren land	Builtup	Water body	Compound parameter (Cp)	Priority	Common priority	
SW1	3.52	3.09	4.57	4.39	0.65	0.25	0.3	0.56	14.28	0.3	13.58				50.62	3.79	37.36	9.5	2.32				
45.28	[2]	[5]	[5]	[6]	[5]	[3]	[1]	[2]	[7]	[2]	[5]		3.9	Very high	[3]	[7]	[4]	[5]	[5]		4.8	High	
SW2	1.98	2.31	3.26	2.88	0.87	0.27	0.58	0.67	4.92	0.37	6.64				60.87	1.32	31.95	4.81	1.03				
27.79	[7]	[7]	[8]	[9]	[3]	[5]	[6]	[5]	[1]	[6]	[3]		5.45	Medium	[5]	[2]	[5]	[1]	[2]		9	Very high	
SW3	2.08	2.72	3.55	3.9	0.73	0.22	0.51	0.61	8.27	0.47	10.61				65.34	0	27	4.42	3.3				
20.53	[5]	[6]	[7]	[7]	[4]	[1]	[4]	[3]	[3]	[9]	[4]		4.81	High	[7]	[1]	[7]	[2]	[7]		4.8	High	High
SW4	1.77	1.84	2.15	2.06	1.09	0.23	0.31	0.55	5.09	0.32	3.8				64.3	18.22	4.96	2.94	9.56				
43.6	[9]	[9]	[10]	[10]	[1]	[2]	[2]	[1]	[2]	[3]	[1]		4.54	High	[6]	[9]	[10]	[3]	[9]		7.4	Low	
SW5	3.38	3.23	4.5	4.93	0.62	0.34	0.31	0.61	20.28	0.29	15.94				40.67	7.02	44.95	9	7.36				
33.47	[1]	[3]	[6]	[5]	[7]	[7]	[2]	[3]	[10]	[1]	[6]		4.63	High	[1]	[6]	[2]	[6]	[3]		4.6	High	High
SW6	1.68	2.15	2.34	2.99	0.93	0.26	0.53	0.65	13.46	0.52	6.42				75.58	15.05	6.69	2.68	0				
14.36	[10]	[8]	[9]	[8]	[2]	[4]	[5]	[4]	[6]	[10]	[2]		6.18	Low	[10]	[8]	[9]	[4]	[1]		6.4	Medium	
SW7	2.16	3.2	5.59	5.24	0.63	0.32	0.59	0.7	11.48	0.36	16.76				86.26	2.05	31.69	0	0				
24.42	[4]	[4]	[4]	[4]	[6]	[6]	[7]	[6]	[4]	[5]	[7]		5.18	Medium	[8]	[4]	[6]	[6]	[1]		5	High	
SW8	1.97	3.35	6.29	6.77	0.6	0.26	0.41	0.61	14.91	0.38	22.7				71.29	1.42	25.37	0	1.42				
26.45	[8]	[2]	[3]	[3]	[8]	[4]	[3]	[3]	[8]	[8]	[8]		5.27	Medium	[9]	[3]	[8]	[6]	[3]		5.8	Medium	Medium
SW9	2.24	3.74	8.18	8.06	0.53	0.38	0.62	0.74	13.5	0.35	30.16				54.78	4.73	38.63	0	1.85				
20.97	[3]	[1]	[1]	[2]	[9]	[9]	[8]	[8]	[5]	[4]	[9]		5.36	Medium	[4]	[5]	[3]	[6]	[4]		4.4	High	
SW10	2.07	3.74	8.1	8.21	0.53	0.36	0.59	0.72	19.74	0.37	30.72				48.79	0	48.33	0	2.88				
20.69	[6]	[1]	[2]	[1]	[9]	[8]	[7]	[7]	[9]	[7]	[10]		6.09	Low	[2]	[1]	[1]	[6]	[6]		3.2	Very high	
Whole basin	3.41	2.88	14.1	4.68	0.69	0.06	0.41	0.05	4.66	0.23	13.52												

**Table3:** Ranks and priorities of sub watersheds in Balatira watershed