## *Original Research Article*

# Soil loss estimation and community awareness assessment on integrated watershed management: the case of Lake Hashenge watershed, Tigray, Ethiopia

**ABSTRACT**

*Ethiopia is recognized as one of the most severely affected regions by soil erosion globally, posing significant threats to its national economy. This study investigates soil loss estimation and community awareness within the framework of integrated watershed management in the Lake Hashenge watershed, Tigray, Ethiopia. Utilizing the Revised Universal Soil Loss Equation (RUSLE) model, we quantified soil erosion rates and identified critical areas prone to severe soil loss. Our findings indicate significant soil degradation, exacerbated by both natural and anthropogenic factors.The estimated soil loss yield entering Lake Hashenge in the form of sheet and rill erosion was 61.94 tons/ha/year. According to the universal soil loss factsheet, the soil loss estimated in the watershed was categorized as severe, indicating that the lake is in danger. Concurrently, we assessed community awareness and participation in soil conservation practices through surveys and interviewswith a multidisciplinary team of researchers. The results reveal a moderate level of awareness and engagement, highlighting the need for enhanced educational and participatory approaches to foster sustainable watershed management. This research underscores the importance of integrating scientific soil loss assessments with community-based integrated watershed management strategies to mitigate soil erosion, protect the lake from sedimentation, and promote environmental sustainability in the region.*

***Keywords:***  *LakeHashenge, sedimentation, Soil Loss Estimation, Community Awareness, Integrated Watershed Management.Soil loss equation*



## INTRODUCTION

### Background

Ethiopia is recognized as one of the most severely affected areas by soil erosion globally. Soil erosion by water and other factors poses significant threats to the national economy[1]. With over 85% of the population relying on agriculture, the physical loss of soil and nutrients leads to food insecurity[2][3]. [4] It is estimated that soil loss due to erosion in Ethiopia amounts to 1,493 million tons per year, with a substantial portion originating from cultivated fields, especially in steep slope areas. Erosion reduces land productivity at a rate of 2.2% per year[5]. The highlands of Ethiopia, particularly Tigray, experience severe soil erosion due to steep terrain, poor surface cover, intensive cultivation of sloped areas, and degradation of grazing lands from population and livestock pressures.

Environmental issues related to sediments are particularly critical in developing countries, where high population growth increases pressure on natural resources, leading to higher sediment production rates[6]. Sediments provide habitat and nutrients for many benthic organisms and are vital to the aquatic ecosystem[7]. However, sediments can also act as long-term sources of pollutants, affecting water quality and aquatic populations[8]. Nutrients, organic contaminants, and heavy metals in sediments can contribute to lake eutrophication[9]. Eroded soil and nutrients are transported to nearby rivers or deposited in reservoirs or lakes. Sediment yield, the amount of sediment exported by a basin over time, also represents the sediment entering a downstream reservoir.

Sedimentation covers large areas of cultivated land, gradually rendering it infertile due to salinization and acidity from transported nutrients, and deteriorates reservoir areas[10][11]. Over time, Lake Hashenge could dry up like Lake Alemaya in the Oromia region. The Hashenge watershed includes cultivated areas, extensive grazing lands, and the region's only highland lake, Lake Hashenge, surrounded by a series of mountains. The lake supports many farmers, investors, and cooperatives in fishing, provides drinking water for livestock, has recreational value, balances the environment, and plays a significant role in addressing global climate change. However, the lake has been significantly damaged and reduced in size due to sedimentation from steep-sloped areas and overgrazing, with no sediment control mechanisms in place.

Soil erosion is a pervasive environmental issue that undermines agricultural productivity, water quality, and ecosystem health. In the Lake Hashenge watershed of Tigray, Ethiopia, soil loss is particularly acute, posing significant challenges to sustainable land management and local livelihoods. This study aims to estimate the extent of soil loss and assess community awareness of integrated watershed management practices. By employing advanced soil erosion models and conducting comprehensive surveys and interviews with residents, the research seeks to provide a detailed understanding of the current state of soil erosion and the effectiveness of existing management strategies. The findings will offer valuable insights for policymakers, stakeholders, and the local community to enhance watershed management practices and promote sustainable agricultural development in the Lake Hashenge watershed. So, this project is proposed to estimate the soil loss yield entering Lake Hashenge and to assess community awareness of soil erosion and watershed management practices.

## METHODS

### Study area

The Hashenge watershed is situated in the southern zone of the Tigray Region, approximately 160 km south of Mekelle city, en route to Addis Ababa. The catchment area spans 82 km², with altitudes ranging from 2400 to 2900 meters above sea level. The watershed experiences a bimodal rainfall pattern, with an average annual rainfall of 979 mm. The mean monthly air temperature varies between 13°C and 19°C [12]. Geologically, the lake basin is located in a faulted graben within the mid-tertiary flood basalt sequence. Microbialite crusts are found on basaltic boulders and bedrock, along with light brown clay, clay, and lacustrine sediment intercalations. The area exhibits various degrees of weathering and brittle deformation in volcanic rocks, with recent Quaternary fluvial-lacustrine sediments overlaying the basaltic formations [12]. The map and location of the selected watershed for soil loss estimation and Lake Hashenge are shown below.

Map 1: Map of the study area locations

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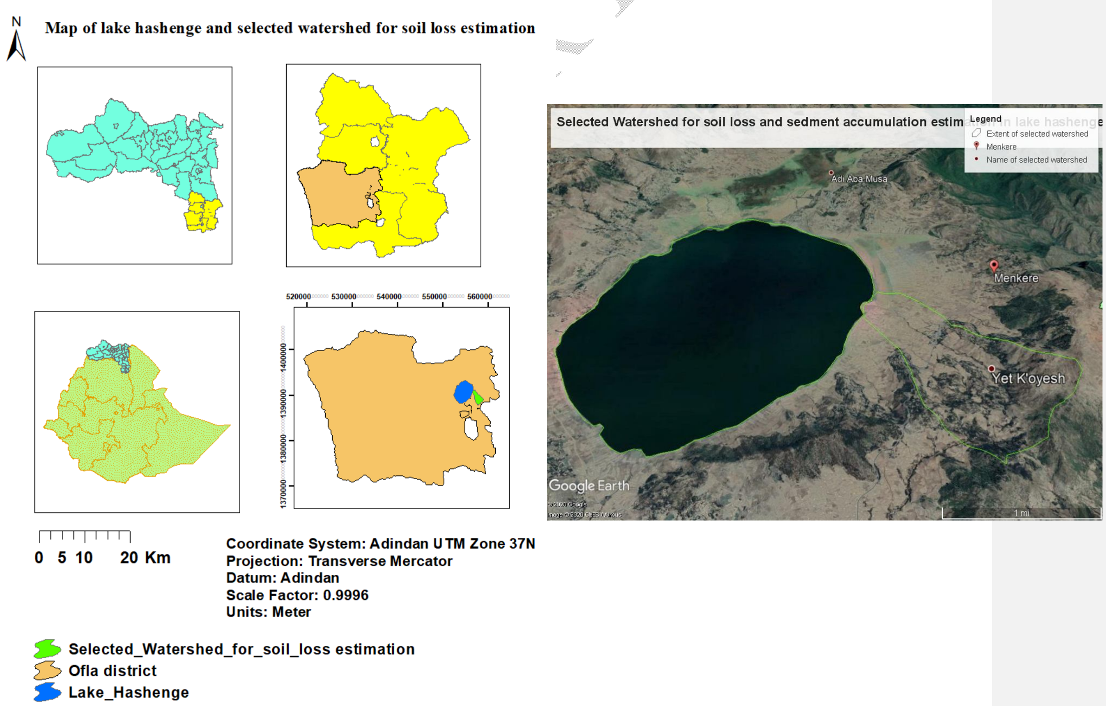

## Sampling Design and Field Survey

### Assessment of community understanding of watershed management

A multi-disciplinary team of researchers specializing in natural resources, livestock, crops, socio-economics, and extension research was assembled to conduct this study. Data were collected on various aspects, including demographic composition, educational backgrounds, wealth and property, household numbers, population size, landholding size, vegetation types and cover, crop production, irrigation practices, livestock production, soiland water conservation (SWC) practices, attitudes towards land degradation and soil erosion, perspectives on watershed management, understanding of climate change, and the benefits and threats to the lake.

The data collection involved preparing questionnaires and conducting interviews with community leaders and elders, religious leaders, district experts, and other stakeholders. These interviews were facilitated through personal contact and purposive group discussions. Approximately 30% of the watershed's residents participated in the interviews. The collected data were analyzed using SPSS software.

### Soil loss Estimation

A topographic transect walk was conducted at 25%, 50%, and 75% across the slope of the watershed, as well as at 50% along the slope length, to assess the existing biotic and abiotic features of the biophysical potential. Regarding the abiotic features, land characteristics such as geological formation, soil texture, drainage, existing soil and water conservation measures, landscape formation, and the living standards of the community were evaluated. Additionally, the distribution and intensity of vegetation species, crop diversification, livestock population, and grazing capacity were assessed during the transect walk. This transect walk facilitated an in-depth study of the watershed. Soil samples were collected from various land uses within the watershed to estimate the soil's erodibility factor. Soil loss was estimated using the Universal Soil Loss Equation (USLE), represented by the following formula:

$$E=R*K*SL*C*P \quad (1)$$

E= loss of soil erosion from the watershed (ton/ha/year)

R= rainfall erosive factor,

K=soil erodibility factor,

SL= slope factor

C = crop management or vegetative cover factor,

P= erosion control practice factor

**Rainfall erosive factor (R)**

R factor is the coefficient of the average erosion by rain (J/m2). Rain has a direct impact on the surface of the soil; its kinetic energy is destroying the soil structure and bringing the soil components together with runoff water. According to [13], the R coefficient is calculated based on the maximum rain volume in 30 minutes, the equation is the following:

$$R = EI30/1000 \text{ --------- } (2)$$

In which: E =the kinetic energy of the rain (J/m2)

I = the maximum rain volume in 30 minutes (mm/h)

However, in many countries, to record enough numbers of EI is difficult, so the equation is hardly applied in many areas. Researchers give other solutions for the R factor. It was suggested to calculate the average rainfall of a year.

According to (Diadato, 2006), the R coefficient can be calculated based on the annual average rainfall, the equation is the following:

$$R = 38.5 + 0.35P \text{ ------------- } (3)$$

In which P is the average annual rainfall (mm/year) [14][15][16].

**Soil erodablity factor (K)**

The K factor represents both the susceptibility of soil to erosion and the amount and rate of runoff. Soil texture, organic matter, structure, and permeability determine the erodibility of a particular soil. This value was estimated using the soil erodibilitynomograph[17]based on the laboratory result of soil texture and organic matter content of the collected soil samples from the watershed.

**Slope factor (SL)**

Slope length and gradient were critical parameters for estimating the slope factor. The slope gradient is the units of fall per unit of horizontal distance and slope length is the horizontal distance downslope from the point runoff starts to the outlet or point of sedimentation[17]. These data were measured at the field to compute the slope factor using Smith and Weischmeier formula.

$$Ls= (length/22.1)\ m\ (0.065+0.0456s+0.006541s2) \text{ -------------- } (4)$$

S= slope in %

m= 0.2 for s< 1%

m= 0.3 for s=1-3%

m=0.4 for s=3.1-4.9%

m= 0.5 for s≥ 5%

**Crop management or vegetative cover factor (C)**

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The crop management factor isthe relation between erosion occurring in bare soil and the erosion observed in a given production or cropping system and will be an estimate based on the bio-physical survey on the representative watershed.

**Erosion control practice factor (P)**

The relation between erosion occurring in a field treated with conservation measures and another reference plot without treatment.

P = 0.5 for slopes 1-8%
P= 0.6 for slopes 8-12%
P= 0.7 for slopes 12-17%
P= 0.8 for slopes 17-20%
P= almost 1 for slopes above 25% [13]

## RESULT AND DISCUSSION

### Assessment of community understanding of watershed management

**Demographic characteristics of the households in the watershed**

Table 1. Demographic characteristics of the households

| | N | Mean | Std. Deviation |
|---|---|---|---|
| Family size | 76 | 5 | 2 |
| Age of the respondent | 76 | 40.5 | 13.1 |
| Years of experience in farming | 76 | 19.6579 | 13.15199 |
| Revenue from on-farm income in birr | 76 | 8.21303 | 12913.67746 |
| revenue from nonfarm income in birr | 76 | 3.41793 | 12801.06740 |

The demographic characteristics of the households provide a comprehensive overview of the socio-economic and farming conditions within the study area. Here is a detailed discussion based on the provided data as discussed in[2][18][19]:

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Use units for each parameters in this table

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Family Size:

The average family size is 5 members, with a standard deviation of 2. This indicates that while most households have around 5 members, there is some variation. Larger family sizes can be beneficial for labor-intensive farming activities but also imply higher consumption needs.

Age of the Respondent:

The mean age of the respondents is 40.5 years, with a standard deviation of 13.1. This suggests that the respondents are generally middle-aged, with a significant range in ages. Middle-aged farmers often have substantial experience and physical capability, but the variation indicates the presence of both younger and older farmers, which can affect the adoption of new agricultural practices.

Years of Experience in Farming:

On average, respondents have 19.66 years of farming experience, with a standard deviation of 13.15. This high level of experience suggests that the farmers are well-versed in traditional farming methods. However, the wide range of experience levels could influence the willingness and ability to adopt innovative farming techniques.

Revenue from On-Farm Income:

The mean revenue from on-farm income is 8,213.03 birr, with a substantial standard deviation of 12,913.68. This large standard deviation indicates significant disparities in income levels among the households. Such disparities could be due to differences in farm sizes, crop types, productivity levels, and market access.

Revenue from Non-Farm Income:

The average revenue from non-farm income is 3,417.93 birr, with a standard deviation of 12,801.07. The high standard deviation suggests that while some households may have substantial non-farm income, others may have little to none. Non-farm income can be crucial for diversifying income sources and reducing vulnerability to agricultural risks.

Implications for Agricultural Development

Resource Allocation: Understanding the demographic characteristics helps in tailoring agricultural interventions. For instance, larger families might benefit from labor-intensive farming techniques, while households with higher non-farm income might invest more in farm improvements.

Training and Extension Services: The variation in age and experience suggests a need for differentiated training programs. Younger and less experienced farmers might require more basic training, while experienced farmers could benefit from advanced techniques and innovations.

Income Diversification: The significant disparities in income highlight the importance of promoting income diversification strategies. Encouraging non-farm activities can provide a buffer against agricultural uncertainties and improve overall household resilience.

These demographic insights are crucial for designing effective agricultural policies and programs that address the specific needs and conditions of the farming community.

**Sex composition of households in the watershed.**

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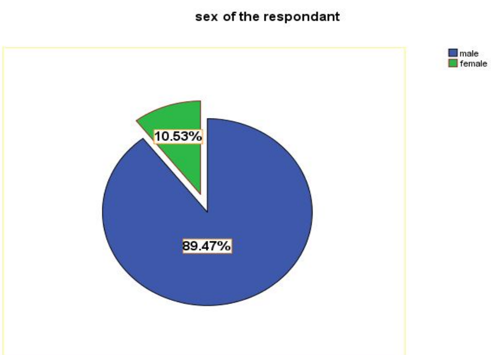


Figure 1. Sex composition of household

The sex composition of the households in the selected watershed, with males comprising 89.47% and females 10.53%, has significant implications for watershed management and community dynamics. The results could be discussed as follows as discussed in [20][21][22].

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**Gender Imbalance:**

The overwhelming majority of males (89.47%) compared to females (10.53%) indicates a significant gender imbalance. This could be due to various factors such as migration patterns, cultural norms, or economic opportunities that favor male presence in the area.

**Impact on Labor Distribution:**

With a higher proportion of males, labor-intensive activities such as land preparation, irrigation, and construction of terraces might be predominantly carried out by men. This could lead to a gendered division of labor where men handle more physically demanding tasks, while women might be involved in less labor-intensive but equally important activities like planting, weeding, and household chores.

**Decision-Making and Leadership:**

The male-dominated composition might influence decision-making processes within the community. Men are likely to hold more leadership positions and have a greater say in community decisions, including those related to watershed management. Ensuring that women's voices are heard and considered is crucial for inclusive and equitable decision-making.

**Access to Resources and Training:**

The disparity in sex composition could affect access to resources and training opportunities. Men might have better access to agricultural inputs, credit, and training programs, while women might face barriers due to their lower representation. Addressing these disparities is essential for promoting gender equality and enhancing the overall effectiveness of watershed management initiatives.

Social Dynamics and Community Cohesion:

The significant gender imbalance can impact social dynamics and community cohesion. It is important to foster an inclusive environment where both men and women feel valued and can contribute to community activities. Encouraging gender-sensitive approaches and promoting women's participation in community affairs can help strengthen social bonds and improve overall community resilience.

**Implications for Watershed Management**

Inclusive Planning and Implementation: Ensuring that both men and women are involved in the planning and implementation of watershed management projects can lead to more effective and sustainable outcomes. Gender-sensitive approaches can help address the specific needs and constraints faced by different groups.

Capacity Building and Empowerment: Providing training and capacity-building opportunities for both men and women can enhance their skills and knowledge, enabling them to contribute more effectively to watershed management. Tailored training programs can address the unique needs of each group.

Policy and Advocacy: Advocating for policies that promote gender equality in resource access and decision-making can help create a more equitable environment. This includes policies that support women's land rights, access to credit, and participation in governance structures.

By considering the sex composition and its implications, watershed management initiatives can be more inclusive, equitable, and effective, ultimately leading to improved livelihoods and sustainable resource management.

**The educational level of households in the watershed**

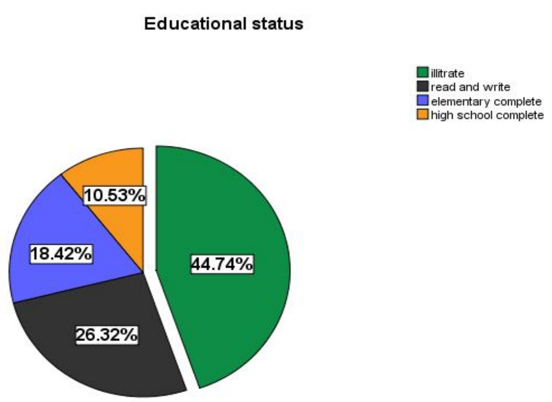


Figure 2. The educational level of the respondents

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The educational level of households in the watershed reveals some important insights as discussed in [23][24][25][26]:

Illiterate (44.74%): Nearly half of the population in the watershed is illiterate. This high percentage indicates a significant barrier to accessing information and resources that could improve their livelihoods. It also suggests a need for targeted educational programs and literacy campaigns to enhance basic reading and writing skills.

Read and Write (26.32%): Over a quarter of the population can read and write but may not have formal education. This group has the potential to benefit from adult education programs and vocational training that can help them apply their literacy skills in practical ways, such as in agriculture or small business management.

Elementary Complete (18.42%): A smaller portion of the population has completed elementary education. These individuals likely have a foundational understanding of various subjects, which can be built upon with further education and training. They are in a better position to adopt new agricultural techniques and participate in community development initiatives.

High School Complete (10.53%): The smallest group has completed high school. These individuals are likely to have a broader knowledge base and better critical thinking skills. They can play a crucial role in leadership positions within the community, advocating for sustainable practices and helping to implement watershed management strategies.

Overall, the data suggests a need for comprehensive educational interventions at multiple levels to improve literacy and educational attainment. Enhancing education can empower the community to better manage their natural resources, adopt sustainable agricultural practices, and improve their overall quality of life.

**The religion of the households**

Table 2. The religion of the household

| Religion | Frequency | Percent |
|---|---|---|
| Orthodox | 75 | 98.7 |
| Muslim | 1 | 1.3 |
| Total | 76 | 100.0 |

The religious composition of the watershed, with 98.7% Orthodox Christians and 1.3% Muslims, can have several impacts on the community and its approach to watershed management:

**Cultural Practices and Beliefs**

Orthodox Christianity: The dominant religion likely influences many cultural practices and community events. For example, Orthodox Christians may have specific traditions related to land use, water conservation, and agricultural practices. Religious holidays and fasting periods can also affect agricultural cycles and labor availability.

Muslim Community: Although a small minority, the Muslim community may have unique practices and beliefs that influence their interaction with the environment. Understanding these practices can help ensure inclusive and respectful watershed management strategies.

**Types of land ownership and land use system**

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Table 3. Land ownership and use

| | N | Mean | Std. Deviation |
|---|---|---|---|
| Owned land under rainfedper 0.25 ha | 76 | 1.1414 | 0.88538 |
| Rented land under rainfedper 0.25 ha | 76 | 0.5987 | 1.12552 |
| Shared land under rainfedper 0.25 ha | 76 | 0.9408 | 1.20821 |
| The total land under rainfedper 0.25 ha | 76 | 2.7270 | 1.69075 |
| Owned land under irrigation per 0.25 ha | 76 | 0.0493 | 0.20420 |
| Rented land under irrigation per 0.25 ha | 76 | 0.0263 | 0.16114 |
| Shared land under irrigation per 0.25 ha | 76 | 0.0066 | 0.05735 |
| Total owned land under irrigation per 0.25 ha | 76 | 0.954 | 0.3239 |

The data on land ownership and land use systems in the watershed provides valuable insights into how land is utilized and managed. Here is a detailed discussion as discussed in[27][28][29]:

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## Types of Land Ownership and Use

**Owned Land under Rainfed Agriculture**

Implications: The majority of the land is owned and used for rainfed agriculture. This indicates a reliance on natural rainfall for crop production, which can be risky due to variability in rainfall patterns. The relatively high standard deviation suggests significant variation in the amount of land owned by different households.

Rented Land under Rainfed Agriculture

Implications: Renting land for rainfed agriculture is also common, though less so than owning. The high standard deviation indicates variability in the amount of rented land, which could reflect differences in economic status or access to land.

Shared Land under Rainfed Agriculture

Implications: Shared land arrangements are prevalent, suggesting a collaborative approach to farming. This can be beneficial for pooling resources and labor but may also present challenges in terms of coordination and management.

Total Land under Rainfed Agriculture

Implications: The total land under rainfed agriculture is substantial, highlighting the importance of this type of farming in the watershed. The high standard deviation again points to significant differences in landholdings among households.

**Land under Irrigation**

Owned Land under Irrigation

Implications: Ownership of irrigated land is minimal, indicating limited access to irrigation infrastructure. This could be a critical area for development to improve agricultural productivity and resilience.

Rented Land under Irrigation

Implications: Renting irrigated land is even less common, suggesting that irrigation resources are scarce and possibly expensive to access.

Shared Land under Irrigation

Implications: Shared irrigation land is rare, which might indicate challenges in managing shared irrigation systems or a preference for individual control over such valuable resources.

Total Owned Land under Irrigation

Implications: The total amount of irrigated land is very low compared to rainfed land. This underscores the need for investment in irrigation infrastructure to enhance agricultural productivity and reduce dependency on rainfall.

Overall Implications

Rainfed Dominance: The data shows a heavy reliance on rainfed agriculture, which is vulnerable to climate variability. Enhancing irrigation infrastructure could significantly improve agricultural resilience and productivity.

Land Ownership Patterns: The variation in land ownership and use suggests economic disparities among households. Addressing these disparities through equitable land distribution and access to resources could improve overall community well-being.

Collaborative Farming: The prevalence of shared land use indicates a tradition of collaborative farming, which could be leveraged for community-based watershed management initiatives.

**Perception of the sampled households on climate change and its effect.**

Table 4. Perception of households on climate change

| | N | Percent |
|---|---|---|
| Yes | 50 | 65.8 |
| No | 26 | 34.2 |
| Total | 76 | 100 |

Majority Awareness: A substantial majority of the households (65.8%) acknowledge the existence of climate change. This indicates a high level of awareness about environmental changes and their potential impacts.

Implications: This awareness can be leveraged to promote community-based adaptation strategies. Households that recognize climate change are more likely to support and participate in initiatives aimed at mitigating its effects, such as sustainable farming practices, water conservation, and reforestation projects.

Minority Skepticism: A significant minority (34.2%) do not perceive climate change as a reality. This skepticism could stem from a lack of information, differing interpretations of environmental changes, or cultural beliefs.

Implications: Addressing this skepticism is crucial for comprehensive community engagement. Educational programs and awareness campaigns can help bridge the knowledge gap and demonstrate the tangible impacts of climate change on local livelihoods and ecosystems.

**Effects of climate change on the watershed**

Table 5. Observable changes in the watershed due to climate change

| | Frequency | Percent |
|---|---|---|
| Rainfall reduction and temperaturefluctuations | 20 | 26.3 |
| Productivity and fertility loss | 13 | 17.1 |
| Reduction in vegetation cover | 13 | 17.1 |
| No response | 30 | 39.5 |
| Total | 76 | 100 |

The perceptions of farmers regarding observable changes in the watershed due to climate change highlight several key concerns:

Rainfall Reduction and Temperature Fluctuations

Perception: A significant portion of farmers (26.3%) have noticed changes in rainfall patterns and temperature fluctuations. This includes reduced rainfall, unpredictable weather, and more extreme temperature variations.

Implications: These changes can lead to water scarcity, affecting crop irrigation and livestock. Farmers may need to adopt water-saving techniques, such as rainwater harvesting and efficient irrigation systems, to cope with these changes.

Productivity and Fertility Loss

Perception: Some farmers (17.1%) have observed a decline in soil productivity and fertility. This could be due to soil erosion, nutrient depletion, and increased soil salinity.

Implications: Loss of soil fertility can reduce crop yields and affect food security. Farmers might need to implement soil conservation practices, such as crop rotation, organic farming, and the use of cover crops, to restore soil health.

Reduction in Vegetation Cover

Perception: Another group of farmers (17.1%) has noticed a reduction in vegetation cover. This could be due to deforestation, overgrazing, and prolonged droughts.

Implications: Reduced vegetation cover can lead to increased soil erosion, loss of biodiversity, and changes in local microclimates. Reforestation, agroforestry, and sustainable grazing practices can help restore vegetation cover and improve ecosystem health.

No Response

Perception: A significant portion of farmers (39.5%) did not respond to observable changes. This could indicate a lack of awareness, uncertainty about the changes, or reluctance to acknowledge them.

Implications: Engaging this group through education and awareness campaigns is crucial. Providing clear information about climate change impacts and practical adaptation strategies can help increase their understanding and participation in mitigation efforts.

Strategies for Addressing Perceptions and Adaptation

Educational Programs: Develop targeted educational programs to raise awareness about climate change and its impacts. Use local examples and practical demonstrations to make the information relatable and actionable.

Community Workshops: Organize workshops that focus on climate-smart agriculture, water management, and soil conservation. Involve local experts and successful farmers to share their experiences and best practices.

Demonstration Projects: Establish demonstration plots that highlight effective adaptation strategies, such as drought-resistant crops, efficient irrigation systems, and agroforestry practices. Seeing tangible results can encourage wider adoption.

Collaborative Efforts: Foster collaboration among farmers, local authorities, and environmental organizations to develop and implement community-based adaptation plans. This can include joint efforts in reforestation, water conservation, and sustainable land management.

**Percentage response of households on the impact of land degradation and its effect on the watershed**

Table 6. Impact of land degradation and its effect on the watershed

| | Frequency | Percent |
|---|---|---|
| Loss of production and soil fertility | 26 | 34.25 |
| Soil erosion and land degradation | 42 | 55.25 |
| No response | 8 | 10.5 |
| Total | 76 | 100 |

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The perceptions of households regarding the impact of land degradation on the watershed reveal significant concerns:

Soil Erosion and Land Degradation

Perception: Most households (55.25%) identify soil erosion and land degradation as major issues. This indicates a widespread recognition of the physical degradation of the land, which can lead to reduced agricultural productivity and increased vulnerability to extreme weather events.

Implications: Soil erosion can strip away the fertile topsoil, reducing the land's ability to support crops. It can also lead to sedimentation in water bodies, affecting water quality and aquatic ecosystems. Addressing soil erosion through practices like terracing, contour plowing, and reforestation is crucial for maintaining land productivity and watershed health.

Loss of Production and Soil Fertility

Perception: A significant portion of households are concerned about the loss of production and soil fertility. This reflects the direct impact of land degradation on agricultural yields and food security.

Implications: Loss of soil fertility can result from nutrient depletion, soil compaction, and erosion. This can lead to lower crop yields and increased reliance on chemical fertilizers, which can further degrade the soil. Implementing sustainable farming practices, such as crop rotation, organic amendments, and conservation tillage, can help restore soil fertility and improve productivity.

No Response

Perception: A smaller group of households (10.5%) did not respond to the question about land degradation. This could indicate a lack of awareness or understanding of the issue, or it might reflect other priorities or concerns.

Implications: Engaging this group through targeted education and awareness campaigns is important. Providing information about the causes and consequences of land degradation, as well as practical solutions, can help increase their understanding and involvement in conservation efforts.

By addressing the concerns and perceptions of households, you can develop a more effective and inclusive approach to managing land degradation and promoting sustainable practices in the watershed.

**Soil loss estimation**

According to the survey, 76% of respondents observed that the lake's size has been decreasing over time. Previously, the lake covered an area of 20 km² [30]. However, our recent GPS delineation shows that the lake's surface area has now reduced to 14.75 km², primarily due to sedimentation.

The estimation of soil loss in the watershed using the Universal Soil Loss Equation (USLE) for each factor and combining all factors yielded the following results:

**Rainfall Erosive Factor ®:** Based on the relationship between mean annual rainfall and the rainfall erosive factor[31], the R factor is calculated to be 65.36.

Table 7. Rainfall erosivity factorfor different land use

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Average RF | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainfall (mm) | 0 | 0 | 53.6 | 127.3 | 42.7 | 42.5 | 211.9 | 272.9 | 67.3 | 70.7 | 0 | 32 | 76.74 | 65.36 |

Ethiopian Metrology Agency, Mekelle branch 2015

**Soil erodibility factor (K)**

This value was estimated using the methodologies described by Westheimer and Smith (1978) and Renard et al. (1996). The estimation was based on the analyzed results from the soil laboratory, which examined soil texture, structure, and organic matter content of the collected soil samples from representative areas in the watershed across different land uses. Consequently, the average soil erodibility factor was determined to be 0.422.

Table 8. Soil erodibility factor for different land use

| S. N | Land use | Soil textural class | Organic matter content (%) | K-value |
|---|---|---|---|---|
| 1 | Grazing land | Sandy loam | 1.35 | 0.31 |
| 2 | Cultivated land | Loam | 1.11 | 0.76 |
| 3 | Homestead | Sandy loam | 0.64 | 0.31 |
| 4 | Rangeland and area closure | Sandy loam | 0.54 | 0.31 |
| Average K value | | | | 0.422 |

**Slope factor (SL)**

Considering the relationship between slope and erosion, the average slope and topographic factor was determined to be 7.83.

Table 9. Slope factor for different land use

| S.N | Land use | Average slope (%) | Average slope length(m) | SL value |
|---|---|---|---|---|
| 1 | Grazing land | 1.65 | 184.6 | 0.299 |
| 2 | Cultivated land | 2.75 | 1173 | 0.790 |
| 3 | Homestead | 9 | 375 | 4.14 |
| 4 | Hillside area | 24 | 621 | 26.12 |
| | | Average SL value | | 7.83 |

**Crop management of vegetative cover factor (C)**

The average crop management factor for the watershed was calculated to be 0.478

Table 10. Crop management factor for different land use

| S.N | Land use | Crop cover | C value |
|---|---|---|---|
| 1 | Grazing land | Grass | 0.01 |
| 2 | Cultivated land | Two cropping season<br>Wheat, sorghum, barley, maize | 0.9 |

| | | | |
|---|---|---|---|
| 3 | Homestead | Grasses, bushes, and a few forest area | 0.5 |
| 4 | Hillside area | Grasses and mostly bare land | 1 |
| Average value | | | 0.478 |

**Erosion control practice factor (P)**

The average erosion control practice factor for the watershed was 0.6.

Table 11. Erosion control practice factor for different land use

| S.N | Land use | Average slope (%) | P-value |
|---|---|---|---|
| 1 | Grazing land | 1.65 | 0.5 |
| 2 | Cultivated land | 2.75 | 0.5 |
| 3 | Homestead | 9 | 0.6 |
| 4 | Hillside area | 24 | 0.8 |
| | | Average P value | 0.6 |

Based on the results above and the factors for soil loss estimation, the estimated soil loss yield entering Hashenge Lake through sheet and rill erosion is summarized in Table 12.

Table 12. Soil loss estimation of Hashenge watershed

| R factor | K factor | SL factor | C factor | P factor | Soil loss(ton/ha/year) |
|---|---|---|---|---|---|
| 65.36 | 0.422 | 7.83 | 0.478 | 0.6 | 61.94 |

Combining these factors, the estimated soil loss for the Hashenge watershed is 61.94 tons per hectare per year.The results align with previous studies, which estimated soil loss in Ethiopia to be 42 tons per hectare per year from cultivated fields [32][i]. In Tigray, northern Ethiopia, soil loss was estimated to range from 30 to 80 tons per hectare per year [33].According to the USLE factsheet [34][13]the soil loss estimated in this study indicates severe potential soil loss.

Table 13. Potential soil loss fact sheet

| Soil erosion class | Potential soil loss (tonnes/ha/year) |
|---|---|
| Very low | <6.7 |
| Low | 6.7-11.2 |
| Moderate | 11.2-22.4 |
| High | 22.4-33.6 |
| Severe | >33.6 |

This value underscores the severity of soil erosion in the area, posing a threat to the lake and emphasizing the urgent need for effective soil conservation strategies. In summary, the soil loss estimation for the Hashenge watershed is influenced by a combination of rainfall intensity, soil properties, topography, crop management, and erosion control practices. Implementing targeted interventions to address these factors can help protect the lake from sedimentation threats, mitigate soil erosion, and promote sustainable land management in the watershed.

## CONCLUSION

This integrated watershed study was conducted in response to the interests of the watershed community and district administration. The soil loss yield entering the lake from the watershed was classified as severe, and the local community's awareness of watershed management and the severity of sediment loss to the lake was found to be moderate to low. Consequently, the lake is endangered. The results reveal a moderate level of awareness and engagement, highlighting the need for enhanced educational and participatory approaches to foster sustainable watershed management. This research underscores the importance of integrating scientific soil loss assessments with community-based watershed management strategies to mitigate soil erosion, protect the lake from sedimentation, and promote environmental sustainability in the region. In addition, intensive soil-conserving interventions, along with biological measures, should be initiated, starting at the top of the mountains with appropriate technologies tailored to each specific area. Experience sharing should be conducted to sensitize the community at similar watersheds, particularly Lake Alemaya in Oromia, Ethiopia. The community should be convinced and mobilized to construct conservation structures and plant grasses, fodder trees, and multipurpose tree species. Additionally, grazing lands, which are exacerbated by livestock grazing, should be protected from grazing in all seasons.

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