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RESEARCH ARTICLE

ASSESSMENT OF SEDIMENT ACCUMULATION IN A TOPOGRAPHICALLY CLOSED HIGHLAND LAKE: THE CASE OF LAKE HASHENGE, NORTHERN ETHIOPIA

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ABSTRACT

Ethiopia is endowed with 22 lakes and many reservoir water resources that can be developed and utilized for the wellbeing of the people. However, improper human interference exerted pressure on lakes, reservoirs and rivers draining into them. Lake Hashenge one of the lakes is suffering from excessive sediment loads that have been caused by deforestation, soil erosion, land use change and improper watershed management. The main objectives of the study were to characterize Hashenge catchment, estimate annual sediment accumulation in the lake and estimate the life span of the lake. Hashenge catchment was characterized using field GPS data and topographic maps. Bulk density of the sediment accumulated in the lake was done in a laboratory. Annual sediment yield in the lake was estimated by using HR Wallingford method based on a catchment characterization procedure which combines qualitative factors describing soil type, vegetation cover and signs of active erosion and quantitative information on slopes, rainfall and catchment area. The result revealed that different maps (to develop different maps like location map, drainage map, land use/cover map, texture map, slope map and altitude map) were developed and an annual sediment yield of 45,865 ton or (6.9 ton ha^{-1} $year^{-1}$) is accumulated in the lake every year. The average bulk density of the sediment accumulated in the lake was found to be 1,725 kg/m^3. The volume of sediment accumulated in the lake every year would, therefore, be 26,588.4 m^3. The corresponding average annual depth of sediment deposition in the lake was estimated to be 3.5 mm. The annual sediment yield observed in this study was found to be comparable with studies conducted in reservoir sediment assessment in the other parts of the region. If the sediment accumulation continues like the current situation, the lake could completely be disappeared after 5,714 years.

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1. INTRODUCTION

Ethiopia is endowed with 22 lakes and many reservoir water resources that can be developed and utilized for the wellbeing of the people. However, due to growing population density, deforestation and catchment land use changes are putting more and more pressure on lakes, reservoirs and rivers draining into them (Becht and Harper, 2002 and Ayenew, 2004). As a result this resource is not yet exploited in proper and sustainable way to meet the increasing demand for food and clean water supply. Lake Hashenge is the only closed and high altitude lake in Tigray region lying at about 2440 m above sea level. As part of the surface water resource it can support the economic growth of the region through irrigated agriculture, fish industry and ecotourism farming.

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However, like any part of the region, clearing of natural forests for agriculture, poor grazing and farming systems and topographic features make the Hashenge catchment vulnerable to land degradation and in turn affect the lake. Ethiopia in general and Tigray region in particular have been expanding irrigated agriculture to ensure food for the people. However, the problem associated with environmental degradation and water management of lakes, earth dams, ponds and other water reservoirs hinder the productions. The lake is suffering from excessive sediment loads that have been caused by deforestation, soil erosion, land use change (Sileshi, 2001), and improper watershed management in the catchment areas (Woube, 1997). Lake Hashenge has no source of information regarding its catchment characteristics, sediment accumulation in the lake. Therefore, this study was designed to provide information on catchment characteristics and give quantitative information regarding the sediment accumulation in the lake.

The main objectives of the study were to characterize Hashenge catchment, estimate annual sediment accumulation in the lake and roughly estimate the life span of the lake.

2. MATERIALS AND METHODS

2.1 Description of the study

The study area is located about 160 km south of Mekelle (capital city of Tigray). It is geographically located within 12°32'41'' to 12°39'41'' N and 39°27'30'' to 39°33'18'' E, having an aerial extent of about 80.69 km^2.

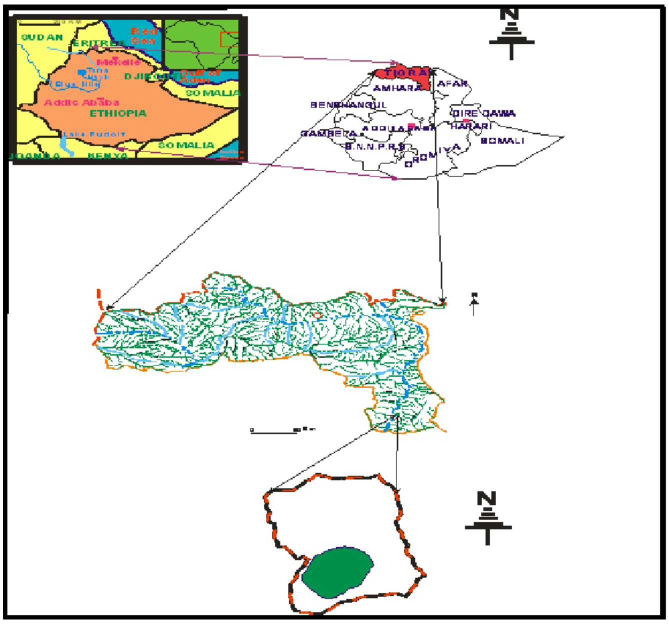

Figure 2.1. Location map of the study area

2.2 Catchment characterization

Soil texture was classified from aerial photograph based on their color. Finger tests (feel method) was used in each types of soil texture for rough identification at field and five composite soil samples from each different soil color map were taken for laboratory and analyzed using hydrometer method. For determination of bulk density of sediment accumulated in the lake, undisturbed soil sample was taken using core sampler and dried for 24 hours at 105 ^{o}C oven dry and was estimated using Equation 1.

$$B_D = M_D/Vc \quad \text{......} \quad (1)$$

Where; B_D = bulk density (kg/m^3), M_D = mass of oven dry soil (kg), V_C = volume of core sampler (m^3).

Data collected from field using GPS was used to develop different maps of the study area. Topographic map was used as a base map to produce all other maps such as location map, land use map, soil textural map and drainage map using Arc view and Ilwis GIS soft ware. Slope and altitude map was also prepared by digitizing contour lines of topographic map using Arcview and Ilwis softwares.

Accordingly, the principal flow path was delineated and the river slope (S) was computed based on the difference in elevation (ΔH) between the end points of the principal flow path and the hydrologic length of the flow path (L) as formulated in Equation 2.

$$S = (\Delta H/L)*100 \quad \text{......} \quad (2)$$

Where; S = slope of the stream (%), ΔH = the difference in elevation over the entire length of the stream (m) and L = length of the stream (m).

2.3 Sediment Estimation

Annual sediment yield in the lake was estimated by using HR Wallingford method which was previously used by Eyasu (2005) for assessment of sediment yield from small catchment in Tigray. HR Wallingford method is based on a catchment characterization procedure which combines qualitative factors describing soil type, vegetation cover and signs of active erosion and quantitative information on slopes, rainfall and catchment area in a simple predictive function. The qualitative factors adopted for the characterization procedures were:

2.3.1 Soil Type and Surface Drainage (SD)

Although the assessment is carried out at the driest time of the year, surface infiltration was gauged by noting soil surface texture (coarse, medium or fine) together with information from local farmers on whether there is extensive ponding on the soil surface after heavy rains.

2.3.2 Vegetation Cover over the whole Catchment (V)

Vegetation cover was done by using plot estimate method in which line transects were laid out. The distance between two consecutive parallel transect lines was 200 m along the transect lines, sample quadrats measuring 20 m X 20 m (400 m^2) were laid down at 50 m interval from each other. In all plots, the proportion of cover by each species and total density were estimated visually (Sutherland, 2000) and finally the score was taken from the HR Wallingford table.

2.3.3 Signs of Active Soil Erosion (E)

Signs of active erosion were verified, by observing the actively eroding gullies draining directly into the lake, and/or active undercutting of riverbanks along main watercourses and finally the score was taken from the HR Wallingford table. Finally sediment yield was estimated by HR Wallingford method (Equation 3) in which qualitative factorial scoring system combined with quantitative data of the catchment (Lawrence *et al.,* 2004).

$$SY=0.0194A^{-0.2}*P^{0.7}*S^{0.3}*E^{1.2}*SD^{0.7}*V^{0.5} \quad \text{......} \quad (3)$$

Where,

SY = Sediment yield (ton/km^2/yr)
A = catchment area (km^2)
P = mean annual precipitation (mm)

S = slope (%) of the main stream that contribute high amount of sediment to the lake.
E = signs of active soil erosion (score from table)
SD =soil type and drainage (score from table)
V = Vegetation conditions over the whole catchment (score from table)

2.4 Materials

The major materials used include GPS, ruler, tape meter, graduated rope, plastic bag, digital camera, topographic map of scale 1:50,000, aerial photograph and GIS software.

3. RESULT AND DISCUSSION

3.1 Catchment Characterization

3.1.1 Drainage characterization

Hashenge catchment is characterized by a centripetal stream patterns that originate from the surrounding highlands and drained towards the lake (Figure 3.1). Each of the small rivers or streams that flow toward the centre of the catchment or lake shows dendritic type.

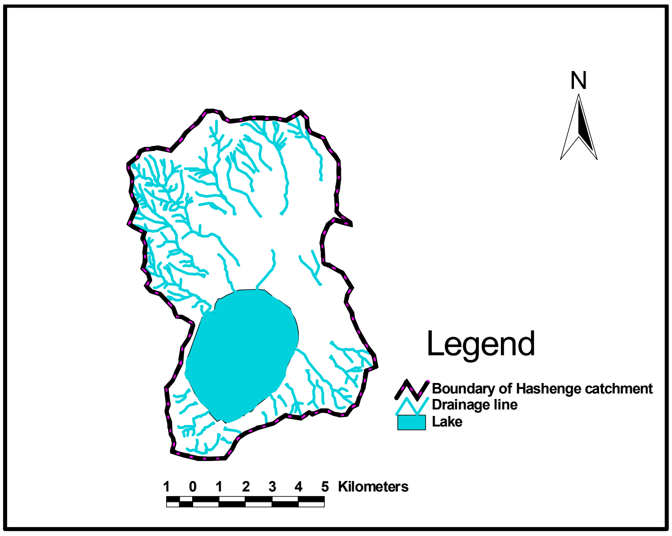

Figure 3.1. Drainage map of the study catchment

Drainage density of Hashenge catchment was found to be 31.4 m/ha. This drainage density shows how well Hashenge catchment is drained by these stream channels. This is because of the upper catchment is characterized by gravel and some exposed bedrock led to an increased in surface water runoff and therefore formed more frequent streams.

3.1.2 Land use/ cover

Four major land use types were identified from the present land use during the field assessment made on the basin. These are cultivated land, grazing land, sparse woodland and water body (Figure 3.2). Of these, cultivated land constitutes 31.8 % of the total area. The agricultural practice is largely undertaken in the slope range 0 -15 %. The major agricultural crops produced in the area were wheat, teff, sorghum, maize, and barely. Grazing land constitutes 9.5 % of the total area. Sparse woodland covers 41.9 %, which is the largest portion of the total area of the catchment. This area which is named as sparse woodland includes areas which are covered with bushes and shrubs. The rest of the land use type is water body which constitutes 16.8 % the total area of the catchment.

Table 3.1. Land use and their respective area coverage

Land Use	Area (m^2)	Area proportion (%)
Grazing land	7631771.028	9.458
Cultivated land	25661466.203	31.803
Water body	13536185.452	16.775
Sparse woodland	33861313.076	41.964
Total	80690735.76	100

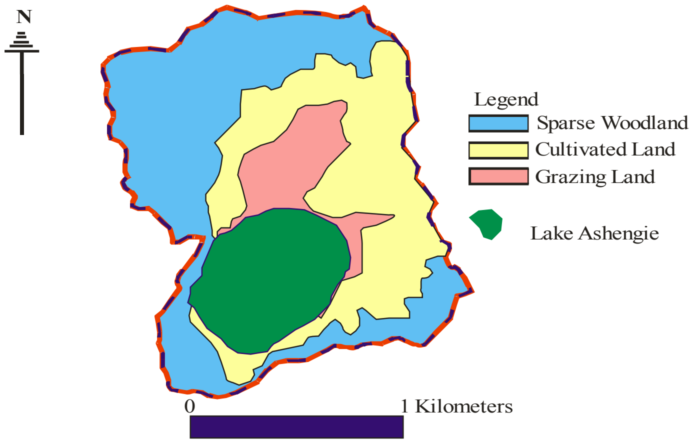

Figure 3.2. Land use-land cover map

3.1.3 Slope characterization

Slope of the catchment was arbitrary categorized into six classes (Figure 3.3). Slope of the main stream reflects the rate of change of elevation with respect to distance along the principal flow path. Since the elevation difference and length of the river were 780 m and 7420 m respectively, the slope of the main stream was found to be 10.5%. On the other hand, the average slope of the watershed calculated using the same approach is 33%. Hashenge catchment is characterized mostly with mountains and flat land surrounding the lake. As a result there are very well defined channels on the steep slopes that can produce extensive runoff.

3.1.4 Altitude characterization

The altitude ranges from 2440 m.a.s.l at the lake border and Hashenge plain to 3600 m.a.s.l at the tip of the North western part of the catchment. The altitude of Hashenge is arbitrary categorized into nine classes (Figure 3.4).

3.1.5 Soil texture and soil hydrologic groups

Based on soil laboratory analysis and aerial photograph for color classification, the grain size and soil texture were classified into different classes based on USDA soil textural classification.

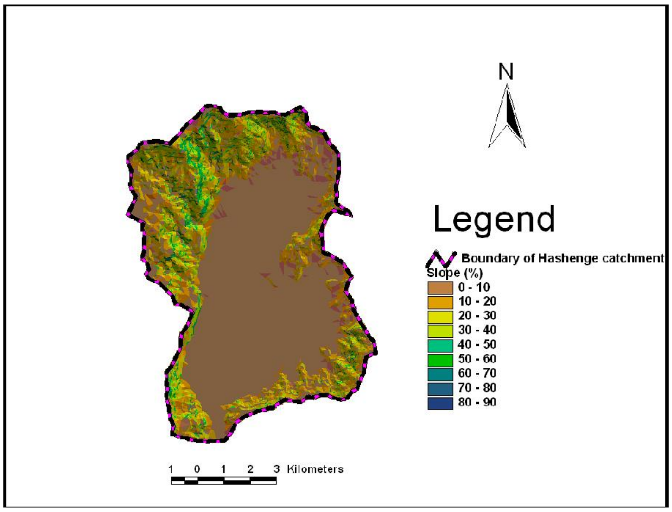

Figure 3.3. Slope map of the study area

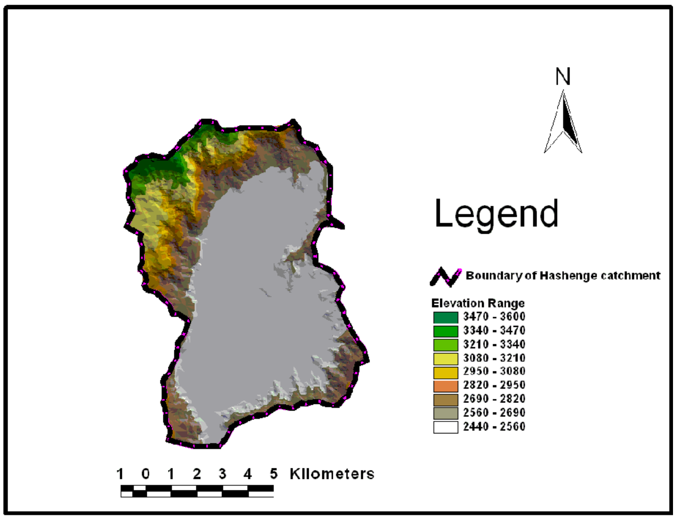

Figure 3.4. Altitude map of Hashenge catchment

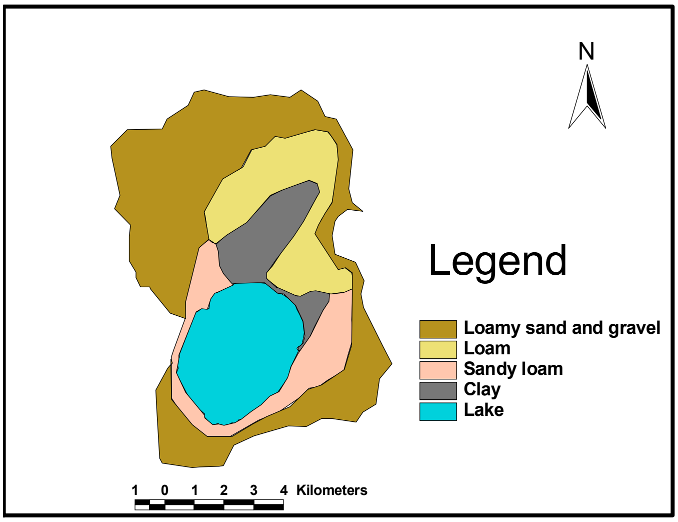

Figure 3.5. Soil texture map

Soil texture results indicate that most of the cultivated land is covered by loam and sandy loam soil while the upper sloppy areas are covered by sand and gravel (rock).

On the other hand marsh area and the grazing land that surround the lake is dominated by clay. This can partly be attributed to alluvial deposit over time as a result of erosion from the steep slopes.

Taking both soil type and drainage and its area coverage into account the weighted average score of the soil type and drainage (SD) was used. Weighted average SD = [(Area of SHG (A)* Score (A) + Area of SHG (B)* Score (B) + Area of SHG (C)* Score (C) + Area of SHG (D)* Score (D))]/ area of (A+B+C+D) = 31.8

Where; A, B, C and D are hydrologic soil groups and the scores were from table.

3.2 Lake sedimentation

The scores for the qualitative factors were taken from table, while the quantitative information was acquired from field data analysis.

Table 3.2 presents the scores for the qualitative taken from table and calculated values of the quantitative information of the catchment

No	Catchment characteristics	Value/Score
1	Catchment area (A) in km^2	66.28
2	Mean annual precipitation(P) in mm	988.7
3	River slope (S)	0.105
4	Signs of active soil erosion(E)	20
5	Soil type and drainage (SD)	31.8
6	Vegetation cover(V)	10

$$SY = 0.0194\ A^{-0.2} * P^{0.7} * S^{0.3} * E^{1.2} * SD^{0.7} * V^{0.5}$$
$$= 0.0194 * (66.28)^{-0.2} * (988.7)^{0.7} * (0.105)^{0.3} * (20)^{1.2} * (31.8)^{0.7} * (10)^{0.5}$$
$$= 8.39*10^{-3} * 124.90 * 0.51 * 36.41 * 11.26 * 3.16$$
$$= 692.37\ ton/km^2/year\ (6.9\ ton\ ha^{-1} year^{-1})$$

This would actually mean an annual sediment yield of 45,865 ton is accumulated in the lake every year. Generally, the sediment yield (6.9 ton $ha^{-1}year^{-1}$) observed in this study was found to be comparable with studies conducted in reservoir sediment assessment in the other parts of the region (Eyasu, 2005) and East Africa studied by (Lawrence *et al.,* 2004). In semi-arid zones, significant runoff events are usually triggered by intense convective rainfall, and annual rainfall totals are approximately proportional to the number of storms that occur. The number of events that erode sediment, and then transport it to reservoir, are thus broadly correlated ($r^2 = 0.95$) with annual rainfall (Lawrence, 2004). According to Eyasu (2005), HR Wallingford method shows a closer relationship between rainfall and for the earthen dam irrigation schemes in Tigray sediment yield. Since no bathymetric survey of sediment thickness has been made in lake Hashenge, this method was used to present the general degree of sedimentation hazard. The average bulk density of the sediment accumulated in the lake was found to be 1,725 kg/m^3. The volume of sediment accumulated in the lake every year would, therefore, be 26,588.4 m^3. The corresponding average annual depth of sediment deposition in the lake was estimated to be 3.5 mm. If the sediment accumulation continues like the current situation, the rough predicted life span of the lake is about 5,714 years. The annual sediment yield of 6.9 ton ha^{-1} yr^{-1} predicted by the

HR Wallingford method is similar to other studies carried out in the region (Eyasu, 2005).

4. Conclusion and Recommendation

The annual sediment yield of 6.9 ton ha $^{-1}$ yr $^{-1}$ predicted by the empirical equation is similar to other studies carried out in the region and can be used as a good indication of the process in the study area. This annual sediment would generally decrease the lake depth by about 3.5 mm annually. Therefore, though Lake Hashenge has a potential to sustainably serve the people, the accumulated sediment is affecting its functions. The on-going integrated watershed management should be continued and its performance needs to be evaluated. Special and immediate attention should be given to the treatment of the big gullies which are contributing huge amount of sediment to the lake. In addition, the on-going practices of cultivation close to the boundary of the lake without leaving any buffer zone should be prohibited and monitoring the depth of the lake at intervals would be very critical to substantiate this result.

5. REFERENCES

Ayenew, T., 2004, "Environmental Implications of Changes in the Levels of Lakes in the Ethiopian Rift since 1970", *Regional Environmental Changes*, 4:192-204.

Becht, R. and Harper, D. 2002, "Towards an Understanding of Human Impact up on the Hydrology of Lake Naivasha".

Eyasu Y., 2005, "*Development and Management of Irrigated Lands in Tigray*", Ethiopia. PhD Thesis. UNESCO-IHE Institute for Water Education. Delft, the Netherlands.

Lawrence, P., Lo Cascio, A., Goldsmith, P. and Abbott, C. L. 2004. Sedimentation in small dams Development of a catchment characterisation and sediment yield prediction procedure impacts on the incomes of poor rural communities akin M.J., Kingham, T.J., Waddams, A.E.,

Sileshi, B., 2001. Investigation of water resources aimed at multi-objective development with respect to limited data situation: The case of Abbaya-Chamo Basin, Ethiopia, [PhD Dissertation], Technical University of Dresden, Germany.

Woube, M., 1997. The geographical distribution and dramatic increase in incidence of malaria: Consequences of the settlement schemes in Gambella, S.W. Ethiopia. *Indian Journal of Malariology,* 34: 140-163.

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