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Assessment of spatial soil erosion hazard in *Ajema* Watershed, North Shewa Zone, Ethiopia

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Abstract

Ajema Watershed is one of the most erosion prone watersheds in the highlands of Ethiopia which contribute all of the water to the *Ajema* Irrigation Dam Project that is under construction. The study was carried out to assess soil erosion hazard, using spatial variability. The spatial soil loss rate of the watershed was predicted using Revised Universal Soil Loss Equation (RUSLE) under Arc GIS environment. Erosion factors in RUSLE was run using rainfall erosivity (R), soil erodibility (K), Land use and cover (C) topography (LS) and conservation practices (P) were identified and analyzed. High erosion risk hotspot areas and priority areas for future conservation planning of the watershed were mapped. Based on the RUSLE analysis, the mean and total annual soil loss potential of the study watershed was 8.25 tons $ha^{-1}y^{-1}$ and 64810 tons y^{-1}, respectively. Dominant factors from RUSLE that contributed too much to soil erosion of the watershed were found to be R, C, P, and K in descending order with spatial variability. Conservation measures should coincide with the hazard zone through improving farmers' awareness.

Keywords: conservation planning, conservation practices, mean total soil loss, RUSLE, soil erosion

Introduction

Globally soil degradation is affecting 1.9 billion hectares and is increasing at a rate of 5 to 7 million hectares each year.[1] Among all degradation processes, including soil acidification, salinization and nutrient mining, soil erosion is by far the most common source of land degradation, accounting for 84% of affected areas.[2] Soil erosion is one of the major factors affecting sustainability of agricultural production.[3,4] The degradation mainly manifests itself in terms of lands where the soil has either been eroded away and whose nutrients have been taken out to exhaustion without any replenishment.[5] About 80% of the current degradation of agricultural land is caused by soil erosion.[6,7] Erosion by water is the major cause for soil degradation in agricultural areas.[8] It generates strong environmental impacts and major economic losses in decreased agricultural production and off-site effects on infrastructure and water quality by sedimentation processes.[9,10] Agriculture is the mainstay of the Ethiopia's economy where its production is highly dependent on natural resources.[11] It has a total surface area of 112 million hectares,[12,13] of which 60 million hectares is estimated to be agriculturally productive, Out of the estimated agriculturally productive lands, about 27 million hectares are highly eroded, 14 million hectares are severely eroded and 2 million hectares have reached the point of no return, with an estimated total loss of 2 billion m^3 of top soil per year.[12,14]

In the Ethiopian highlands, an annual soil loss reaches 200-300 tons $ha^{-1}yr^{-1}$ from farm land.[15,16] About 1900 million tons of soil was annually eroded from the highlands, which is equivalent to an average net of 100 tons $ha^{-1}yr^{-1}$ soil loss, this is also equivalent to 8 mm in soil depth annum.[17] Erosion rates were estimated at 130 tons $ha^{-1}yr^{-1}$ for cropland and 35 tons $ha^{-1}yr^{-1}$ averages for all land in the highlands which had been regarded as high estimates.[18] Soil erosion and sedimentation cause reduction of irrigation conveyance capacities and reservoir storage volumes in Ethiopia.[19] Erosion also reduces irrigation water quality by increasing water turbidity.[20] The rapid loss of storage volume due to sedimentation is the major problem of all water reservoirs in Ethiopia. Some preliminary studies indicated that the levels of some water reservoirs such as Koka and Gibe I reservoir in Ethiopia and many lakes like Alemaya, Shalla, Awassa, Abaya and Langano have decreased in volume and diminished. The process is so challenging that the initial water carrying capacity of the dams has reduced due to progressive silt accumulation. For example, the Koka dam has accumulated about 3.5 million m^3 of silt within 23 years.[21,22] *Ajema* Watershed is located in the upstream side of the newly built *Ajema* Irrigation Dam Project which is under construction. The *Ajema* watershed is located in North Shewa Zone 30 km from north of Deber Berhan town at the upper parents of the dam which faces siltation problem. Therefore, studying soil erosion hazard assessment in the watershed is important for several reasons. First, the study was presented an updated estimate of actual soil losses and sediment load for the watershed by considering and evaluating erosion promoting factors. Second, the prepared erosion hazard map of the watershed will serve as a base map in planning appropriate conservation methods for mitigating erosion and sediment load by identifying erosion hazard zones. Third, the data generated can be used as input or baseline data for other similar watersheds of the District with similar socio-economic and biophysical condition. Thus the objective of this work was to assess the soil erosion hazard in *Ajema* and generate spatial maps of soil erosion hazard.

Materials and methods

Study Location: *Ajema* Watershed is found within two Districts (Angolela, and *Tera* and Asagirt) of North Shewa Zone of Amhara National regional state, Ethiopia. The watershed is located between 9° 31'58'' to 9°17'30'' North and 39° 29'25'' to 39° 35'02'' East in Geographic coordinates. The total area of the watershed is estimated to be 7855.68 ha (Figure 1).

Erosion estimation using RUSLE, GIS and RS: According to USDA (23) the equations for the sub-factors of RUSLE were primarily calibrated and erosion values were computed for a wide range of conditions using data from USDA Agricultural handbook 537.[23] Those data were taken from a summary of more than 10000 plot-years of data. Therefore, the validity of RUSLE is dependent on the acceptance of pimples used while it's calibrated. In this study, therefore, the model was used by considering those principles.

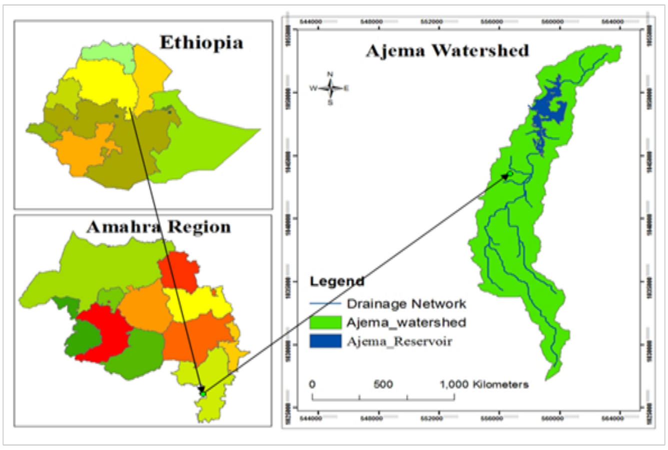

Figure 1 Location map of *Ajema* Watershed, North Shewa Zone, Ethiopia.

For the determination of soil loss factors, the following five input thematic data were used, which are sub factors of the RUSLE equation, (Equation 1).

$$A = R*K*L*S* C*P \qquad 1$$

Where, A is the average annual soil loss (mass area^{-1} year^{-1}); R is the rainfall erosivity index; K is the soil erodibility factor; L is the slope length factor; **S** is slope gradient factor; C is the vegetation cover factor, and P is the conservation protection factor. The RUSLE is used to predict the long-time average soil loss over a field and the loss at various points on the slope. The RUSLE is described by:

Rainfall eerosivity factor (R): Monthly rainfall records from Debre Berhan Agricultural Research Center, Sheno and Chacha covering the period 2007-2016 were used to calculate the mean rainfall erosivity factor (R value). The mean annual rainfall for 10 years was first interpolated to generate continuous rainfall data for each grid cell by "3D Analyst Tools Raster Kriging Interpolation" in Arc GIS environment. Then, the R-value corresponds to the mean annual rainfall of the watershed was found using the R-correlation established by[24] to Ethiopian condition.

$$R = -8.12 + 0.562P \qquad 2$$

Where R is the rainfall erosivity factor and P is the mean annual rainfall (mm).

Soil erodibility factor (K): Soil unit map of the study watershed was found from Amhara Region digital soil map developed at a scale of 1:50,000 by Development Studies Associates DSA and Shawel Consult International SCI.[24] The soil erodibility (K) factor for the watershed was estimated on soil unit types referred from FAO[25] soil database adapted to Ethiopia by Hurni.[24] Finally, the resulting shape file was changed to raster with a cell size of 20mx20m. The raster map was reclassified based on the erodibility values (Table 1).

Topographic factors (LS): The influence of topography on erosion is complex. The local slope gradient (S sub-factor) influences flow velocity and thus the rate of erosion. Slope length (L sub-factor) describes the distance between the origin and termination of inter-rill processes. Slope length and slope steepness was determined using 20m spatial resolution digital elevation model (DEM) to generate slope. The flow accumulation and slope steepness was computed from the DEM using Arc GIS 10.3. Flow accumulation and slope maps was multiplied by using "Spatial Analyst Tool Map Algebra Raster Calculator" in Arc GIS 10.3 environment to calculate and map the slope length (LS factor)[23] as shown in equation 3.

$$LS = \left(\text{flow accumulation*cell size} / 22.1\right)^{m} * \left(0.065 + 0.045S + 0.0065S^{2}\right) \qquad 3$$

Where, Cell size is 20m, m exponent that depends on slope steepness, S= slope in per cent/slope steepness, m = 0.2 if S < 1%; 0.3 if S [1-3%]; 0.4 if S [3-5%]; 0.5 if S > =5%

Table 1 Soil erodibility factor (K) value

Soil type	Erodibility (K factor)
Eutric Cambisols	0.2
Eutric Vertisols	0.2
Eutric Leptosols	0.15
Rock and Water body	0

Source: Hurni[24]

Land covers factor (C): A land-use and land-cover map of the study watershed was prepared from Landsat satellite image and supervised digital image classification technique through ERDAS 2014 software. In addition ground truth data were used as a vital reference for supervised classification, accuracy assessment and validation of the result. In supervised image classifications technique, land use types classified so as to use the classified images as inputs for generating crop management (C) factor (Table 2). Based on the land use classification map, a corresponding C value is assigned to each land use of the *Ajema* Watershed.[24]

Table 2 Land use factor C value of each land use type

Land use	C-factor values
Grazing Land	0.12
Crop Land	0.37
Built Up Areas	0.01
Rocky Area	0.05

Source: Hurni[24]

Management practices factor (P): The erosion management practice, P value is also one factor that governs the soil erosion rate. The P value ranges from 0-1 depending on the soil management activities employed in the specific plot of land. These management activities are highly dependent on the slope of the calculated P value by delineating the land into two major land uses, agricultural land and other land.[3,23] The agricultural land sub-divided into six classes based on thel slope percent to assign different P value (Table 3).

Computation of soil loss using RUSLE in Arc GIS environment

After the R, K, LS, C and P factor layers were developed; finally all layers were overlaid using "Spatial Analyst Tool Map Algebra Raster Calculator" in Arc GIS 10.3 environment to calculate or to model the annual soil loss rate (Figure 2).

Table 3 Management practice factor P value

Land use type	Slope (%)	P-value
Cultivated Land	<50	0.33
	30-50	0.25
	15-30	0.19
	15-Aug	0.14
	8-Mar	0.12
	0-3	0.1
Built up Area	All	1
Forest Land	All	1
Grazing Land	All	0.9
Rocky Area	All	0.8
Terraces	All	0.6

Source: Wischmeier & Smith[23]

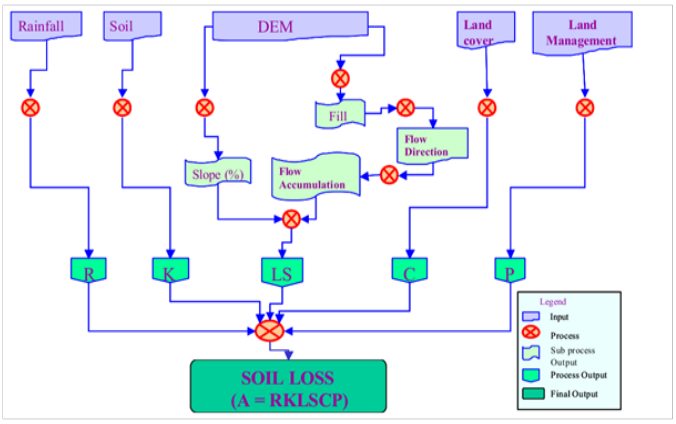

Figure 2 Flow chart showing analysis of soil loss based on GIS application.

Sediment yield

Finally, sediment yield was calculated in order to see the amount of sediment delivered from the watershed to *Ajema* irrigation dam project i.e. the outlet of the watershed. The sediment delivery ratio (SDR) denotes the ratio of the sediment yield at a given stream cross section to the gross erosion from the watershed upstream from the measuring point.[5] To generate the sediment yield at the outlet, empirical equation was used.

$$SDR = A^{-0.2} \qquad 4$$

Where, SDR denotes the sediment delivery ratio and area of the watershed. The SDR physically means the ratio of the sediment routed to the outlet over the watershed, both over land and channel. Sediment yield is commonly estimated by the following empirical formula.

$$Sy = E^{*}\left(\frac{1}{A^{0.2}}\right) \qquad 5$$

Where, S_Y =Sediment yield (tons) at the watershed outlet; E = total erosion (tons); A=watershed area (ha).

Spatial erosion hazard mapping: Satellite images, thematic maps, meteorological data, soil type and depth map digital elevation model (DEM) was acquired using software/instrument organized analyzed and produced information for decision making. Supervised classification was undertaken on Enhanced Thematic Mapper (ETM+) and land use/land cover of the area was developed. Land classification contingency matrix developed and evaluated for the accuracy to be more than 85%, and histogram of the classification was also evaluated. Priority areas were identified and categorized into different severity classes based on FAO guideline for conservation planning, soil loss rating of the watershed.[15]

Results and discussion

Spatial soil erosion analysis using RUSLE

Rainfall erosivity factor (R): The annual rainfall of the watershed is ranging from 925 to 1240mm. The calculated R factor was converted to raster surface with 20m*20m grid cell using Inverse Weight Distance (IWD) interpolation technique (Figure 3). The result showed that R-factor value in the watershed ranges from 593.62 to 599.86 in the watershed. The upper part (*Mgezzeze* Mountain) of the watershed had higher amount of rainfall and this resulted in high erosion rate when compared with downstream (Figure 3).

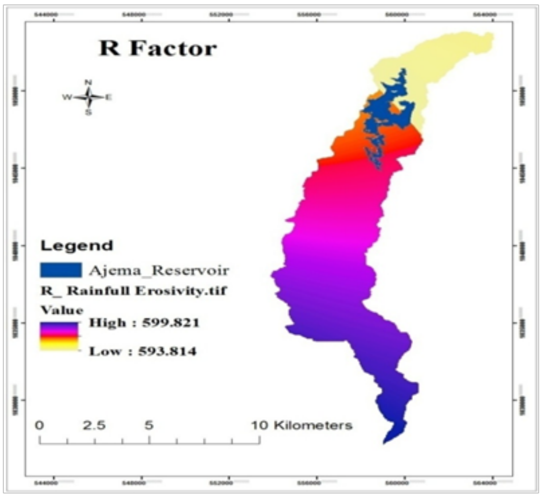

Figure 3 Rainfall erosivity factor (R) map.

Soil erodibility factor (K): Four major soil type categories were identified in the study area. After assigning K values for each soil type, the soil map was reclassified using adopted K values[24] and reported in Table 2 with a grid map of 20m* 20m cell size. The soil types of the study area are Eutric Cambisols, Eutric Vertisols, Eutric Leptosols, and Rock and Water body in the watershed are found to cover 71.06, 15.50, 13.43, and 0.002%, respectively. Their corresponding K value is given to be 0.15, 0.2, 0.2, and 0, respectively. The result indicated that soil erodibility value in the study watershed ranges from 0.15 to 0.20 (Figure 4). Eutric Cambisols was contributing 71% erosion potential to the watershed.

Topographic factor (LS): In RUSLE, the LS factor represents a ratio of soil loss under given conditions to that at a site with the "standard" slope steepness of 9% and slope length of 22 m plot. The steeper and longer the slope, the higher is the erosion. The slope length and slope steepness can be used in a single index, which expresses the ratio of soil loss as defined by Wischmeier & Smith.[21] Finally, the LS factor map was generated using the formula in ArcGIS spatial analysis raster calculator function.

As it is mentioned in Figure 4, due to slope steepness and the

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slope length factor the watershed contributes 0 up to 128.565 to soil erosion. The mean LS value of the study watershed was 1.13 with standard deviation of 3.11. The standard deviation was quite high. This showed that the slopes of the watershed are ranging from none to very high. But the majority value was concentrated near to zero and hence topographic factors had less effect on soil erosion in the watershed.

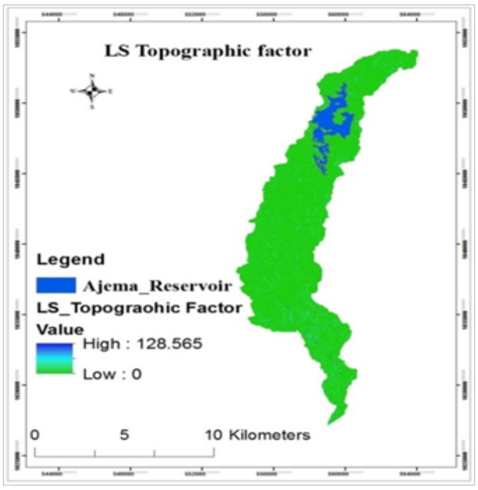

Figure 4 Topographic factor (LS) map.

Land covers factor (C): The cover management factor (C) measures the combined effect of cropping and management practices in agricultural system and the effect of ground cover, tree canopy and grass covers in reducing soil loss in non- agricultural condition (Figure 5).[23]

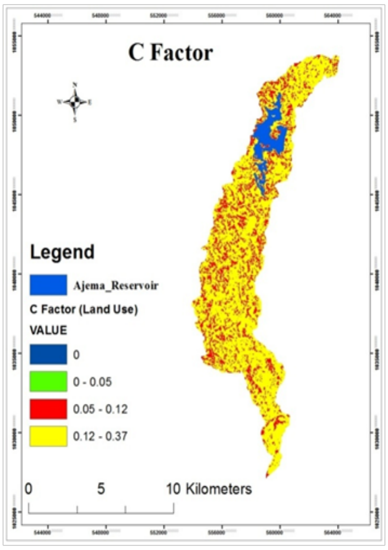

Figure 5 Derivation of land use factor (C) from land use type map.

The results in Table 3 and Figure 5 indicated that six land use classes were classified in the watershed, dominated by crop land (5979.8 ha) and grazing (grassland) (1322.22 ha) and forest land (544.36 ha), built up area (9.14 ha), and water body (16 ha), with the corresponding C factor value of 0.37, 0.12, 0.05, 0, 0.01, and, 0 respectively. Based on this result, crop land contributed large the highest amount of soil erosion in the watershed and also covered 76.12% of the watershed area. Therefore, C factor was the dominant factor next to rainfall for soil erosion in the watershed.

Management practices factor (P): In the study area, there is only a small area that has been treated with terracing through the agricultural extension program of the government and these are poorly maintained. Biological soil and water conservation measures and regarding ploughing system, all farmers plough along contour line. Because of these, the P value of each land cover classes was determined based on the value adapted to Ethiopian condition.[24] Hence, the agricultural lands were classified into six slope categories and assigned P values suggested by Bewket & Teferi[8] and Atesmachew et al.[3,14] The results in Table 3 and Figure 6 indicated that most of the watershed was covered by cultivated land (5229.75 ha). Out of the total cultivated land, 75.9% has a slope range of 0-15%. The P value of the cultivated land was 0.1 up to 0.14. The actual erosion assessment is based on the principles of RUSLE model, which multiplies the six parameters rainfall erosivity, soil erodibility, slope gradient and length, land cover, and soil conservation practices. This computation was made by using raster calculator of ArcGIS spatial analysis function, which enables the multiplication of the parameters cell by cell (Figure 7). Based on the analysis, the mean and the total annual soil loss potential of the study watershed were found to be 8.25 tons $ha^{-1}y^{-1}$ and 64809.36 tons y^{-1}, respectively. Thus, the estimated soil loss rate was generally realistic Table 4. Compared to other studies, the current soil loss result (8.25 ton ha^{-1} y^{-1}) was higher than the study conducted near Addis Abeba, Dira and Legedadi watershed (4.81 ton ha^{-1} y^{-1})[27] but less than in Hageremariam Kessem District (247.9 tons ha^{-1} y^{-1})[28] and *Zingin* watershed in Awi Zone (9.10 tons ha^{-1} y^{-1}).[29] The estimated average soil loss from croplands in the highlands of Ethiopia is about 100 m^3 tons ha^{-1} y^{-1} and more than 300 m^3 tons ha^{-1} y^{-1} on specific plots.[24] Estimated mean soil loss from cultivated fields as 42 m^3 tons ha^{-1} y^{-1}. Generally *Ajema* Watershed was characterized by gentle sloping to moderately steep sloppy area leading the rate of erosion to fall under the mean of central highlands of Ethiopia.

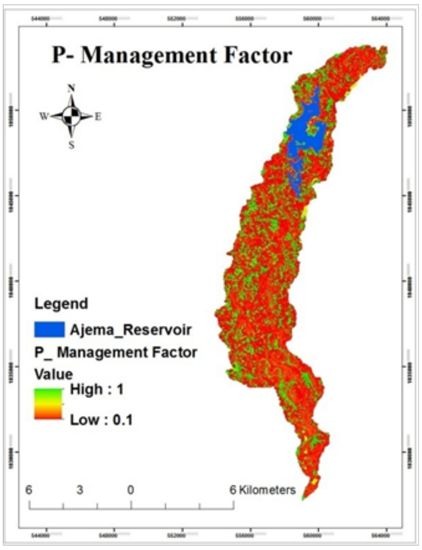

Figure 6 Conservation practice/ management factor (P) map.

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Spatial erosion hazard map

About 75.24% (5910.83 ha) of the watershed was categorized under none to slight erosion hazard zone, which values ranging from 0 to 5 tons $ha^{-1}yr^{-1}$ and from slight to moderate erosion hazard zone was 20.137% (1581.14 ha) of land.[28] The remaining 4.63% (363.71 ha) of land was classified under high to severe hazard zone. Based on the average soil depth (100-150cm) the maximum tolerable soil loss of the whole watershed was 7-9 tons ha^{-1} y^{-1} (Figure 8).[28] Table 4 presents estimated rate of actual soil erosion for the two Districts and kebeles. The area of severe erosion hazards account 3.81% and 7.12% of Angolela and Tera and Asageret, District respectively. In addition to high to sever erosion hazard zone slight to moderate erosion hazard zone needs special attention, because, 1186.68 ha (20.28%) of land from Angolela and Tera District and 394.47 ha (20.28%) of land from Asageret District have slight to moderate erosion hazard (Table 5).

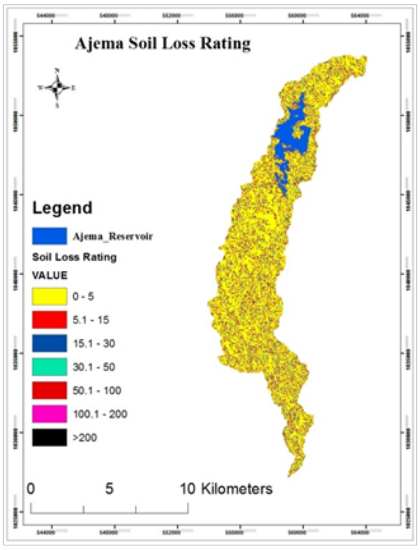

Figure 7 Spatial soil loss rate based on RUSLE and ArcGIS application.

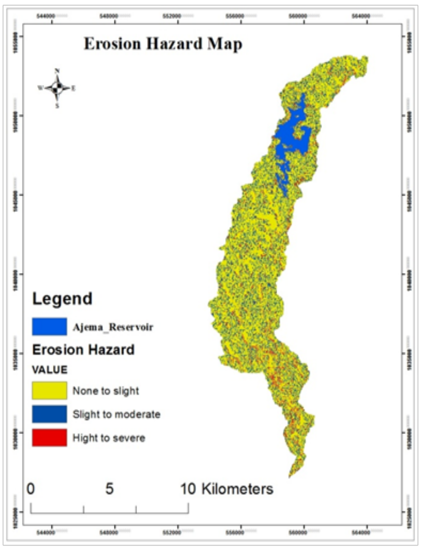

Figure 8 Erosion hazard map of *Ajema* Watershed.

Sediment yield

Sediment yield is very important for irrigation dam projects; because it tells us how our top soils are being eroded by running water and reaching the outlet of the watershed. Similar to the soil losses, sediment yields are also very high at the outlet of the watershed. Hence, sediment yield was also calculated using (Equation 7).

$Sy = 64809.36 * \left(\frac{1}{7855.68^{0.2}}\right) Sy = 10779.66$ tons per year RUSLE method

$Sy = 178481 * \left(\frac{1}{7855.68^{0.2}}\right) Sy = 29686.24$tons per year Erosion pin method

Sediment yields of the watershed were 10779.66 tons per year and 29686.24 tons per year based on RUSLE and erosion pin method respectively. For Sediment yields the study uses result found from erosion pin method because it is closer to the reality. However, it was impossible to get the dead load estimate for the *Ajema* Dam designed by the respective engineers to compare whether it is high or not related with this study result. A total of 7855.8 ha of *Ajema* Watershed were analyzed for its soil erosion status using RUSLE and erosion pin methods. The mean annual soil loss of the watershed using RUSLE was 8.25 tons $ha^{-1}yr^{-1}$. It is better using RUSLE at watershed level to assess the amount and its spatial distribution. Five factors used for analyzing soil erosion, rainfall (R), land use/land cover factor (C) and conservation management factor (P), were the dominant factors, respectively in promoting high soil erosion in the watershed. The majority of the watershed area falls under tolerable soil loss limit. Only 1759.71 ha (22.36%) were above tolerable limit. More than 4.63% of the watershed areas were characterized by high to very high soil erosion hazard zone. Therefore, it should be given special priority to reduce the rate of soil erosion by means of proper soil and water conservation. On the other hand, slight to moderate erosion hazard zone (1581.14 ha) should be protected from further erosion. A sediment yield of the watershed was 10779.66 tons y^{-1}.

Table 4 Soil loss rating of Ajema Watershed from RUSLE model analysis

Soil loss rating			Area coverage	
Class	tons/ha/yr	Descriptions	ha	%
I	0-5	None to slight	5910.83	75.24
II	15-May	Slight	827.12	10.53
III	15-30	Slight to moderate	560.97	7.14
IV	30-50	Moderate	193.06	2.46
V	50-100	High	249.68	3.18
VI	100-200	Very High	84.69	1.08
VII	>200	Very High	29.34	0.37
		Total	7855.68	100

Table 5 Erosion hazard breakdown of *Ajema* Watershed in district and county

Name of district and kebele	Erosion hazard			
	Non to slight	Slight to moderate	Severe zone	Grand total
Angolelana Tera	4498.34	1186.68	225.27	5910.29
Aganeda	11.84	3.09	0.08	15.01
Asa Bahir	2435.78	619.26	103.49	3158.53
Kitalegn	1095.1	325.77	72.43	1493.31
Tengego	931.79	231.76	48.98	1212.53
Tsegereda	23.83	6.81	0.29	30.93
Asagerete	1412.49	394.47	138.44	1945.39
Gola Zuriya	897.42	251.66	75.15	1224.24
Koso Amba	171.9	46.49	16.62	235.01
Megezeze Wenberi	343.17	96.32	46.66	486.15
Grand total	5910.83	1581.14	363.71	7855.68

Conclusion

The mean annual soil loss of the study watershed using RUSLE was 8.25 tons $ha^{-1}yr^{-1}$. A sediment yield of the watershed was 10779.66 tons y^{-1}. From the five factors used for analyzing soil erosion, rainfall (R), land use/land cover factor (C) and conservation management factor (P), were the dominant factors, respectively in promoting high soil erosion in the watershed. More than 4.63% of the watershed areas were characterized by high to very high soil erosion hazard zone. Therefore, it should be given special priority to reduce the rate of soil erosion by means of proper soil and water conservation. The watershed management practices should be adopted in this area. Upgrading of the present agricultural and livestock management practices and introduction of appropriate soil conservation measure are essential for mitigating erosion and reducing *Ajema* reservoir from sedimentation.

Acknowledgments

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Conflicts of interest

Authors declare that no competing interests exist.

References

1. Gossa Wordofa. Soil erosion modeling using GIS and RUSLE on the eurajoki watershed. Finland: Temered University. 2011.
2. Toy TJ, Foster GR, Renard KG. Soil Erosion: processes prediction, measurement, and control. USA John Wiley and Sons Inc; 2002. 352 p.
3. Atesmachew Bizuwerk, Girma Taddese, Yasin Getahun. Application of GIS for modeling soil loss rate in Awash River Basin, Ethiopia. Ethiopia: National Livestock Research Institute (ILRI); 2010.
4. Mitiku Haile, Kjell E. Tor Gunnar V, et al. Soil conservation in Tigray, Ethiopia, Report No. 5. 2002.
5. Gizachew Ayalew. A geographic information system based soil loss and sediment estimation in Zing watershed for conservation planning, highlands of Ethiopia. *International Journal of Science, Technology and Society*. 2015;3(1):28–35.
6. Angima SD, Stott DE, O'Neill MK, et al. Soil erosion prediction using RUSLE for central Kenya highland conditions. *Agriculture Ecosystem and Enviromenv*. 2003;97(1–3):295–308.
7. Tamene, L. 2005. Reservoir siltation in the dry lands of northern Ethiopia: causes, source areas and management options. PhD Thesis, Ecology and Development Series 30, Center for Development Research, University of Bonn; 2005. p. 84–138.
8. Bewket W, Sterk G. Assessment of soil erosion in cultivated fields using a survey methodology for rills in the Chemoga watershed, Ethiopia. *Agriculture, Ecosystems and Environment*. 2003;97(1–3):81–93.
9. Amsalu Aklilu, Graaff JD. Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland. *Ecological Economics*. 2006;61(2–3):294–302.
10. Haregeweyn Nedusi, Jean PT, Jan N, et al. Specific sediment yield in Tigray–Northern Ethiopia. Assessment and semi quantitative modeling. *Geomorphology*. 2005;69(1–4):315–331.
11. Amsalu Aklilu, Leo S, Jan DG. Long–term dynamics in land resource use and the driving forces in the Beressa watershed, high lands of Ethiopia. *Environmental Management*. 2007;83(4):448–459.
12. Bobe BW. Evaluation of soil erosion in the Haregie Region of Ethiopia using soil loss models, rainfall simulation and field trials. Doctoral Thesis, Pretoria University. 2004.
13. Makombe G. A comparative analysis of rain fed and irrigated agricultural production in Ethiopia. *Irrigation Drainage System*. 2007;21:35–44.
14. Bewket W, Teferi E. Assessment of soil erosion hazard and prioritization for treatment at the watershed level: case study in the Chemoga watershed, Blue Nile basin, Ethiopia. *Land degradation & development*. 2009;20(6):609–622.
15. FAO (Food and Agricultural Organization). Ethiopian Highland reclamation Study (EHRS). Final Report. 1984; p. 1–2.
16. Abdelsalam A, Hamid U.Sediment in the Nile River system. *UNESCO–IHP–International Sediment Initiative*. 2008;26(1):93.
17. Hurni H. Land degradation, famine and land resource scenarios in Ethiopia: World Soil Erosion and Conservation. In: Pimentel D, editor. UK: Cambridge University Press; 1993:27–61.
18. Berry L, Olson J, Campbell D. Assessing the extent, cost and impact of land degradation at the national level, findings and lessons learned from seven pilot case studies. Commissioned by global mechanism, support from the World Bank. 2003. 204 p.

19. Nyssen JJ, Poesena JM, Jozef D, et al. Human impact on the environment in the Ethiopian and Eritrean highlands. *A state of the art Earth–Science*. 2004;64(3–4):273–320.

20. Omuto CT, Vargas RR, Parson P. Soil erosion and sedimentation modeling and monitoring framework of the areas between rivers Juba and Shabelle in southern Somalia. FAO–SWALIM Technical Report No. 15–16, Nairobi, Kenya. 2009.

21. Zemadim B, Cartne M, Sharma B. Establishing hydrological and meteorological monitoring networks in Jeldu, Diga and Fog era Districts of the Blue Nile Basin, Ethiopia. Report Produced for CPWF Nile Project 2: Integrated rainwater management strategies technologies, institutions and policies. 2012.

22. Desale Kidane, Binyam Alemu. The effect of upstream land use practices on soil erosion and sedimentation in the upper Blue Nile Basin. *Ethiopia Research Journal of Agriculture and Environmental Management*. 2015;4(2):55–68.

23. Wischmeier WH, Smith DD. Predicting Rainfall erosion losses: A guide to conservation. *Agricultural Handbook* . 1978. 537 p.

24. Hurni H. Erosion productivity conservation systems in Ethiopia. Proceedings of the 4th International Conference on Soil Conservation, Maracay, Venezuela. 1985;654–674.

25. DSA and SCI (Development Studies Associates DSA) and SCI (Shawel Consult International). 2006. Potential survey, Identification of opportunities and preparations of projects profiles and feasibility studies. Addis Ababa, Ethiopia.

26. FAO (Food and Agricultural Organization). *Reconnaissance physical land evaluation in Ethiopia*. Addis Ababa, Ethiopia. 1989.

27. Samuel Chemeda. Soil erosion hazard assessment using USLE model: a case study of Legedadi and Dire reservoir Catchment. 2007;1–57.

28. Tesfaye Mebrate. Assessment of the effect of traditional drainage systems on soil erosion, in North Sewa Zone, Amhara Region. MSc Thesis, Haramaya University, Haramaya, Ethiopia. 2008.

29. Ayenaw Maleda. Guideline for watershed management study draft. Addis Ababa Ethiopia; 2008.

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