Multi-criteria based Watershed Prioritization for Soil and Water Conservation: The case of Gotu Watershed, Awash River Basin, Ethiopia

Tesfaye Wasihun Abro

Department of Geography and Environmental Studies, Dire Dawa University, Dire Dawa, Ethiopia

Abstract

Background: In Ethiopia, soil and water conservation has often been implemented haphazardly through community mobilization during dry seasons. However, in the process, the question "which part of the watershed should be conserved first considering different criteria and which one should be the last?" is never been answered.

Objective: This study was undertaken to prioritize sub-watersheds on the basis of myriad of parameters: morphometric, soil loss, socioeconomic and related criteria for soil and water conservation activities in five catchments in Gotu watershed, Awash River basin, Ethiopia.

Materials and Methods: Advanced Space borne Thermal Emission and Reflection Radiometer Digital Elevation Model, Revised Universal Soil Loss Equation (RUSLE), socioeconomic and related data like population density, share of cultivated land, economic status, land pressure, potential labor force for conservation, conservation work performance, and share of unirrigated land were used for prioritization exercise.

Results: It was found that Gotu watershed has seven order streams with a mean bifurcation ratio of 2.1; higher stream frequency = 6.4–7.9 streams km^{-2}; low drainage density (0.52–2.85 km km^{-2}) and moderate drainage texture (3.7–5.7); elongated shape (Form factor = 0.16–0.23; elongation ratio = 0.45–0.53; circulatory ratio = 0.17–0.24). Using RUSLE model, the soil loss of the study catchments ranged from 0 t $ha^{-1}yr^{-1}$in the plain area up to 197.2 t ha^{-1} yr^{-1} in the steeper, and fragile part of the watershed which made catchment two an area of severe soil erosion. Considering socioeconomic parameters, catchment five and catchment two have been shown with low and high status, respectively. Therefore, the combined result showed that catchment five that measures about 17.77 km^2 out of 160.56 km^2 of the total area of the study watershed requires the first priority for soil and water conservation measures.

Conclusion: It is concluded that catchments with high soil loss may not usually guarantee primary attention for conservation unless the condition of socioeconomics, morphometry of catchments and related parameters simultaneously contribute to the decision-making process of conservation planners. This implies that land conservation planners should reconsider prioritization criteria of resource flows to soil and water conservation initiatives.

Keywords: Morphometric parameter; RUSLE model; Socioeconomics; GIS and RS

1. Introduction

A watershed is an area of land and water bounded by a drainage divide within which the surface runoff collects and flows out of the watershed through a single outlet into a larger river or other water bodies (Russo *et al.,* 2008; Rahman *et al.,* 2015). A watershed is an ideal unit that enables interactions among various natural resources, humans, and animals as they all make a unique geo-hydrological entity. Hence, any disruption caused to a watershed is the disturbance of the whole aspects of socioeconomic development and environmental sustainability (Woldeamlak Bewket, 2003). In countries like Ethiopia, where a major part of the population primarily depends on natural resources for livelihoods, the prevailing form of agricultural land use, and the geomorphology of the country makes them susceptible to watershed resources stress.

Land degradation in the form of soil erosion (Woldeamlak Bewket, 2003; Temesgen *et al.,* 2017) is a common problem in the highlands of Ethiopia. For example, in Awash River basin alone, up to 259 Mt $year^{-1}$ total erosion occurs contributing to high sedimentation (AwBA, 2017); and the country is losing 2 to 6.75% of agricultural GDP annually from its basins (Sonneveld, 2002). These demands conservation and or development of watershed, for sustainable production of food, fodder, and other agriculture and forest resources for immediate and long-term benefits to the farmers, community, and the basin as a whole.

However, watershed development requires financial, human, organizational and other resources which may not be achieved at a time especially in larger watersheds (Mulatie Mekonnen and Assefa Melesse, 2011) making prioritization imperative. Yet, prioritization criteria need to be framed in consideration of the actual reality on the watershed. Because a watershed may be higher in soil loss but the socioeconomic condition of the society may be better off. For example, Sharma and Thakur (2016) found out that micro-watersheds with

*Corresponding Author: tesfayebecon@gmail.com

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severe soil loss were prioritized least based on socioeconomic and demographic prioritization criteria for conservation. Unfortunately, consideration of these variables in soil and water conservation prioritization is lacking in Ethiopia, much emphasis has been given to severity of soil loss as a criterion (Ermias Teferi*et al*., 2009; Woldeamlak Bewket and Ermias Teferi, 2009; Temesgen Gashaw *et al*., 2017) and community mobilization during dry season haphazardly.

Therefore, this study was intended to prioritize Gotu watershed in consideration of relatively many parameters (Physical, RUSLE indices, socio-eco-demographic and related). The study area was selected for multiple reasons. First the area is prone to soil erosion problems due to overgrazing, over-cultivation, over-exploitation of the vegetation cover; and due to expansion of crop land to steep slopes. Besides, since resource managers have made significant efforts to conserve the area, it is still better to convey prioritization scientifically. The findings of this study could serve as hands on checklist for conservation planners in making knowledge-based decision or for financial and human resource flow in soil and water conservation programs.

2. Material and Methods

2.1. Study Area

The study area, Gotu watershed, is part of the Awash River basin and administratively found in North Habru woreda (district), North Wollo Zone of the Amhara National Regional State, Ethiopia. Geographically, it lies between 11°34'44" and 11°45'4"N latitude, and 39°34'11" and 39°45'2"E Longitude (Figure 1). The area is 160.56 km² wide, covering 9% of Habru woreda (1671.83 km²). The present complex topography of the area has been formed by a large-scale tectonic and volcanic activity and covered by Cenozoic volcanic rocks (Mohr 1971). It is composed of a rugged topography and relatively vast plain areas with elevations ranging between 1364 to 3508 meters above sea level.

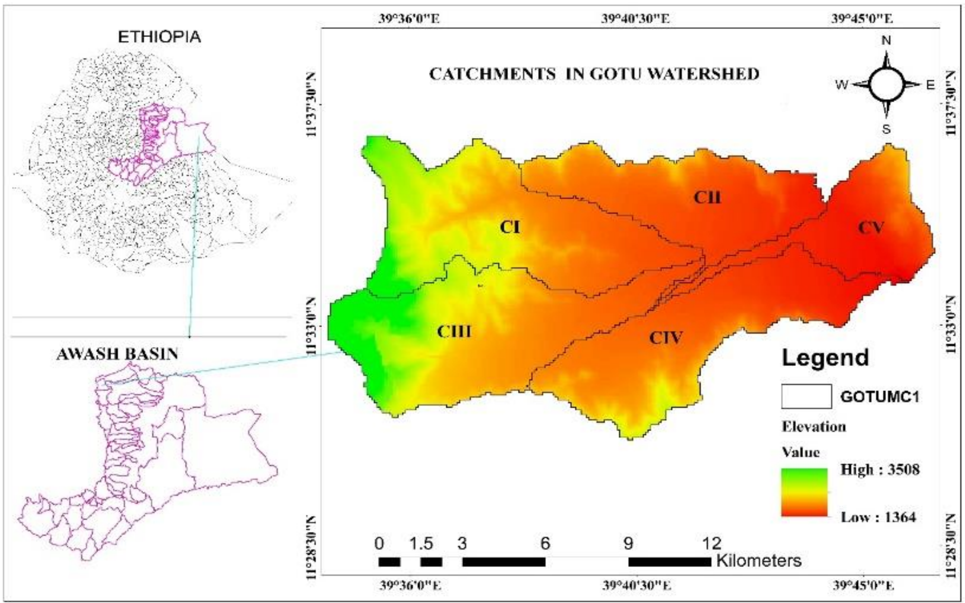

Figure 1. Location map of the study area: bottom left—Awash Basin, top left—Ethiopia watersheds right—Gotu watershed with catchments and elevation information.

According to the traditional agro climatic classification, the study area dominantly lies within *Dega* (2300–3300masl), *weyna dega* (1500–2300masl), and *kola* (1364–1500masl) zones. Based on a data set from five meteorological stations from the year 2000–2017 the mean annual temperature was 24.5 °C; and characterized by bi-modal pattern of rainfall with a mean annual rainfall of 935.7mm for the years from 2007–2017. The major soil types in the study area are Vertisols, Cambisols, and Regosols (Amhara design and supervision works enterprise, 2011). The study watershed is inhabited by a total population of 48108 with a density of 299 persons/km², which is far higher than the average for Amhara regional state (108.2 persons km⁻²) (CSA, 2007). Agriculture is the main economic activity with mixed crop-livestock production on a subsistence level.

2.2. Input Data and Methodology

For the analysis of morphometry of Gotu watershed, ASTER DEM 30 meter resolution (http://earthexplorer.usgs.gov/) was used to delineate and generate the value of different parameters like bifurcation ratio (Rb), stream frequency (Fs), drainage density (Dd), drainage texture (Dt), elongation ratio (Re), circulatory ratio (Rc), form factor (Ff), compactness coefficient (Cc), basin relief (H), relief ratio (Rh), and ruggedness number (Rn). Identification of smaller geohydrological units is needed for more efficient and better targeted resource management programs (Sharma and Thakur, 2016). Based on this, Gotu watershed has been classified in to five catchments using ArcSWAT in ArcGIS 10.4 which were coded as: Catchment one = CI; Catchment two = CII; Catchment three = CIII; Catchment four = CIV and Catchment five = CV. Then, after creating shape file of watersheds, DEM of each catchment was masked and filled the sink; flow accumulation threshold value of 1000 was used and the result stream networks were cross checked with toposheet (1:50,000 scale) of Mersa to have approachable results and generated streams of five catchments (Figure 4). On the other hand, for soil loss estimation using RUSLE model, input data like rainfall data (2008–2017) from national meteorological agency, soil data, ASTER DEM 30 m, and LULC were used. ERDAS 9.2 was used for layer stacking of Landsat 8 bands for LULC classification but other RUSLE indices outputs were generated using ArcGIS 10.4 software.

Table 1. Parameters and prioritization scheme as adapted from Sharma and Thakur (2016).

Morphometric parameter	Definition/formula	Priority condition	References
Bifurcation ratio (Rb)	Rb = Nu/Nu+1	Higher the value, More the Priority	Schumm (1956)
Stream frequency (Fs)	Fs = Nu/A	Higher the value, More the Priority	Horton (1932)
Drainage density (Dd)	Dd= Lu/A	Higher the value, More the Priority	Horton (1932)
Drainage texture (Dt)	Dt = Nu/P	Higher the value, More the Priority	Horton (1945)
Compactness Coefficient (Cc)	$Cc = 0.2821P/A^{0.5}$	Higher the value, More the Priority	Horton (1945)
Form factor (Ff)	$Ff=A/Lb^2$	Lower the value, More the Priority	Horton (1932)
Elongation ratio (Re)	$Re=2/L_b*(A/\pi)^{0.5}$	Lower the value, More the Priority	(Schumm (1956)
Circulatory ratio (Rc)	$Rc = 4 * \pi * A/P^2$	Lower the value, More the Priority	Miller (1953)
Basin relief (H)	HE-LE	Higher the value, More the Priority	Hadley and Schumm
Relief ratio (Rh)	Rh = H/Lb	Higher the value, More the Priority	Schumm (1956)
Ruggedness no. (Rn)	Rn = H * D	Higher the value, More the Priority	Melton (1957)
Soil loss	A=R.K.L.S.C. P	Higher the Average Annual Soil Loss Risk, More the Priority	Wischmeier and Smith (1978)
Economic demographic parameters*			
Population density (Pd)	Low, medium, high	The higher the density, higher the Priority	Badar *et al.*, (2013)
Average Economic status (ES)	Low, medium, high	The lower the status, higher the Priority	Badar *et al.*, (2013)
Cultivated land (CL)	Calculated from the generated LULC	The lower the percentage, higher the Priority	Satellite image analysis (http://earthexplorer.usgs.gov/)
Unirrigated land (Unirr.)	Very low, moderate, high, very high	Higher the unirrigated land, more the Priority	
Land Pressure (LP)	Low, medium, high	Higher the pressure, more the Priority	
Training received (Tr)	Number of trained farmers	The lower the number in relative to other catchment, the higher the priority	Badar *et al.*, (2013)
Potential labor force (PLF)	Low, medium, high	The lower the productive age group, the higher the priority	Badar *et al.*, (2013)
WSD performance rank (PR)	1st, 2nd, 3rd, 4th, 5th	The lower the rank, the more the priority	
Other parameters			
Ground cover	Low, moderate, high	Higher the NDVI, lower the priority	Rouse (1973)
STI	$(\text{Flow Acc.}/22.13)^{0.6} * (\sin\beta/0.0806)^{1.3}$	Higher the value, more the Priority	
SPI	(Flow Acc. + 1)* (tan β)	Higher the value, more the Priority	Moore *et al.,* (1991), Florinsky (2012)
TWI	ln (Facc/ tan β)	Lower the value, more the Priority	Beven and Kirkby, (1979), Florinsky (2012)

Note: *A = average annual soil loss potential;* R *= rainfall erosivity; K = soil erodibility;* L *= slope length; S = slope steepness; C = land cover management factor; P = conservation practices factors; NDVI = normalized difference vegetation index; WSD = watershed; and PLWSDD = potential labor force for watershed development.*

Analyzed on the basis of secondary data from Habru Woreda Agriculture and Rural Development Office and woreda Socioeconomic development and Finance Office (2017).

Moreover, socio-eco-demographic data regarding the various parameters like population density, economic status, cultivated land, unirrigated land, participation in watershed conservation, training received related to watershed development, potential labor force, and land pressure for all the catchments of study watershed were collected from the Habru Woreda Agricultural Office and personal interviews with natural resource and rural development experts. Furthermore, other parameters such as ground cover condition, sediment transport index (STI), stream power index (SPI) and topographic wetness index (TWI) were also considered for prioritization exercise.

Das *et al.* (2012) indicated that criteria for watershed prioritization are subjective in nature. Therefore, in this study, the basis for assigning weightage to different themes (morphometric, socio-eco-demographic, and mixed- RUSLE factors) was in consideration of which parameter need more attention in relation to prioritization for soil and water conservation. Based on this, soil loss using RUSLE model has given more weight (5) because human interventions (C and P factors) have more influence on soil loss plus physical indices are also embedded in the model. Then, the compound value of all the parameters was generated using the following weighted mean formula.

$$Wx^{-} = \frac{W1*X1+W2*X2+W3*X3\ldots WnXn}{W1+W2+W3\ldots Wn}$$

Where, Wx^{-} = Weighted mean; W_1 = Weight one; W_2 = Weight two ….; and X's = parameters.

Finally, based on average value of these parameters, catchments having the least rating value were assigned the highest priority; the next value was assigned second priority and so on.

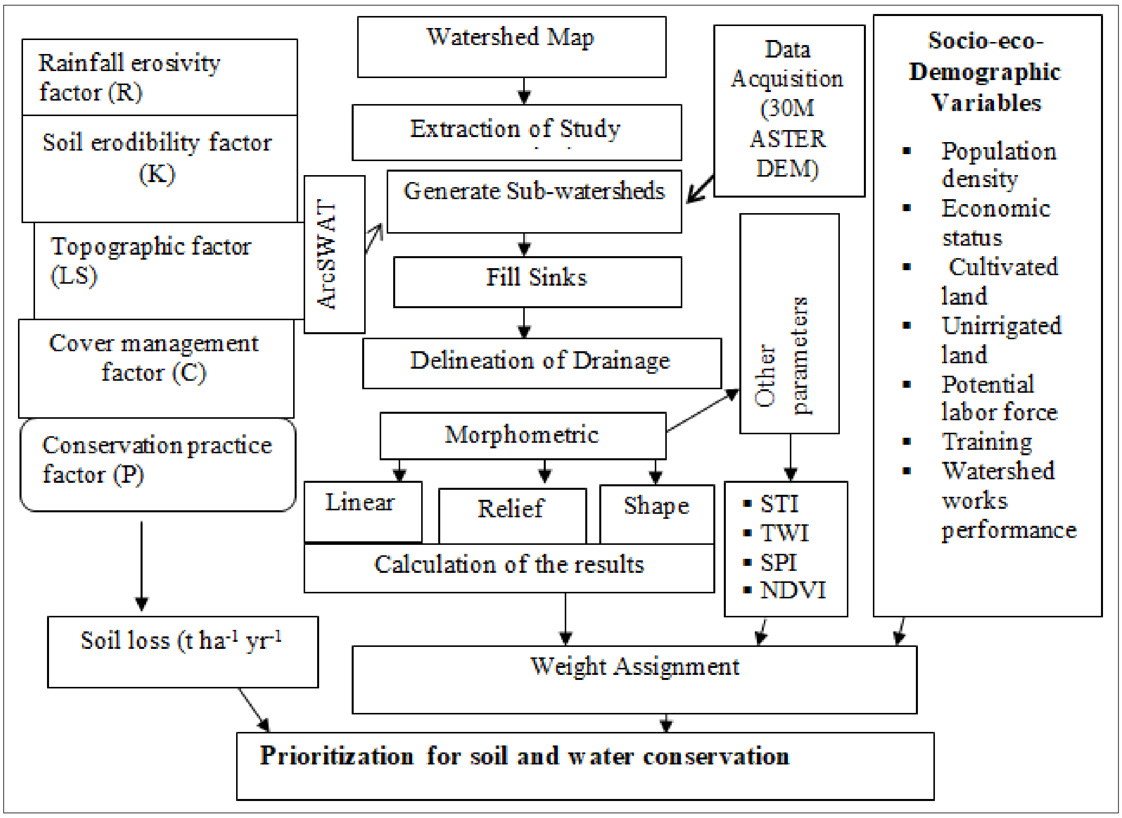

Figure 2. Flow chart of methodology.

3. Results and Discussion

3.1. Morphometric Analysis

Using Strahler (1957) system of stream ordering, Gotu watershed has seven order main streams, each order streams in each catchment having a varying number of streams (Figure 3). The study area has a total of 1127 streams, of which 562 were first order; 278 were second order; 130 were third order; 84 were fourth order; 38 were fifth order; 34 were sixth order; and 1 was seventh order streams with the corresponding stream length (km) of 123.5, 50.4, 30.42, 10.07, 4.68, 4.92 and 5.04, respectively (Table 2).

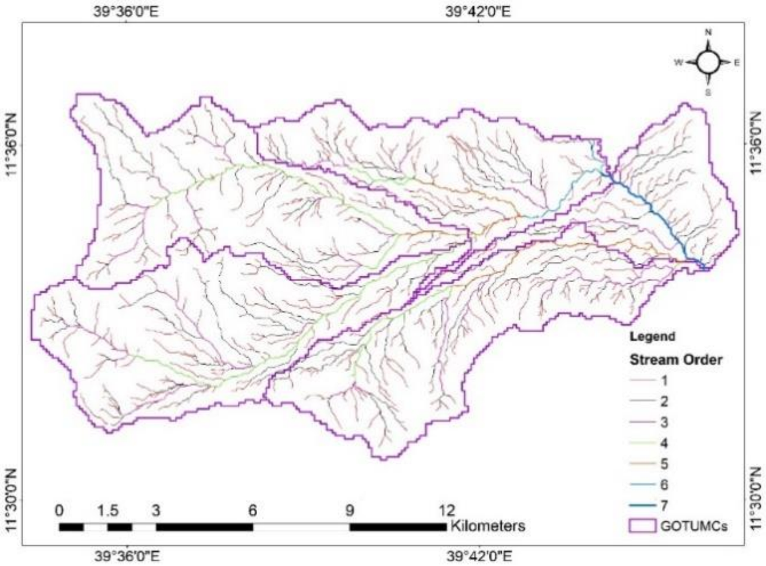

Figure 3. Stream orders of Gotu sub-watersheds produced from ASTER DEM.

The study watershed has an area of 160.56 km^2 with 675 total streams with a total stream length of 219.12 km. This means that there are about 7.04 streams in each km^2 area and an average of 1.36 km stream length per km^2 area. Catchment (C) wise, catchment four and catchment two are the highest in terms of stream length with 58.29 km, and 51.35 km, respectively (Table 2).

The morphometric parameters (Table 1) have been used for prioritizing watersheds. The linear parameters such as bifurcation ratio, stream frequency, drainage density, and drainage texture have a direct relationship with soil loss; the higher the value, the more is the soil loss. In contrast, shape parameters such as circularity ratio, elongation ratio, form factor, and compactness coefficient have an inverse relationship with erodibility. The intensity of dissection (expressed as bifurcation ratio) influences the discharge and flooding. In the present study, out of the five catchments, only catchment one has bifurcation ratio (Rb) of 3.0 (Table 2) that qualify Horton's (1945) natural drainage characteristics of Rb value (3.0 to 5.0).

Horton (1945) noted that the value of stream frequency depends on the total number of streams and the corresponding basin area. In the present study, stream frequency varies from 6.4 to 7.9 streams per square kilometer. In general, the higher the drainage density, the less the density of vegetation cover (Table 3 and Figure 6) and the more impermeable soil and rock surface which lets the movement of overland flow of runoff and hence reflecting the presence of enhanced soil erosion. The drainage density varies from 0.52 to 2.85 km km^{-2} reflecting comparatively high permeable surface and lower soil erosion rate.

3.2. Estimating Soil Loss

The soil loss in Gotu sub-watershed was estimated using RUSLE model–an efficient and quite reliable method of predicting soil loss as it considers both the physical and anthropogenic factors which are responsible for causing soil erosion (Wischmeier and Smith, 1978). Catchment wise, a moderate soil loss was observed in three catchments (CV, CIII and CIV) while the remaining two catchments experienced a severe soil erosion (Figure 5).

Table 2. Linear aspects of morphometrical parameters.

Catchment	Parameter	Stream order						
		1st	2nd	3rd	4th	5th	6th	7th
1	No. of streams	134	62	31	34	5		
	Stream Length/km	18.8	11.52	1.49	5.75	0.12		
	Ave. length/km	0.99	0.96	0.37	1.15	0.12		
	Basin Length (km)	11.24						
	Mean Rb	**3**						
2	No. of streams	133	68	33	26			
	Stream Length/km	30.45	7.69	11.15	2.06	-		
	Ave. length/km	1.12	0.64	0.85	1.03	-		
	Basin Length (km)	13.02						
	Mean Rb	**1.7**						
3	No. of streams	125	65	32	15	13		1
	Stream Length/km	13.61	2.8	0.13	0.012	4.56		0.35
	Ave. length/km	1.04	0.93	0.07	0.012	0.41		
	Basin Length (km)	10.49						
	Mean Rb	**1.8**						
4	No. of streams	105	55	23	9	13	11	
	Stream Length/km	32.28	18.54	7.47	-	-	4.92	
	Ave. length/km	1.19	1.09	0.93	-	-		
	Basin Length (km)	13.88						
	Mean Rb	**1.7**						
5	No. of streams	65	28	11		7	23	
	Stream Length/km	28.41	9.85	10.18	2.25	-	4.69	
	Ave. length/km	1.05	0.98	0.78	2.25	-		
	Basin Length (km)	14.34						
	Mean Rb	**2.4**						

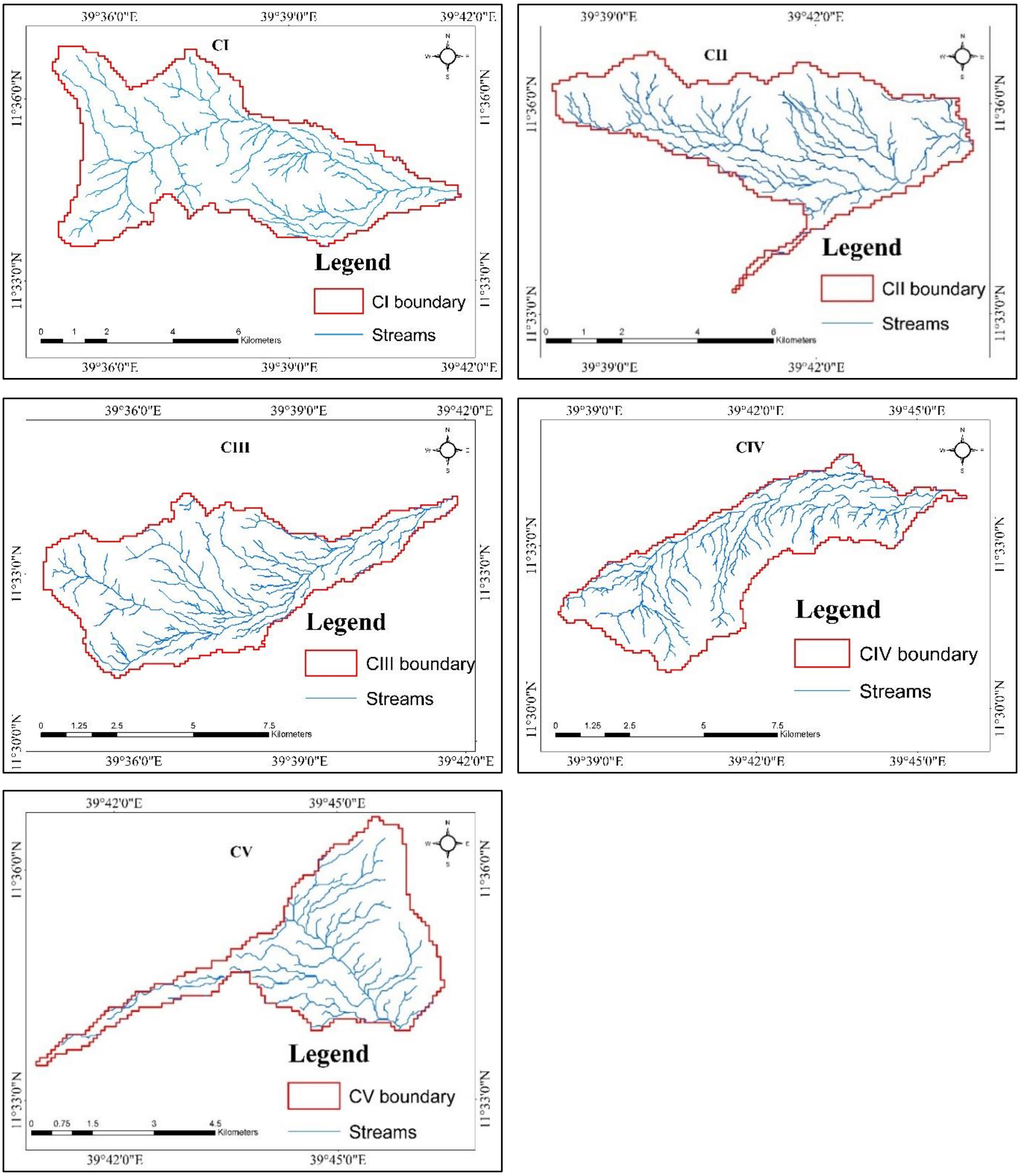

Figure 4. Streams in Gotu catchments derived from ASTER DEM.

Table 3. Morphometric parameters.

Catchment	A (km^2)	P (km)	Fs	Dd	Dt	Ff	Re	Rc	Cc	H (km)	Rh	Rn
CI	40.08	46.07	6.6	0.94	5.7	0.23	0.53	0.23	2.05	1.88	0.14	2.41
CII	27.41	42.71	7.9	1.87	5.1	0.21	0.52	0.19	2.30	0.7	0.060	0.96
CIII	40.44	45.69	6.4	0.52	5.6	0.21	0.50	0.24	2.02	2.02	0.145	2.9
CIV	34.9	45.88	7.1	1.67	5.4	0.17	0.46	0.20	2.19	2.19	0.063	1.32
CV	17.77	35.44	7.5	2.85	3.7	0.16	0.45	0.17	2.37	0.61	0.05	0.73

Note*: A = Area; P = Perimeter; Fs = Stream frequency; Dd = Drainage density; Dt = Drainage texture; Ff = Form factor; Re = Elongation ratio; Rc = Circulatory ratio; Cc = Constant of channel maintenance; H = Basin relief; Rh = Relief ratio; and Rn = Ruggedness number.*

The later may be attributed to the physical relief (average of H, Rh and Rn is highest) (Table 3) which was consistent with previous studies by Woldeamlak Bewket and Ermias Teferi (2009); Mulatu Mekonnen and Assefa Melese (2011); Temesgen *et al.* (2017); Birhan Asmame and Assefa Abegaz (2017), and Gezahegn *et al.* (2018). However, CIII showed higher physical relief but moderate soil loss. This may be due to better land use and land cover conditions (Figure 5).

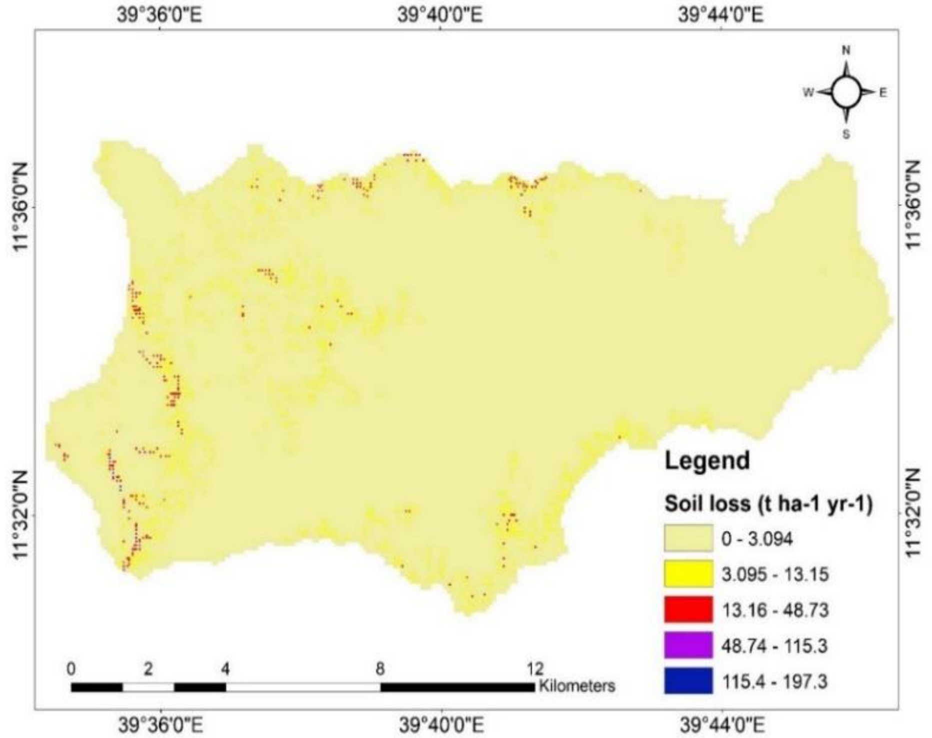

Figure 5. Soil loss computed using RUSLE model.

Table 4. Soil loss (t ha^{-1}year^{-1}) of each catchment.

Catchment	Soil loss (t ha^{-1}yr^{-1})	Area (km^2)
CI	<3.5	19.0
	3.6–22	7.0
	22.7–69.9	14.08
CII	<10.8	13.6
	10.9–64.2	6.0
	64.3–197	7.81
CIII	<2.09	19.0
	2.09–7.25	13.4
	7.26–19.07	8.04
CIV	<2.7	21.8
	2.7–10.2	4.6
	10.3–32	8.5
CV	<0.58	10.1
	0.58–2.19	6.2
	2.2–7.79	1.4

Note: *CI = Catchment one; CII = Catchment two; CIII = Catchment three; CIV = Catchment four; and CV = Catchment five.*

3.3. Socio-economic and Demographic Analysis

The socioeconomic and demographic data (Table 5) revealed that catchment four and catchment five were the highest and the lowest in terms of population density and economic status, respectively. The higher population density is attributed to the presence of congested town (*Girana*) largest market center pulling the surrounding population, suitable climate, and much irrigable land and thus the population has relatively better economic status. Conversely, the lowest population density and economic status is found in the eastern part of the watershed i.e. catchment five which lies near to Afar region in an area of hot temperature and low rainfall amount, low irrigation access, and relatively steep terrain.

According to a report of Habru Woreda Agriculture Office (2017), potential labor force for working to develop the watershed was identified from all 35 rural *kebeles* in the *woreda,* and training was offered to farmers in relation with watershed development activities. Based on this, the greater the number of trained farmers in a catchment, the lower the priority for soil and water conservation expecting that the trained farmers may mobilize other farmers for participation in conservation activities.

Table 5. Socioeconomic and demographic data with respect to different catchments.

Criterion	Catchment				
	CI	CII	CIII	CIV	CV
Population density	224	273	280	296	199
Economic status	4th	2nd	3rd	1st	5th
Potential labor force	1820	3206	3102	3312	1815
Cultivated land (%)*	38.9	47.8	30.9	42.7	43.6
Unirrigated land	Low	Medium	High	Very low	Very high
Land Pressure	High	VH	Low	Low	High
Number of farmers received training	305	313	281	432	190
WSD conservation performance rank	8	1	12	16	22

Note: *CI = Catchment one; CII = Catchment two; CIII = three; CIV=Catchment four; and CV= Catchment five. Analyzed on the basis of secondary data from Habru Woreda Agriculture and Rural Development Office and woreda socioeconomic development and Finance Office (2017). *Analyzed from Landsat 8 image.*

Thus, the results in Table 5 showed that catchment five has lower number of trained farmers (190) relative to other catchments. Concerning cultivated land, the analyzed image of Landsat 8, the analysis showed that about 64.0161 km^2 (39.87%) area of total land is under cultivation in the five catchments of Gotu watershed (Figure 6). Catchment wise, almost half (47.8%) of the total area is under crop cultivation in CII. It observed that crop cultivation is a dominant activity and has a significant share as an economic pursuit in the remaining catchments.

The woreda agriculture and rural development office (2017) report revealed that watershed development work performance of each *kebele* is usually evaluated quarterly by experts using field observations in each catchment area and by releasing performance ranking. Accordingly, population in catchment two and catchment one has a better record in watershed development activities and catchment five with the lowest performance (Table 5). Catchment two and catchment one are the leading ones in terms of pressure exerted on the land due to the presence of cross over main asphalt road in these catchments. Farmers usually sell fuelwood collected from the available bush lands in the highlands to make ends meet.

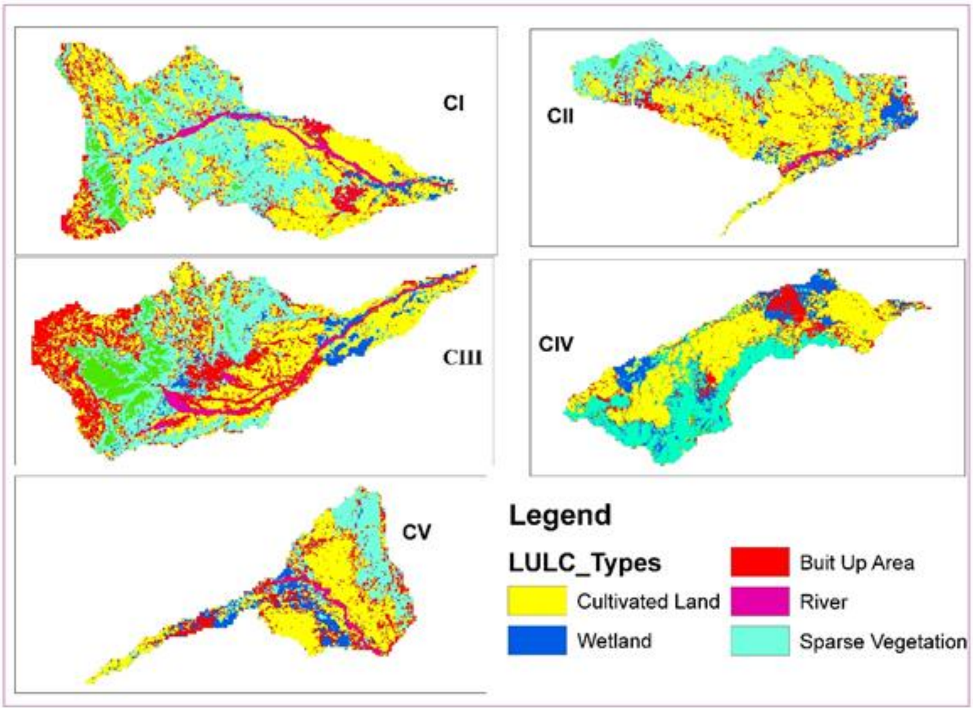

Figure 6. Land use land cover of Gotu catchments derived from Landsat 8.

3.4. Other Parameters

Sediment transport index value ranged from 1.88 in CV to 5.22 in CIII. The highest value was associated with steep slope and ridges which may contribute to sediment transportation and consequent soil erosion and degradation. The sediment transport index result has relative similarity with the relief parameters i.e. the higher sediment transport index value is found in areas with steep slopes (Tables 3 and 6).

Table 6. Other parameters (derived from DEM and Landsat-8 OLI).

Parameter	Catchment				
	CI	CII	CIII	CIV	CV
Sediment transport index	4.86	2.03	5.22	2.30	1.88
Stream power index	31.58	26.78	35.71	14.07	64.91
Topographic wetness index	15.53	16.93	15.09	15.68	18.04
NDVI as a proxy for ground cover condition	0.37	0.43	0.38	0.35	0.45

Note: *CI = Catchment one; CII = Catchment two; CIII = three; CIV = Catchment four; and CV = Catchment five.*

Similarly, high stream power index values represent areas on the landscape where high slopes and flow accumulations exist and thus areas where flows can concentrate with erosive potential. The higher the power of stream, the greater the probability of vulnerable topsoil washing down and contributing strongly to the land degradation process, and then transporting soil material and sediment to the plain areas. So, in the present study, the western and eastern parts of the watershed (CV = 64.91) have high stream power which may be associated with more inflow of water from the upper areas (increase in the stream orders i.e. seventh order stream is entirely found in CV). This implies that more attention should be given to soil conservation due to high probability of erosion. Topographic wetness index, on the other hand, was used to show wetness of an area and related to slope of the area i.e. water tend to accumulate in flat area than steep slope area and hence the more the topographic wetness index, the flatter the slope and hence more flow accumulation and wetness (Beven and Kirkby, 1979).

3.5. Prioritization of Catchments

All catchments in Gotu watershed have been prioritized by considering the weighted average of different parameters–morphometric, soil loss, socio-eco-demographic and others (Table 7). The value of the comprehensive weightage of all the parameters varied from 2.71 (lowest) to 3.3 (highest). Out of the five catchments, CV was assigned as high priority while CIV as low priority. Catchments with high priority indicate the need of soil and water conservation attention to them before other catchments. The least prioritized catchment, i.e., CIV has better socio-economic status, and lower aggregate morphometric ranking with medium soil loss priority (Table 7) whereas CV– given high priority which was characterized as lower relative soil loss and lower socio-eco-demographic condition. However, in terms of individual parameters, catchments with high priority in soil loss ranked the second least in terms of priority in aggregate morphometric indices. But Hlaing *et al.* (2008) has found sub watersheds with high priority in soil erosion also ranked in the morphometric parameters.

Table 7. Comprehensive ranking of catchments.

Aspect	Parameters	Weight (W)	Ranking									
			CI	W*CI	CII	W*CII	CIII	W*CIII	CIV	W*CIV	CV	W*CV
Morphometric	Rb	3	1	3	4	12	3	9	4	12	2	6
	Fs	3	4	12	1	3	5	15	3	9	2	6
	Dd	3	4	12	2	6	5	15	3	9	1	3
	Dt	3	1	3	4	12	2	6	3	9	5	15
	Ff	3	5	15	3	9	3	9	2	6	1	3
	Re	3	5	15	4	12	3	9	2	6	1	3
	Rc	3	4	12	2	6	5	15	3	9	1	3
	Cc	3	2	6	4	12	1	3	3	9	5	15
	H	3	4	12	3	9	1	3	2	6	5	15
	Rh	3	3	9	1	3	4	12	2	6	5	15
	Rn	3	3	9	1	3	4	12	2	6	5	15
Soil	Soil loss	5	2	10	1	5	4	20	3	15	5	25
Socio-eco-demographic	Pd	4	4	16	3	12	2	8	1	4	5	20
	Es	4	2	8	4	16	3	12	5	20	1	4
	Cl	4	2	8	5	20	1	4	3	12	4	16
	Unirr	4	4	16	3	12	2	8	5	20	1	4
	LP	4	2	8	1	4	4	16	4	16	2	8
	PLF	4	2	8	4	16	3	12	5	20	1	4
	WPR	4	4	16	5	20	3	12	2	8	1	4
	Tr	4	3	12	4	16	2	8	5	20	1	4
Others	NDVI	4	4	16	2	8	3	12	5	20	1	4
	STI	3	2	6	4	12	1	3	3	9	5	15
	SPI	3	3	9	4	12	2	6	5	15	1	3
	TWI	3	2	6	4	12	1	3	3	9	5	15
Sum		83		247		252		232		275		225
WX-				2.9		3.0		2.79		3.3		2.71
Rank			3rd		4th		2nd		5th		1st	

Note: *Pd = Population density; Es = Economic status; Cl = Cultivated land; Unirr = Un-irrigated land; LP = Land pressure; PLF = Potential labor force; WPR = Watershed conservation activities performance rank; and Tr = Training received related to conservation.*

In the present study, it was also observed that catchments with high soil loss, low economic status, high population density, low potential labor force, high unirrigated land, high land pressure, and low watershed conservation performance were prioritized first against catchments with lower soil loss and better socioeconomic condition. This result is consistent with the findings of Sharma and Thakur (2016). In their finding micro watersheds with high soil loss risk, high population size, low agricultural land, high relief ratio, lower economic status was given high priority for soil and water conservation planning while watersheds with low lying area, less areas under steep slope, and low drainage density were assigned to low priority. Similarly, Vittala *et al.* (2008) found out that sub watersheds having population with low economic status were given high priority while sub watersheds with better natural resource base were given prioritized least.

The aggregate results of prioritization may have their own limitation and, in some cases, inconsistent results may be observed because of the subjective nature of weight assignment to the parameters. Therefore, the author acknowledges that the methodology has inherent limitations and may result in assignment of erroneous weight to the parameters. Again, this study was not able to include other important variables affecting prioritization for soil and water conservation. Finally, there may also be some overlapping parameters.

4. Conclusion

This study has demonstrated that Gotu watershed has seven order streams with a mean Rb of 2.1; low drainage density (0.52–2.85 km km^{-2}) and moderate drainage texture (3.7–5.7); elongated shape (Ff = 0.16–0.23; Re = 0.45–0.53) and 74.81% of Gotu watershed have a less than 0.145 and 2.9 of relief ratio and ruggedness number, respectively. These proved that the watershed has relatively less dissected terrain features; low and extended flood flow and dominance of low sloped terrain. Soil erosion was very severe (64.2–197.2 t $ha^{-1}yr^{-1}$) in CII as per RUSLE model. The results of socioeconomic and demographic characteristics, on the other hand, showed that out of the five catchments of Gotu watershed, CV was characterized by low economic status, labor force, watershed work and related training participation which made this catchment feasible for primary conservation. Finally, the compound results have revealed that relatively CV having an area of 17.77 km^2 (11.06%) of Gotu watershed, should get the first priority for soil and water conservation. The results of this study could be useful for watershed planners and managers towards implementing various water and soil conservation measures in the study area. It is deduced that catchments with high soil loss may not usually guarantee primary attention for conservation unless the condition of socioeconomics, morphometry of catchments and related parameters are considered simultaneously and contribute to the decision making process of conservation planners. Similar studies should be made to understand the condition of different watersheds in Ethiopian highlands versus resource flow for soil and water conservation work.

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