MORPHOMETRIC ANALYSIS TO IDENTIFY EROSION PRONE AREAS ON THE UPPER BLUE NILE USING GIS (CASE STUDY OF DIDESSA AND JEMA SUB-BASIN, ETHIOPIA)

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Abstract – *Basin morphometric analysis refers to mathematically calculating diverse aspects of a drainage basin. For both sub basin, the analysis were done to evaluate the hydrological features and soil erosion potentials based on the morphological appearances. DEM data of (30x30m) in GIS environment were used. The extracted drainage network for both sub basins has 5th order permitting to Strahler's stream orders. Initially basic parameter obtained from GIS software were used for analysis of Linear, areal and relief aspect parameter. The linear and relief aspect parameter have direct correlation with soil erosion. But the areal parameter have inverse relationship with soil erosion. The Average parameter of all were considered to determine the final priority classes and categorized as high (≤ 2.55), medium (2.55 to 3.55) and low (≥ 3.55). Moreover the final priority Map also indicates that; high priority classes of Jema sub watersheds covers larger area of about 7292.57km² (49.45%) whereas 5099.43km² (29.85%) of from Didessa sub watersheds were vulnerable to soil erosion. This indicates that comparatively; Jema watersheds were more vulnerable to soil erosion than that of Didessa watersheds where phase wise implementation of soil and water conservation extent have to be involved first for the highland areas.*

***Key Words*: GIS, Soil erosion, Morphometric analysis, sub watershed Prioritization, Erosion prone area and management**

1. INTRODUCTION

Land and water are the two most key and vital capitals essentially required not only for sustenance of life but also for the socio-economic and community progress of the country throughout the world and it is strongly affected by anthropogenic influences. Topsoil erosion originates with detachment, which is caused by break down of aggregates by raindrop impact or drag forces of water and wind. Detached elements are conveyed by flowing water and wind, and may get deposited when the transport capacity of water or wind decreases. However, water is perhaps the most vital agent initiating soil erosion. Enhanced erosion due to human activities is a severe ecological problem as it rises level of sedimentation in the watercourses and reservoirs reduce storage capacity and life as well. These embrace diminished terrestrial resources and reduced land productivity, as well as sediment delivery [1].

Blue Nile River, which originates from the falling highlands of the Ethiopian Plateau, is the foremost source of sediment loads in the Nile basin. For the reason of that rugged topography and, the degrees of soil erosion and land degradation are high. Although the country is one of the fastest rising populations of the world, people cultivate lands that were previously under forest cover to sustain its growing population. But this land use has a tremendous contribution to soil erosion [2]. The primary tributaries of Blue Nile includes Anger, Beshilo, Didessa, Dabus, Fincha'a , Jema, Muger and Guder on the left bank and the Bir, Beles, Chemoga, and Timochia, on the right bank. However; out of those tributaries; this case study will be emphasized to identify most erosion prone areas for Jema river basin at the upstream and Didessa river basin at the downstream.

The processed Digital Elevation Model was used for producing the stream network and other supporting layers [3], [4]. Geographical information systems (GIS) have been used for evaluating various basin constraints, providing flexible environment and that is great tool for determination, understanding and analysis of spatial information correlated to river basins. Geology, relief and weather are the main determinants of a running water ecosystem working at the basin scale. Comprehensive study of morphometric study of a basin is great help in accepting the impact of drainage morphometry on landforms and their characteristics [5].

1.1 Study Area Description

The Ethiopian Plateau has been intensely engraved by the Blue Nile River and its tributaries. Didessa is one of the Blue Nile tributaries that starts from the mounts Gomma and Guma area, where Gabba and Gojeb rivers arise from, and drains big rivers of the Jimma, Illubabor and Wolega areas. It flows in a northwestern way to its union where the course of the Abay has curved to its southern most point before turning northwards at a geographical coordinates of about 9°57′-0°00′N and 35°41′-37°15′ E latitude and longitude respectively in western part of Ethiopia. The Didessa's drainage area is about 17,085km², covering portions of the Benishangul-Gumuz region and the West Wolega zones of the Oromia region. It joints with the Blue Nile downstream of the river. Its size at mouth is analogous to that of the Baro River, and it constitutes about 13% of the Nile.

Jema drains from portions of the Semien Shewa Zones of the Amhara and Oromia regions of Wanchet and Salale parts and passes near to Fiche town to merge with the Blue Nile. It's one of a river in central Ethiopia that was located in Amara region about 180 km north of Addis Ababa at the central coordinates of 39° 3′ 6″ East 10° 11′57″North. It takes a drainage area of about 14,748km2 and an altitude at 1,300 m, and 2,000 m at the top of the gorge. There is an Old Portuguese bridge on this river and it contributes about 5% of the Nile.

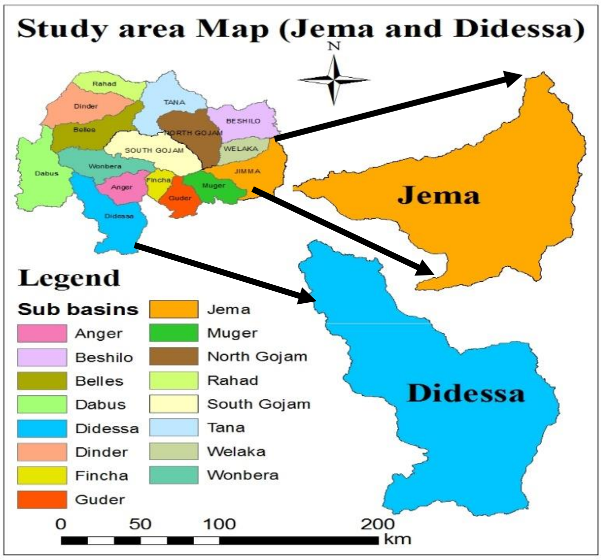

Figure 1: Showing study areas Map of Both Didessa and Jema

2. DATAS AND METHODS

2.1 Data and Software used for Analysis Tool

Digital Elevation Model (DEM) data of (30m by 30m resolution) acquired from Ministry of Water, Mineral and Energy were used. Digitization of dendritic stream pattern was processed by GIS environment. Stream network of the basin was examined and the stream order was made using Strahler's law. For each sub basin, watershed and basin boundary were delineated with the help of Arc SWAT software. Inlet and outlet are well-defined to demarcate the sub-watershed. Arc GIS Version 9.3 with Arc SWAT were used for creating, managing and generation of different layer and maps. The Microsoft excel was used for measured calculation.

2.2 Hydrologic Modeling for Watershed Characterization using GIS

Hydrologic modeling in GIS environment focuses on hydrology for flow modeling and watershed delineation. Hydrologic investigation extension in ArcGIS offers a system to define the physical features of a surface using a Digital Elevation Model (DEM) as input. Hydrological model analysis were used to determine the behavior of where the water comes from and where it is going is important for morphometric characterization through watersheds delineation. Delineation was explained as generating a boundary that characterizes the contributing zone for a specific control point or outlet that was Used to define boundaries of the study area, and/or to divide the study area into sub-areas. It is required for basin modeling and watershed characterization report.

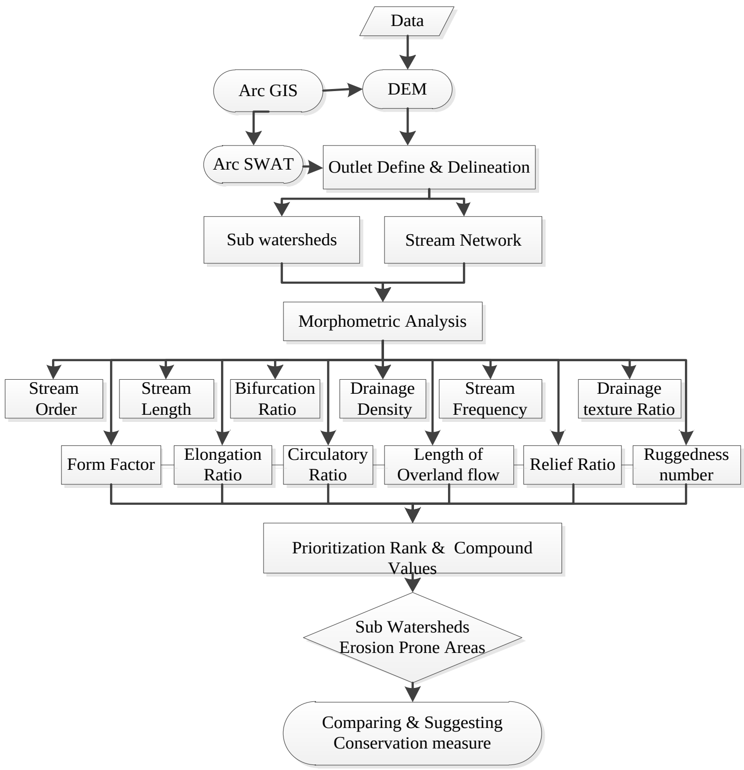

Figure 2: Flow Chart showing the work frames

2.3 Computation of Morphometric Parameter

Stream networks and sub-watersheds were delineated first. The basic parameter considered as the geometric characteristics were automatically obtained from GIS software by direct measurements. Three aspects were assumed for Morphometric analysis, i.e., linear aspect, aerial aspect and relief aspect. Formula for calculations of those morphometric parameters was discussed in the next table 1.

Table 1 : Methods for Calculation of Morphometric Parameters

S.no	Parameter	Methods /Formulas	Citations
Linear Aspects			
1	Stream Order (U)	Hierarchical rank	[6]
2	Total Stream Length (Lu)	Lu= L1+ L2+…Ln, Length of the stream of each order	[7]
3	Mean Stream Length(Lsm)	Lsm= Lu/Nu Where, Nu= Total number of stream segment of order u	[6]
4	Bifurcation ratio (Rb)	Rb= Nu/Nu+1 Where, Nu+1= Number of stream segment of next higher order	[8]
5	Mean Bifurcation ratio (Rbm)	Rbm= average of bifurcation ratio of all orders	[6]
Areal Aspects			
1	Basin length (Lb)	$L_b= 1.312*A^{0.568}$ Where,L_b= length of basin (km) A= area of Basin (km^2)	[9]
2	Drainage Density(Dd)	Dd= Lu/A	[6]
3	Stream Frequency (Fs)	Fs= Nu/A	[6]
4	Drainage texture ratio (Dt)	Dt= Nu/P, Where P= Perimeter (km)	[10]
5	Form Factor (Rf)	$Rf= A/L_b^2$ Where, L_b^2= Square of the basin length	[7]
6	Circulatory Ratio (Rc)	$Rc= 4\pi A/P^2$, Where	[11]
7	Elongation Ratio(Re)	$Re= (2/Lb)*(A/\pi)^{0.5}$,	[8]
9	Constant of channel maintenance (C)	$C = 1/D_d$	[8]
10	Length of Overland flow (Lof)	$Lof = 1/ 2D_d$,	[7]
Relief Aspects			
1	Basin Relief(Bh)	Bh = Max. - Min. elevation of sub watershed	[8]
2	Relief ratio (Rh)	Rh= Bh/ Lb	[8]
3	Ruggedness number (Rn)	Rn= Bh* Dd	[8]
4	Relative relief (Rr)	Rr = Bh/P	[8]

2.4 Sub Watershed rank on the bases of Morphometric Analysis Outcome

For linear aspect, high weightage has been set for high values. The highest value of bifurcation ratio, drainage density, stream frequency and Drainage texture ratio for each sub watersheds was given a rating of 1, the next highest value was given as rating of 2, and so on. Those parameters generally shows positive co-relation with soil erosion.

Conversely, the aerial aspects were assigned low weightage for high values of form factor, circularity ratio elongation ratio, length of overland flow and compactness constant. The lowest value was given a rating of 1, the next lowest value was given a rating of 2, and so on. They shows negative co-relation with soil erosion [12].

2.5 Average Ranking and Final Priority

All single parameter, rated values for each watershed were averaged to attain at a composite value. Depending on the average value of these parameters, the sub watershed taking the least value of composite rating is consigned the highest significance denoted by 1, next highest value of composite rating is assigned a priority denoted by number 2, and so on. Sub watershed that became the highest value of composite number is given the last priority number. Lastly, final priority classes were given and highest priority of the sub watersheds indicates most vulnerable areas to soil erosion.

3. RESULTS AND DISCUSSIONS

3.1 Watershed Delineation

Basically there are two Methods of Watershed Delineations named as Manual watershed delineation and Automatic watershed delineation methods. However this thesis was done by Automatic watershed delineation method by using Arc SWAT for both Didessa and Jema sub basins.

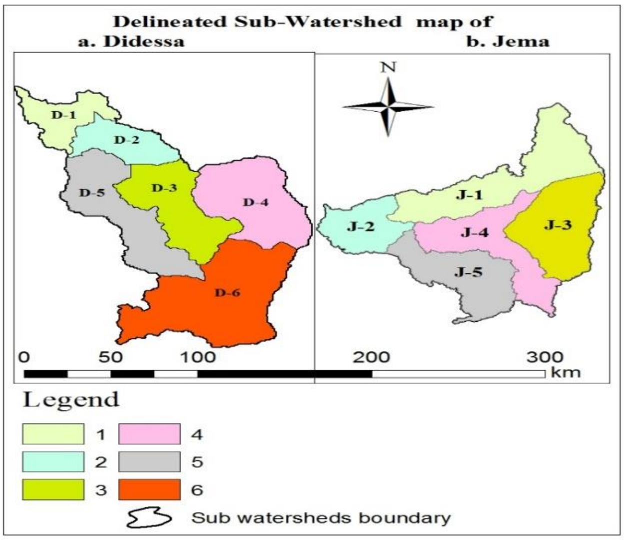

Figure 4: Delineated sub watershed of Didessa and Jema Sub basin

Furthermore, other hydrological parameters in GIS like Fill operation for Identifying and filling sinks in the DEM, Calculating and creating the flow direction map, Calculating and creating flow accumulation map, creating stream network map from the flow accumulation grid and creating stream order raster from the stream network raster map were obtained using Arc GIS. Though Arc SWAT cannot display the raster map, it uses them as an input. For the prioritization of each sub watersheds, were done using the Physical implication of numerous morphometric parameters such as linear aspect, aerial aspect and relief aspect as indicated in respective descriptions.

3.2 Linear Aspect

3.2.1 Stream order

Stream order by [7], method is used to analyze the drainage pattern of the area. When two channel of different order join then the higher order is maintained. the least, un-branched perfect streams are designated as 1st order, the union of two 1st order channels give 2nd order, two 2nd order streams join to form a part of 3rd order and so on. In this paper, the whole drainage in both watersheds was strewn in five orders.

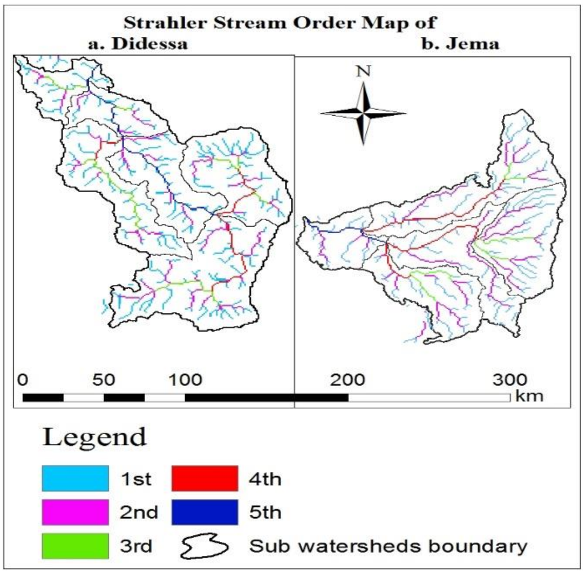

Figure 5: Strahler Stream order map of Didessa and Jema

3.2.2 Stream number

It's the number of stream segments of various orders in watersheds. Every segment of the stream was numbered preliminary from the first order to the maximum order present in the sub-basins [7]. Furthermore, availability of large number of streams directs that the topography is still undergoing erosion. However, less number of streams indicates mature topography.

Table 2: Stream number of both Didessa and Jema sub basin

Sub basin		**Stream Number (Nu) of all order**					**Tota l**
		1st	**2nd**	**3rd**	**4th**	**5th**	
Didessa Sub watersheds	D-1	15	7	7	-	4	**33**
	D-2	23	7	2	-	12	**44**
	D-3	55	20	1	-	24	**100**
	D-4	53	23	7	9	1	**93**
	D-5	40	18	18	9	1	**86**
	D-6	90	50	13	24	1	**178**
Jema Sub watersheds	J-1	46	23	5	26	-	**100**
	J-2	29	10	-	-	14	**53**
	J-3	30	19	11	1	-	**61**
	J-4	22	15	-	11	-	**48**
	J-5	29	17	5	6	-	**57**

3.2.3 Total Stream length and Mean stream length

Numbers of streams of several orders in a watershed are counted and their lengths from entrance to drainage divide are evaluated with the help of GIS software. The sum of all lengths of the whole stream order provide total stream length. Mean stream length for that order can be obtained as by dividing total stream length by the number of stream segments of that order [6].

The mean stream length of a channel is a dimensional property and tells the distinctive size of the drainage network components and its involvement to watershed that was expressed in 'km'. Comparatively, stream of smaller length is characteristics of areas with larger slopes and finer textures. Longer lengths of streams are normally indicative of flatter gradient.

Table 3: Total stream length of both Didessa and Jema Sub basin

Sub basin		Stream Length(Lu) of all order (km)					Total(km)
		1st	2nd	3rd	4th	5th	
Jema Sub watersheds	J-1	234	145	32	120	-	532
	J-2	129	37	-	-	65	232
	J-3	252	146	97	2	-	497
	J-4	117	137	-	79	-	334
	J-5	148	110	68	40	-	368
Total		882	578	198	242	65	1966

Sub basin		Stream Length(Lu) of all order (km)					Total (km)
		1st	2nd	3rd	4th	5th	
Didessa Sub watersheds	D-1	99	35	34	-	20	188
	D-2	74	50	13	-	57	194
	D-3	173	96	1	-	93	363
	D-4	255	95	45	57	4	456
	D-5	201	66	90	32	6	395
	D-6	361	197	58	89	4	709
Total		1163	539	241	178	185	2307 1

3.2.4 Stream Length Ratio

It can be explained as the ratio of the mean stream length of a given order to the mean stream length of next lower order and has significant relationship with surface flow and discharge [7]. Its values vary from 0.19 (D-3) to 2.21 (D-2) for Didessa sub-watersheds and from 0.25 (J-3) to 2.12(J-5). These variations of RL values among streams of various order in the basin tells the variations in slope and topography.

3.2.5 Bifurcation Ratio

It can be expressed as the ratio of the number of stream segments of given order to the number of segments of the next higher order.

Table 5: Bifurcation Ratio of both Didessa and Jema sub basin

Sub basin		Bifurcation Ratio(Rb)					Mean Rb
		1st	2nd	3rd	4th	5th	
Didessa Sub watersheds	D-1	2.1	1	-	-	-	1.6
	D-2	3.3	3.5	-	-	-	3.4
	D-3	2.7	20	-	-	-	11.4
	D-4	2.3	3.3	0.8	9	-	3.8
	D-5	2.2	1	2	9	-	3.5
	D-6	1.8	3.8	0.5	24	-	7.5

Sub basin		Bifurcation Ratio(Rb)					Mean Rb
		1st	2nd	3rd	4th	5th	
Jema Sub watersheds	J-1	2	4.6	0.2	-	-	2.3
	J-2	4.5	3.8	-	-	4.7	2.9
	J-3	1.6	1.7	11	-	-	4.77
	J-4	1.5	-	-	-	-	1.5
	J-5	1.7	3.4	.8	-	-	2

The analysis result showed that the mean Bifurcation ratio of both Didessa and Jema sub watersheds were varied for all orders. Its Low value shows that humble structural disturbance and the drainage patterns have not been distorted [6], though the high value specifies the shape of the basin that has structural disturbance.

3.3 Aerial Aspects

Basin Area: verified as the total area proposed upon a level plane. For hydrologic design, it is probably the only most essential basin parameter. It can reflects capacity of water that generated from the rainfall. Thus drainage area is mandatory as an input to models ranging from simple linear prediction equations to complex computer models that is expressed in km² and obtained from Arc SWAT.

Basin perimeter: is the length of the basin boundary articulated in km and also obtained from Arc SWAT.

Maximum length of basin: the distance between basin outlet and farthest point in the watersheds. Used to define the shape of the basin. High basin length shows elongated basin. It is expressed in 'km'.

Table 6: Basic Parameter for analysis of areal aspect for Didessa and Jema sub watershed

Sub Basin		Area (A)km^2	perimeter (P)km	Basin length(Lb)km
Didessa Sub watersheds	D-1	1389.24	317.10	79.99
	D-2	1439.66	258.72	81.63
	D-3	2718.43	375.42	117.12
	D-4	3266.04	353.46	129.99
	D-5	3171.28	476.04	127.83
	D-6	5099.43	530.34	167.42
Jema watersheds	J-1	4037.69	659.46	146.63
	J-2	1737	309.90	90.81
	J-3	3254.88	398.76	129.73
	J-4	2967.74	618.78	123.10
	J-5	2749.46	513.48	117.88

Therefore; Areal Aspect focus with the total area proposed upon a horizontal plane involving overland flow to the network segment of the particular order and contains all tributaries of lower order.

3.3.1 Drainage Density

Can be described as the entire length of streams of all orders to full drainage area. Its low value commonly results in the areas of extremely resistant, condensed vegetation and little relief. However, its high result indicates weak or resistant sub-surface material, thin vegetation and mountainous relief. The small value of drainage density effects greater infiltration.

Table 7: Drainage densities of Didessa and Jema sub-watersheds

Sub basin	Drainage density; $Dd = \Sigma Lu/A$					
Didessa	**D-1**	**D-2**	**D-3**	**D-4**	**D-5**	**D-6**
	0.136	0.135	0.134	0.140	0.125	0.139
Jema	**J-1**	**J-2**	**J-3**	**J-4**	**J-5**	
	0.142	0.134	0.153	0.113	0.134	

3.3.2 Stream frequency/Drainage frequency

Is also called channel frequency defined as a number of stream segments per unit area. Essentially depends on the lithology of the basin and imitates the texture of the drainage network.

Table 8: Stream Frequency of Didessa and Jema sub-watersheds

Sub basin	Stream frequency; $Fs = \Sigma Nu/A$					
Didessa	**D-1**	**D-2**	**D-3**	**D-4**	**D-5**	**D-6**
	0.024	0.031	0.037	0.028	0.035	0.027
Jema	**J-1**	**J-2**	**J-3**	**J-4**	**J-5**	
	0.025	0.031	0.019	0.016	0.021	

For the morphometric arrangement of drainage basins ,both drainage Density and Stream frequency were the most valuable criterion that certainly control the runoff configuration, sediment yield and other hydrological constraints of the drainage basin.

3.3.3 Drainage Texture ratio

It is an important feature in drainage morphometric study and is reliant on the principal lithology, infiltration capability of the material below earth's surface and relief features of the terrain. It is calculated as the ratio between total streams number and perimeter of the basin [10]. High texture ratio of designates great runoff and small infiltration capacity.

Table 9: Drainage Texture ratio of Didessa and Jema sub-watersheds

Sub basin	Drainage Texture ratio; $Dt = \Sigma Nu/P$					
Didessa	**D-1**	**D-2**	**D-3**	**D-4**	**D-5**	**D-6**
	0.104	0.170	0.266	0.263	0.181	0.336
Jema	**J-1**	**J-2**	**J-3**	**J-4**	**J-5**	
	0.152	0.171	0.153	0.078	0.111	

3.3.4 Form Factor

Basins with high form factors generates great peak flows of shorter duration, while elongated sub watersheds with little form factors take lower peak flow of longer period representing elongated shape and telling flat hydrograph highest for longer duration. Flood movements of such elongated basins are easier to control than those of circular basin.

Table 10: Form factor of Didessa and Jema sub-watersheds

Sub basin	Form factor; $Rf = A/Lb^2$					
Didessa	D-1	D-2	D-3	D-4	D-5	D-6
	0.217	0.216	0.198	0.193	0.194	0.182
Jema	J-1	J-2	J-3	J-4	J-5	
	0.188	0.211	0.193	0.196	0.198	

3.3.5 Circulatory ratio

[9], described that the Rc value of 0.4 and below indicates basin is elongated and values greater than 0.75 indicate circular basin. Rc values in 0.4 - 0.75 indicate intermediate shape of basin. Therefore, the Rc values of the study areas varying from 0.174 to 0.329 in case of Didessa sub watershed and it also varying from 0.117 to 0.257 in case of Jema sub watershed. These values indicate that low circulatory ratio for both the sub basins and they were elongated in shape.

Table 11: Circulatory ratio of Didessa and Jema sub-watersheds

Sub basin	Circulatory ratio; $Rc = 4\pi * A/P^2$					
Didessa	D-1	D-2	D-3	D-4	D-5	D-6
	0.17	0.27	0.24	0.33	0.17	0.23
Jema	J-1	J-2	J-3	J-4	J-5	
	0.12	0.23	0.257	0.097	0.131	

3.3.6 Elongation Ratio

These Re values can be clustered into three groups, namely, circular (> 0.9), oval (0.9 - 0.7) and less elongated (<0.7) [13]. Suggested that, if the value is very low, it shows great relief and steep slope.

Table 12: Elongation ratio of Didessa and Jema sub-watersheds

Sub basin	Elongation ratio; $Re = \frac{2}{Lb} * \left(\frac{A}{\pi}\right)^{0.5}$					
Didessa	D-1	D-2	D-3	D-4	D-5	D-6
	0.526	0.525	0.496	0.502	0.497	0.481
Jema	J-1	J-2	J-3	J-4	J-5	
	0.489	0.518	0.496	0.499	0.502	

3.3.7 Length of overland flow

Can be expressed as a measure of erodibility and it is similarly one of the utmost essential independent variables disturbing hydrologic and physiographic change of watershed drainage.

Table 13: Overland Flow Length of Didessa and Jema sub-watersheds

Sub basin	Length of Overland Flow; $Lof = 1/2Dd$					
Didessa	D-1	D-2	D-3	D-4	D-5	D-6
	3.684	3.710	3.738	3.578	4.011	3.595
Jema	J-1	J-2	J-3	J-4	J-5	
	3.524	3.733	3.269	4.434	3.731	

Greater the values of Length of overland flow, lesser will be the relief and minor the values, advanced will be the relief with steep earth slopes, replicating the areas connected with high run-offs and low infiltration.

3.3.8 Constant channel maintenance

Can be expressed as the area of the basin outward wanted to withstand a unit length of a stream passage and is stated by inverse of drainage density, meaning constant of channel maintenance is the reciprocal of drainage density and indicates how greatly drainage area is mandatory to maintain a unit length of channel.

Table 14: Constant channel maintenance of Didessa and Jema sub-watersheds

Sub basin	Constant channel maintenance; $C = \frac{1}{Dd}$					
Didessa	D-1	D-2	D-3	D-4	D-5	D-6
	7.368	7.421	7.477	7.156	8.021	7.190
Jema	J-1	J-2	J-3	J-4	J-5	
	7.047	7.465	6.537	8.868	7.461	

3.4 Relief Aspect

Relief aspects comprise Basin relief (Bh), relief ratio (Rh), ruggedness number and relative relief. Explanation and exploration results of the terms were given below [14].

3.4.1 Basin Relief

Basin relief is the extreme vertical distance among the lowest and highest altitude in a basin. This is a key factor in understanding the denudation features of a basin. Basin reliefs for both Didessa and Jema watersheds were 2.07km and 2.72km respectively. The higher value of Basin relief of Jema watershed shows that it has lower infiltration and higher runoff than Didessa watershed.

Table 15: Relief Aspect Analysis Result for Didessa Sub watershed

Sub watersheds	P(km)	Lb (km)	Dd	Elevation(m)		Relief aspects			
				Max	Min	Bh(km) = Max-Min	$Rh = Bh/Lb$	$Rr = Bh/P$	$Rn = Bh * Dd$
D-1	317.10	79.99	0.136	2151	875	1.276	0.016	0.0040	0.17
D-2	258.72	81.63	0.135	2130	922	1.208	0.015	0.0047	0.16
D-3	375.42	117.12	0.134	2549	1179	1.37	0.012	0.0036	0.18
D-4	353.46	129.99	0.140	2946	1322	1.624	0.012	0.0046	0.23
D-5	476.04	127.83	0.125	2398	1165	1.233	0.010	0.0026	0.15
D-6	530.34	167.42	0.139	2889	1322	1.567	0.009	0.0030	0.22

Table 16: Relief Aspect Analysis Result for Jema Sub watershed

Sub watershed	P (km)	Lb (km)	Dd	Elevation(m)		Relief aspects			
				Max	Min	Bh(km) = Max-Min	$Rh = Bh/Lb$	$Rr = Bh/P$	$Rn = Bh * Dd$
J-1	659.5	146.63	0.132	3803	1158	2.645	0.0180	0.0040	0.349
J-2	309.9	90.81	0.134	3467	1086	2.381	0.0262	0.0077	0.319
J-3	398.8	129.73	0.153	3686	1558	2.128	0.0164	0.0053	0.326
J-4	618.8	123.10	0.113	3550	1222	2.328	0.0189	0.0038	0.263
J-5	513.5	117.88	0.134	3287	1222	2.065	0.0175	0.0040	0.277

3.4.2 Relief ratio

Total relief of the basin divided by the maximum length of the watershed can provide Relief ratio. It is used to measures the overall steepness of a drainage basin and can display of the strength of erosion process operating on slope of the basin. Greater values of Rh designate that strong erosion practices are happening and have fundamental structural complexity in connotation with relief and drainage density. On the other hand, this value supports for Rain water harvesting and watershed management plan.

3.4.3 Ruggedness number

Is expressed as the product of the maximum basin relief and its drainage density. It affords an idea of overall unevenness of a watershed. It also implies that the area is vulnerable to soil erosion. So, small values of ruggedness number for watershed suggests that area is fewer prone to soil erosion and have essential structural complexity in association with relief and drainage density.

3.4.4 Relative relief

[15]; suggested relative relief expressed by dividing basin relief to the perimeter of the watershed.

To generalize the analyses result of the paper, overall Summary for morphometric output of both sub basins were tabulated.

Table 17: Summery of Morphometric Analysis result for Didessa sub watersheds

Sub watersheds	Mean Rb	Dd	Fs	Dt	Rh	Rn	Rf	Rc	Re	Lof	C
D-1	1.57	0.136	0.024	0.104	0.016	0.173	0.217	0.174	0.526	3.684	7.368
D-2	3.39	0.135	0.031	0.170	0.015	0.163	0.216	0.270	0.525	3.710	7.421
D-3	11.38	0.134	0.037	0.266	0.012	0.183	0.198	0.242	0.496	3.738	7.477
D-4	3.84	0.140	0.028	0.263	0.012	0.227	0.193	0.329	0.502	3.578	7.156
D-5	3.56	0.125	0.035	0.181	0.010	0.154	0.194	0.176	0.497	4.011	8.021
D-6	7.55	0.139	0.027	0.336	0.009	0.218	0.182	0.228	0.481	3.595	7.190

Table 18: Summery of Morphometric Analysis result for Jema sub watersheds

Sub Watersheds	Mean Rb	Dd	Fs	Dt	Rh	Rn	Rf	Rc	Re	Lof	C
J-1	2.26	0.142	0.025	0.152	0.018	0.375	0.188	0.117	0.489	3.524	7.047
J-2	2.90	0.134	0.031	0.171	0.0262	0.319	0.211	0.227	0.518	3.733	7.465
J-3	4.77	0.153	0.019	0.153	0.0164	0.326	0.193	0.257	0.496	3.269	6.537
J-4	1.47	0.113	0.016	0.078	0.0189	0.263	0.196	0.097	0.499	4.434	8.868
J-5	1.98	0.134	0.021	0.111	0.0175	0.277	0.198	0.131	0.502	3.731	7.461

3.5 Developing Prioritization Rank and Compound Value

3.5.1 Prioritization of Sub Watersheds

For all sub watersheds, the greater value of the linear morphometric constraint were much more vulnerable to soil erosion. Therefore, the upper assessment were rated as rank 1, second uppermost value was rated as rank 2 and so on. Conversely, Areal aspect parameters take reverse relationship with soil erosion. Hence, lesser value those parameter is an indication of advanced risk of erodibility. Therefore, by way of each analysis, ranks were given for the whole constraints.

3.5.2 Compound Value parameter

Compound values were done for the combination each rank of the morphometric result to determine the degree of susceptibility of each watershed to soil erosion potential. All sub watersheds were ranked for facilitating stage wise implementation for soil and water conservation at a place to reduce rate of erosion potential. Since it was very difficult to manage the whole watershed at once, providing priority was responsible. Because of these, depending on analysis result the Compound values were generated and sub Watersheds priorities were broadly categorized into three priority classes as High, medium and low.

Table 19: Compound values for priority classes

Compound Values	Prioritization Classes
≤ 2.55	High Priority
2.55 – 3.55	Medium Priority
≥ 3.55	Low Priority

The prioritized classifications and the compound value for all sub watersheds were done and shown in Table 20 and 21 for both Didessa and Jema sub watersheds respectively.

Table 20: Compound Values and Prioritization rank of Didessa Sub watersheds

Sub Watersheds	Mean Rb	Dd	Fs	Dt	Rh	Rn	Rf	Rc	Re	Lof	C	Compound values	Rate of Soil erosion
D-1	6	3	6	6	1	4	6	1	6	3	3	4.09	Low
D-2	5	4	3	5	2	5	5	5	5	4	4	4.27	Low
D-3	1	5	1	2	4	3	4	4	2	5	5	3.27	Medium
D-4	3	1	4	3	3	1	2	6	4	1	1	2.64	Medium
D-5	4	6	2	4	5	6	3	2	3	6	6	4.27	Low
D-6	2	2	5	1	6	2	1	3	1	2	2	2.45	High

Table 21: Compound Values and Prioritizations of Jema Sub watershed

Sub Watersheds	Mean Rb	Dd	Fs	Dt	Rh	Rn	Rf	Rc	Re	Lof	C	Compound values	Rate of Soil erosion
J-1	3	2	2	3	3	1	1	2	1	2	4	2.55	High
J-2	2	4	1	1	1	3	5	4	5	4	3	2.82	Medium
J-3	1	1	4	2	5	2	2	5	2	1	1	2.36	High
J-4	5	5	5	5	2	5	3	1	3	5	5	4.00	Low
J-5	4	3	3	4	4	4	4	3	4	3	2	3.27	Medium

High Priority: Sub-Watersheds dropping in high priority were beneath exact severe erosion prone zone. Consequently need instantaneous consideration to take up best management for soil and water preservation measures.

Medium Priority: watersheds falling in medium priority classes comprise of moderate slopes, relatively enough values of linear and shape parameters.

Low Priority: watersheds falling under low priority consist of lower slopes, very low linear and shape parameters.

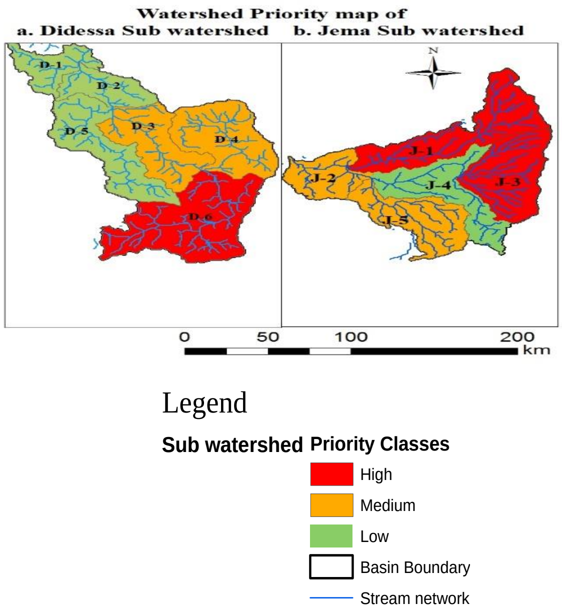

Figure 6: Prioritized Rank of Didessa and Jema Sub Watershed

Moreover the final priority Map also indicates that; high priority classes of Jema sub watersheds covers larger area of about 7292.57km^2 for both J-3 and J-1, whereas 5099.43km^2 of D-6 from Didessa sub watersheds. This shows that about 49.45% of the total areas of Jema watersheds were vulnerable to soil erosion. However about 29.85% of the total areas were vulnerable to soil erosion in case of Didessa watersheds. This indicates that comparatively; Jema watersheds were more vulnerable to soil erosion than that of Didessa watersheds.

3.6 Conservation measures for management

Although managing the whole watershed at once is very difficult, the final priority ranks of sub watersheds guides for phase wise implementation plan for management. Thus managements of Land and water conservation practices, made within agricultural fields will be recommended. Management's practices like construction of contour bunds, contour ploughing, terraces building, and agro forestry or channel practice and extra soil-moisture preservation practices will be applied. These practices protect land degradation, rise soil-moisture obtainability and groundwater rejuvenate. Additionally, outside of the agronomic field, erection of check dam, farm pond, gully control structures, grass waterways and pits dig across the stream network would be applied. Such watershed managing practices decrease peak discharge in order to recover gully development and harvest extensive quantity of runoff, which upsurges groundwater revive and irrigation capability in watersheds.

Therefore, for sub watersheds J-3 and J-1 from Jema and D-6 from Didessa both conservation measures will be applied sequentially. Similarly; in-situ management were recommended for the sub Watersheds falling in Medium priority classes (J-2 & J-5 from Jema and D-3 & D-4 from Didessa) indicates relatively moderate soil erosion zone and comprise of rational slopes, reasonable values of linear and shape parameters. Also, sub watersheds falling under low priority classes (J-4 from Jema and D-1, D-2 and D-5 from Didessa) can be considered in very minor erosion vulnerability zone and could want application of agronomical events such as Contour farming, Mulching practices, Strip cropping and Mixed cropping to keep the sheet and rill erosion. Therefore; Erosion control is essential to maintain the productivity of the land as well as to control sedimentation and pollution of streams and lakes. Since erosion is a natural process, it cannot be prevented. But it can be reduced to a maximum acceptable level or soil loss tolerance.

4. CONCLUSION

The Hydrology in GIS environment focuses on flow modeling and Watershed delineation to characterize watershed system. Linear, areal and relief features of morphometric constraints can be analyzed. Depending on the Morphometric analysis result, priority ranks were developed for each sub watershed to know the patterns of soil erosion potential. Combination of the whole morphometric analysis result using average compound values were developed and classified as High, medium and low to locate erosion pruned areas. As per analysis result, the sub-watershed J-3 and J-1 from Jema and D-6 from Didessa with a compound parameter value of 2.36, 2.55 and 2.45 respectively received the highest priority classes. This indicates existence of high soil erosion zone. Likewise, the sub Watersheds falling in Medium priority classes (J-2 & J-5 from Jema and D-3 & D-4 from Didessa) indicates relatively moderate soil erosion zone. Again the Sub watershed falling under low priority classes (J-4 from Jema and D-1, D-2 and D-5 from Didessa) indicates low soil erosion.

In general about 49.45% and 29.85% of the total areas of Jema and Didessa watersheds were vulnerable to soil erosion. This indicates that comparatively; Jema watersheds were more vulnerable to soil erosion than that of Didessa watersheds. Both in-situ and ex-situ management will be recommended for the most vulnerable areas of the sub watersheds to take up soil conservation measures on the field as well as at an areas of gully formation to protect the topsoil loss, Land degradation and downstream reservoir sedimentation. Finally, for sub watersheds falling under medium and low priority classes, In-situ managements or agronomical measures such as Contour farming, Mulching practices, Strip cropping and Mixed cropping to protect the sheet and rill erosion were recommended.

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