Sustainable Water Resources Management (2023) 9:117
https://doi.org/10.1007/s40899-023-00891-6

ORIGINAL ARTICLE

Evaluation of land use/land cover effect on streamflow: a case of Robigumero watershed, Abay Basin, Ethiopia

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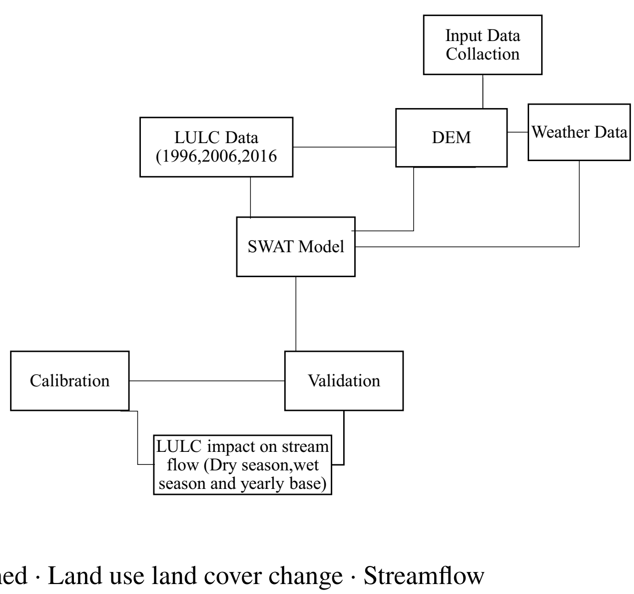
Received: 17 September 2022 / Accepted: 6 June 2023 / Published online: 4 July 2023

Abstract
Land use land cover change has an impact on hydrology of the watershed on the Robigumero watershed. The study mainly focused on estimating land use change and stream flow under different land use land cover changes of the Robigumero watershed. Land use land cove maps of 1996, 2006 and 2016 were collected from Ethiopian water irrigation and energy office. The soil and water assessment tool model (SWAT) was used to simulate LULC effects on the streamflow of Robigumero Watershed. The SWAT model performance was evaluated through sensitivity analysis, calibration, and validation. During the study period the land use land cover has changed due to growth in population of the study area. The Agricultural land increased by 22.4% and while grass land & forestland decreased by 17.5 and 5.3% Respectively in the year between 1996 to 2016. The findings of the stream flow simulation were used to assess the seasonal variability in stream flow caused by changes in land use and land cover. Both the calibration and validation result shows very good agreement between observed and simulated stream flow with NSE values of 0.81 and R^2 values of 0.83 for calibration and NSE Values of 0.86 and R^2 values of 0.87 for validation. The result of this study indicated that mean monthly stream flow were increased by 44.1m^3/s for wet season and decreased by 2.3m^3/s in dry season over 21 years' period. In general redaction of agricultural land and increment of forest land on the degraded land reduce stream flow which shows the reduction of soil erosion. Therefore, this study results can be used to encourage different users and policymakers for planning and management of water resources in the Robigumero watershed as well as in other regions of Ethiopia.

Graphical abstract



Keywords Robigumero watershed · Land use land cover change · Streamflow

Extended author information available on the last page of the article

Introduction

Background

The land and water resource of the watershed and its ecosystem are danger due to the nature of the watershed, rapid population growth, deforestation, overgrazing, and soil erosion or soil detachment from the surface are the serious problems in Nile basin (Mengie et.al. 2019). The land use and land cover of the certain basin is subjected to the given change from one land use to the other land use from time to time (Lambin et al. 2003; Welde and Gebremariam 2017a; Bewket and Woldeamlak 2002). The change in land use and land cover are the direct and indirect consequence of human activities (Hassen and Assen 2017; Tadele and Förch 2007). Land use and land cover also has impact on hydrology the basin and these impact are integrated strongly (Hassen and Assen 2017; Ayele et.al. 2017; Getachew and Melesse 2012). In Ethiopia where nearly about 85% of the population is engaged primarily in agriculture and depends heavily on available water resources, the assessment and management of available water resources is a matter of prime importance. Surface water flow modeling is an important tool frequently used in studies in surface water system and watershed management (Bezawit A., 2019). The land use land cover condition is dynamically changing, especially in developing country like, Ethiopia, whose economy depending on agriculture. In particular, the forest land, shrubs, and grass land changed to agricultural and settlement land in most part of the country (Ayele et.al. 2017; Tadele and Förch 2007). For example, studies conducted in Gilgel Abay watershed of Blue Nile basin show that there was the redaction of forest land and shrub land with the increment of agricultural land. About 570 km^2 of forest and shrub land converted to agriculture and settlement in the year between 1973 to 2001 (Getachew and Melesse 2012). There are several available and important hydrological models which consider physical environment or land use land cover condition to estimate the stream flow or surface runoff including HEC-HMS, MIKE SHE, SWAT, etc. (Tadele and Förch 2007). There are many hydrological models within each class of modeling. Hence choosing the particular model is one of the challenge of model use community. the Two criteria in order to select the hydrological model structure are suggested by (Lambin et al. 2003; Mohammed and Thatiparthi 2020; Jain et al. 2017; Nicótina et al. 2008; Ghonchepour *et.al.*, 2003). The model must be readily and freely available within available documentation and should be applied over arrange of watershed size from large to global (Ghonchepour *et.al.*, 2003). Based on the above criteria Soil and Water Assessment Tool (SWAT) model was selected and used for many studies in Ethiopia. The Soil and Water Assessment Tool (SWAT) model was examined for its applicability to the assessment of water resources in the Upper Awash watershed by (Chekol et al. 2007). In the last thirty years, the land use land cover change was huge which were due to the increment of agricultural land and reduction of forest and grass land in the Robigumero watershed. Several visible change in stream flow and surface run off were observed in the form of flooding and soil erosion during rainy season while reduction of stream flow in dry season in the study area. However, these change of stream flow were not well understood that what couse the change in the watershed. In the study area the major cause of altering streamflow is observed primarily the change in land use land cover including deforestation activities and conversion of grass land to agricultural land. This causes various effects on resource bases like deforestation and agricultural land this leads to the changes in hydrology of the watershed and sediments deposited in stream channels reduce flood carrying capacity, resulting in more frequently over flows and greater floodwater damage to adjacent properties. The main objective of this study is to evaluate land use land cover change effects of on stream flow of Robigumero Watershed. Moreover, this research tried to evaluate the land use land cover changes between 1996, 2006 and 2016 and its implication on stream flow. The outcome of this study befits the stakeholders, water resource planers, farmers, residents' decision makers and beneficiaries to get aware of the land use land cover change in the watershed and further adaptive important measures to control and protect the negative impact of land use land cover change on the stream flow in the study area.

Methods and materials

Description of the study area

The Jemma River is one of the biggest tributaries of the Blue Nile (Abay River) Basin and founds in the central highlands of Ethiopia, 180 km North of Addis Ababa. It includes parts of the Wollo, North Shewa Zones of the Amhara, and Oromia Regions. Jemma River is located in the East of the Blue Nile River Basin between 9° 05′ 37''–11° 10′ 07'' N latitude to 37° 12′ 07''– 40° 0′ 01'' E longitude and cover an area of 15,720 km^2. From the number of small tributaries flowing from the east of the basin into the Jemma River, the Robigumero River is one of the major gauged tributaries. It covers, the catchment area of 914.7 km^2 in between 9° 25'–9° 55' N and 38° 54''– 39° 20' East position.

The watershed's altitude varies from slightly over 2546 m above mean sea level (m.a.s.l) in the southern part to 3624 m a.s.l. The study site has two major seasons: a wet season from May to October and a dry season that extends from November to April. Based on the records from 31 years (1988–2018) at nearby meteorological stations, the annual rainfall depth ranges from 986.7 to 1266.7 mm. More than 85% of the rains fall during the wet season.

According to the FAO soil classification, the dominant soil for the Robigumero watershed was grouped as Calcic Vertisols, Eutric Leptosols, Eutric Vertisols, and Eutric cambisols The most common soil texture for these soil types i.e. for Calcic Vertisols, Eutric Vertisols is clay, for Eutric cambisols is clay-loam, and for Eutric Leptosols is loam.

In this study, according to the Minister of Water Resource, Irrigation, and Electricity land uses land cover data the dominant land covers of the study area are Agricultural land, grassland, deciduous forest, and the catchment area < 1% covered with the Urban area.

SWAT model input and data analysis

Physically based Soil and Water Assessment Tool (SWAT) was used for watershed delineation, hydrologic response unit analysis (HRUs), weather data write up, sensitivity analysis and other watershed characteristic determinations. The watershed delineation operation uses and expands Arc-GIS and spatial analyst extension functions to perform watershed delineation (Easton et al. 2010; Tadele & Förch, 2007; Khalid et al. 2016a, b; Wheater 2007; Bekele et al. 2021). The initial stream network and sub-basin outlets were defined based on drainage area threshold approach. Multiple Hydrological response units (HRU) of the watershed were formed using 20%/10%/20% threshold levels of land use, soil and slope classes respectively (Neitsch et al. 2011; Arnold et al. 2012). After creating multiple HRUs weather write up and simulation of the model follows (Neitsch et al. 2011; Setegn et al. 2008). The swat model simulates land phase of the hydrologic cycle based on the balance equation (Arnold et al. 2012; Githui and Mutua 2009; Neitsch et al. 2011).

$$\mathrm{SWAT} = \mathrm{SWo} + \sum_{i=1}^{t} \left(\mathrm{R_{day}} - \mathrm{Q_{surf}} - \mathrm{E_a} - \mathrm{W_{seep}} - \mathrm{Q_{gw}}\right) \quad (1)$$

where, SWt: the final soil water content(mm), SWo: the initial soil water content(mm), t: the time (days), Rday: the amount of precipitation on day(mm), Qsurf: the amount of surface runoff on day(mm), Ea: the amount of evapotranspiration on day(mm), Wseep: the amount of water entering the vadose zone from the soil profile on day (mm), and, Qgw = the amount of return flow on day (mm).

Runoff in SWAT model may be estimated by ether the soil conservation curve number (Mohammed and Thatiparthi 2020) or green and Ampt infiltration method (Green& Ampt, 1911). For this study, the curve number method was employed. because of it is efficient and most popularly used in estimation of runoff (Bewket and Woldeamlak 2002); Mengie et al. 2019) mainly based on the physical characteristics including the land use, soil and the slope of the study area and the hydrology condition (Githui and Mutua 2009; Githui et al. 2010; Tang et al. 2012). Soil conservation curve number method estimates the runoff based on the Eq. 2 (Narsimlu et al. 2015; Nicótina et al. 2008); Alemu 2013); Sloan and Sayer 2015).

$$Q_{Sur} = \frac{\left(R_{day} - 0.2_S\right)^2}{\left(R_{day} - 0.8_S\right)} \quad (2)$$

where, Rday: the amount of precipitation on day(mm), Qsurf: the amount of surface runoff on day(mm), s: retention parameter on day (mm).

The retention parameter(S) is given by the Eq. (3) (Bewket and Woldeamlak 2002; Setegn et al. 2008; Chaubey et al. 2005; Narsimlu et al. 2015).

$$S = 25.4\left(\frac{1000}{CN} - 10\right) \quad (3)$$

Digital elevation model (DEM)

The topography is defined by DEM, which describes the elevation of any point in a given area at a specific spatial resolution, which is used for watershed delineation. A 30 by 30-m resolution DEM was collected from Ministry of water, Irrigation and Energy of Ethiopia.

Soil data

Soil data is one of the major input for SWAT model with inclusive and chemical properties (WaleWorqlul et al. 2018; Barbalho 2014; Pontes et al. 2016). The soil map of the study area was also obtained from Ministry of Water, Irrigation and Energy of Ethiopia. According to the FAO soil classification, the dominant soil for the Robigumero watershed was grouped as Calcic Vertisols, Eutric Leptosols, Eutric Vertisols, and Eutric cambisols and summarized in Table 1. To integrate the soil map with SWAT model, a user soil data base

Table 1 Soil data classification and SWAT Code for Robigumero watershed

ID	Soil name	SWAT CODE	Area (km^2)	Area (%)
1	Calcic Vertisols	CALCICFLV	105.421	11.53
2	Eutric Leptosols	EUTRICLEPT	1.175	0.13
3	Eutric Vertisols	EUTRICFLV	769.726	84.15
4	Eutric Cambisols	EUTRICCAM	38.378	4.20

which contains textural and chemical properties of soils was prepared for each soil layers and added to the SWAT user soil data bases.

Climatic data

Meteorological data is needed by the SWAT model to simulate the hydrological conditions of the watershed. The meteorological data required for this study were collected from National Meteorological Agency of Ethiopia. The meteorological data collected were precipitation, maximum and minimum temperature, relative humidity, and wind speed and sunshine hours for four stations (Debrebirhan, Chacha, Deneba and Lemi) from the year 1988 -2018.In this study, the weather generating station was Debrebirhan rain gauge station. The monthly statistical weather parameters needed when WGEN was prepared from daily weather data are rainfall parameters (PCPMM, PCPSTD, PCPSKW, PCP_W1, PCP_W2, PCPD, RAINHHMX), temperature parameters (TMPMX, TMPMN, TMPSTDMX, TMPSTDMN), solar radiation parameters (SOLARAV), wind parameters (WNDAV) and dew point temperature parameters (DEWPT). The rainfall parameters were calculated by using pcpSTAT.exe, whereas the dew temperature parameters were calculated using dewp02.exe (Neitsch et al. 2011).

$$\text{Dew} = \frac{234.18(\log 10(\text{ea}) - 184.2)}{8.204 - \log(\text{ea})} \quad (4)$$

$$\text{es} = 0.6108 \times e^{\frac{17.27\times T}{T+237.3}} \quad (5)$$

$$\text{es} = \text{RF} \times \frac{\text{es}}{100} \quad (6)$$

where: dew is dew point temperature [0c], *es* is saturation vapor pressure [hpa], *ea* is actual vapor pressure [hpa], RF is relative humidity [%], T is temperature [0c] e = 2.7183 (base natural logarithm).

A. Filling missing data

Data were missing from a particular gauge site or representative precipitation is necessary at a point of interest. There are different methods for filling the missing data from those methods station average and normal ratio method were used for the rainfall in this study (Rientjes et al., 2011). All of the rainfall recorded from the stations has missing data with ranging greater than 10% of missing. Therefore, before using the data to runoff modeling it was first essential to apply a gap filling techniques.

$$Px = \frac{Nx}{N} \times \left[\frac{P1}{N1} + \frac{P2}{N2} + \frac{P3}{N3} + \cdots + \frac{Pn}{Nn}\right] \quad (7)$$

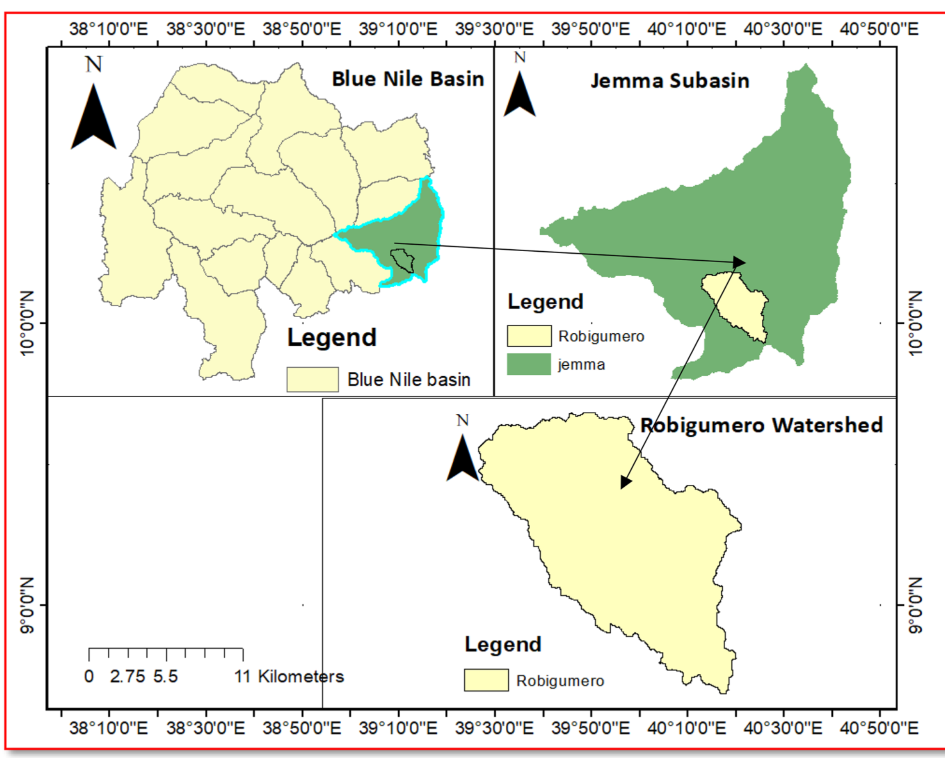


Fig. 1 Location of the Study Area

where *PX* is the missing data at station x, Nx is the missing data stations normal annual rainfall, Ni is normal annual rainfall at station i, and n is number of nearby gauges The station-average method for estimating missing data uses n gages from a region to estimate the missing point rainfall Fig. 1.

B. Consistency

The consistent record is one where the characteristics of the record have changed with time. Adjusting for gauge consistency involves the estimation of the effect rather than a missing value (Pontes et al. 2016; Richards 1998; Nicótina et al. 2008). For this study double mass curve method was used in order to estimate the consistency of four stations in the study area and as shown in Figs. 2, 3 below the station rainfall dates were consistent.

C. Homogeneity test

Homogeneity analysis was used to identify a change in the statistical property of the time series (Neitsch et al. 2011; Arnold et al. 2012). The cause may be either natural or man-made. Therefore, to select the representative metrological station for the analysis of areal rainfall estimation, checking the homogeneity of group is essential. The RAINBOW software is used based on the cumulative deviation from the mean (Wheater 2007; Neitsch et al. 2011).

D. Areal rainfall computation

The average rainfall over an area may be considered as the main input on the watershed modeling process, especially of those which deal with surface runoff because, the rain is the only climatic variable that can explain fast increasing flow

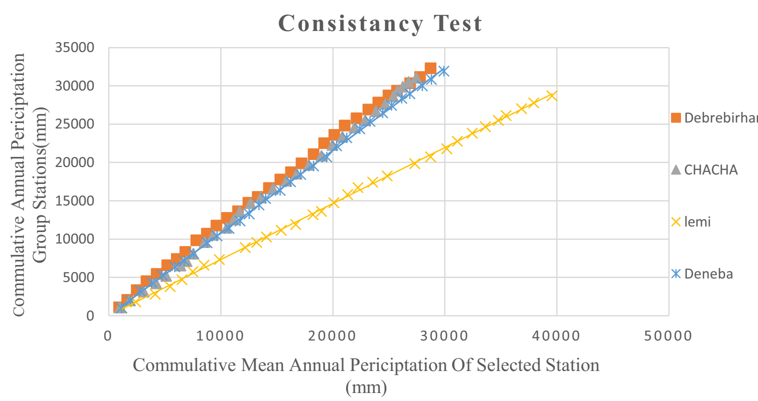


Fig. 2 Double mass curve of the selected station

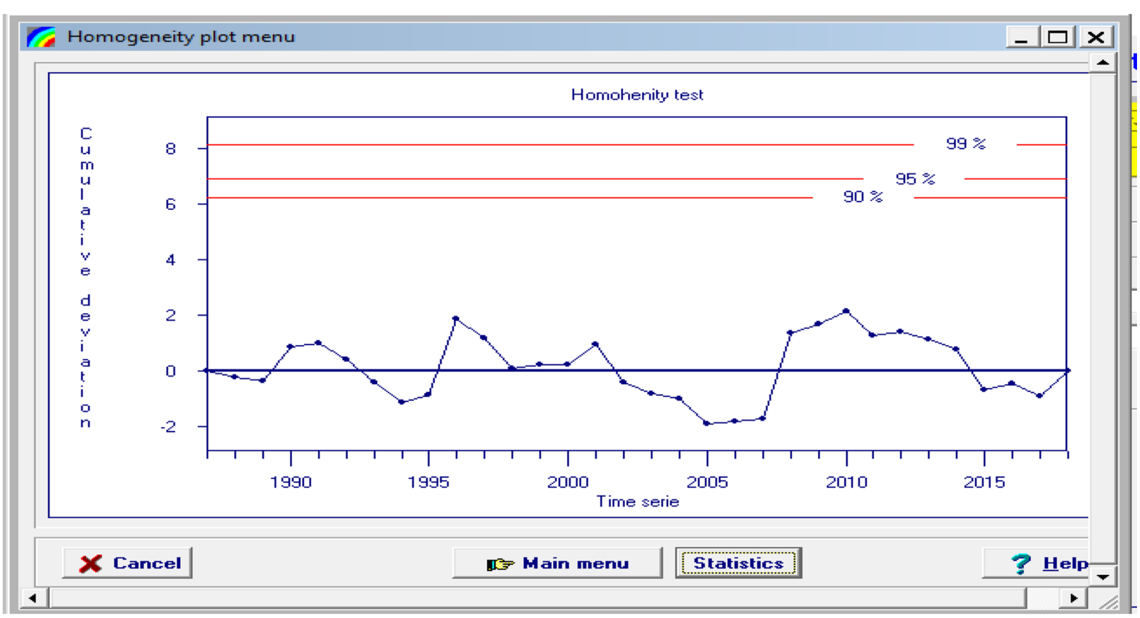


Fig. 3 Homogeneity test of Rainfall gauging stations of Robigumero

(Anctil et al. 2006; Wheater 2007). According to Andréassian et al. 2001; Nicótina et al. 2008;Younger 2010), spatial variability of rainfall over the basin and their distribution pattern, as well as its interaction with the basin, have a considerable effect on runoff response generated. There are different methods used to calculate the mean annual rainfall which represents its distribution on the watershed (Tadele and Förch 2007; Chaubey et al. 2005). However, The Thiessen-polygon method is the best technique that shows the convergence for increasing the rain gauge density in the basin (Barbalho (2014). The average rainfall over the catchments was calculated as Equation below.

$$\text{Pav} = \sum_{i=1}^{n} \frac{\text{piAi}}{\sum_{i=1}^{n} \text{Ai}} \quad (8)$$

where *Pav* is mean areal precipitation (mm), *Pi* is mean annual precipitation (mm) and *Ai* is coverage area at *ith the* station, within Thiessen polygon respectively.

Stream flow data

The observed daily streamflow data is the required data for calibration and validation of the simulated streamflow from the Watershed (Rientjes et al., 2011; Getachew and Melesse 2012; Githui et al. 2010). The streamflow in the Blue Nile basin including the Robigumero watershed was recorded by the Ministry of Water, Irrigation, and Energy (MoWIE). The available observed daily streamflow data recorded at Robigumero gauging station from 1990–2009 years was collected from the Ministry of Water, Irrigation, and Electricity.

Land use land covers data

Land use is also The most important factor that affects runoff, evapo-transpiration and surface erosion in a watershed (van Griensven et al. 2006;Pontes et al. 2016). There are many studies on land use and land cover change in the districts and catchments of the Blue Nile basin. These studies support this study in many aspects especially in the continuous expansion of farm land (WaleWorqlul et al. (2018). The Land use and land cover change studies usually need the development of land cover units before the analysis is started (Nicótina et al. 2008; Sloan and Sayer 2015). The Three different year's land use/land cover data were collected from mister of water irrigation and energy.

A model sensitivity analysis can be help full in understanding which model input are the most important. Sensitivity analysis is a method of identifying the most sensitive parameters that significantly affects the model calibration and validation (Neitsch et al. 2011; Tang et al., 2012 ;Abbaspour, 2013). Sensitivity analysis describes how model output varies over a range of a given input variable (Khalid et al. 2016a, b; Welde and Gebremariam 2017b; Andualem and Gebremariam 2016).So that twenty-six flow, parameters were checked for sensitivity (Garzanti et al. 2006; Khalid et al. 2016a, b). For this study, the global sensitivity analysis was employed in SWAT-CUP 2012 and the p-value were used to select the sensitive parameters (Abbaspour 2012; Arnold et al. 2012).

Model calibration and validation

Calibration is the process whereby model parameters are adjusted to make the model output match with the observed data (Rientjes et al. 2011). The period from 1990 to 2002 was used as a calibration period since the data for this period was with little missing data or representative data. Validation is the comparison of the model outputs with in independent data set without making any adjustment. The purpose of model validation is to check whether the model can predict flow for another range of period (Tang et al. 2012). The period from 2003 to 2009 was used as a validation period.

Model performance evaluation

Model evaluation is an essential measure to verify the robustness of the model. In this study, two model evaluation methods were used, which were Nash–Sutcliffe efficiency (NSE) and coefficient of determination (R^2) Barbalho (2014).

$$\text{NSE} = \frac{\sum_{i=1}^{n} (\text{Oi} - \text{Si})^2}{\sum_{i=1}^{n} ((\text{Oi} - \text{Omin})^2} \quad (9)$$

where Si and Oi are simulated and observed values during model evaluation at time step ith respectively, O_{min} is the average observed value, and "n" is the number of values.

The coefficient of determination (R^2) describes the proportion the variance in measured data by the model. It is the magnitude linear relationship between the observed and the simulated values. R^2 ranges from 0 (which indicates the model is poor) to1 (which indicates the model is good), with higher values indicating less error variance, and typical values greater than 0.6 are considered acceptable according to (Barbalho 2014).

$$R^2 = \frac{\sum_{i=1}^{n} ((\text{Oi} - \text{Omin})(\text{Si} - \text{Smin}))^2}{\sum_{i=1}^{n} ((\text{Oi} - \text{Omin})^2 \sum_{i=1}^{n} (\text{Si} - \text{Smin})^2)} \quad (10)$$

where Si and Oi are simulated and observed values during model evaluation at time step ith respectively, O_{min} and Smin is the average observed and simulated value, and "n" is the number of values Fig. 4.

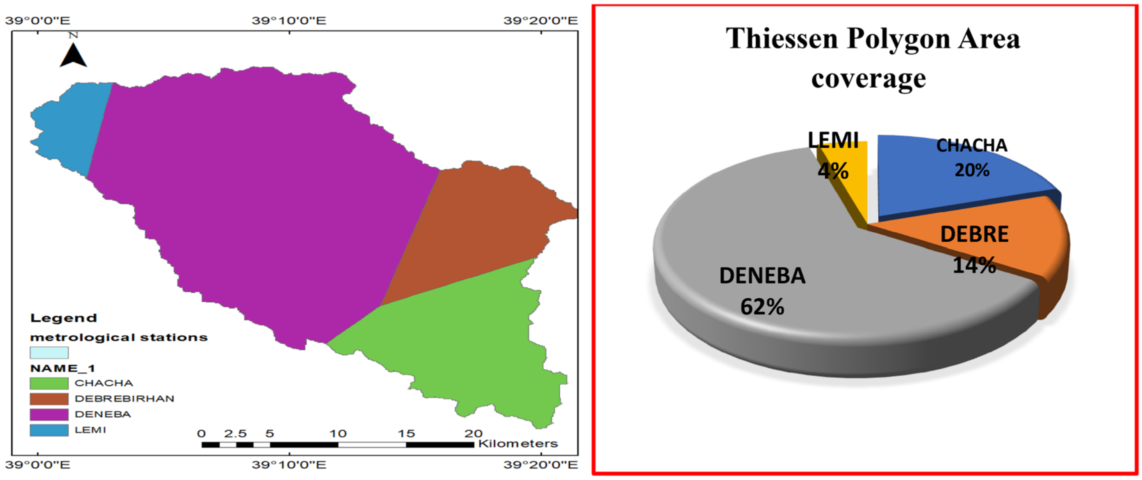


Fig. 4 Thiessen Polygon of The Robigumero Watershed

Result

Land use and land cover analysis

The Three-land use cover maps of 1996, 2006 and 2016 were collected from minster of water irrigation and energy (Fig. 5). It is easily shown that there is an increase of agricultural land, and urbanization and decrease of forested areas, and grassland over 21 years. In general, during 21-year period the Agricultural land increases at about 22.4% whereas the forested area decreased by 5.3%. For the individual class area and change statistics for the three periods are summarized as follows (Table 2).

The land use land cover map of 1996 (Fig. 5) showed that the total agricultural land coverage was about 63.3% of the sub basin and increased rapidly to 85.7% of the Watershed in 2016 (Tables 3, 4 and Fig. 3). The reason is mainly the growth of the population that caused the increase in demand for new Agricultural land and settlement, which in turn resulted shrinking of other types of land use percentage of the watershed. On the other hand, the total forest coverage in 1996 was about 14.9% and then reduced to 9.6% in 2016. This was due to deforestation activities that have taken place for the purpose of agriculture, firewood and new settlement.

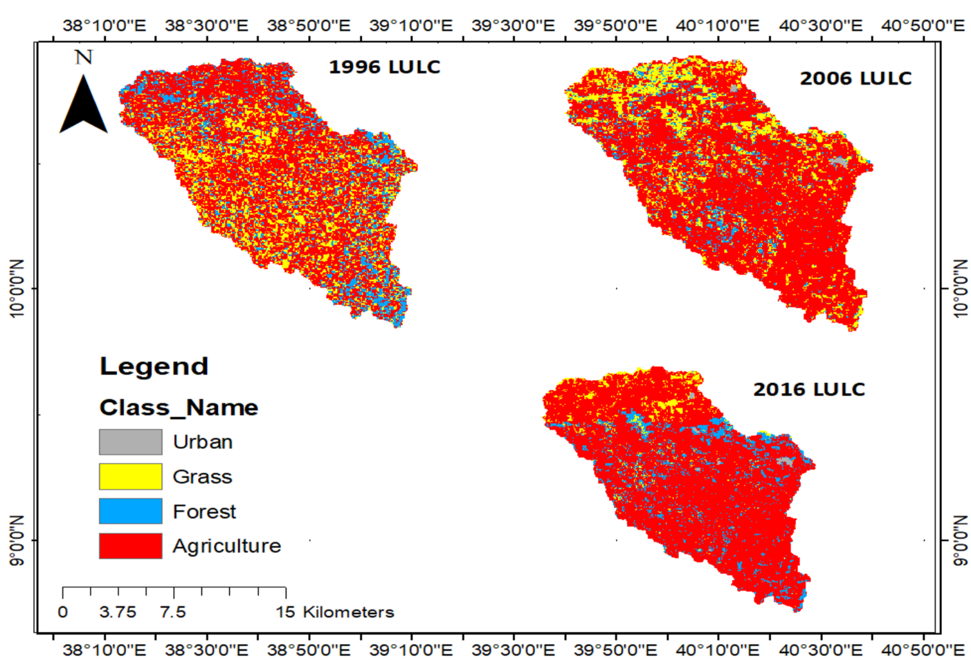


Fig. 5 Land use land cover change of Robigumero at 1996,2006 and 2016 scenario

Table 2 Selected meteorology station in Robigumero watershed

ID	Station	Data type	Latitude	Longitude
1	Chacha	Precipitation only	9.55	39.45
2	Debrebirhan	Precipitation, temperature(Max, Min),wind speed, solar radiation, relative humidity	9.633333	39.5
3	Deneba	Precipitation only	9.766667	39.2

Table 3 Land use and land cover of Robigumero watershed with SWAT code

Land use/LAND cover	Land use according to SWAT database	SWAT code
Agricultural land	Agriculture land to grown	AGRL
Forest land	Forest mixed	FRSD
Grass land	Range-grass	RNGE
Urban	Less dense settlement	URBN

Stream flow modeling

Sensitivity analysis

Sensitivity analysis of simulated stream flow for the sub basin was performed using the daily observed flow data for identifying the most sensitive parameter and for further calibration of the simulated stream flow (Neitsch et al. 2011; Lambin et al. 2003).Twenty-six flow parameters were checked for sensitivity and five of them were found to be highly sensitive (Table 5).

Flow calibration

After sensitivity analysis has been done, the calibration of stream flow was done automatically. The result of calibration for the average monthly stream flow showed a very good agreement between observed and simulated stream flow (Fig. 6) with Nash –Sutcliffe simulation efficiency of 0.81 and coefficient of determination (R^2) of 0.83.

Model validation

After calibration was done manually and getting acceptable values of NSE and R^2, validation was checked using monthly-observed flows. The model validation also showed a very good agreement between simulated and measured monthly flow (Fig. 7) with the NSE value of 0.86 and R^2 0.87.

The calibrated and validated stream flow result shows a very good agreement between observed and simulated stream flow. Therefore, the results of stream flows (Table 6) indicate that SWAT model is a very good predicator for stream flow of Robigumero Watershed.

Different studies that were conducted in the upper Blue Nile basin also showed similar result. For example, The SWAT model showed a good match between measured and simulated flow of Gumara watershed both in calibration

Table 4 Land use coverage area in percent for Robigumero watershed in 1996, 2006 and 2016 scenario

Land use type	1996	2006	2016	2006–1996	2016–2006	2016–1996
Agriculture	63.3	75.95	85.7	12.7	9.8	22.4
Grass land	21.8	16.6	4.31	− 5.2	− 12.3	− 17.5
Forest	14.9	7.01	9.6	− 7.9	2.6	− 5.3
Urban	0.01	0.42	0.44	0.4	0.0	0.4

Table 5 Streamflow Sensitivity of parameter for Robigumero watershed

Parameter name	Parameter value range	*p* value	*t* stat	Calibrated value	Sensitivity rank
R__CN2.mgt	− 5%–25%	0.0001	− 11.22	6.25	1
R__SOL_K(..).sol	− 25%–25%	0.0002	4.99	24.75	2
R__SOL_AWC(..).sol	− 25%–25%	0.001	4.95	4.25	3
V__GW_DELAY.gw	30–450	0.002	− 3.56	74.10	4
R__REVAPMN.gw	0–500	0.03	2.25	417.5	5

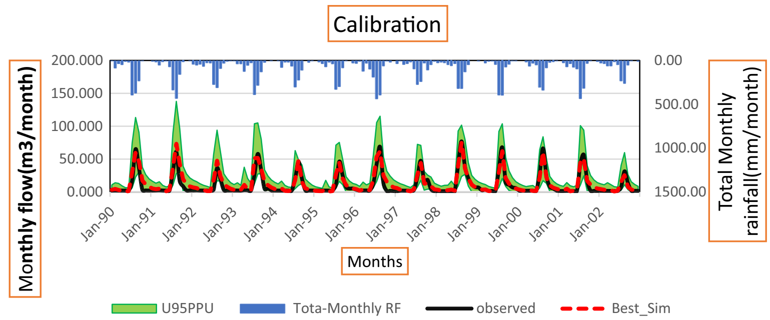


Fig. 6 Calibrated average monthly stream flow (1990 to 2002)

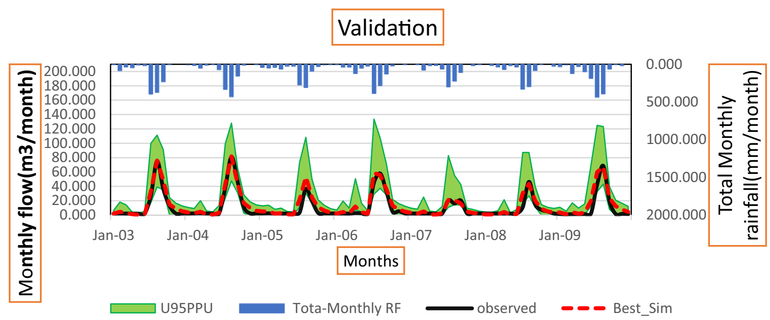


Fig. 7 Validated average monthly stream flow (2003 to 2009)

Table 6 Calibration and validation result for LULC-1996 using SUFI-2 method

period	Mean Monthly stream flow(m^3/s)		R^2	NSE
	Observed	Simulated		
Calibrated (1990–2002	10.0	12.4	0.83	0.81
Validated (2003–2009)	12.1	13.9	0.87	0.86

and validation periods with (NSE = 0.76 and R^2 = 0.87) and (NSE = 0.68 and R^2 = 0.83), respectively (Awlachew, 2006). This indicates that SWAT can give sufficiently reasonable result in the upper Blue Nile basin. The following figure shows that the scatter plots of observed and simulated value for both calibration and validation (Fig. 8, 9). This shows good linear correlation between observed and simulated values.

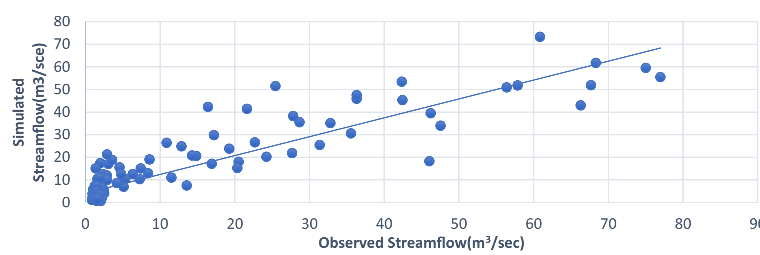


Fig. 8 The calibrated Scatter plot of observed versus simulated streamflow in Robigumero

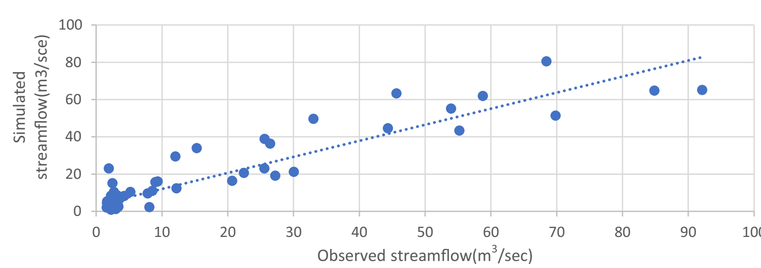


Fig. 9 The validated Scatter plot of observed versus simulated streamflow in Robigumero

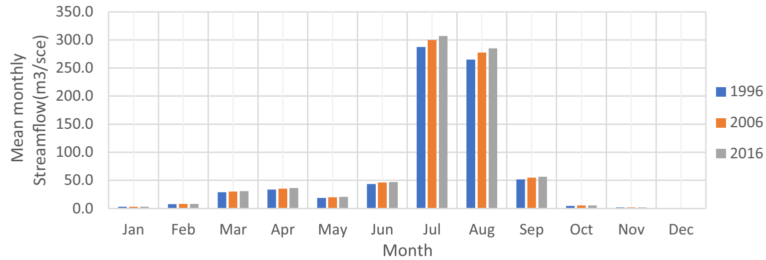


Fig. 10 Comparison of mean monthly Streamflow for the years 1996, 2006 and 2016 LULC

Table 7 Mean monthly wet and dry month streamflow simulation and their variability

Mean Monthly streamflow (m^3/sce)				Mean monthly flow change	
LULC	1996	2006	2016	2006–1996	2016–2006
Dry	39.8	41.7	42.1	1.9	0.4
Wet	604.1	632.1	648.3	27.9	16.2

Table 9 Surface runoff and groundwater flow of the stream simulated using different LULC

parameter	LULC map			Change of SURQ(mm)	
	1996	2006	2016	1996 to 2006	2006 to 2016
SURQ (mm)	211.63	221.81	227.17	10.18	5.36

Impact of LULC change on stream flow

This study assessed the impact of LULC change on streamflow in Robigumero watershed. Also, seasonal variability of streamflow was evaluated on wet (July, August, and September) and dry (Jan, Feb, and March) months. The simulation results of mean monthly streamflow for 1996, 2006 and 2016 LULC maps are shown in Fig. 10. The wet and dry mean monthly streamflow of 1996, 2006 and 2016 LULC and its variability during the study period are presented in Table 7, 8, 9. The results indicated that mean monthly streamflow was increased in the wet months (27.9%) and increase in dry months (1.9%) in the year 1996 and 2006 (Table 7, 8, 9). This was attributed to increase in the area under agriculture and decrease of forest land in the Robigumero watershed. This is due to rainfall satisfies soil moisture deficit more quickly in the agricultural land than forest there by generating more runoff in agricultural land. As a result, more runoff was generated due to streamflow in the year 2006 than 1996 (Fig. 11). Moreover, expansion in agricultural land decreased rainfall infiltrated into the soil and increase surface runoff. Therefore, the streamflow was increased in wet months and decreased in dry months. The streamflow was contributed more in wet months from surface runoff while in dry months, it was contributed more from groundwater. However, streamflow was increased in 2016 both in wet (16.2%) and dry (0.4%) seasons as compared to 2006 due to LULC change (Fig. 8). Besides, a slight decrease in land under grassland which contributed to increases of groundwater in the watershed. It generates more surface runoff in grassland due to less infiltration.

The result indicates that mean monthly streamflow was increased by 6% in the year 1996 to 2006 and 2.3% between the years 2006 to 2016 (Table 8). The dominant land cover in the year 2006 was agriculture and there was high agricultural expansion at the expense of other land use from the year 1996 to 2016. As a result, high runoff was generated during this period; this increases streamflow of 2006 as compared to 1996. In the year 2016, there was a further expansion of the land under agriculture and decrease of the grass land with slightly increase in forest land. Therefore, for the same reason, the streamflow was increased in 2016 as compared to 2006. Generally, during the study period, Robigumero watershed experienced an increase of streamflow due to extreme LULC change.

Discussion

The expansion of cultivated land at the expense of forest, and grassland in the study watershed between 1986 and 2016 periods is aligned with many studies in the Ethiopian Highlands has reported the expansion of cultivated land at the reduction of forest, shrub land and grassland in the Andassa watershed during 1985–2015 periods. There was also an increase of cultivation land and decrease of shrub land in the Lake sub-basin between 1986 and 2010 periods.

Table 8 Streamflow simulation on monthly basis for 1996, 2006 and 2016 LULC

Mean Monthly streamflow (m^3/sce)			Mean monthly flow change			
LULC map			2006–1996		2016–2006	
1996	2006	2016	m^3/sce	%	m^3/sce	%
211.0	224.4	229.8	13.4	6.0	5.4	2.3

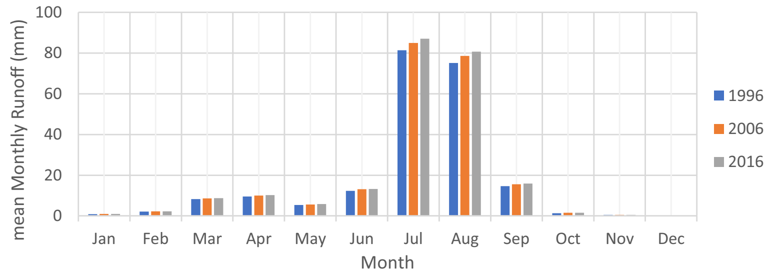


Fig. 11 Comparison of mean monthly surface runoff for the years 1996, 2006 and 2016 LULC

The area covered by natural vegetation showed was also decreased in Kasiry catchment (Upper Blue Nile Basin) during 1982–2016/17 periods. Getachew and Melesse (2012) also found that urban settlement and cultivated land were increased significantly in Angereb watershed during 1985 and 2011 periods while forest and grassland were reduced in these periods.

The reduction of Grass land and increase of Agricultural land in the Robigumero watershed during 1996–2016 periods is also in agreement with many other previous studies in Ethiopia. For instnace, Yeshaneh et al. (2014) has found that the expansion of Agricultural land at the expense of forest and grazing lands in Koga watershed during 1957 and 2010 periods. The decreasing of forest cover by 5.2% in Kasiry watershed, Fageta Lekoma District was mainly through increasing agricultural land from 2010 to 2015 periods (Wondie and Mekuria, 2018). Nigussie et al. (2017) has also indicated that the reduction of grass land in the Upper Blue Nile Basin between 2006 and 2017 periods was mainly attributed to the farmers' growing interest in allocating more land to agricultural land to increase crop productivity. Shawul et al. (2019) study in the Upper Awash Basin has also shown that the redaction of vegetation cover in the 2000–2014 periods could be due to the deforestation, and over grazing practices.

The change in monthly stream flow due to LULC change was assessed for years 1996, 2006 and 2016 (Fig. 9). It was found that the mean annual surface runoff was increased to 211.63 mm to 221.81 mm from 1996 to 2006 (Table 9). Therefore, high surface runoff was generated in the year 2006 as compared to 1996 due to increment in the area under agriculture. In the year 2016, there was also increase of agriculture and urban at the expense of other land covers, this result increase of surface runoff. Surface runoff was slightly increased from 221.81 mm to 227.17 mm (Table 9). Similar, studies were also conducted in Ethiopian region to evaluate the impact of LULC change on stream flow. The mean wet monthly stream flow was increased by 39% and dry average monthly flow decreased by 46% for 2011 as compared to 1985 due to LULC change in Angereb Watershed (Rientjes et al. 2011). Also, the mean monthly stream flow for wet months had increased by 16.26 m^3/s. While the dry season had decreased by 5.41 m^3/s for the years 1986 to 2001 due to the LULC change in Gilgel Abay watershed (Geremew 2013). Therefore, the changes in LULC are expected to have a great impact on watershed hydrology. LULC change alters the hydrologic cycle which has direct effects on hydrological processes such as precipitation, evapotranspiration regime and surface runoff.

Conclusions

The performance and evaluation of the model were found very good (NSE = 0.81 and R^2 = 0.83 for calibration) and (NSE = 0.86 and R^2 = 0.87 for validation). From this study, the Land area under agriculture increased by 12.7% in expenses of other land cover classes while the land area under forest decreased by 7.9% during 1996 to 2006. Between the year 2006 and 2016, further increase of the land under agriculture, forest and urban in the expense of other land cover was observed in the Robigumero watershed. The impact of LULC dynamics showed that mean monthly streamflow was increased by 27.9% in wet months and decreased by 1.9% in dry months between the years 1996 and 2006. While in 2016, it was increased by 16.2% and 0.4% for wet and dry, respectively as compared to 2006 due to LULC change.

The annual Surface runoff was increased from 211.62 mm to 221.81 mm in the years 1996 and 2006. Also, the annual surface runoff was increased from 221.81 mm to 227.17 mm in the year 2006 and 2016. This is mainly attributed to conversion of forest cover to agricultural land, which in turn increased surface runoff during the wet and dry season. In 2016, a minor decrease of the land under grassland and bare land which contributed to increases streamflow in the watershed from the year 2006 to 2016. In general redaction of agricultural land and increment of forest land on the degraded land reduce stream flow which shows the reduction of soil erosion. Therefore, this study results can be used to encourage different users and policymakers for planning and management of water resources and adoption of suitable adaptation measures in the Robigumero watershed as well as in other regions of Ethiopia.

Author contributions Author contributions All authors have equal contributions.

Data availability The data sets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest There is no conflict of interest between researchers in this manuscript.

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