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ORIGINAL ARTICLE

The Effect of Land use land cover Change on Flow and Sediment Concentration: Case of Gilgel Abay watershed, Upper Blue Nile Basin, Ethiopia

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ABSTRACT

In recent years, there have been significant hydrological changes worldwide due to human activities such as converting land for industrial use, urban expansion, and agriculture. This study aimed to investigate how changes in land use and land cover affect streamflow and sediment concentration in the Gilgel Abay watershed. Data on streamflow was obtained from the Ministry of Water and Energy (MWE), while sediment concentration data was derived using flow and sediment rating curves of the Gilgel Abay River. Historical land use and land cover data for the years 2000, 2010, and 2020 were obtained from satellite images using supervised classification techniques. The study utilized the SWAT model to simulate streamflow and sediment concentration, and SWAT-CUP was employed for calibration and validation. The results indicated a decrease in cultivated land and grassland by 15.48% and 4.13% respectively, while urban areas, shrub land, and forest increased by 12.13%, 3.52%, and 2.72% respectively. Over the 20-year period, streamflow and sediment concentration decreased by 2.53m3/s and 4.41mg/l respectively, with favorable statistical values for the daily streamflow. The reduction in base flow was attributed to eucalyptus plantation and irrigation expansion, while the increase in forest and shrub land led to a decline in sediment concentration. This research is expected to provide valuable insights for researchers, decision-makers, and stakeholders to enhance the effective management of land and water resources.

Keywords: *Land use/Land cover, sediment concentration, streamflow, Gilgel Abay watershed, SWA, remote sensing*

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1. Introduction

Water resource sedimentation occurs due to land erosion in the catchment area, and this is supported by the findings of Ffolliott et al. (2013), Trimble (1997), and Aksoy and Kavvas (2005). The erosion of land significantly impacts the physical and chemical characteristics of soils, leading to on-site nutrient loss as well as off-site sedimentation and nutrient enrichment of water resources, as highlighted by Gachene et al. (1997). When it comes to managing water resources, the focus is typically on the watershed level, as highlighted by Pande and Pande (2020) and Dixon (1987), as well as by Wang et al. (2013). At this level, the watershed serves as the fundamental hydrologic unit and allows for the examination of complex processes and relationships that connect the land surface, climate conditions, and human activities, as emphasized by Wang et al. (2013) and Dixon (1987). Furthermore, it is essential to note that changes in land use represent a significant global ecological trend, as pointed out by Aznar-Sánchez et al. (2019) and Song et al. (2018). In the realm of water resource sustainability, effective land use planning and management are crucial. Changes in land use significantly impact water variability through various hydrological processes (Niu et al., 2015). The relationship between land use and hydrology is intricate, encompassing different geographical and temporal scales (Fohrer et al., 2001). Land cover/land use directly influences the amount of evaporation, groundwater infiltration, surface runoff and erosion during and after rainfall events (Niu et al., 2015). Elevated sediment concentration leads to an increase in fluid density, viscosity, and a decrease in settling velocity (Elgaddafi et al., 2012). This effect becomes more pronounced with higher sediment concentration, resulting in flow behavior distinct from normal streamflow (Shu et al., 2008). In instances of high sediment concentrations, the transport capacity may increase (Celik and Rodi, 1991). The overall impact of these changes on flow dynamics is not always clear, including their effects on flow velocity and resistance. Nonetheless, erosion models addressing high sediment concentrations cannot disregard these effects (Elgaddafi et al., 2012). The utilization of land for economic, residential, recreational, conservation, and government purposes by humans is known as land use, as stated by Mesfin Reta Aredo in 2018. The alteration of land use and cover in a watershed significantly affects river flow and sediment concentration, according to Mesfin Reta Aredo in 2018. As human activities increase, changes in land cover within the watershed may lead to reduced stream flow and sediment concentration in rivers, as suggested by Aneseyee et al. in 2020.The research conducted by da Fonseca et al. (2022) has revealed significant connections between changes in land use/land cover and the indicators of stream flow and sediment concentration. The findings from these investigations, as reported by Choto et al. (2019) and Andualem and Gebremariam (2015), have provided valuable insights into the estimation and comprehension of stream flow and sediment concentration in rivers through the application of diverse methods and methodologies. The increased flow of water in streams and higher levels of sediment are often linked to changes in land use resulting from human activities and economic development within watershed areas (Tang et al., 2011). However, understanding these relationships on a catchment scale throughout different seasons is still limited due to the extensive area and challenges in monitoring (Karfs et al., 2009). In Ethiopia, human activities such as rapid urbanization, agricultural expansion, and deforestation have significantly impacted land use and land cover changes, consequently affecting stream flow and sediment concentration across the country. This situation has prompted the need for further research (Bewket and Sterk, 2005, Dagnew et al., 2017). Specifically, there is a requirement to analyze case studies of land use and land cover modifications in highland areas and their impact on river flow and sediment concentration, with a focus on the Ethiopian Highlands irrigation circuit (Welde et al., 2017) (Ababa, 2006). Sediment transported by rivers enters Lake Tana and accumulates on the lake bed, leading to eutrophication (Dersseh et al., 2020, Kebedew et al., 2020). To address this issue, it is crucial to determine changes in land use and land cover, which can aid in predicting stream flow and sediment concentration. Additionally, this information can be used to design hydraulic structures within the catchment and develop a watershed management plan. The Gilgel Abay watershed is experiencing significant population growth, leading to detrimental impacts on its resources such as deforestation, the expansion of residential areas, and agricultural land. Moreover, the watershed is heavily affected by erosion due to intense rainfall, which further exacerbates the changes in its land cover (Andualem and Gebremariam, 2015, Gumindoga et al., 2014). The main goal of this study is to assess how changes in land use and land cover impact the hydrological processes of the Gilgel Abay River in the Upper Blue Nile Basin of Ethiopia. Specifically, the study aims to: 1) analyze the changes in land use and land cover within the Gilgel Abay watershed, 2) investigate the influence of these changes on stream flow, and 3) assess the impact on sediment concentration.

2. Materials and methods

2.1 Description of the Study Area

The Gilgel Abay watershed is situated in the Amhara region in northwestern Ethiopia, with latitudes ranging from 10° 56′ to 11° 51′ N and longitudes ranging from 36° 44′ to 37° 23′ E. Notably, the Gilgel Abay River contributes around 60% of the flow into Lake Tana (Wale et al., 2009). Originating from a small spring at Gish Abay Mountain near Gish Abay town, the catchment area of the Gilgel Abay River at its discharge to Lake Tana spans approximately 4,043.6 km2. The elevation of the Gilgel Abay watershed varies from 1787 meters to 3528 meters above mean sea level (m.a.s.l.). This watershed experiences an average annual rainfall of 1845mm, with the average daily maximum and minimum temperatures ranging between12 – 36.2°C and 0 – 23.5°C, respectively.

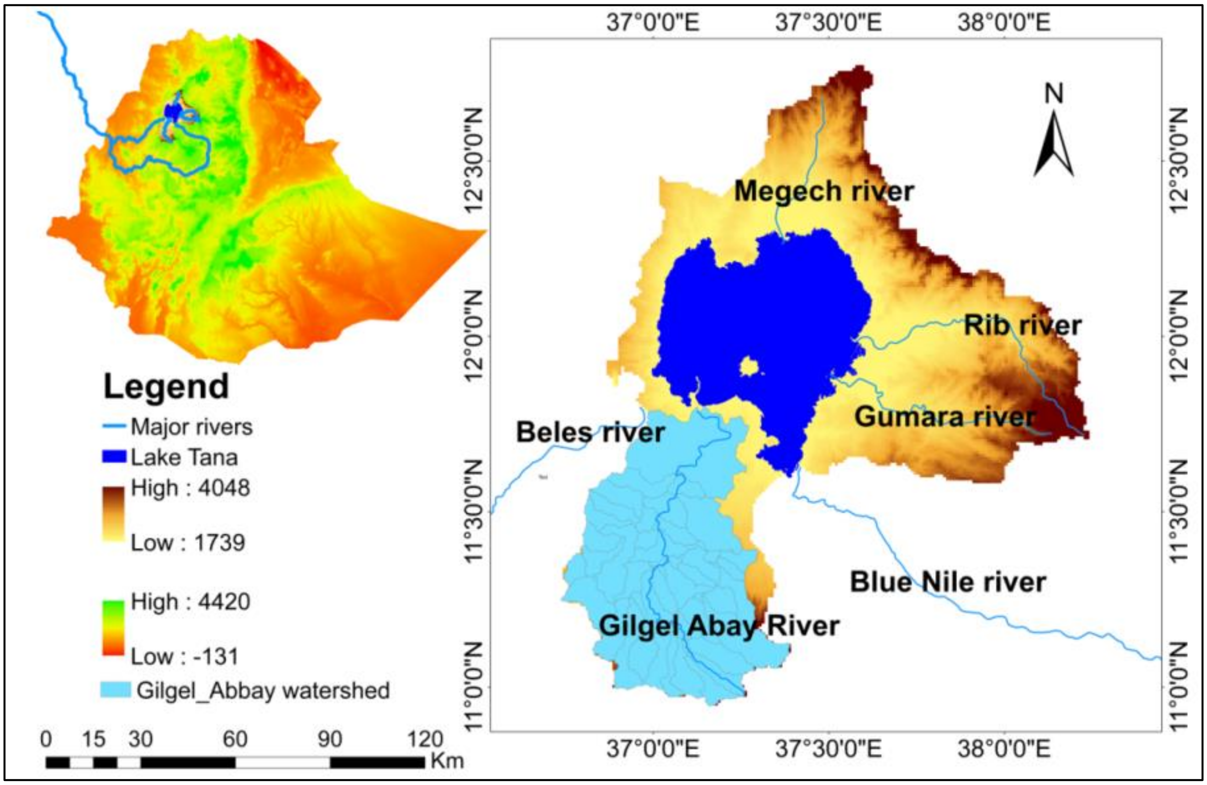

Figure 1: Elevation map of Ethiopia (left), Tana sub basin (right) and map of Gilgel Abay Watershed i.e. the study area (south of the right, blue in color).

The watershed encompasses 10 woredas from West Gojjam and Awi administrative zones of Amhara National Regional State (ANRS): Sekela, Fagtalekoma, Quarit, South Achefer, Dangila, Banja, North Achefer, Bahir Dar Zuria, Mecha, and Yilmanadensa (Andualem and Gebremariam, 2015). The river originates from a small spring near Gish Abay at an elevation of 2900m a.m.s.l and flows into the southern part of Lake Tana. The catchment area of Gilgel Abay River at the outlet to Lake Tana is approximately 4,021.8 km2 (Andualem and Gebremariam, 2015). It is the largest tributary of the Lake Tana basin, accounting for around 30% of the total area of the basin. This catchment contributes the largest inflow into the lake (Abdo et al, 2009).

2.2 Datasets

The study utilized various data sources including hydrological data (flow and sediment concentration), climate data, soil data, satellite imageries, and digital elevation model (DEM) (Table 1). The land use/land cover (LULC) map and all datasets for the years 2000, 2010, and 2020 were obtained from USGS Earth Explorer. To refine the area's LULC map, supervised classification techniques were employed based on Google Earth and satellite imageries from USGS Earth Explorer. Ground control points from Google Earth were used to create signature files for Landsat5 (2000), Landsat-8 (2020), and daily meteorological data was sourced from Ethiopian Meteorology Institute (EMI) at Wetet Abay, Kilti, and Koga stations. Additionally, stream flow and sediment concentration data for calibration and validation were obtained from the Ministry of Water and Energy (MoWE).

Table 1: Data source, acquisition and resolution for 2000, 2010 and 2020

Reference Data	Source/Sensor	Date of acquisition	Resolution
Images 2000	Landsat 5	31/05/2000	30m
Images 2010	Landsat5	31/05/2010	30m
Images 2020	Landsat 8	31/05/2020	30m
DEM	SRTM	2000	30m
Climate data	ENMA	2000-2020	
Flow and sediment concentration data	MoWE	2000-2020	
Soil data	MoWE, BECOM	1998	

2.3 Methods and data Analysis

2.3.1 Land use land cover classification and change detection

Upon analyzing the reflectance values, raw remotely sensed satellite images were categorized into fewer distinct Land Use/Land Cover (LULC) classes in the process of image classification (Nasiri et al., 2022, Viana et al., 2019). This involved digitization, image rectification, terrain analysis, and picture exporting. The picture rectification technique facilitated manual input of image pixel and ground control coordinate inputs and simplified tagging of recognized points on the image along with their corresponding locations on a base map layer. Advance options were utilized in selecting the rectification method, resampling scheme, and ground control projection parameters. In this study, one of the main objectives was to examine the impact of LULC (land use and land cover) change on the Gilgel Abay watershed. To achieve this, we conducted comprehensive analysis and mapping of LULC for the years 2000, 2010, and 2020, focusing on seven distinct LULC classes: cultivated land, water body, grassland, shrub land, forest, urban area, and bare land. By employing spatial analysis, we were able to identify significant trends in land use and land cover across the watershed. Supervised classification techniques of the ArcGIS 10.3 software were employed in classifying the satellite images (Shah et al., 2021). The maximum likelihood was selected as the parametric rule for the supervised classification. The parameters derived from the maximum likelihood statistical method facilitated the optimal grouping of unknown pixels. Ground control points (GCPs) obtained from the field and Google Earth served as the signature for supervised classification. To quantify the extent of LULC changes over the study period, a post-classification comparison was conducted. This involved comparing photos captured at different times of the year or using different sensors post-categorization, resulting in high change detection accuracy, as noted by Zhou et al., 2008.

2.3.2 Accuracy Assessment of Land Covers Classification

Accuracy assessment was accomplished using land-use maps, ground truth sites, and Google Earth. The accuracy rating was based on GPS points collected during fieldwork and the original mosaic image. The use of GPS points in determining classification accuracy was distinct from the use of ground truths in the categorization process. Confusion matrix and error matrix were used to indicate classification accuracy. The confusion matrix is a powerful tool for thoroughly evaluating the performance of a classifier. It offers an extensive representation of how well the classifier is performing (Krstinić et al., 2020). The error matrix, which is used for organizing and presenting data to evaluate the thematic precision of a land-cover map (Stehman, 1997).

2.3.3 SWAT Model Setup, Sensitivity, Calibration and Validation

The initial step in developing the SWAT model input involved delineating the watershed from a DEM (Mengistu et al., 2019). This process required projecting inputs such as the soil map, LULC map, and DEM into the same UTM Zone 37N projection. The watershed delineation phase encompassed several key processes, including DEM setup, stream definition, outlet and inlet definition, selection and definition of watershed outlets, and computation of sub-basin characteristics.

Subsequently, HRU analysis was conducted to incorporate the land use, soil layers, and slope map into the project. The LULC, soil, and slope map were reclassified to align with SWAT database parameters. After this reclassification, these physical properties were overlaid for HRU definition.

Following this, sensitivity parameters for the calibration were selected based on prior calibration settings and materials from SWAT. The SWAT-cup stream flow calibration was executed using the Sequential Uncertainty Fitting software (SUFI2) to assess simulated outcomes (Biru and Kumar, 2018). The calibrated simulations' performance was evaluated based on the Nash-Sutcliffe Efficiency (NSE) and coefficient of determination (R2). Further validation of the stream flow was conducted by simulating 35% of the flow data period using the SUFI2 results.

The performance of the SWAT model was rigorously assessed multiple times until acceptable values for surface runoff and sediment concentration were attained (Kiros et al., 2015). Stream flow validation was carried out using statistical model performance measures identical to those used in the calibration process (Kiros et al., 2015).

2.3.4 Model Sensitivity analysis, Calibration and Validation of Sediment concentration

A relationship was established between the movement of sediment and pairs of water discharge data. The sediment concentration in the Gilgel Abay watershed was determined by employing a spatially semi-distributed rating curve model, which took into consideration calibrated and validated sediment data for the years 2000, 2010, and 2020, while also accounting for land use and land cover changes. In addition to estimating sediment flow based on observed sediment concentration versus discharge, sediment simulators were utilized for further refinement and validation.

$$C = aQ^{b-1} \quad (1)$$

In the specified calculation, the sediment concentration (C) is determined by the discharge (Q) and numerical constants (a and b). The sediment concentration used in the calculation was derived from the observed flow or discharge, and it incorporated the regression parameters a and b, which were found to be 4 and 1.65 respectively for the Gilgel Abay watershed (Moges et al., 2016).

The default simulation indicated agreement between the observed and simulated data. Calibration was carried out for sensitive sediment data parameters with daily sediment concentration data in document SWAT. Additionally, sensitivity analysis was performed for the Gilgel Abay watershed hydrology to identify parameters that need enhancement for improved simulation results and better understanding of the hydrologic system behavior and to assess the model's applicability.

2.3.5 Model Performance Evaluation of streamflow and sediment concentration

The model simulation underwent thorough evaluation, considering efficiency criteria like the coefficient of determination (R^2), Nash and Sutcliffe (NSE), and RSR simulation efficiency (Chicco et al., 2021). These metrics gauge the accuracy with which the simulated results replicate trends in the measured data across specific time periods and steps. Numerical formulae (Barbosa et al., 2019, Chicco et al., 2021):

$$R^2 = \left(\frac{\sum_{i=1}^{n}(Oi-Omean)*(Si-Smean)}{(\sum_{i=1}^{n}(Oi-Omean)^2)^\wedge 0.5*(\sum_{i=1}^{n}(Si-Smean)^2)^\wedge 0.5}\right)^2 \quad (2)$$

$$NSE = 1 - \frac{(\sum_{i=1}^{n}(Oi-Si)^2)}{\sum_{i=1}^{n}(Oi-Omi))} \quad (3)$$

Where: O_i, O_{mean} are observed and observed mean respectively, S_i and S_{mean} predicted and predicted mean values respectively

$$RSR = \frac{RMSE}{STDEVob} \quad (4)$$

where RMSE and $STDEV_{ob}$ are root mean square and standard deviation of observed data respectively.

2.3.6 Evaluation of LULC change on sediment concentration

The impact of changes in land use and land cover (LULC) on the sediment concentration in the watershed was examined using verified sediment concentration data. By utilizing the confirmed sediment concentration data for each sub-basin, the spatial variance of sediment concentration in the Gilgel Abay watershed was determined. Additionally, potential areas were pinpointed through the variation in sedimentation rates. The measured sediment concentration was considered to be representative of the time period. When analyzing the runoff events based on cumulative effective precipitation during the rainy phase, the relationship between sediment concentration and discharge exhibited a consistent pattern that was applicable to the entire watershed.

2.3.7 Evaluation of LULCs change on stream flow

Based on the LULC change detection of the three different years, the satellite image results revealed a significant impact on the streamflow of the watershed. The calibrated and validated simulation results of the daily average streamflow for the 2000, 2010, and 2020 LULC were showcased. Of particular interest were the effects of agricultural activities on water load, considering the use of the prior appropriation doctrine to allocate water rights. Understanding how agricultural practices affect the quantity of water lost from these lands becomes crucial for accounting for the effects of more efficient water usage and determining the potential availability of water for appropriation by other users.

3. Result and discussion

3.1 Accuracy Assessment of Land Covers Classification

In assessing the imagery from the years 2000, 2010, and 2020, data from 590, 934, and 1036 points on Google Earth were utilized. The results revealed that the overall accuracy for the maps of 2000, 2010, and 2020 stood at 99.1, 97.8, and 98.7 respectively. Moreover, the producer's accuracy values fell within the range of 96% to 99% for all three years. Additionally, the overall users' reliability in this research varied from 96% to 100% across the three years (See Table 2 and 3).

Table 2: outlines the confusion matrix and potential measures of the Gilgel Abay watershed for the 2010 LULCC.

	Reference LULC change							
Classified data	CL	SL	BL	FL	UA	WB	GL	Row total
CL	354	1	1	1			2	359
SL	3	71		2				76
BL	2		145		1	1		149
FL		1		116			1	118
UA			1		82			83
WB						44		44
GL	1		1		2		102	106
Column total	360	73	148	119	83	45	105	934

Table 3: -Different measurement from error matrix for the year 2010

LULC	Omission error	Producer accuracy	Commission error	User accuracy
CL	6/360=0.0166	354/360=0.98	5/359=0.014	345/360=0.96
SL	2/73=0.027	71/73=0.97	5/76=0.066	71/76=0.93
BL	3/148=0.02	145/148=0.98	4/149=0.027	145/149=0.97
FL	3/119=0.025	116/119=0.97	2/118=0.017	116/118=0.98

UA	3/83=0.036	82/83=0.99	1/83=0.012	82/83=0.99
WB	1/45=0.022	44/45=0.97	0/44=0.00	44/44=1
GL	3/105=0.028	102/105=0.97	4/106=0.0377	102/106=0.96
Total	**0.025**	**0.97**	**0.025**	**0.97**

Note: BL=Bare Land; CL=Cultivated land; SL=Shrub land; FA=Forest Area: UA =Urban Area; WB=Water Body; GL=Grass Land

According to Gao et al., (2017), the above results showed that a high level of agreement between the ground truth and categorized images, which means they can be used for further analysis and change detection.

3.2 LULC Change Analysis

Our findings revealed interesting insights. Between 2000 and 2020, cultivated land experienced a substantial decrease of 15.48%, while urbanization increased by 12.13%. Additionally, there was a 4.13% decrease in grassland, a 3.52% increase in shrub land, a 0.12% increase in water bodies, and a 1.12% decrease in bare land (Table 4). Furthermore, the study indicated that the decline in cultivated land was influenced by the rapid increase in shrub land, urban area, and forest.

Evaluating the LULCC (Land Use and Land Cover Change) results for the three time periods, the data suggests that LULC was more favorable in 2000 compared to 2010. However, in 2010, we observed a decline in shrub land and forest cover, accompanied by an increase in urban areas. The LULC analysis for 2020 demonstrated a decrease in cultivated land but an overall improvement in LULC.

This study provides valuable insights into the changing LULC patterns in the Gilgel Abay watershed, highlighting the dynamic nature of land use and land cover over the past two decades.

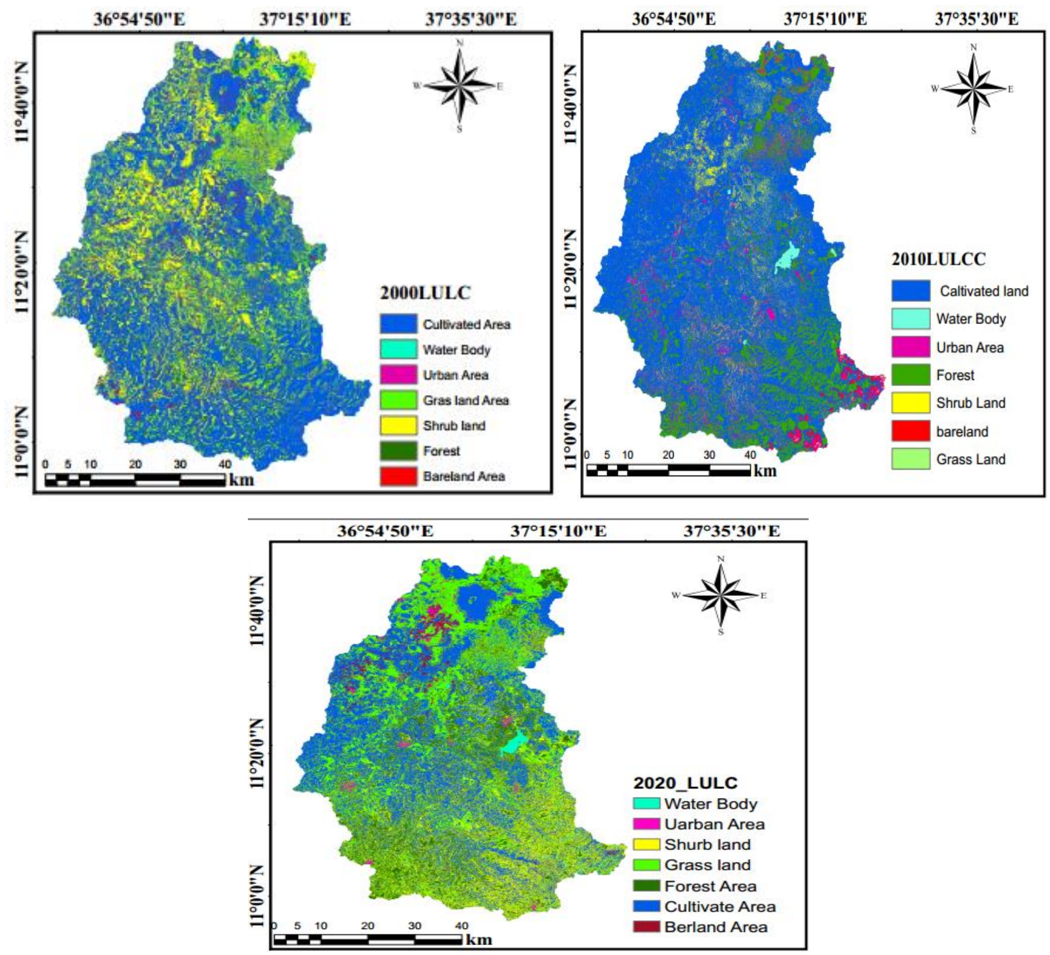

Figure 2: Land use land cover map of year 2000, 2010 and 2020 for Gilgel Abay watershed.

Table 4: - Summary result of LULC change of Gilgel Abay Watershed

LULCC (in %)	years			LULCC Detection		
	2000	2010	2020	2000-2010	2010-2020	2000-2020
Cultivated	57.28	58.3	43.86	-1.02	14.44	13.42
Water body	1.36	1.75	1.48	-0.39	0.27	-0.12
Shrub land	19.94	18.2	23.4	1.74	-5.2	-3.46
Forest	4.8	1.46	7.52	3.34	-6.06	-2.72
Grass land	11.25	9.17	8.12	2.08	1.05	3.13
Bare land	3.9	2.13	1.02	1.77	1.11	2.88
Urban area	1.47	8.99	14.6	-7.52	-5.61	-13.13

3.3 Stream Flow Modeling

3.3.1 Sensitivity Analysis of Simulated Stream Flow

In the study, we conducted a sensitivity analysis of simulated stream flow for the watershed. The analysis involved using the daily observed flow to pinpoint the most sensitive parameter and to calibrate the simulated stream flow accordingly. Specifically for runoff, the sensitivity analysis was carried out on the flow parameters of the SWAT model on daily time steps, using observed flow data. Thirteen parameters were considered in this study, and it was found that five of them are sensitive, namely: R-CN2, V-GW-DELAY, R-SOL-AWC, R-ESCO, and R-ALPHA-BNK (refer to Table 5).

Table 5: -The sensitive parameters identified for Gilgel Abay Watershed in SWAT model

No	Parameter Name	t-Stat	P-Value	Min -value	Max- value
1	R__SOL_K(..).sol	0.04	0.97	-0.59	-0.420
2	R__REVAPMN.gw	0.21	0.83	1.05	1.17
3	R__GW_REVAP.gw	0.52	0.61	13.32	29.68
4	V__GWQMN.gw	-0.55	0.58	0.64	0.80
5	V__ALPHA_BF.gw	0.64	0.52	356.02	484.28
6	R__CH_N2.rte	1.01	0.31	152.28	201.12
7	R__CH_W2.rte	-1.24	0.22	0.005	0.10
8	R__CH_K2.rte	-1.46	0.15	0.04	0.06
9	R__ALPHA_BNK.rte	2.13	0.03	-36.58	69.78
10	R__ESCO.hru	2.52	0.01	-3034.02	-2633.12
11	R__SOL_AWC(..).sol	-2.52	0.01	0.94	1.12
12	V__GW_DELAY.gw	8.64	0.00	0.23	0.32
13	R__CN2.mgt	-14.17	0.00	0.92	1.34

3.3.2 Calibration and validation of stream flow

With the default parameter settings, the flow simulation demonstrated a strong agreement between the simulated and observed stream flow hydrograph. Subsequently, SWAT's sensitive flow parameters were utilized for calibration, employing observed average daily streamflow data. The calibration and validation analysis focused solely on the 2010 SWAT output data, simulating 65% of the flow data period. The results of the calibration for daily flow revealed a high level of correspondence between the observed and simulated data. This study conducted two validation outputs on Wetet Abay and the outlet of Lake Tana (Chimba) station, both of which exhibited favorable agreement between the simulated and measured daily flow data (Table 6).

Table 6: - Calibration and validation results for daily flow of 2010

Calibration (65%)			Validation for Gilgel Abay (35%)			Validation for Chimba (35%)		
R^2	NSE	RSR	R^2	NSE	RSR	R^2	NSE	RSR
0.61	0.64	0.08	0.68	0.60	0.075	0.67	0.54	0.086

In the same field, other studies have also reaffirmed the findings of this study for monthly data. For instance, (Setegn et al., 2008) found NSE and R2 values of 0.64 and 0.80 for calibration and 0.71 and 0.80 for validation periods, respectively, for the Gilgel Abay watershed. Andualem & Gebremariam (2015) also noted that the validated streamflow results of the Gilgel Abay watershed were satisfactory, with NSE and R2 values of 0.90 and 0.91, respectively. In this study, the NSE and R2 results were 0.64 and 0.61 for calibration and 0.60 and 0.68 for validation at the Gilgel Abay station. Additionally, the NSE and R2 were 0.54 and 0.67, respectively, for the Chimba station.
The calibrated streamflow results for the LULC change in 2010 yielded NSE and R2 values greater than 0.6, solidifying this model as the most accurate predictor (indicating a strong correlation and agreement with the observed mean). Daily observed flows were utilized to validate the streamflow simulation for a 35% time span, including a two-year warm-up period, after automatic calibration and achieving the necessary NSE and R2 values. NSE and R2 values exceeding 0.60 and 0.68 for the three separate years, respectively, were used to validate the results.

Table 7: -Dry and Wet Period season average stream flow(m^3/s) results of 2000, 2010 and 2020

Years	2000	2010	2020	Change in flow		
				2000-2010	2010-2020	2000-2020
Dry period	22.87	5.94	20.34	16.93	-14.4	2.53
Wet period	205.2	251.25	290.93	-46.05	-39.68	-85.73

Based on the data presented in (Table 7), the months of February, March, April, and May were designated as the dry period, while July, August, and September were identified as the wet season. The purpose was to analyze the variance in stream flow between the dry and wet seasons.

Over the past two decades (2000-2020), there has been a general increase in stream flow during the rainy season, amounting to 85.73 m3/s. The initial period (2000-2010) witnessed a rise of 46.05 m3/s, followed by a further increase of 39.68 m3/s in the subsequent period (2010-2020). Conversely, stream flows during the dry period (2000–2020) experienced a decrease of 2.53 m3/s, with the first period (2000–2010) showing a reduction of 16.93 m3/s.

3.3.3 Effect of Stream Flow due to LULC Change

The study aimed to assess the impact of changes in land use and land cover (LULC) on streamflow within the Gilgel Abay watershed. It was observed that the expansion of eucalyptus plantations in the area, mainly for commercial purposes, led to afforestation, consequently reducing the land available for cultivation. Eucalyptus plantations are widely recognized for their timber and charcoal production, and their rapid growth contributes to the depletion of shallow groundwater, thus affecting the water cycle. The study also indicated that cultivated land demonstrated higher runoff compared to uncultivated land. Furthermore, there was no significant disparity in discharge volume between grassland and eucalyptus woodlot. The increase in irrigated land and the expansion of urban areas and eucalyptus plantations were identified as factors leading to diminished base flow and elevated runoff in the watershed over the years. The research findings further highlighted noticeable alterations in streamflow as a result of LULC changes recorded in categorized images from three different years. The simulated monthly average stream flow for the land cover in 2000, 2010, and 2020 is provided in Table 8. This comprehensive analysis supports the necessity of incorporating the extent of eucalyptus patches and forests in the management of groundwater resources as emphasized by Enku et al. (2014) and necessitates prudent considerations in future land use planning.

Table 8: - Total stream flow change from 2000-2020

	Flow from 2000 to 2020 (m^3/s)			**Change of flow due to LULCC**		
Months	2000	2010	2020	2000-2010	2010-2020	2000-2020
Jan	102.42	7.98	5.22	94.44	2.76	97.2
Feb	69.63	1.19	0.72	68.44	0.47	68.91
Mar	15.67	5.29	2.17	10.38	3.12	13.5
Apr	4.94	9.6	22.74	-4.66	-13.14	-17.8
May	1.21	7.67	75.94	-6.46	-68.27	-74.73
June	0.05	41.01	67.41	-40.96	-26.4	-67.36
July	220.22	280.21	293.97	-59.99	-13.76	-73.75
Aug	256.03	299.68	332.43	-43.65	-32.75	-76.4
Sep	139.34	173.87	246.39	-34.53	-72.52	-107.05
Oct	64.59	82.06	150.83	-17.47	-68.77	-86.24
Nov	49.97	26.29	35.42	23.68	-9.13	14.55
Dec	7.66	36.72	13.57	-29.06	23.15	-5.91
Average	77.65	80.96	103.9	-3.31	-22.94	-26.25

The results of the model's simulated flow suggest that land use and land cover change (LULCC) in the Gilgel Abay watershed had an impact on streamflow. During the study period from 2000 to 2020, the simulated maximum flow showed an increasing trend. This outcome could be attributed to the expansion of eucalyptus trees and urban development. Previous research has indicated that eucalyptus expansion may lead to heightened soil water repellency and increased runoff (Thompson et al., 2016). Further investigation is required to establish a detailed relationship between surface runoff and eucalyptus trees. Another contributing factor could be the extensive cultivated land in the watershed. Despite a decreasing trend in cultivated land, the majority of the watershed still consists of cultivated areas, ranging from 41.8% to 57.3% during the study period, as shown in Table 8.

In general, the monthly average stream flow in the Gilgel Abay watershed has increased due to LULC changes from 2000 to 2020. Specifically, the monthly average flow escalated by 3.32 m3/s from 2000 to 2010, by 22.94 m3/s from 2010 to 2020, and by 26.25 m3/s from 2000 to 2020.

3.4 Sediment Concentration Modeling

When it comes to reservoir design and environmental applications, having accurate information about sediment concentration in rivers is crucial. The relationship between concentration and discharge is quite unique, and while it can satisfactorily predict loads, it may be less useful for forecasting concentration, especially in scenarios where fish production and reservoir storage are affected by sediment concentrations.

An analysis of data from three separate years of satellite images revealed that changes in land use and land cover (LULC) had a significant impact on stream flow in the watershed, as well as on sediment concentration. The simulated daily sediment concentration data statistics for LULC changes in 2000, 2010, and 2020 showed an overall increase in sediment concentration throughout both the calibration and validation periods. As the available sediment data was not sufficient for the calibration and validation model, a new sediment data set was generated based on a previous study's equation.

In this study, the generated sediment data was used as observed sediment concentration data. Previous research has indicated that sediment concentration relies on the sediment available for transport by runoff (Moges et al., 2016).

3.4.1 Sensitivity analysis of simulated sediment concentration

Upon analyzing the daily observed sediment concentration for the watershed, sensitive parameters were identified through the testing of fourteen sediment parameters. This sensitivity analysis revealed five parameters to be particularly sensitive, namely R-USLE-K, R-CH-N2, A-SLSUBBSN, R-SOL-AWC, and V-SPEXP (refer to Table 9). These findings will guide further simulation and calibration of sediment concentration.

Table 9 Sensitive parameters for sediment concentration.

No	Parameter Name	t-Stat	P-Value	Min -value	Max-value	Fitted value
1	R__CH_W2.rte	0.12	0.90	0.92	1.12	1.07
2	R__SOL_K(..).sol	-0.37	0.71	0.29	0.33	0.31
3	R__USLE_P.mgt	0.76	0.45	1.119	1.24	1.18
4	R__CH_K2.rte	-0.82	0.41	-3272.79	2938.27	-3189.16
5	R__CN2.mgt	-0.97	0.33	-19.10	77.38	-4.63
6	V__SURLAG.bsn	-0.99	0.32	0.13	0.272	0.26
7	R__ESCO.hru	1.01	0.31	129.36	158.83	148.51
8	R__ALPHA_BNK.rte	1.07	0.29	357.25	410.78	392.05
9	R__REVAPMN.gw	1.30	0.20	7.73	33.07	19.13
10	V__SPEXP.bsn	-2.46	0.01	0.39	1.04	1.01

11	R__SOL_AWC(..).sol	6.14	0.00	2.10	2.86	2.74
12	A__SLSUBBSN.hru	36.13	0.00	2.1	2.86	2.75
13	R__CH_N2.rte	51.90	0.00	0.39	1.04	1.01
14	R__USLE_K(..).sol	133.33	0.00	7.73	33.07	19.13

3.4.2 Calibration and validation of sediment concentration

The sediment concentration parameters for SWAT were calibrated using observed daily sediment concentration data. The default simulation demonstrated strong agreement between the observed and simulated data. Initially, SUFI2 was used to calibrate the simulated sediment flow results, with 65% of the data used for calibration and 35% for validation, including a two-year warm-up period for each. The NSE and R2 values indicated good performance, as shown in Table 10.

Table 10:Sediment calibration and validation results for daily 2010

Calibration (65%)			Validation for Wetet Abay (35%)			Validation for Chimba		
R^2	NSE	RSR	R^2	NSE	RSR	R^2	NSE	RSR
0.65	0.64	0.05	0.64	0.61	0.06	0.63	0.43	0.08

3.4.3 Evaluation of LULC change on sediment concentration

The impact of land use/land cover (LULC) changes on sediment concentration in the watershed was assessed by analyzing the sediment concentration results calibrated and validated for the 2010 LULC changes.

Table 11: - Monthly sediment concentration(mg/l) Changes on three LULCC

LULC from 2000 to 2020				Change of Sediment Concentration due to LULCC		
Months	2000	2010	2020	2000-2010	2010-2020	2000-2020
Jan	1.52	0.07	0.00	-1.45	-0.06	-1.52
Feb	1.07	0.56	0.29	-0.51	-0.27	-0.78
Mar	5.23	0.43	1.06	-4.80	0.64	-4.16
Apr	10.95	12.26	66.60	1.30	54.34	55.64
May	7.41	8.79	8.35	1.37	-0.44	0.93
June	127.44	245.02	157.83	117.59	-87.20	30.39
July	177.05	128.05	83.41	-49.00	-44.65	-93.64
Aug	157.85	98.65	51.76	-59.20	-46.89	-106.09
Sep	18.47	18.05	19.22	-0.42	1.18	0.75

Oct	28.53	3.26	63.90	-25.27	60.65	35.38
Nov	9.53	0.50	42.80	-9.02	42.30	33.27
Dec	3.37	0.01	0.27	-3.36	0.26	-3.10
Average	45.70	42.97	41.29	-2.73	-1.68	-4.41

The model's simulated flow output suggests that Land Use and Land Cover Change (LULCC) in the Gilgel Abay watershed has impacted sediment concentration. Over the period of 2000-2020, there was a 4.41% reduction in sediment concentration. Specifically, there was a 2.73% decrease from 2000-2010 and a 1.68% decrease from 2020-2010. This could be attributed to a decrease in cultivated land and an increase in forest and shrub land within the study area (refer to Figure 9). Furthermore, it's important to note that the Koga Dam, located in this watershed, has been affected by sedimentation. Previous studies have indicated a sedimentation rate of 5 ton/ha/year, while a calibrated SWAT model resulted in 8.6 ton/ha/year (Alemaw et al., 2016).

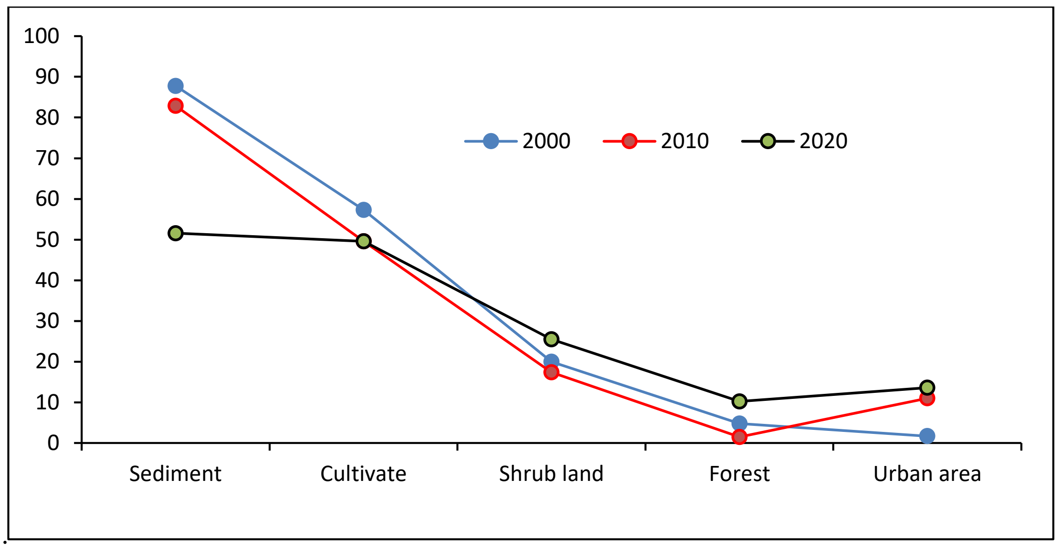

Figure 9: Relationship between major land covers and sediment concentration

During the period of 2000-2020, there was a noticeable reduction in sediment concentration data within the Gilgel Abay watershed. The documented pattern reveals an increase in forest and shrub land, and a decrease in cultivated land, as indicated in Table 4.10. This shift led to a decrease in sediment concentration, attributed to the decreased rainfall erosivity in forest and shrub lands, which in turn enhanced soil erodibility (Aneseyee et al., 2020).

3.5 Exploring the Interconnection of Land Use and Land Cover, Stream Flow, and Sediment Concentration

The impact of land use and land cover changes (LULCC) on stream flow and sediment concentration is a complex interaction in the watershed. Understanding the relationship between LULC, stream flow, and sediment concentration is crucial due to the influence of multiple physical processes on hydrologic variables over time. Different types of land cover significantly affect the watershed, particularly with regards to sediment concentration (Abe et al., 2019). It is important to carefully select the types of plants to be introduced when covering the watershed with forest and shrub, in order to minimize the impact on base flow. The findings of the study indicate a decreasing trend in sediment concentration over the years, attributed to the extensive forest and shrub land cover in the watershed. Diverse plant cover in the watershed not only impacts stream flow significantly but also makes a substantial contribution to reducing sediment concentration.

4. CONCLUSION

It's clear that from 2000 to 2010, there was a decrease in forest, shrub land, and cultivated land, while from 2010 to 2020, the cultivated land and grass land decreased. However, during the period from 2010 to 2020, there was a recovery in shrub land and forest. This regrowth can be attributed to the extensive expansion of eucalyptus plantations due to its use as a profitable cash crop in recent years. Changes in Land Use and Land Cover (LULC) have had a significant impact on hydrological processes, affecting sediment concentration in the Gilgel Abay watershed. Over the 20-year period from 2000 to 2020, the conversion of grass and cultivation land into urban areas led to a reduction in sediment content by 15.8%, resulting in an average reduction of 4.41mg/l in sediment content. The presence of cultivated land has shown a clear correlation with sediment concentration, with the decreasing cultivated area leading to reduced sediment content. The relationship between LULC changes, stream flow, and sediment concentration indicates that while sediment concentration has decreased due to the conversion of land into forest and shrub land, the baseflow has decreased as a result of increased irrigated land and eucalyptus plantations. This study provides valuable insights for decision-makers and stakeholders in effectively planning and managing land and water resources. It can be used to forecast hydrological changes in various watersheds where digital time-sequenced land cover data is available. It's important that any potential impact on water resources by the plantations in this watershed is thoroughly assessed, as the watershed holds significant ecological importance for Lake Tana and the Great Ethiopian Renaissance Dam.

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