VOL 8(2), 238-256
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ISSN: 2523-1901 (Online)
URL: http://jessd.mwu.edu.et/
Email: JESSDeditorials@mwu.edu.et
JESSD Journal of Equity in Sciences & Sustainable Development

DOI: https: //doi.org/10.20372/mwu.jessd.2025.1586

Full Length Research Paper

Assessment of Farmers' Socioeconomic Characteristics and Conservation Practices for Watershed Management in Southwest Ethiopia

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Article Info

Article History
Received: 06 April 2025
Accepted: 4 Jun 2025

Keywords:
Water quality, Conservation practice, Gilgel-Gibe, Reservoir, Local people, Watershed degradation

Abstract

Conserving watershed resources is crucial for both the environment and communities. Identifying the socioeconomics and conservation practices of farmers can help address environmental threats. The study area, which surrounds the Gilgel Gibe Reservoir I, is important regionally and nationally due to a hydroelectric dam project. This study is a cross-sectional study focused on the socioeconomic and conservation practices of 305 households in four districts of the Jimma Zone which were selected using probability proportion (proportion allocation). A semi-structured questionnaire (made up of demographic characteristics, socio-economic and watershed conservation and management practice) with open-ended and codified answers was developed in English, translated from English to Afan Oromo and vice versa by another person to assess its precision. The questionnaire was pre-tested outside the study area to assess respondents' understanding of the questions and to identify any problems encountered during interviews. The data was analysed using SPSS version 20. The study found one hundred and ten (36%) farmers were within the good practice range whereas most farmers about ninety-five (63.9%) had poor conservation practices like unwise farming, putting stress on natural resources and degrading watersheds, leading to pollution and affecting water quality. To improve their livelihoods, farmers are forced to engage in harmful practices. This underscores the urgent need for improved conservation practices among farmers to protect natural resources and highlights the importance of sustainable farming to prevent pollution and maintain water quality. These findings help policymakers prioritize farmers' needs, enhance land management, and promote best agricultural practices for sustainability. We suggest that stakeholders establish a team of elders and officials at the woreda and zonal level and set criteria, recommend technologies to promote conservation activities, income-generating activities such as conservation agriculture, at the household level and access to resources

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1. Introduction

Watershed management is the application of a set of resource management practices to ensure water quality while sustaining the ecosystems (Tomer, 2004). Watersheds exhibit complex and dynamic characteristics, in which several processes occur simultaneously within well-defined natural systems (Bishop et al., 2005) and it is an area of exceptional land enclosed by hills and ridges that drains rainwater or snow into one location or common water body such as a stream, river, lake or wetland (Walter et al., 2007). Thomas et al. (2009) have identified three benefits of watershed management to human beings. Firstly, it sustains the productive capacity of natural resources in the watershed area; secondly, ecologically it arrests the degrading routes; and thirdly, economically it is more cost-effective than the rehabilitation of damaged watersheds, encompassing the final goal to increase the economic and social wellbeing of the local people of the watershed specifically and the nation as a whole.

Watershed performance can be disturbed directly or indirectly due to different factors, Soil erosion (Durga Rao and Kumar, 2004) watershed slope, intensity and development size (Goff and Gentry, 2006) vegetation cover, landscape, vicinity to watercourses and soil (Chowdary et al., 2013). Throughout the world, due to population growth, there is pressure on resource exploitation of the watershed ecosystem for food and other services essential to humans. Numerous socio-economic pressures together with pollution and scarcity of water, Land degradation are problems encountered in watersheds in tropical regions (Firdaus et al., 2014). In Ethiopia and most developing countries, human activity aggravates natural resource degradation (Bewket and Sterk, 2005). In many parts of the world, this situation initiated increased economic and environmental problems. In Ethiopia accelerated population growth, extensive soil degradation, widespread deforestation, sparse vegetation, and an imbalance between crop and livestock production (Asnake, 2024) hence there is a growing requirement to sustain the structure and function of watersheds to improve their role in supporting human populations while simultaneously maintaining ecosystem needs (Randhir and Hawes, 2012).

Ethiopia's community-based watershed development (CWD) program is a nationwide, integrated initiative that utilizes mass mobilization to implement soil and water conservation measures. Its objectives include protecting soil, water, and vegetation; capturing excess water to establish water sources and replenish groundwater; encouraging sustainable farming practices to ensure stable crop yields; restoring and reclaiming degraded lands; and improving the livelihoods of individuals, particularly the most vulnerable rural populations. Extensive land rehabilitation and natural resource conservation activities are being carried out across the country, including in the Oromia region (MEFCC, 2018).

Among the most widely applied resource management strategies, watershed management is an effective approach applicable across various climatic conditions (Reddy et al., 2017). In Ethiopia, the current strategy focuses on mobilizing conservation practices at the watershed level and promoting greater participation (Teshome et al., 2016). Watershed management covers a range of skills and knowledge and aims to restore damaged lands and water bodies while minimizing the impact of natural and human-induced pollutant loading, ensuring harmony with human needs (Wortmann et al., 2008). Though watershed management is also another area of focus so far, it is not encouraging at the local level (Birhane, 2002). Watershed management in developing countries is more focused on local peoples' requirements and sustainable livelihoods and in the contemporary context, it is people-oriented and process-based (Tiwari et.al, 2008). Information can be obtained from farmers' knowledge of their fields and watershed (Wortmann et al., 2008). Intellectuals give attention to peoples' environmental perceptions and attitudes to conserve natural systems (Lee and Zhang, 2008). Many studies revealed environmental attitudes particularly farmers are important in decision-making and this makes it easier to improve effective conservation and management strategies (Abdulkarim et al., 2017). The top-down approach did not bring about significant results in soil and water conservation (Bewket and Sterk, 2002) therefore effective operation of the program requests Peoples' involvement, which is known to be a key factor (Reddy et al., 2017).

Agriculture and conservation are essential for human well-being and environmental health. The challenge is balancing food production with ecosystem protection, ensuring that land and water resources remain sustainable for future generations. Agriculture serves as a provisioning ecosystem service by supplying food, while nature conservation supports a combination of all four types of ecosystem services (provisioning, regulating, supporting, and cultural) helping maintain ecological balance and overall sustainability (**Franks** et al**., 2017**). In order to guarantee the ecological security of the land, it also requires that areas with important ecological functions be included in the protection (Lin et al., 2016).

In Ethiopia, as in many other African nations, the expansion of agriculture is the primary economic factor contributing to deforestation and the decline of biodiversity (Tsegaye, 2022). It plays a major role in driving the current biodiversity decline (Kehoe, et al., 2017), and finding effective strategies to balance agriculture and biodiversity conservation continues to be a significant challenge for researchers (Johnson et al., 2017). This issue is especially crucial for tropical and subtropical forests, which are rich in biodiversity but also heavily affected by agricultural expansion and intensification (Barlow et al**.**, 2018**).** A detailed examination of deforestation patterns in Ethiopia reveals that the southwest region, home to 1.7 million hectares of forest, experiences the highest rates of conversion of natural forests to other land uses (Franks et al., 2017).

The study area holds significant importance and plays a vital role at both regional and national levels. Its impact is evident in several key areas like Power Supply & Development, as the Gilgel Gibe dam generates electricity essential for local economic activities, industrial growth, and infrastructure improvement; Agricultural Benefits, where regulated water flow enhances irrigation, supporting farming communities and boosting productivity; Environmental Impact, through watershed conservation efforts that mitigate soil erosion and sustain biodiversity, benefiting ecosystems; Employment Opportunities, as construction, operation, and maintenance of the dam create jobs, improving local livelihoods; and Economic Growth, with hydroelectric power strengthening national industries, attracting investments, and advancing Ethiopia's economic development goals. Based on a reconnaissance survey, we identified substantial watershed degradation caused by agricultural activities, leading to severe soil erosion, declining soil fertility, and reduced biodiversity. These findings highlight the urgent need for research aimed at developing sustainable watershed management strategies within the sub-watershed of the Gilgel Gibe catchment. Excessive sedimentation is one of the factors that reduced the lifespan of the hydropower plant (Devi et al., 2008). Lack of appropriate conservation practices in watershed management may cause sedimentation or siltation of the dam. Gilgel Gibe I reservoir water quality is strongly associated with land-use changes and has the highest pollution load (Woldeab et al., 2019). Therefore, the study aimed to assess farmers' conservation practices on sub-watershed management across the Gilgel Gibe catchment as a means of determining necessary interventions for addressing environmental threats. Furthermore, the study is important to transfer the current status of the watershed, farmers' conservation and management practices as to aware stakeholders for future management plan and other interested parties found in similar agroecological areas can use the information and organize the required action.

Our primary focus in formulating the hypothesis is to evaluate their conservation practices in watershed management. Accordingly, we propose the research question: what factors are likely to influence the watershed ecosystem? Based on this, we hypothesize that the absence of proper conservation practices would negatively impact the ecosystem of the watershed.

2. Materials and Methods

2.1 Description of the study area

The Gilgel Gibe catchment is situated in southwest Ethiopia, approximately 260 km from Addis Ababa. It spans an area of about 4,225 km², with an elevation ranging from 1,096 to 3,259 meters above sea level. The catchment comprises four sub-watersheds—Gibe, Nedi, Nadaguda, and Yedi—located within the districts of Kersa, Omo Nada, Sekoru, and Tiro Afeta. Geographically, it lies between 7° 22' 72" and 7° 34' 84" latitude north and 37° 21' 05" and 37° 28' 80" longitude east. The study area features rugged hills and mountains, with an average elevation of around 1,700 meters above mean sea level. It has a wet climate, receiving an annual average rainfall of approximately 1,550 mm, with an average temperature of 19°C (Tamene et al., 2013).

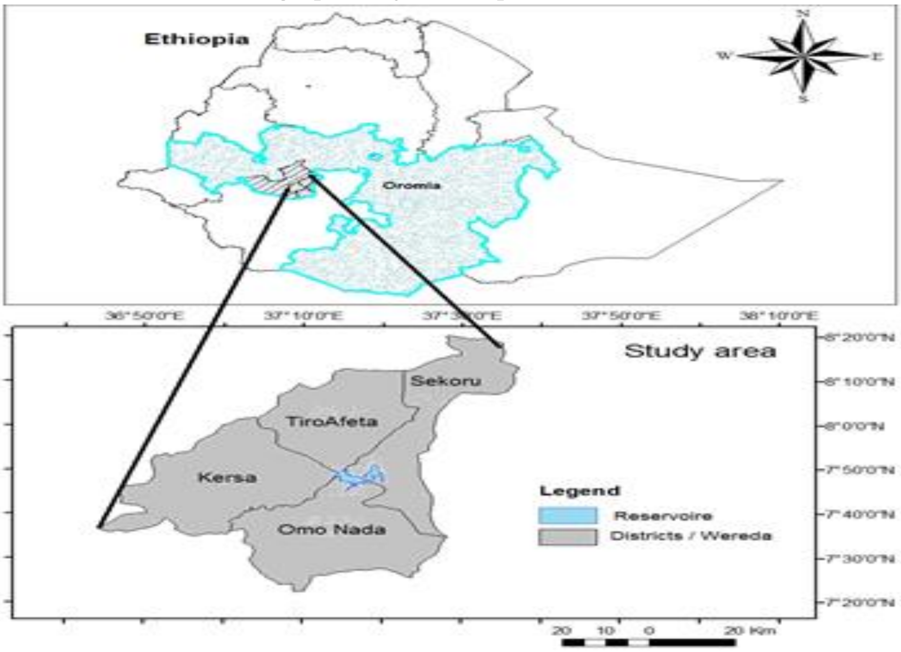

Figure 1: Study area location of districts (weredas) in Gilgel Gibe watershed

2.1.1. Climate

The study area is characterized by high-relief hills and mountains with an average elevation of about 1,700 m above mean sea level. The climate of the study area is classified as tropical humid and belongs to the high-altitude cool tropic area of the country. There is unimodal pattern of seasonal rainfall distribution where up to 60% of the rainfall falling during the rainy season (Demissie et al., 2013). According to unpublished data of Ethiopian National Meteorological Agency, from the year 1968–2015, the average annual rainfall in Jimma stations was 243 mm and minimum (43 mm) recorded in August and December, respectively. The maximum mean monthly rainfall (287 mm) was occurred during June.

2.1.2 Soil and landuse

The study area has fertile soils that support diverse agricultural activities. The region is characterized by Nitisols and Vertisols, which are well-suited for coffee cultivation, a major economic activity. Land use in Jimma includes forests, farmlands, grazing areas, and urban settlements. However, soil degradation due to deforestation, intensive farming, and erosion poses challenges to sustainable land management (Foth, 1990).

2.2 Sampling and Sample size

Sampling was conducted between June 29 and July 15/2017. According to the population and housing census made in 2007, the total number of households in the study districts was 9442 (Sokoru=3656, Tiroafeta=1410, Kersa=1344, and Omonada=3032). The sample size was determined using the single population proportion formula; $n = Z^2pq/\delta^2$

Where **z** is the 95% confidence level (1.96), P is the proportion (75%) and **δ** is the margin of error and to keep (maintain) the nonresponse rate we have calculated 10% of the total sample and add on it.

2.3 Method of data collection and analysis

The study population for interviews consisted of all farmers living, cultivating, or managing land within the Gilgel Gibe watershed. Households were selected through quota sampling, based on the assumption that they shared similar knowledge of watershed conservation. Farmers encountered during the selection process were interviewed until the required sample size was met. Additionally, relevant literature was reviewed to support the study.a semi-structured questionnaire made up of demographic characteristics, socio-economic and watershed conservation and management practice with open-ended and codified answers was developed in English. It was translated from English to Afan Oromo and vice versa by another person to assess its precision. The questionnaire was pre-tested outside the study area to assess respondents' understanding of the questions and to identify any problems encountered during interviews. Some questions in the knowledge and attitude parts were modified based on the feedback from this pre-test. Data collectors who are high school students and fluent in the local language were selected from members of the local communities in their respective districts.

The questionnaire consisted of 24 questions, including 7 on demographic characteristics, 11 on socio-economic aspects, and 6 aimed at assessing watershed conservation and management practices for quantitative data analysis. Interviews were conducted at the household level, considering all individuals residing in the same dwelling, and focused on demographic and socio-economic characteristics as well as local watershed conservation efforts. The study was designed for 305 households across four districts—Omonada (97), Tiroafeta (46), Kersa (38), and Sokoru (124)—covering the sub-watersheds of Gibe, Nadaguda, Nedi, and Yedi within the Gilgel Gibe Reservoir I area. Data collection took place between June 29 and July 15, 2017, with the number of respondents in each sub-watershed determined through proportional allocation. Prior to data collection, official permission was obtained from district offices and kebele administrators, and the purpose of the study was explained to each participant, ensuring verbal prior consent.

Our field observation also focused on observation of biophysical characteristics of the watershed like land degradation, settlements, individual activities in the farming plots, farmers’ land management practices, and other relevant aspects in the catchment. To obtain additional information detailed interviews were also held with the farmers. To achieve the objective of the study a descriptive research method was used to analyse the farmers' demographic, socioeconomic, and watershed conservation practices.

Field observations revealed that respondents who had been displaced from their original location had resettled and were engaged in farming along the buffer zone boundary. Data collection was based on a household survey, the presence of farmers during the study period, and their willingness to participate. Additionally, a questionnaire was distributed to Developmental Agents (DAs), as well as district and zonal experts, to gather general insights on institutional roles in watershed management and their perceptions at the kebele, district, and zonal levels. The method also used focus group discussions (FGDs) of farmers and village leaders in the area for qualitative data.

Face-to-face interview was conducted following a structured process. First, we scheduled the interviews at a convenient time and location. Next, identification of the specific information needed and selected key informants, primarily elders and long-term residents of the area then developed an interview tool, including an outlined script and a set of open-ended questions. During the interviews, we took detailed notes, and afterward, compiled and organized the collected data for further analysis.

Three focus group discussions (FGDs) were conducted, and the discussions concluded once ideas reached saturation or when previous points were repeated. The number of participants was determined based on Krueger and Casey (2000), who suggested that six to eight individuals are generally sufficient. Finally, the collected data were entered into SPSS Version 20 for analysis, utilizing descriptive statistics, cross-tabulations, and a chi-square test.

3. Results

3.1 Respondents' Demographic Characteristics

The study sample included 305 households, with 72.5% of respondents aged between 30 and 45. Nearly all were male, and a significant majority (94.1%) had lived in the area for over 20 years, making them valuable sources of information due to their extensive experience. All respondents were farmers and married, with 76.1% having households of more than five members, while the remaining 23.9% had fewer than five. Data on educational status revealed that 86.2% had no formal education and were unable to read or write, while only 13.8% possessed literacy skills (Table 1).

Table 1. General farmers' profile, number (%) of respondents with in the Gilgel Gibe Sub-watersheds

Socio-demographic characteristics	Description	Sub-watersheds				
		Gibe N(%)	Nadaguda N(%)	Nedi N(%)	Yedi N(%)	Total N(%)
Gender	Male	77(96.2%)	61(93.8%)	74(88.1%)	71(93.4%)	283(92.8%)
	Female	3(3.8%)	4(6.2%)	10(11.9%)	5(6.6%)	22(7.2%)
Age (year)	18-30	9(11.2%)	5(7.7%)	11(13.1%)	8(10.5%)	33(10.8%)
	30-45	50(62.5%)	51(78.5%)	57(76.9%)	63((82.9%)	221(72.5%)
	45-60	21(26.2%)	9(13.8%)	16(19%)	5(6.6%)	51(16.7%)
Marital status	Married	80 (100%)	65(100%)	84(100%)	76(100%)	305(100%)
Family size	2-5	27(33.8%)	7(10.8%)	27(32.1%)	12(15.8%)	73(23.9%)
	>5	53(66.2%)	58(89.2%)	57(67.9%)	64(84.2%)	232(76.1%)
Education and occupational status	Can't read and write	61(76.2%)	61(93.8%)	71(84.5%)	70(92.1%)	263(86.2%)
	Can read and Write	19(23.8%)	4(6.2%)	13(15.5%)	6(7.9%)	42(13.8%)
	Farmer	80(100%)	65(100%)	84(100%)	76(100%)	305(100%)
Duration of stay	≤ 20 years	3(3.8%)	3(4.6%)	9(10.7%)	3(3.9%)	18(5.9%)
	>20 years	77(96.2%)	62(95.4%)	75(89.3%)	73(96.1%)	287(94.1%)

3.2 Respondents' Socioeconomics Characteristics

Farmland is the main land use type (66.2%) in the studied watershed and 86.9% of the households owned 1 ha and above (Table 2). The dominant means of making a livelihood in the study area is agriculture (distinguished predominantly as males' activity). All of the interviewed farmers owned farmland and engaged in farming activities, of these 85.2% have land ownership certificates and 27.5% have farmland less than one km distance from the dam. Most of the farmers informed us that they are unfamiliar with the distance left from the edge of the dam to protect it. We have observed farmers in the study area are farming inside the buffer zone, even near the dam (Figure 2 A & B). Majority of the respondent (86.9%) regulate weed manually. Maize (*Zea mays*) is the dominant crop produced in the study areas and accounts 47.6% - 67 .1%. The second dominant crop is Tef which accounts 11.8% - 35.4% of respondents (Table 2). The important sources of fodder for their livestock in the sub-watersheds obtained from the farmland account for 63.2% - 72.6%. (Table 2), the rest either from the nearby land use types (wetland grazing land etc.). Farmers maximize the yield from their land with the expense of chemical fertilizer, hence in the study area, most of the farmers (86.9 %) used 100 and above kg of chemical fertilizer (Table 2).

Table 2. Farmers' Socioeconomic character with in the Gilgel Gibe Sub-watersheds

Socioeconomic Characteristics	Descrip-tion	Sub-watersheds				
		Gibe N(%)	Nadaguda N(%)	Nedi N(%)	Yedi N(%)	Total N(%)
Main source of in-come	Farming	80 (100)	65 (100)	84 (100)	76 (100)	305 (100%)
Farmland ownership	Yes	80 (100)	65 (100)	84 (100)	76 (100)	305 (100%)
	No	-	-	-	-	-
Farmland size	1ha & bove	62(77.5) %	58(89.2) %	78(92.9)%	67(88) %	265(86.9)%
	< 1ha	18(22.5)%	7(10.8)%	6(7)%	9(11.8) %	40(13%)
Farm land distance from the dam	<1km	38 (47.5)	8(12.3)	22(26.2)	16(21.1)	84(27.5)
	>1km	42(52.5)	57(87.7)	62(73.8)	60(78.9)	221(72.5)
Land ownership cer-tificate	Yes	68(85)	57(87.7)	69(82)	66(86.8)	260(85.2)
	No	12(15)	8(12.3)	15(17.9)	10(13.2)	45(14.8)
Most cultivated crop type	Maize	48(60)%	33(50.8)%	40(47.6)%	51(67.1) %	172(56.4)%
	Teff	16(20)%	23(35.4)%	26(31)%	9(11.8) %	74(24.3)%
	Pepper	7(8.8)%	0(0)%	1(1.2)%	0(0) %	8(2.6)%
	sorghum	9(11.3)%	9(13.8)%	17(20.2)%	16(21.1)%	51(16.7)%
Weed control mecha-nism	Manually	63(78.8)%	61(93.8)%	72(85.7)%	67(90.8)%	265(86.9)%
	chemically	17(21.3)&	4(6.2)%	12(14.3)%	7(9.2)%	40(13)%
Main land use type	Farm land	58(72.5)	49(75.4)	49(58.3)	46(60.5)	202(66.2)
	Settlement	22(27.5)	16(24.6)	35(41.7)	30(39.5)	103(33.8)
Fertilizer used per ha	< 100 kg	18(22.5)%	7(10.8)%	6((7)%	9(11.8)%	40(13)%
	100kg & above	62(77.5)%	58(89.2)%	78(92.9)%	67(88)%	265(86.9)%
Livestock presence	Yes	80 (100)	84 (100%)	65 (100)	76 (100)	305 (100)
	No	-	-	-	-	-
Fodder source for livestock	Farm land	58(72.5)	42(64.6)	61(72.6)	48(63.2)	209(68.5)
	Forest	16(20)	-	11(13.1)	-	27(8.9)
	Grazing land	6(7.5)	11(16.9)	8(9.5)	14(18.4)	39(12.8)
	Wetland	-	12(18.5)	4(4.8)	14(18.4)	30(9.8)

Size of farmland, farmland distance from the dam, fertilizer used per hectare, most cultivated crop types, weed control mechanism and fodder source for livestock showed significant difference (Table 3).

Table 3 significant test among farmers' socio economic characteristics

Farmers socio economic characteristics	Chi - square test		
	Pearson chi-square	df	P -value
Size of farm land	9.24	3	0.026
Distance of farm land from the dam	25.2	3	0.000

Fertilizer used per hectare	10.47	3	0.015
Types of crop most cultivated	32.57	9	0.000
Weed control mechanism	8.53	3	0.036
Source of fodder for livestock	52.16	9	0.000

* Significant at the 0.05

3.3 Activities that cause watershed ecosystem degradation

3.3.1 Inappropriate farming

Approximately 48% of respondents identified unwise farming as the primary cause of watershed degradation, while 25.6% acknowledged tree cutting for firewood as a contributing factor. Additionally, 15% attributed the degradation to overgrazing, and 11% cited a combination of unwise farming, overgrazing, and tree cutting for firewood as key causes (Table 4).

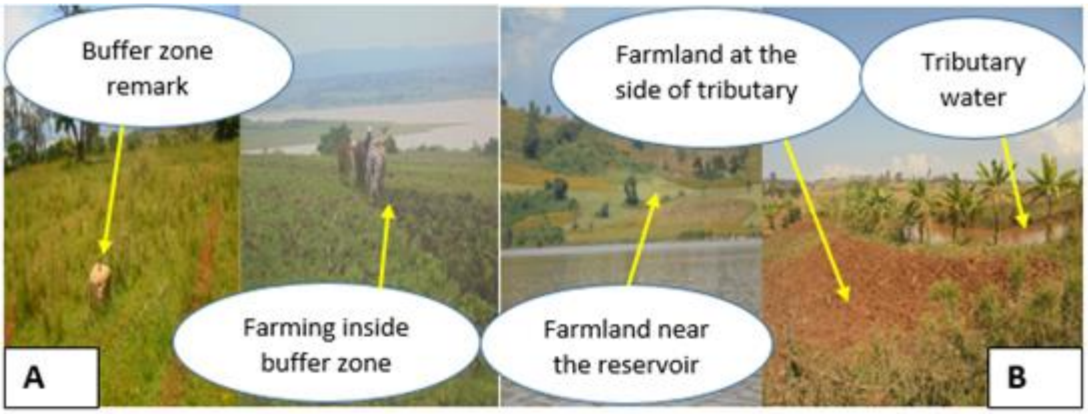

Figure 2: Farming activity inside the buffer zone (A) Farmland near the reservoir and tributary (B) of the study area (Gilgel Gibe watershed) (Picture taken by the principal)

3.3.2 Sand mining and siltation

Sand mining can be the source of turbidity of the water, affecting pH, BOD, COD, increases temperature, conductivity, and the presence of heavy metals this change water properties and cause risk for human and aquatic life (Mahananda et al.; 2010: Ashraf et al., 2011: Pereira et al., 2012).

Sand extraction becomes a common activity in the area (Figure 3A). Sand mining deteriorates tributaries of the Gilgel Gibe watershed. It has an impact on biodiversity, water turbidity, and land loss and generally affects the river ecosystem.

Figure 3: Pile of sand taken out of the tributary (A) Portion of the Gilgel Gibe I Reservoir occupied by sediment (B) in the study area (Gilgel Gibe watershed) (Picture taken by the principal)

We also observed that Gilgel Gibe I Reservoir has accumulated sediment that maybe later hinders the benefits of the hydroelectric dam by decreasing the water level (Figure 3B).

3.3.3 Deforestation and soil degradation

All respondents throughout the watershed acknowledged that deforestation and land degradation have resulted in declining agricultural productivity, increased poverty, and social instability, including displacement. They also agreed that soil erosion poses a severe challenge in their area (Table 4 and Figure 5). Additionally, woody vegetation is commonly used for charcoal production (Figure 4), which is then sold to travellers along the roadside.

Figure 4: Charcoal preparation sites in the study area (Gilgel Gibe watershed) (Picture taken by the principal)

In addition, roads (footpaths) and vegetation by the roadside are impaired due to soil erosion.

Figure 5: Gully erosion and footpath impairment near the farmland in the study area (Gilgel Gibe watershed) (Picture taken by the principal)

3.3.4 Measures taken

There are different watershed protection measures taken in the study area, like construction of gabion (Figure 6) and planting of vetiver grass (Figure 7).

Figure 6: Gabion constructed for protection of erosion in the Gilgel Gibe watershed (Picture taken by the principal)

We observed soil erosion has damaged the planted vetiver grasses (Figure 7) which are important to slow down runoff on the farmland and reduce siltation and loading of agrochemicals into water bodies.

Figure 7: vetiver grass being removed by erosion after planted for conservation in the study area (Gilgel Gibe watershed) (Picture taken by the principal)

Table 4. Farmers additional information associated with watershed conservation in the Gilgel Gibe Sub-watersheds

Items	**Description**	**Sub-watersheds**				
		Gibe	**Nadaguda**	**Nedi**	**Yedi**	**Total**
		N(%)	**N(%)**	**N(%)**	**N(%)**	**N(%)**
Possible causes of watershed degradation	Unwise farming	33(41%)	32(49%)	38(45%)	44(57.9%)	147(48.2%)
	overgrazing	12(15%)	12(18.5%)	13(15.5%)	9(11.8%)	46(15%)
	Tree cutting for firewood	25(31%)	13(20%)	26(31%)	14(18.4%)	78(25.6%)
	All are causes	10(12.5%)	8(12%)	7(8.3%)	9(11.8%)	34(11%)
difference between soil degradation, forest degradation and watershed degradation	No difference	72(90%)	57(87.7%)	9(10%)	65(85.5%)	269(88%)
	I don't know	8(10%)	8(12.3%)	16(19%)	11(14.5%)	36(11%)

Soil erosion is a serious problem in your locality	Very serious	80 (100 %)	65 (100 %)	84 (100 %)	76 (100 %)	305 (100%)
Deforestation and soil degradation cause decrease in agricultural products, poverty and social instability	Yes	80 (100 %)	65 (100 %)	84 (100 %)	76 (100 %)	305 (100%)
landform (surface feature) in the area	Mountainous, hills and valleys	6(7.5%)	3(4.6%)	23(27.4%)	10(13%)	42(13.8%)
	Plain	74(92.5%)	62(95.4%)	61(72.6%)	66(87%)	263(86.2%)
distance left from the edge of dam	Yes	18(22.5%)	7(10.8%)	10(11.9%)	3(3.9%)	38(12.5%)
	I don't know	62(77.5%)	58(89.2%)	74(88%)	73(96%)	267(87.5%)

3.3.5 Farmers watershed conservation and management practice

Practices toward watershed conservation were assessed by asking six questions; each response was in the form of 'Yes' or 'No', as shown in Table 5. Each question was labeled with good or poor practice. A score of 1 was given to bad while 0 was given to good practice, with a score range of a maximum of 6 to a minimum of 0. A cut-off level of ≥3 was considered a good practice whereas ≤ 3 was considered a negative practice for watershed conservation. This cut-off level relies on certain scientific base mostly mean value. One hundred and ten (36%) farmers were within the good practice range whereas 195 (63.9%) showed bad practice towards watershed conservation. The mean score for watershed conservation-related practices was 2.8 ± 1.0.

Table 5. Farmers watershed conservation and management practice in the Gilgel Gibe Sub-watersheds

Watershed conservation practice items		**Sub watersheds** Gibe	Nedhi	Nadaguda	Yedi	total
Did you supervise any time the watershed environment?	Yes N (%)	22 (27.5%)	31 (36.9%)	20 (30.8%)	25 (32.9%)	98 (32.1%)
	No N (%)	58 (72.5%)	53 (63.1%)	45 (69.2%)	51 (67.1%)	207 (67.9%)
Local dwellers protect their field from water run off during the wet season	Yes N (%)	13 (16.3%)	15 17.9%)	9 (13.8%)	19 (25%)	56 (18.4%)
	No N (%)	67 (83.8%)	69 (82%)	56 (86.2%)	57 (75%)	249 (81.6%)
farmers share information about their farmlands to protect it from erosion/degradation	Yes N (%)	23 (28.8%)	27 (32%)	18 (29.2%)	25 (32.9%)	94 (30.8%)
	No N (%)	57 (71.3%)	57 (67.9%)	46 (70.8%)	51 (67.1%)	211 (69.2%)
have you done anything in group to protect watershed degradation	Yes N (%)	22 (27.5%)	31 (36.9%)	23 (35.4%)	22 (28.9%)	98 (32.1%)
	No N (%)	58 (72.5%)	53 (63.1%)	42 (64.6%)	54 (71.1%)	207 (67.9%)
currently using any soil conservation activities	Yes N (%)	41 (51.3%)	43 (51.2%)	33 (50.8%)	41 (53.9%)	158 (51.8%)

	No N (%)	39 (48.8%)	41 (48.8%)	32 (49.2%)	35 (46.1%)	147 (48.2%)
Conservation can be practiced as traditional management activity in the area	Yes N (%)	44 (55%)	48 (57.1%)	23 (35.4%)	10 (13.2%)	125 (41%)
	No N (%)	36 (45%)	36 (42.9%)	42 (64.6%)	66 (86.8%)	180 (59%)

Table 6. Test of significant relationship among the farmers' practice of conservation with in the Gilgel Gibe Sub-watersheds

Items	Chi - square test		
	Pearson chi-square	**Df**	**P -value**
Conservation can be practiced as traditional management activity in the area - Yes - No	21.9	3	.000**
Is there any currently used any type of conservation activity - Yes - No	20.9	3	.000**

**significant at p-value < 0.01

3.3.6 Focus Group Discussion

Focus group discussions with six to eight members in each group were carried out on watershed conservation (Figure 8).

Figure 8: Focus group discussion during the study period (Gilgel Gibe watershed) (Picture taken by the principal)

Elders and volunteer farmers were involved in the focus group discussion. Farmers were clarified about the discussion and guide questions were raised for farmers regarding their conservation practice to obtain their view and general information about the watershed conservation.

3.3.7 Development agents, district and zonal expert general information

We asked DAs and experts (Jimma zone Rural land and environmental protection, zone Agricultural Office and Irrigation development authority) mostly open-ended questions that were selfadministrated after an instructional briefing. Most of them stated that anthropogenic activities like farming, grazing, deforestation, and resettlement in the area are the major causes of watershed degradation. Farming inside the buffer zone, negligence, and failure to participate in biological conservation activities (planting of trees) in areas where soil erosion is protected through gabion are among the challenges facing the experts. They also support the extinction of plant and animal species even if they are not able to identify them.

4. Discussion

Overall, farmers had unfair conservation practices. Farmers' conservation practices are critical in developing effective watershed management. Riparian buffers are transition zones between water and land that link terrestrial upland ecosystems to stream, river, lake, or wetland ecosystems and provide important functions, such as protecting and improving water quality, etc. Depending on the needs and hydrological, biological, and physical characteristics of the site, the widths of existing riparian and wetland buffers range from 10 to 500 m (Klemas, 2014). In the present study, most farmers are unable to tell the distance of the buffer zone from the reservoir, and they do not know about the buffer zone remark marked in the watershed. Farming and others activities such as grazing, overwhelm the buffer zone of the study area. This cultivation of marginal areas within the catchment area (Figure 2A & B) can exacerbate intensified soil erosion and reservoir sedimentation (Figure 3B). Robert et al. (2003), also describe the fact that agricultural practices near streams can increase soil runoff and the transport of chemicals in streams. Loss of soil due to such kind of unwise farming system not only causes siltation of the dam, it also degrades fertile land for agriculture, that causes a serious challenge to agricultural productivity and economic growth (Mulugeta, 2004), later aggravate food insecurity.

These activities may be associated with an increased need for livelihoods due to their poor way of life. Generally, farmers differ in their views on watershed conservation, with some identifying unwise farming as the main cause rather than tree cutting or overgrazing. This variation stems from differences in exposure, perspectives, and the specific environmental challenges they face in their local areas. During the discussion and open-end question, they remarked that the compensation payment paid when displaced from their former place was not enough, and no off-farm activity to reduce the pressure exerted on local natural resources, therefore we are forced to exploit the resource irresponsibly. Cultivation of maize most often can hinder the use of cultural method (like crop rotation) to maintain soil fertility and weed prevention. Fertilizers are primarily designed to enhance agricultural productivity, yet their excessive use can negatively impact ecosystems (Kopittke, 2019). In recent years, global fertilizer consumption has surged, leading to severe environmental challenges, particularly due to the presence of heavy metals such as cadmium and chromium, as well as elevated concentrations of radionuclides (Savci, 2012).

In Ethiopia, the use of chemical fertilizers has increased significantly to boost crop yields. Given that farmland constitutes the dominant land use in the study area, the expansion of agricultural land has necessitated greater reliance on agrochemicals. Consequently, this heightened usage may have contributed to increased pollution levels in rivers and lakes through storm water runoff (Mateo-Sagasta et al., 2017). Chemical fertilizers are processed fertilizers derived from minerals and natural substances, with many containing nitrogen. As nitrogen fertilizer usage increases, nitrate ion levels surpass those in the natural nitrogen cycle, where nitrates would typically return to the atmosphere as nitrogen gas. Consequently, excess nitrate ions and other nitrogen compounds accumulate in the environment, exacerbating ecological strain. Additionally, nitrogen release into the atmosphere in the form of nitrous oxide—a potent greenhouse gas—intensifies environmental concerns (Nozak, 2022).

In addition to imprudent agriculture (Figure 2 A & B), the search for firewood/charcoal production in the sub-watersheds has also encroached on the very small patch of trees without replacement (Figure 4). Removal of woody species and other vegetation would facilitate the flow of sediment, organic matter, nutrients, and pesticides into the reservoir, thereby disrupting the aquatic ecology. These activities can also have resulted in the disappearance of animals and plant species. Based on open-ended questions and FGDs, they told us about animals such as the lion (Leenca), the tiger (Qeerransa), the pig (boyyee), the warthog (karkaarro), the Menelik's bushbuck (bosonuu), Oribi Antelope (kuruphee), the Hippo (Roobii), the Buffalo (gafarsa), and concerning plant species *Cordia africana* (Waddessa), *Hagenia* abyssinica (Koosso), *Pouteria adolfi-friederici* (Kerero), *Ficus* sp. (Oodda, qilxu), *Podocarpus falcatus* (birbirsaa), *Rhus ruspolii* (xaaxeessaa), *Accacia abyssinica* (laaftoo) and rukeenso /known for charcoal/, satiyaa are among the lost fauna and flora.

Farmers also argued that the current conservation practice was inappropriate. Watershed conservation practices are restricted to certain areas. For instance, the Gabion built to prevent soil erosion around the Tiroafeta district (Figure 6) is not uniform across all sub-watersheds where the problem is common. There are areas which are exposed to gulley erosion (Figure 5). Most of the farmers (67.9%) do nothing in group to protect against watershed degradation (Table 4), for example, the destruction of footpaths needs care as part of watershed management before the situation becomes intense because watershed management involves also common property resources like roads and footpaths, and vegetation along streams and rivers (Swallow et al., 2001).

During FGDs, two elder farmers indicated that areas even after the implementation of conservation measures are eroded from year to year, and the maintenance of these areas seems difficult. For example, vetiver grass planted for erosion protection has also been damaged by landslides and erosion (Figure 7). So, despite conservation progress in the Gilgel Gibe watershed land degradation continues.

Farmers are involved to prevent their farmland from erosion individually only when it happens (during the rainy season), this may be associated with a lack of proper coordination and reduced responsibility feeling. This aspect is also addressed through the interview and FGDs (Figure 8). As the discussion progressed, participants highlighted key concerns, noting that escalating economic challenges have compelled individuals to depend on scarce resources. They also express their concerns regarding inadequate or discrepancies in compensation structures. In addition, they are not in frequent contact with DAs (Development Agents).

The expansion and formation of the gully is one of the main difficulties in degraded watersheds, it reduces the cultivable area and grazing lands, assists erosion from upstream-degraded landscapes, and carries a huge volume of sediment posing a problem of siltation in downstream dams, rivers (Gebregziabher et al., 2016). There are sub-watershed areas in critical conditions that need priority, for example, the one in Omo nada woreda (Assendabo) highly exposed to gully erosion near the dam (Figure 5), which seems to lack of integrated approach between upland and lowland or fail to share information to protect soil degradation (Table 5). Therefore, managing the entire route including upland soil loss, sediment accumulation, and channel bed erosion is critical (Wortmann et al., 2008).

Most farmers feed their livestock from farmlands. The burden applied on farmland for grazing of animals could cause vegetation loss, physical trampling of soil during the dry season, and soil compaction in the wet season which will assist wind erosion and decrease infiltration and increase runoff. Hubbard et al. (2004) also found that grazing animals and pasture production can have a negative impact on water quality through erosion and transport of sediment in surface water. In addition, grazing on agricultural land can cause difficulties in cultural weed management mechanisms due to the distribution of weed seeds by animal manure.

The studied sub-watersheds exhibit both similarities and differences in land use variation and degradation levels, as reflected in the descriptive data. For instance, when comparing factors such as educational status (illiteracy rate), farmland size, ownership, fertilizer application per hectare, and fodder sources from farmland, the Nedi and Yedi sub-watersheds have a higher number of respondents than Gibe and Nadaguda (Table 1 & 2).

Significant test about farmers' practice in watershed management (Table 6) reveals, that there was a difference in current conservation practice, (especially the type of soil conservation activities) and a significant difference also exists in noticing conservation practice as traditional management activity in the area. The majority of the farmers (59%) suggested that conservation could not be practiced as traditional management activity with in the area. In areas where prevention measures were done (physical conservation activities like gabion), sediment is accumulated behind the constructed gabion (Figure 6), but proper tree species (indigenous to the area) were not planted to strengthen the prevention of soil erosion. Studies also indicated that the lack of the integration of physical and biological conservation activities would seem environmentally, economically, and socially unacceptable, because watershed management includes the treatment of land by using proper biological and physical measures (Lakew et al., 2005). Farmers tend to have low adoption rates of certain conservation practices due to multiple interconnected factors. Limited awareness and knowledge can prevent them from understanding the benefits of conservation efforts, while risk perception makes them hesitant to adopt new techniques if they fear negative impacts on crop yields or profitability. Additionally, short-term priorities often lead farmers to focus on immediate survival and productivity rather than long-term sustainability, making conservation a lower priority. Social and cultural factors also play a role, as traditional farming methods and community beliefs may discourage innovation and change.

Governments and non-governmental organizations (NGOs) understood that watershed conservation could not be achieved without the voluntary participation of local community (Pretty and Ward, 2001). Besides conservation, activity farmers' participation is also essential during the planning of sustainable management of land and water resources (Habtamu, 2011) because they are closer to the difficulties, and conscious to issues that are omitted by professionals. In the study area, the majority of farmers in the open-ended question and focus group discussion indicated that they are discouraged because of a lack of rational use of the local resource. They are not benefited from the nearby resource. They blamed that "we are displaced from our land for the construction of the dam but we are not using electric power, pure drinking water and no free/communal grazing land for our cattle". Robert et al. (2003) suggested that both government policy, farmers' motivations, and attitudes could influence conservation practices and agricultural landscape patterns.

5. Conclusions

The study assessed farmers’ practices for conserving the Gilgel Gibe watershed. Findings revealed that all participants were landowners with tenure certificates, but lacked literacy skills. Most had lived in the area for over 20 years, making them a strong source of local knowledge and information. However, poor conservation practices and low income have pressured natural resources, reducing biodiversity and degrading watershed health. Farmers interact with their environment primarily for subsistence, but inadequate conservation efforts contribute to pollution, soil erosion, and deteriorating water quality. Additionally, insufficient compensation for land displacement discourages responsible resource use, exacerbating environmental decline. This underscores the urgent need for improved conservation practices among farmers to protect natural resources and highlights the importance of sustainable farming to prevent pollution and maintain water quality.

As an immediate step, these findings can inform that farmers lack proper conservation practices, which contributes to watershed degradation. In addition, economic hardships push them toward unsustainable resource exploitation. Poor land management further accelerates watershed pollution and biodiversity loss, and unfair compensation payments weaken farmers' motivation to preserve natural resources. Implementing sustainable farming methods is crucial for maintaining water quality and ensuring ecological balance.

To ensure sustainable watershed management, we recommend policymakers should prioritize farmers' needs when designing strategies and promote sustainable land-use practices. Community engagement is essential, and stakeholders should establish a team of local representatives (elders) and officials at the woreda and zonal levels to enhance trust and transparency in compensation discussions. Economic support is crucial, and farmers should be encouraged to pursue income-generating activities such as planting fruit trees, creating vegetable gardens, and growing fodder trees without expanding farmland. Conservation efforts should focus on rehabilitating gullies through physical and biological techniques before the rainy season. Regular watershed assessments by Development Agents (DAs) and experts should be conducted, along with the establishment of buffer zones to protect sensitive areas. Lastly, an integrated approach should be adopted, ensuring that conservation structures are tailored to the severity and extent of erosion damage to promote long-term ecological sustainability.

6. Future outlook

Future watershed management will rely on enhanced farmer participation, driven by incentives, education, and collaboration for better conservation outcomes. Expanding techniques like agroforestry, soil conservation, and efficient water use will promote sustainability. Technological integration, including digital tools and data-driven strategies, will enhance effectiveness, while economic incentives, such as improved market access for sustainably grown crops, will encourage conservation-focused farming. Strong policy and institutional support will shape long-term strategies, reinforced by continuous monitoring. Regular assessments through data analysis and community engagement will enable adaptive management, ensuring ecological balance and long-term watershed protection.

Acknowledgments

The authors would like to thank Jimma University and Mada Walabu University of Ethiopia for financing. The authors also wish to thank the local community and Mr. Seyifu Mohamed, who helped us during fieldwork.

References

Abdulkarim, B., Yacob, M.R., Abdullahi, A.M., Radam, A. (2017). Farmers’ perceptions and attitudes toward forest watershed conservation of the North Selangor Peat Swamp Forest. *Journal of Sustainable Forestry*, *36*(4), pp.309-323.

Ashraf, M.A., Maah, M.J., Yusoff, I., Wajid, K. A. (2011). Mahmood, Sand mining effects, causes and concerns: a case study from Bestari Jaya, Selangor, Peninsular Malaysia, Sci. Res. Essays 6 (6) 1216–1231.

Asnake, B. (2024). Land degradation and possible mitigation measures in Ethiopia: A review. *J Agric Ext Rural Dev*, pp.23-9.

Barlow, J., França, F., Gardner, T.A., Hicks, C.C., Lennox, G.D., Berenguer, E., Castello, L., Economo, E.P., Ferreira, J., Guénard, B. and Gontijo Leal, C. (2018). The future of hyperdiverse tropical ecosystems. Nature, 559(7715), pp.517-526.

Bewket, W., Sterk, G. (2005). Dynamics in land cover and its effect on stream flow in the

Chemoga watershed, Blue Nile basin, Ethiopia. *Hydrological Processes*, *19*(2), pp.445-458.

Birhane, G. (2002). Present and future water resources development in Ethiopia related to research and capacity building. *Integrated water and land management research and capacity building priorities for Ethiopia*, *11*.

Bishop, K., Buffam, I., Fölster, J., Laudon, H., Temnerud, J. (2005). Spatial Variability and the Assessment of Forest Streams.

Chowdary, V.M., Chakraborth, D,, Jeyaram, A., Krishna, Murthy, Y.V.N., Sharma, Dadhwal, V.K. (2013). Multi-criteria decision making approach for watershed prioritization JR, using analytic hierarchy process technique and GIS. Water Resour Manag 27(10):3555–3571

Demissie, T., Saathoff, F., Seleshi, Y., Gebissa, A. (2013). Evaluating the effectiveness of best management practices in Gilgel Gibe basin watershed—Ethiopia. Journal of Civil Engineering and Architecture, 7(10), 1240–1252.

Devi, R., Tesfahune, E., Legesse, W., Deboch, B., Beyene, A. (2008). Assessment of siltation and nutrient enrichment of Gilgel Gibe dam, Southwest Ethiopia. Biosource Technology 99: 975-979.

Durga, Rao, K.H.V., Kumar, D.S. (2004). Spatial decision support system for watershed management. Water Resour Manag 18(5):407–423

Ethiopian Ministry of Environment, Forest and Climate Change MEFCC. (2018). https://www.epa.gov.et Accessed 10th May 2025.

Firdaus, R., Nakagoshi, N., Idris, A. (2014). Sustainability assessment of humid tropical watershed: a case of Batang Merao watershed, Indonesia. *Procedia Environmental Sciences*, *20*, pp.722-731.

Franks, P.J., Berry, J.A., Lombardozzi, D.L. and Bonan, G.B. (2017). Stomatal function across temporal and spatial scales: deep-time trends, land-atmosphere coupling and global models. *Plant Physiology*, *174*(2), pp.583-602.

Foth, H.D. (1990). Fundamentals of soil science, 8th Ed. John Wiley and Sons, Inc., NewYork, USA. 360p.

Gebregziabher, G., Abera, D.A., Gebresamuel, G., Giordano, M., Langan, S. (2016). An assessment of integrated watershed management in Ethiopia. Colombo, Sri Lanka: International Water Management Institute (IWMI), https: //doi: 10.5337/2016. 214. 28p. (IWMI Working Paper 170).

Goff, K.M., Gentry, R.W. (2006). The influence of watershed and development characteristics on the cumulative impacts of stormwater detention ponds. Water Resour Manag 20(6):829–860

Habtamu, T. (2011). Assessment of sustainable watershed management approach case study lenche dima, tsegur eyesus and dijjil watershed. *A Project Paper Presented to the Faculty of the Graduate School of Cornell University in Partial Fulfillment of the Requirements for the Degree of Master of Professional Studies*.

Hubbard, R.K., Newton, G.L., Hill, G.M. (2004). Water quality and the grazing animal. *Journal of animal science*, *82*(13_suppl), pp.255-E263.

Johnson, C.N., Balmford, A., Brook, B.W., Buettel, J.C., Galetti, M., Guangchun, L. and Wilmshurst, J.M. (2017). Biodiversity losses and conservation responses in the Anthropocene. Science, 356(6335), pp.270-275.

Kehoe, L., Romero-Muñoz, A., Polaina, E., Estes, L., Kreft, H. and Kuemmerle, T. (2017). Biodiversity at risk under fu-

ture cropland expansion and intensification. Nature ecology & evolution, 1(8), pp.1129-1135.

Klemas, V. (2014). Remote sensing of riparian and wetland buffers: an overview. *Journal of Coastal Research*, *30*(5), pp.869-880.

Krueger, R. A., Casey, M.A. (2000). *Focus groups: A practical guide for applied research*, 4th ed. Thousand Oaks, CA: Sage Publications Inc.

Lakew, D., Carucci, V., Asrat, W-A., Yitayew, A. (2005). Community Based Participatory Watershed Development: A Guideline. Ministry of Agriculture and Rural Development, Addis Ababa, Ethiopia.

Lee, H. F., Zhang, D.D. (2008). Perceiving the environment from the lay perspective in desertified areas, Northern China. Environmental Management, 41 (2), 168–182. doi:10.1007/ s00267-007-9052-8

Lin, Y.; Fan, J.; Wen, Q.; Liu, S.; Li, B. Primary exploration of ecological theories and technologies for delineation of ecological redline zones. Acta Ecol. Sin. (2016). 36, 1244–1252.

Mahananda, M.R., Mohanty, B.P., Behera, N.R. (2010). .Physico-chemical analysis of surface and groundwater of Bargarh District Orrisa, India, Int. J. Res. Rev. Appl. Sci.
2 (3) pp 284–295.

Mateo-Sagasta, J., Zadeh, S.M., Turral, H., Burke, J. (2017). *Water pollution from agriculture: a global review. Executive summary*. Rome, Italy: FAO Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE).

Mulugeta, L. (2004). Effects of Landuse Change on Soil Quality and Native Flora Degradation and Restoration in the Highlands of Ethiopia. Implication for Sustainable Land Management. Swedish University of Agricultural Science. Uppsala, Sweden

Nozak, S. (2022). Reducing The Environmental Impact of Chemical Fertilizers is Increasingly Important for Sustainable Agriculture [online]

Pereira, H.M., Navarro L.M., Martins, I.S. (2012). Global biodiversity change: the bad, the good, and the unknown, Annu Rev. Environ. Resour. 37 25–50.

Pretty, J., Ward, H. (2001). Social capital and the environment, World Development, Vol.29, No.2, 209-227.

Randhir, T.O., Hawes, A.G. (2012). Ecology and Poverty in Watershed Management. In *Integrating Ecology and Poverty Reduction* (pp. 113-126). Springer New York.

Reddy, V.R., Saharawat, Y.S., George, B. (2017). Watershed Management in South Asia: A Synoptic Review. *Journal of Hydrology*. V 551,pp 4-13.

Robert, L., Ryan, D., Erickson, L., Raymond, De, Y. (2003). Farmers' Motivations for Adopting Conservation Practices along Riparian Zones in a Mid-western Agricultural Watershed, Journal of Environmental Planning and Management, 46:1, 19-37

Swallow, B.M., Garrity, D.P., van, Noordwijk, M. (2001). The effects of scales, flows and filters on property rights and collective action in watershed management. Water Policy 3:457-474.

Tamene, A., Fokke, S., Seleshi, Y., Alemayehu, G. (2013). Evaluating the effectiveness of best management practices in Gilgel Gibe basin watershed—Ethiopia, 7(10), 1240–1252.

Teshome, A., de, Graaff, J., Kassie, M. (2016). Household-level determinants of soil and water conservation adoption phases: evidence from North-Western ethiopian highlands. *Environmental management*, *57*(3), pp.620-636.

Thomas, K.J., Babu, K.S., Thomas, E.K. (2009). Watershed-based Development for Rural Prosperity—Evidences from Kerala. *Agricultural Economics Research Review*, Vol. 22 (2009) pp 407-414.

Tiwari, Krishna, R., Roshan, M., Bajracharya, K., Bishal, S. (2008). "Natural Resource and Watershed Management in South Asia: A Comparative Evaluation with Special References to Nepal" *The Journal of Agriculture and Environment* Vol:.9, June.

Tomer, M.D. (2004). Watershed Management. P. 306-314. *In* D. Hillel. Encyclopedia of Soils in the Environment (Vol. 4). Elsevier Ltd. Oxford, UK.

Tsegaye, H., Tesfaye, Y., Abebaw, D., Kassa, H., Abdelkadir, A. and Gizachew, K. (2022). Trade-off between forest conservation and agricultural expansion in Gura-ferda district, Southwest Ethiopia. International Journal of Agricultural Research, Innovation and Technology, 12(1), pp.45-55.

Walter, T., Dosskey, M., Khanna, M., Miller, J., Tomer, M.D., Wiens, J. (2007). The science of targeting within landscapes and watersheds to improve conservation effectiveness. In: Schnepf, M., Cox, C., editors. Managing Landscaping for Environmental Quality: Strengthening the Science Base. Soil and Water Conservation Society, Ankeny, IA. p. 63-89.

Woldeab, B., Ambelu, A., Mereta, S.T., Beyene, A. (2019). Effect of watershed land use on tributaries' water quality in the east African Highland. *Environmental monitoring and assessment*, *191*(1), p.36.https://doi.org/10.1007/s10661-018-7176-3

Wortmann, C.S., Helmers. M., Gelder. B., Morton, L.W., Devlin, D., Barden, C., Anderson, S., Broz, R., Franti, T., Regassa, T., Shea, P. (2008). Targeting of watershed management: Practices for water quality protection.