Open Access Library Journal
2022, Volume 9, e8161
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Understanding the Impact of Land Use and Land Cover Change on Local Hydrology: Implications for Long-Term Planning in the Sore and Geba Watersheds, Southwestern Ethiopia

Jemal M. Hassen

Ethiopian Institute of Agricultural Research/Werer Agricultural Research Center, Addis Ababa, Ethiopia
Email: jemsmoha@gmail.com

How to cite this paper: Hassen, J.M. (2022) Understanding the Impact of Land Use and Land Cover Change on Local Hydrology: Implications for Long-Term Planning in the Sore and Geba Watersheds, Southwestern Ethiopia. *Open Access Library Journal*, **9**: e8161.
https://doi.org/10.4236/oalib.1108161

Received: November 6, 2021
Accepted: February 25, 2022
Published: February 28, 2022

Abstract

This study aims to evaluate the impacts of land use and land cover change on surface runoff in the Sore and Geba watersheds, the upper Baro-river basin covering an area of about 6551 km^2 located in East Africa. Landsat images were used to analyze the land use and land cover change trends for the periods of three decades (1987-2015). Land use and land cover maps were produced using the maximum likelihood algorithms based on supervised classification. Trends of land use and land cover change showed that cultivated land has increased by 16.55% within the periods between 1987 and 2015 with annual expansion by 36.15 km^2 at the expense of other land use types such as open forest, dense forest and wood land. The impacts of land use and land cover change on surface runoff were evaluated using the Soil and Water Assessment Tool (SWAT) model. Nine sensitive flow control parameters were identified and used for calibration of the model. Good performance was obtained in both calibration and validation periods. Results show that between 1987 and 2015, a 16.5% cultivated land expansion was observed which may explain an increase of about 6.65 m^3/s annual surface runoff. In general, significant influences of land use and land cover change were reflected in changes to the region's hydrologic system during the study period, with important management implications for this region as well as other similar regions in Africa.

Subject Areas

Agricultural Science

Keywords

Land Use Change, Sore and Geba Watershed, SWAT, Surface Runoff, Landsat Image

1. Introduction

Water is an essential natural resource for humans, animals, plants and the environment. The quality and the available amount of water in relation to human needs and population growth are still limited. Land and water resource management is a key issue in maintaining the sustainability of natural resources and satisfying the current demands of the population. Sustainable land use planning has a close link with water resources as the changes in land use have an effect on water resources through the relevant process of the hydrological cycle [1]. The availability of water in an area depends very much on how the precipitation in the area is separated into various components of the hydrologic cycle, such as groundwater recharge, interflow, evaporation, and surface runoff. Proportions of these components in an area are mainly affected by the land use and land cover of the catchment. Hence, a change in land use and land cover of the area can modify the proportions of the above-mentioned components, which, in turn, results in a change in the ecological system of the area. Recent research suggests that there has been a substantial change in land use and land cover in the past few decades over many parts of the globe [2]. In Ethiopia, a decline in natural vegetation such as forest and shrubs, together with an increase in cultivated and bare lands, has resulted in increased surface runoff and soil losses from the catchment [3]. This research also suggests that the removal of top soils from the catchment because of land use and land cover change resulted in a reduction in soil fertility, sedimentation in the downstream and a scarcity of soil water availability. In the highland parts of Ethiopia, the expansion of cultivated lands at the expense of natural forests and vegetation covers has intensified the problem of land degradation, specifically through soil erosion by water [4].

The natural resources of the Baro river basin in southwestern Ethiopia are under continuous change because of land use and land cover changes starting since 1986 due to resettlement, population growth, overuse of resources, and the expansion of commercial farming [5]. The downstream human settlement and agricultural (both grazing and crop) lands are seriously affected by unusual occurrences of floods overflowing riverbanks beyond the normal flooded zones caused by changes in rainfall patterns and also by human interference within the catchment due to the absence of land use planning [6].

The change in land use from forest, shrub, and grasslands to agricultural lands has an impact on the stream flow of the river and evapotranspiration from the catchment. Cultivated land increases stream flow and decreases evapotranspiration during the main rainy season, while there is inconsistency during the small rainy season and dry periods [7]. Estimation and assessment of surface runoff is an important issue of hydrological and geographical research. Surface runoff is a significant factor affecting the development and progress of floods, soil erosion and other hydrological hazards. The runoff characteristics of a drainage basin are influenced to a large extent by land use and land cover changes, which in turn affect the availability of surface and groundwater in the area, and hence lead to further changes in land use and land cover [8]. The impact of land use on the hydrological regime influences both groundwater and surface water resources. The effects of land use practices on surface water can be divided into two categories: effects on overall water availability or mean annual runoff, and effects on the seasonal distribution of water availability. Therefore, the effects of land use practices on surface runoff should be assessed to predict their impacts on the environment and the community.

Southwestern Ethiopia is the origin of Coffee Arabica and the area is suitable for coffee production. As a result, it attracts private investors to produce commercial crops like tea and coffee. There is also illegal deforestation by local farmers who cultivate coffee and other cereal crops on the lands. All these activities are some of the causes of land use and cover change. In this region, all the activities appear to be done without sustainable land use planning and consideration of the change impacts on the hydrological process. The local residents in southwestern Ethiopia claim that the deposition of sediments, gravel, and sand in the riverbed is a new phenomenon that occurred after deforestation [9]. The Baro-Akobo River basin, which is found in the southwestern parts of Ethiopia, is one of the areas that is rich in diversified natural resources and a habitat for different peoples with different working cultures and farming practices. Despite this fact, there have been very few studies in the area. In the Baro-Akobo river basin, not much is known about the details of the water resources, and there is a need to understand the possible threats that may happen to the hydrologic system as a result of anthropogenic and climate variability [10]. The increasing population, coupled with the expansion of cereal cropping practices, resettlement, and commercial farming like palm oil, tea, and coffee plantations, is one of the threats to deteriorating the original natural forest cover, the traditional farming practices, and livelihoods of the community living in that region. The conversion of forest areas to open farmland has an impact on the water balance of the catchment by changing the pattern and magnitude of surface runoff, which results in riverbank degradation and increases the extent of water and land management problems. Consequently, the communities living in the lower parts of the Baro river basin are affected by recurrent flooding and sedimentation in their irrigation channel [10]. In the Baro basin, there is also a research gap to represent the hydrological behavior and understanding of the flow of the basin. Quantifying and understanding the effects of land use and land cover change on the hydrological components will help in identifying the causes of floods and their implications on the watershed. To apply a corrective source-based measure to the problem and develop a new plan in the catchment, assessing the effects of land use practices on hydrology is an important first step in making a better decision about land use planning by the government and the decision makers. The aim of this research was, therefore, to assess land use change impacts on surface runoff using the soil and water assessment tool (SWAT) model. Specifically, by understanding the impact of different land use practices on runoff response and identifying land cover change trends in the region.

2. Data and Methods

2.1. Description of the Study Area

Baro river is one of the major rivers in Baro-Akobo basin which lies in southwestern part of Ethiopia located between 33˚23'39" to 36˚18'21"E and 9˚25'2" to 7˚27'8"N, which defines part of Ethiopia border with South Sudan. From its source in the southwestern Ethiopian highlands, it flows west for 306 kilometers to join the Pibor river that flows to White Nile after forming Sobat River system. The drainage area of the basin including its tributaries are about 41,400 km^2 and is bordered by the Sudan in the Northwest, Abbay Basin in the east and Akobo basin in the Southwest. The elevation of the catchment ranges from 3244 m a.s.l. in the Southwestern highlands of Ethiopia and 390 m a.s.l. at the point where the border of South Sudan. For this specific study, Sore and Geba watershed about 6551.07 km^2 which is sub watershed of Baro river basin (one of the main tributaries) was selected (**Figure 1**). The elevation of Sore and Geba watershed ranges from 937 to 3001 meter above sea level.

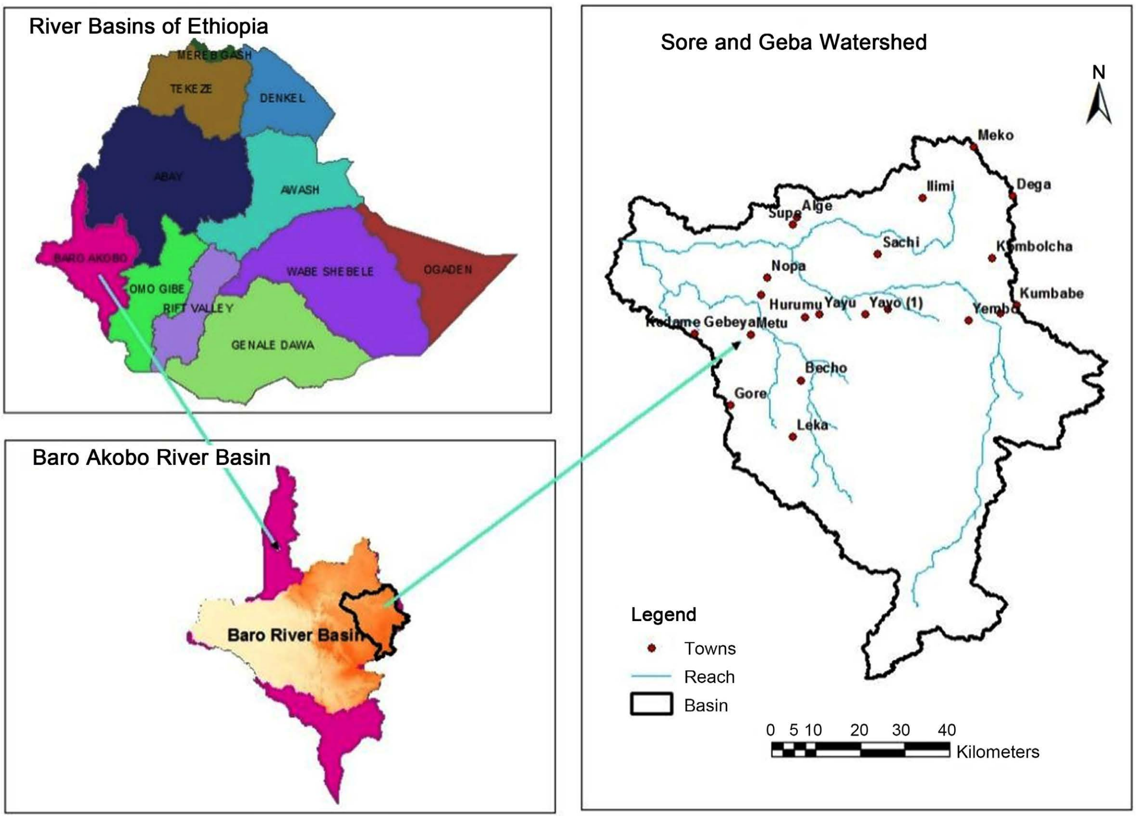


Figure 1. Location map of the study area.

2.2. Data Required

For this study, various climatic and topographic data were acquired such as Digital Elevation model (DEM), land use and land cover, soil data, daily data of precipitation, maximum and minimum temperature, wind speed, relative humidity and solar radiation. The land cover satellite image and DEM were obtained from United State Geological Survey (USGS) website. The climatic data were obtained from National Meteorological Agency of Ethiopia. Hydrological and Soil data were obtained from Ministry of Water, Irrigation and Electricity of Ethiopia.

2.3. Methods

The general workflow framework of the study is described in **Figure 2**.

2.4. Hydrological Cycle

The land phase of the hydrologic cycle is modeled in Soil and Water Assessment Tool (SWAT) based on the following Water balance Equation (1) [11]:

$$SW_t = SW_o + \sum_{i=1}^{t}\left(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}\right) \tag{1}$$

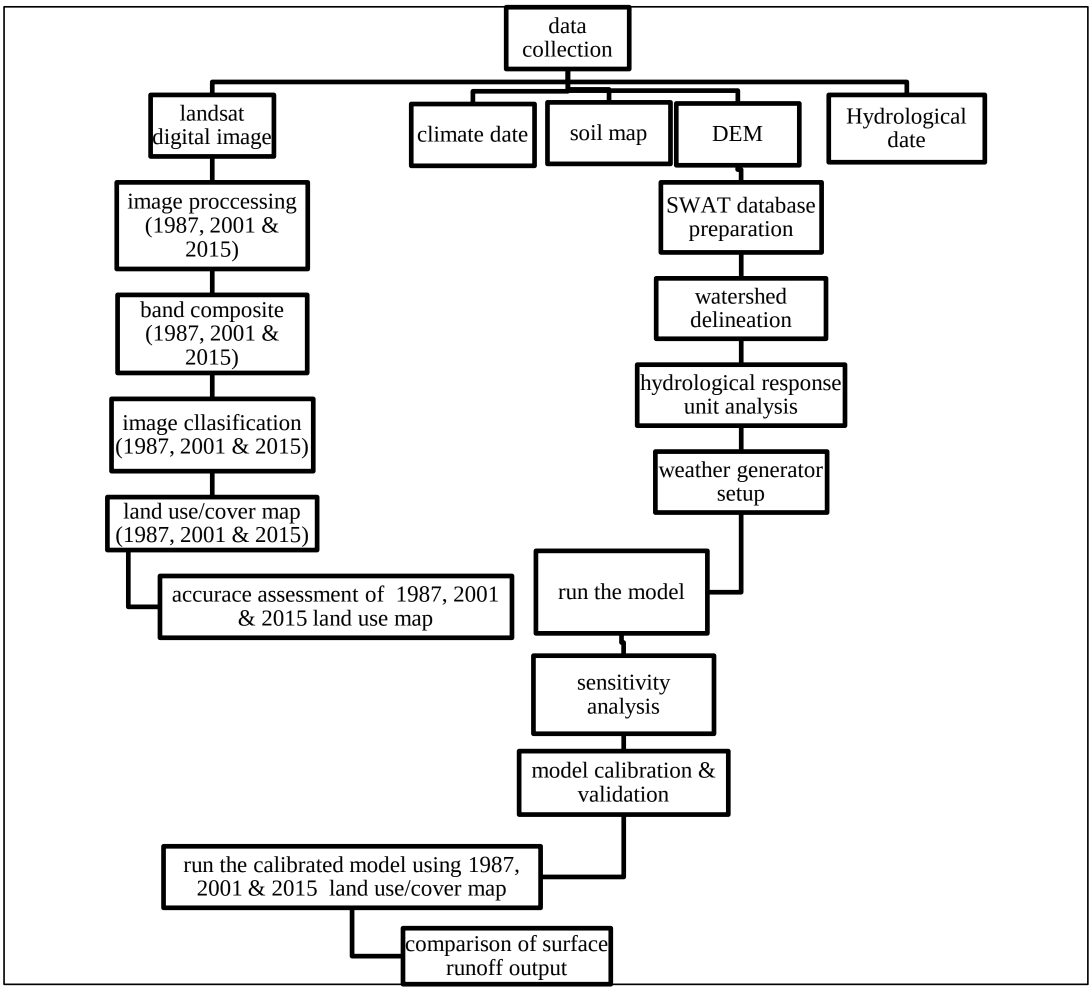


Figure 2. Framework of the study.

where, SW_t is the final soil water content (mm), SW_o is the initial soil water content on day i (mm), t is the time (days), R_{day} is the amount of precipitation on day i (mm), Q_{surf} is the amount of surface runoff on day i (mm), E_a is the amount of evapotranspiration (ET) on day i (mm), W_{seep} is the amount of water entering the vadose zone from the soil profile on day i (mm), and Q_{gw} is the amount of return flow on day i (mm). The computation of each of the mass balance is documented in [11].

2.5. Image Processing

Satellite imageries of different bands for each year were used to identify the land use and land cover change distribution in Sore and Geba watershed over 30 years' period from 1987 to 2015. Landsat-5-TM, Landsat-7-ETM+ and Landsat 8 were selected for the period of 1987, 2001 and 2015 respectively. The selection of the acquired data was made as much as possible within the same annual season to avoid a seasonal variation in vegetation pattern and distribution throughout the year. The images were orthorectified to a Universal Transverse Mercator projection using Geodetic datum Adindan UTM zone 37. All the input satellite images were composite to RGB color composition. To view and discriminate the surface features clearly, the images were composed of false color composition. The path/row, acquisition dates, sensor, resolution and the producers of images are described in **Table 1**.

2.6. Image Classification

There are several image classification techniques existing in literature for remote sensing image classification. This is broadly categorized as supervised or unsupervised image classification techniques. The most widely used and found to be accurate method is supervised image classification techniques [12]. For this study, by selecting training sites and generating signature files, supervised image classification techniques were applied to classify the image using a maximum likelihood classification algorithm. Image classification was done by using ArcGIS image processing tools. Majority filter was used to remove unwanted isolated pixels and to refine the image views.

Table 1. The path/row, acquisition dates, sensor, resolution and the producers of images.

Path/row	Acquisition dates	Sensor	Resolution (m)	Producer
170/054 170/055	1987-01-22	Landsat-5-TM	30	USGS
170/054 170/055	2001-02-05	Landsat-7-ETM+	30	USGS
170/054 170/055	2015-02-04	Landsat 8	30	USGS

2.7. Accuracy Assessment

Quality analysis was done by the confusion matrix. The various parameters describing the quality of image classifications are derived from the confusion matrix. The confusion matrix is a table with rows which represented the mapped (classified) categories derived from remote sensing data and the columns which represent the reference (observed) classes [13]. The most commonly used indices are overall accuracy, producer's accuracy, and user's accuracy. These were calculated using the resulting error matrix.

2.8. Model Setup

2.8.1. Watershed Delineation

The sore and Geba watershed was delineated into 29 sub-watersheds having an estimated area of 6551.07 km^2. To define hydrological response unit (HRUs), the model requires data on soil type, land use and slope. For the land use map, 30 m by 30 m resolution of Landsat imageries was obtained from the USGS website. After supervised classification in ArcGIS, it was loaded onto the delineated area.

The soil map of the basin was clipped from the soil map of Ethiopia and overlapped with the delineated area. The slope of the watershed and sub-watershed were also generated from the DEM data. Subdividing the catchment into areas having unique land use and soil combinations enables the model to reflect differences in evapotranspiration and other hydrologic conditions for different land covers and soils [14].

To overlay land use, soil and slope using the HRU definition the SWAT user's manual suggested for most modeling application a threshold value of 20% land use, 10% soil and 20% of slope combination. However, a research conducted in Ethiopia with a threshold value of 10% land use, 20% soil and 10% of slope combination was good for better estimation of stream flow [15]. Thus, for this study the HRU definition with multiple options a threshold of 10% land use, 20% soil and 10% of slope combination was used. Hence, the Sore and Geba watershed was divided in to 345, 344 and 300 HRUs for the land use map of 1987, 2001 and 2015 respectively; each has a unique combination of soil and land use.

The weather data was formatted into the SWAT weather generator files and accordingly input into the database. The model is then set up and run. Thus, for understanding the effect of land use and land cover change on surface runoff over different time periods, the model was run by varying the land use map and keeping the other SWAT input parameters constant.

2.8.2. Calibration and Validation

For this study, calibration, validation, sensitivity and uncertainty analysis of stream flow parameters were done by SWAT-CUP (SWAT calibration and uncertainty programs). SWAT-CUP is a public domain computer program for calibration of SWAT models. The program links the Sequential Uncertainty Fitting, version 2 (SUFI-2), Particle Swarm Optimization (PSO), Generalized Likelihood Uncertainty Estimation (GLUE), Parasol Solution (ParaSol) and Markov

Chain Monte Carlo (MCMC) procedures to SWAT model output files [16]. For this study, the Sequential Uncertainty Fitting program (SUFI-2) algorithm was used for calibration of Sore and Geba watershed (Sore River gauge) for the monthly SWAT runs. The available stream flow data of sore river gauge covered 10 years (1996-2005). The data were split into two for calibration period (1996-2000) and validation period of (2001-2005).

2.8.3. Model Performance Evaluation

There are different model performance evaluation techniques such as, Nash-Sutcliffe efficiency (NSE), coefficient of determination (R^2), percent bias (PBIAS) and by the ratio of the root mean square error of the standard deviation of measured data (RSR) etc. To judge the simulation of stream flow as satisfactory NSE > 0.50, RSR < 0.70 and PBIAS+ 25% [17]. For this study, the calibration and validation performance were carried out using the p-factor, r-factor, R^2 and NS model performance techniques.

3. Results and Discussion

3.1. Land Use and Land Cover Analysis

3.1.1. Accuracy Assessment

The confusion matrix result of overall accuracy for the maps of 1987, 2001 and 2015 were 89%, 95.3% and 96.3% respectively. The most accurate map is in 2015, which is the latest product of the Landsat 8 satellite image. The minimum value suggested by [18] for overall accuracy is 85%. Therefore, the classification carried out for this study for all land cover maps produces an overall accuracy that fulfills the minimum value.

The producer's accuracy result for the land use map of 1987, 2001, and 2015 ranges from 60% to 100%, 72.7% to 100%, and 63.6% to 100%, respectively. Whereas the user's accuracy ranges from 75% to 96.7%, 85.7% to 100% and 88.9% to 100% respectively for the land use maps of 1987, 2001 and 2015. The lowest values were found due to the spectral similarity of different land uses.

The accuracy assessment results from the Kappa coefficient statistics are 0.85, 0.94, and 0.95 for the periods of 1987, 2001, and 2015, respectively. A kappa of 0.85 for the period of 1987 means there is 85% better agreement than by chance alone.

3.1.2. Land Use and Land Cover Maps

Figure 3 shows the land use map of 1987, 2001, and 2015 that has been generated from Landsat-5-TM, Landsat-7-ETM+ and Landsat 8 image classifications respectively. Over the last 30 years (1987-2015), in the Sore and Geba watersheds, there has been an increase in cultivated land and a decrease in dense forest, open forest, wood land, and water bodies. The total cultivated land area covered in 1987 was about 33% and in 2001 it was about 34% of the total area of the watershed, but in 2015 it rapidly increased to 50%. This is because of the gain of land from the shrinkage of other types of land use due to population growth and deforestation. For example, the total area coverage of dense forest, open forest, wood land, and water bodies in 1987 land use and land cover maps was about 3%, 49%, 4% and 11% of the total area of the watershed respectively. However, in 2015, land use and land cover decreased to around 0%, 44%, 1%, and 5% of the total area of the Sore and Geba watershed, respectively. The individual area coverage and change statistics for the three periods, 1987 to 2001, 2001 to 2015 and 1987 to 2015, are summarized in Table 2.

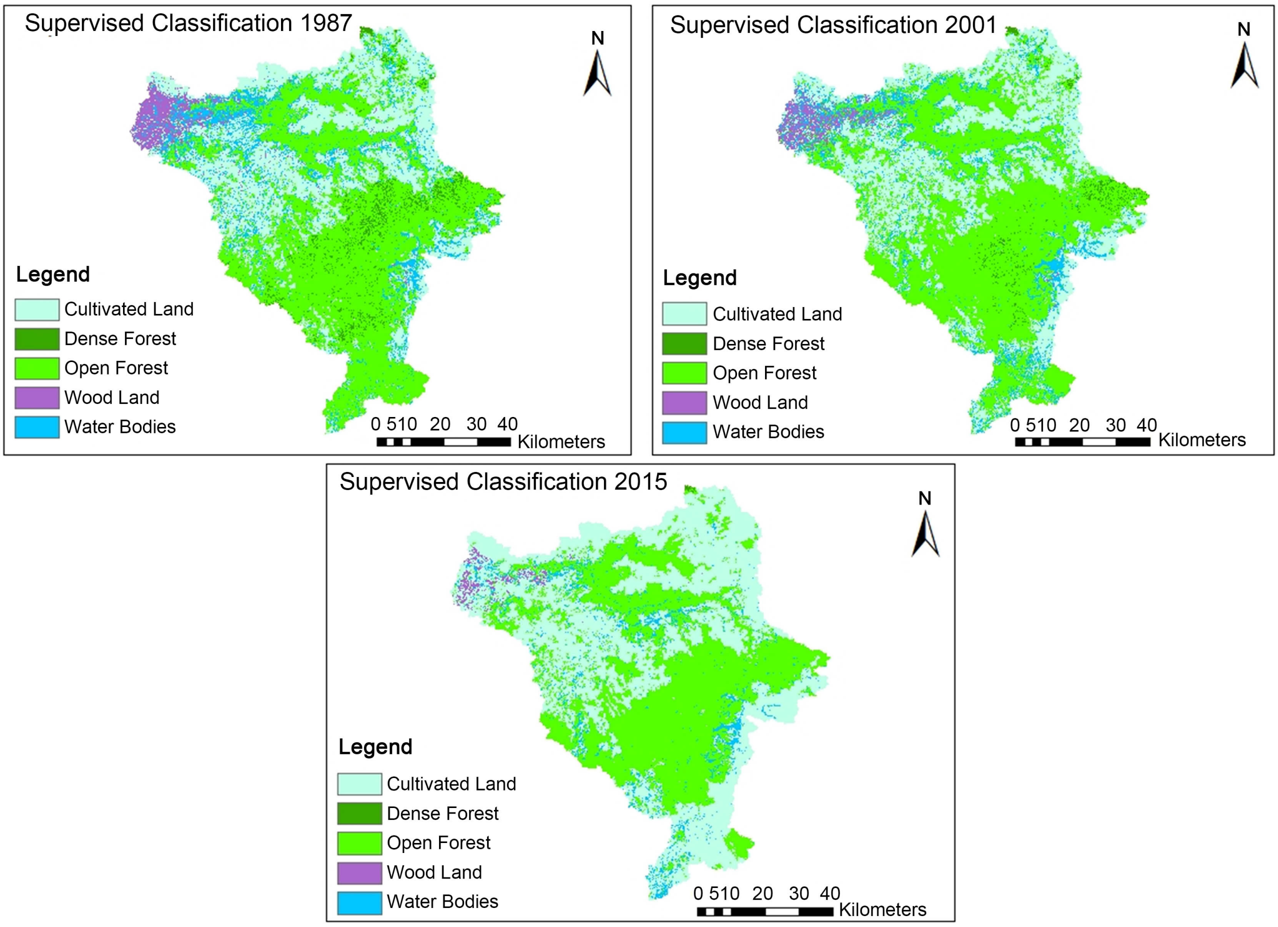


Figure 3. Land cover map of Sore and Geba watershed in 1987, 2001 and 2015.

Table 2. Area of land use types and change statistics of Sore and Geba watershed for the period of 1987, 2001 and 2015.

Land use types	Land/cover types (%/km^2)						Land use/cover change (%/km^2)					
	1987		2001		2015		2001-1987		2015-2001		2015-1987	
	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
Cultivated Land	2161.20	32.99	2240.62	34.20	3245.66	49.54	79.42	1.21	1005.04	15.34	1084.46	16.55
Dense Forest	222.04	3.39	84.52	1.29	4.14	0.06	−137.52	−2.10	−80.38	−1.23	−217.90	−3.33
Open Forest	3231.68	49.33	3447.04	52.62	2887.37	44.08	215.36	3.29	−559.66	−8.54	−344.30	−5.25
Wood Land	235.27	3.59	169.35	2.59	70.96	1.08	−65.92	−1.00	−98.39	−1.50	−164.31	−2.51
Water Bodies	700.88	10.70	609.54	9.30	342.94	5.24	−91.35	−1.40	−266.60	−4.07	−357.94	−5.46

The results of this study are consistent with the results of previous studies in different parts of Ethiopia. For example, in the south-western parts of Ethiopia, forest cover was diminished from 19.55% in 1986 to 11.8% by 2001 [19]. In Blue Nile basins of Ethiopia within the period of four decades (1957 to 2001), forest cover and shrub grassland decreased by 64% and 6%, respectively, and a consistent increase in cultivated land and rural settlement were identified [4]. The current widespread environmental problems in the southwestern parts of Ethiopia where the study site is located are forest cover change due to population growth, deforestation, exploitation of natural resources for firewood, construction and other household uses [19].

3.2. Sensitivity Analysis, Calibration and Validation

3.2.1. Sensitivity Analysis

The sensitive parameters were selected based on Global sensitivity embodied in SWAT-CUP. The t-stat and the p-value in SWAT-CUP helps one to identify sensitive parameters. The larger, in absolute value, the value of t-stat and the smaller the p-value, the more sensitive the parameters [16]. Nine sensitive flow parameters were obtained for Sore and Geba watershed based on t-stat and p-value from Sore River gauge simulation. These sensitive parameters are SCS runoff curve number for moisture condition II (CN2), groundwater delay time (GW_DELAY), maximum canopy storage (CANMX), available water capacity of the soil layer (SOL_AWC), soil evaporation compensation factor (ESCO), base flow alpha factor (ALPHA_BF), manning's "n" value for the main channel (CH_N2), threshold depth of water in the shallow aquifer for "revaporation" to occur (REVAPMN), threshold depth of water in the shallow aquifer required for return flow to occur (GWQMN). The first three most flow sensitive parameters for Sore and Geba watershed were SCS runoff curve number for moisture condition II (CN2) followed by groundwater delay time (GW_DELAY) and maximum canopy storage (CANMX).

3.2.2. Calibration and Validation

The model was calibrated for the Sore and Geba watersheds with the help of the Sore River gauging station. **Figure 4** depicts a time series plot comparison of measured and simulated monthly stream flows for the Sore and Geba watersheds on the Sore River over five years of calibration (1996-2000) and validation (2001-2005). The SWAT model accurately tracked the lowest observed stream flows, but some of the highest observed flows in the first year of simulation were predicted for both the calibration and validation periods. However, the simulated flows in the calibration period closely follow the observed flows more closely than in the validation period. The model performance measures during calibration were stronger than those computed for the validation period. According to a threshold value suggested by different scholars, the computed statistics for the Sore and Geba watersheds showed satisfactory results for both the calibration and validation periods. For example, for monthly data simulation, the p-factor of 0.78, r-factor of 1.02, coefficient of determination (R^2) 0.8, and Nash-Sutcliffe efficiency (NS) 0.79 were found during the calibration period. While the performance indicators of p-factor 0.78, r-factor 1.26, coefficient of determination (R^2) 0.75, and Nash-Sutcliffe efficiency (NS) of 0.54 were determined during the validation period, in general, the statistics show a strong correlation between simulated and measured values.

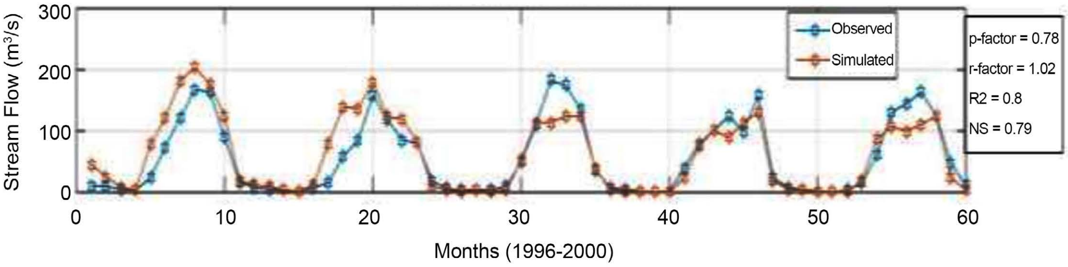
As shown in Table 3, the simulated average monthly stream flow at Sore River gage for both calibration and validation periods were pretty much close to observed flows with the agreement slightly is better in calibration period. Overall, the model performance was good.

Results of this study are consistent with other studies in different parts of Ethiopia. The study conducted by [20] in Baro-Akobo river basin for calibration and validation of monthly stream flow simulation at Gambela gauging station gives the Nash-Sutcliffe efficiency (NS) 0.9 and Coefficient of Determination (R^2) 0.92 for calibration period and 0.81 and 0.89 for validation period, respectively.

Table 3. Comparison of measured and simulated average monthly stream flow at Sore River gauging station for calibration and validation period.

Period	Average Monthly Flow (m^3/s)		p-factor	r-factor	R^2	NS
	Measured	Simulated				
Calibration (1996-2000)	56.75	60.47	0.78	1.02	0.8	0.79
Validation (2001-2005)	43.12	61.34	0.78	1.26	0.75	0.54

(a) Calibration Period From (1996-2000)



(b) Validation Period From (2001-2005)

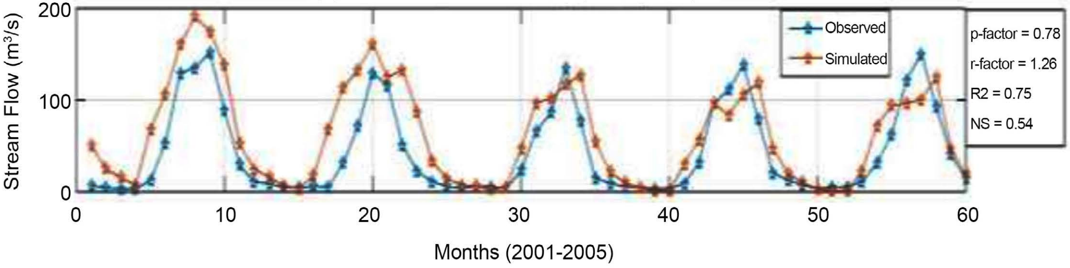


Figure 4. Time series plot of observed and simulated stream flow at sore river gauging station for (a) calibration and (b) validation period.

3.3. Effect of Land Use and Land Cover Change on Surface Runoff

The annual simulated amount of surface runoff contribution to stream flow from the land use map of 1987, 2001, and 2015 is 39.32 m^3/s (189.28 mm), 39.78 m^3/s (191.52 mm), and 45.95 m^3/s (221.19 mm) respectively. The average annual contribution of surface runoff to stream flow increased from 39.32 m^3/s to 39.78 m^3/s due to the land use and land cover changes that occurred between the periods of 1987 and 2001 (increased by 1.18%). The land use change that occurred between the periods of 2001 and 2015 led to an increase in the surface runoff from 39.78 m^3/s to 45.95 m^3/s (which is increased by 15.49%). Whereas, during the period between 1987 and 2015, land use land cover changed, the surface runoff contribution to stream flow increased from 39.32 m^3/s to 45.95 m^3/s (which increased by 16.86%) (**Table 4**).

The average monthly and annual contribution of surface runoff to stream flow during the periods of 1987 and 2001 land use and land cover change doesn't show significant change. However, during the periods between 2001 and 2015, the surface runoff rapidly increased by 15.49%. This is because of the expansion of cultivated land over dense and open forest between the periods of 2001 and 2015 that resulted in increased surface runoff following rainfall events. The increments of cultivated land between the periods of 1987 and 2001 were 1.21%, while between the periods of 2001 and 2015, the cultivated land increased by 15.34%. The higher increment of surface runoff between the periods of 2001 and 2015 in the Sore and Geba watersheds is strongly related to the expansion of cultivated land.

3.4. Implication of Land Use Change on Stream Flow

To understand the implications of land use and land cover change on stream flow in the Sore and Geba watershed, the stream flow obtained from the whole watershed was simulated from (1996-2005) using land use maps of 1987, 2001, and 2015. The highest mean monthly stream flow simulated using the land use map of 1987 occurred in August, which is equal to 499.70 m^3/s, and the lowest stream flow occurred in March, which is 7.73 m^3/s. From the land use map of 2001, the simulated highest mean monthly stream flow occurred in August, which is equal to 499.73 m^3/s, and the minimum stream flow was 8.31 m^3/s, which occurred in March. The highest mean monthly stream flow simulated using the land use map of 2015 occurred in August, which is equal to 501.42 m^3/s, while the minimum flow occurred in February and was equal to 10.05 m^3/s. The mean annual stream flow simulated using the land use map of 1987, 2001, and 2015 is 188.06 m^3/s, 187.92 m^3/s, and 190.84 m^3/s respectively. The highest mean annual stream flow is obtained from the simulated result of the land use map of 2015. This is because of the highest cultivated land in 2015, compared to 2001 and 1987. The mean annual stream flow obtained from the land use map of 2001 is lower than in 2015 and 1987 because of the highest area covered by open forest. The stream flow has increased by 2.78 m^3/s due to land use and land cover

Table 4. Average annual surface runoff basin values change statistics for the period of 1987, 2001 & 2015.

Year	Surface runoff			Change in surface runoff					
	1987	2001	2015	2001-1987		2015-2001		2015-1987	
Unit	mm	Mm	mm	mm	%	mm	%	mm	%
Surface runoff	189.28	191.52	221.19	2.24	1.18	29.67	15.49	31.91	16.86

changes that occurred between the periods of 1987 and 2015. In general, within the periods of 1987 and 2001, there was no significant change in stream flow because of the similarity in area coverage of land use types.

3.5. Environmental Implications of the Observed Surface Runoff

The change in land use and land cover has had a significant effect on the hydrology, including surface runoff, stream flow, evapotranspiration, sediment loading, and water yield of the study watershed. Vegetation cover helps to reduce soil erosion by intercepting and dissipating the erosive energy of raindrops, runoff, and wind. It also has a role in reducing the volume of runoff through increasing infiltration by following the root system and increasing soil organic content, which increases the aggregate stability of the soil. Within the study period, there has been a decline in natural forests and an expansion of agricultural lands. As can be quantified in this study, the expansion of agricultural lands generates the highest surface runoff. The highest surface runoff will accelerate the erosion process such as detachment and transportation. Sediment loading was also at its highest due to the expansion of agricultural lands. These phenomena have implications for the environment, such as biodiversity loss, flooding and sedimentation on the downstream water storage structures.

4. Conclusions

Land use and land cover trend analysis within the three decades from 1987 to 2015 in the Sore and Geba watershed shows a significant change over the years. The areas covered by cultivated land, open forest, dense forest, wood land, and water bodies of the Sore and Geba watersheds in 1987 were 33%, 49%, 3%, 4%, and 11% of the total watershed, respectively. In 2015, the proportions of open forest, dense forest, wooded land, and water bodies were 44%, 0%, 1%, and 5% of the total watershed, respectively. The coverage of cultivated land increased to 50% of the total watershed. Cultivated land is gained from other types of land use. Scattered rural settlements that are closely associated with cultivated land have increased in the last three decades. The highest land use and land cover changes occurred during the periods between 2001 and 2015 because of deforestation.

In the study watershed, nine sensitive flow control parameters were identified using the SWAT-CUP computer program by the SUFI-2 algorithm that were targets of the calibration process. During the calibration period, the values of

Nash-Sutcliffe (NS), coefficient of determination (R^2), p-factor and r-factor were 0.79, 0.8, 0.78, and 1.02 respectively. Whereas during the validation period, the values of the performance indicators were 0.54, 0.75, 0.78, and 1.26 respectively. This performance is deemed satisfactory for both the calibration and validation periods.

After calibration and validation of the SWAT model, the effects of land use and land cover change on surface runoff and stream flow were evaluated. The observed land use and land cover change show a significant change in the hydrological process of the study watershed, particularly surface runoff and stream flow. The simulated average annual surface runoff from the land use and land cover map of 1987 was 189.28 mm, while from the land use map of 2015, the average annual surface runoff increased to 221.19 mm. This result showed that during the last three decades (1987-2015) land use and land cover change indicated an increase of surface runoff by 16.86%. The average annual stream flow increased from 188.06 m^3/s to 190.84 m^3/s between the periods of 1987 and 2015 land use and land cover change. Quantified land use and land cover change and surface runoff have an impact on the environment, such as loss of biodiversity, loss of top soil by erosion, flooding and sedimentation problems in the downstream communities.

This study suggests promoting non-timber forest products, planning and regulating the expansion of settlements and soil fertility management activities should be implemented. This would increase existing farming productivity and help in controlling the expansion of cultivated land. Finally, this study highlights the application of the SWAT model integrated with GIS tools in the study basin, which provides a better understanding of the process of land use change impacts on local hydrology.

Acknowledgements

I would like to thank the Ministry of Water, Irrigation and Electricity of Ethiopia and the National Meteorological Agency of Ethiopia for helping me by providing hydrological and meteorological data to conduct this study.

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] Guo, H., Hu, Q. and Jiang, T. (2008) Annual and Seasonal Streamflow Responses to Climate and Land-Cover Changes in the Poyang Lake Basin, China. *Journal of Hydrology*, **355**, 106-122. https://doi.org/10.1016/j.jhydrol.2008.03.020

[2] Lindquist, E.J., *et al.* (2012) Global Forest Land-Use Change 1990-2005. Food and Agriculture Organization of the United Nations, Rome.

[3] Gessesse, B., Bewket, W. and Bräuning, A. (2014) Model-Based Characterization and Monitoring of Runoff and Soil Erosion in Response To Land Use/Land Cover Changes in the Modjo Watershed, Ethiopia. *Land Degradation and Development*,

26, 711-724. https://doi.org/10.1002/ldr.2276

[4] Bewket, W. and Abebe, S. (2013) Land-Use and Land-Cover Change and Its Environmental Implications in a Tropical Highland Watershed, Ethiopia. *International Journal of Environmental Studies*, **70**, 126-139. https://doi.org/10.1080/00207233.2012.755765

[5] Tilahun, A.K. (2015) Land Use Land Cover Change and Its Implication on Surface Runoff: A Case Study of Baro River Basin in South Western. *Journal of Environment and Earth Science*, **5**, 53-58.

[6] Woube, M. (1999) Flooding and Sustainable Land-Water Management in the Lower Baro-Akobo River Basin, Ethiopia. *Applied Geography*, **19**, 235-251. https://doi.org/10.1016/S0143-6228(99)00004-1

[7] Getahun, Y.S. and Haj, V.L. (2015) Assessing the Impacts of Land Use-Cover Change on Hydrology of Melka Kuntrie Subbasin in Ethiopia, Using a Conceptual Hydrological Model. *Hydrology: Current Research*, **6**, Article ID: 1000210. https://doi.org/10.4172/2157-7587.1000210

[8] Sajikumar, N. and Remya, R.S. (2015) Impact of Land Cover and Land Use Change on Runoff Characteristics. *Journal of Environmental Management*, **161**, 460-468. https://doi.org/10.1016/j.jenvman.2014.12.041

[9] Kassa, H., Dondeyne, S., Poesen, J., Frankl, A. and Nyssen, J. (2016) Transition from Forest- to Cereal-Based Agricultural Systems: A Review of the Drivers of Land-Use Change and Degradation in Southwest Ethiopia. *Land Degradation and Development*, **28**, 431-449. https://doi.org/10.1002/ldr.2575

[10] Alemayehu, T. (2016) Groundwater Recharge under Changing Landuses and Climate Variability: The Case of Baro-Akobo River Basin, Ethiopia. *Journal of Environment and Earth Science*, **6**, 78-95.

[11] Neitsch, S.L., Arnold, J.G. and Kiniry, J.R. (2011) Soil & Water Assessment Tool Theoretical Documentation Version 2009.

[12] Ismail, M.H., Hz, P. and Mf, S. (2009) Evaluating Supervised and Unsupervised Techniques for Land Cover Mapping Using Remote Sensing Data. *Malaysian Journal of Society and Space*, **5**, 1-10.

[13] Olofsson, P., Foody, G.M., Herold, M., Stehman, S.V., Woodcock, C.E. and Wulder, M.A. (2014) Remote Sensing of Environment Good Practices for Estimating Area and Assessing Accuracy of Land Change. *Remote Sensing of Environment*, **148**, 42-57. https://doi.org/10.1016/j.rse.2014.02.015

[14] Arnold, J.G., Kiniry, J.R., Srinivasan, R., Williams, J.R., Haney, E.B. and Neitsch, S.L. (2013) Soil & Water Assessment Tool: Input/Output Documentation. Version 2012. Texas Water Resources Institute, TR-439, College Station, 650. http://swat.tamu.edu/media/69296/SWAT-IO-Documentation-2012.pdf

[15] Setegn, S.G. (2008) Hydrological and Sediment Yield Modelling in Lake Tana Basin, Blue Nile Ethiopia. Licentiate Thesis, KTH-Hydraulic Engineering Research Group, Department of Land and Water Resources Engineering, Royal Institute of Technology (KTH), Stockholm.

[16] Abbaspour, K.C. (2015) SWAT-CUP SWAT Calibration and Uncertainty Programs—A User Manual. Eawag (Swiss Federal Institute of Aquatic Science and Technology), Dübendorf.

[17] Moriasi, D.N., Arnold, J.G., Van Liew, M.W., Bingner, R.L., Harmel, R.D. and Veith, T.L. (2007) Model Evaluation Guidelines for Systematic Quantification of Accuracy in Watershed Simulations. *Transactions of the ASABE*, **50**, 885-900. https://doi.org/10.13031/2013.23153

[18] Anderson, B.J.R., Hardy, E.E., Roach, J.T. and Witmer, R.E. (1976) A Land Use and Land Cover Classification System for Use with Remote Sensor Data. Geological Survey Professional Paper 964. https://doi.org/10.3133/pp964

[19] Wubie, A.M. (2015) GIS and Remote Sensing Based Forest Change Detection for Sustainable Forest Management in Bench Maji Zone, Ethiopia. *International Journal of Remote Sensing and Geosciences*, **4**, 1-6. https://www.ijrsg.com

[20] Mengistu, D.T. and Sorteberg, A. (2012) Sensitivity of SWAT Simulated Streamflow to Climatic Changes within the Eastern Nile River Basin. *Hydrology and Earth System Sciences*, **16**, 391-407. https://doi.org/10.5194/hess-16-391-2012