Impact of Land Use/Land Cover Change on Watershed Hydrology: A Case Study of Upper Awash Basin, Ethiopia

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Abstract

Land use/land cover (LULC) change is one of the important factors which have direct impacts on watershed hydrology. The impact of LULC change on streamflow of Upper Awash watershed was carried out using Soil and Water Assessment Tool (SWAT). The LULC change analysis was performed by using unsupervised classification method using Earth Resources Data Analysis System (ERDAS) imagine 8.5 software. The study results showed that the watershed experienced significant LULC change during 1986 to 2009. SWAT model was calibrated for periods 1986 to 1999 and validated for the periods 2000 to 2009. SWAT model was calibrated and validated for the sensitivity of streamflow parameters. Consequently, ten parameters were identified to be sensitive. Further, this model was utilized to assess the impact of LULC change on streamflow for period 1986 to 2009. The result showed that there was a reasonable agreement between observed and simulated streamflow with coefficient of determination (R^2) and Nash-Sutcliffe efficiency values 0.86 and 0.77 for calibration, and 0.84 and 0.76 for validation, respectively. The evaluation of SWAT hydrologic response unit (HRU) due to LULC change showed that monthly streamflow was increased by 16.13 % in wet months and decreased by 20.8 % in dry months between the years 1986 and 2000. While between the year 2000 and 2009, it was increased by 0.92 % and 5.82 % for wet and dry months, respectively. Similarly, surface runoff was found increased and groundwater decreased during the study period. Further, the calibrated model can be utilized to understand risk and reliability of different structures and analysis of climate change, water quality, and sediment yield. Hence, this type of study can be useful for sustainable development in the Upper Awash basin as well as in other regions of Ethiopia.

Keywords: LULC change, Streamflow, Hydrological responses, SWAT, GIS, Upper Awash Basin, Ethiopia

1. Introduction

Hydrologic modeling and water resources management studies are inter-related with each other to the spatial processes of the hydrologic cycle at watershed, sub-watershed and basin level. This cycle is intensified by several factors which include natural and anthropogenic activities. Especially, land use/land cover (LULC) change has a significant impact on the watershed hydrology by affecting the magnitude and pattern of surface runoff, groundwater and soil moisture content (Setyorini et al. 2017). Thus, understanding the interaction between LULC and hydrological cycle is imperative. The LULC changes are caused by a number of natural and human driving forces (Meyer and Turner 1994). The LULC change mainly caused due to high population growth and it is most common in developing countries like Ethiopia (Tekle and Hedlund 2000). The dynamic nature of land use arising from an increasing population at an alarming rate in Ethiopia (Haile and Assefa 2012). The anthropogenic activities result in an expansion of agricultural land and urbanization thereby deforestation.

Several studies are carried out on hydrology of the watershed by utilizing LULC data in the different regions of the World and in Ethiopia using Soil and Water Assessment Tool (SWAT) (e.g. Setegn et al. 2008; Legesse et al. 2010; Haile and Assefa 2012; Geremew 2013; Adeba et al. 2015; Getahun and Haj 2015; Meshesha et al. 2016; Chaemiso et al. 2016; Tibebe et al. 2017). Only a few studies have focused on explaining the effects of LULC change on river flow with hydrologic modeling (Kimaro et al. 2006). Many hydrological studies have shown that LULC changes have affected the hydrology of various watersheds of the World (Ambika 2012). The LULC change can alter both the infiltration and runoff amount by following the falling of precipitation (Hougton 1995).

Haile and Assefa (2012) reported that the mean wet monthly streamflow was increased by 39% and dry average monthly flow decreased by 46% for 2011 land cover as compared to 1985 land cover due to LULC change on Angereb watershed in Ethiopia. Geremew (2013) found that LULC change affected the streamflow of Gilgel Abbay watershed, Ethiopia. The mean monthly streamflow for wet months had increased by value 16.26 m^3/s while the dry season had decreased by 5.41 m^3/s during the year 1986 to 2001 due to the LULC change. However, such studies are lacking in the case of Awash basin, where LULC and climate variability have significant impacts on the hydrology of the basin. Therefore, providing a scientific understanding of how LULC change affects the watershed hydrology is very important.

The Awash basin is most intensively utilized basin in Ethiopia. Mainly, Upper Awash basin is characterized by urbanization and wetter hydrological regime due to relatively high rainfall in the highlands of the upper basin (Belete and Semu 2013). The watershed is densely populated and has intensive agricultural activity (Kefyalew 2003). Land degradation like loss of top fertile soil, siltation of Koka reservoir, flood risk during the rainy season, shortage of water supply for irrigation and power generation during the dry season which resulted from a reduction in reservoir capacity are common and foremost problems in the Upper Awash basin. Therefore, this study utilizes SWAT model on ArcGIS platform to analyze the impact of LULC changes on the hydrology of Upper Awash basin in Ethiopia.

2. Materials and Methods

2.1 Study area description

The Upper Awash watershed is found in the high lands of central Ethiopia above 1500 m above mean sea level (Figure 1). The Koka reservoir is located in the upper reaches of the Awash Basin approximately 75 km south-east of Addis Ababa. The climate of the Koka sub-basin come under the influence of the Inter-Tropical Convergence Zone (ITCZ) and the seasonal rainfall distribution results from the annual migration of the ITCZ. There is high variation in elevation and in rainfall that leads the area to the high occurrence of the flood (Halcrow 1989). In the Upper Awash watershed, there are two rainy seasons (bi-modal rainfall patterns) such as heavy rainfall from Jun-August and low rainfall from March-April (Figure 2). The watersheds receive its maximum rainfall during June to September (70 % to 75 % of the annual rainfall). The second rainy period covers the period from February to May. Figure 3 (a&b) indicates that the long-term average monthly and annual rainfall pattern of the selected stations in the study region, respectively. The highest records are observed in July and August whereas the lowest records are observed in November and December. The annual rainfall varies from 650 mm to 1600 mm. Figure 3(c) presents the average annual temperature pattern of weather generator station which varies from 16.07 to 17.29 ^{o}C.

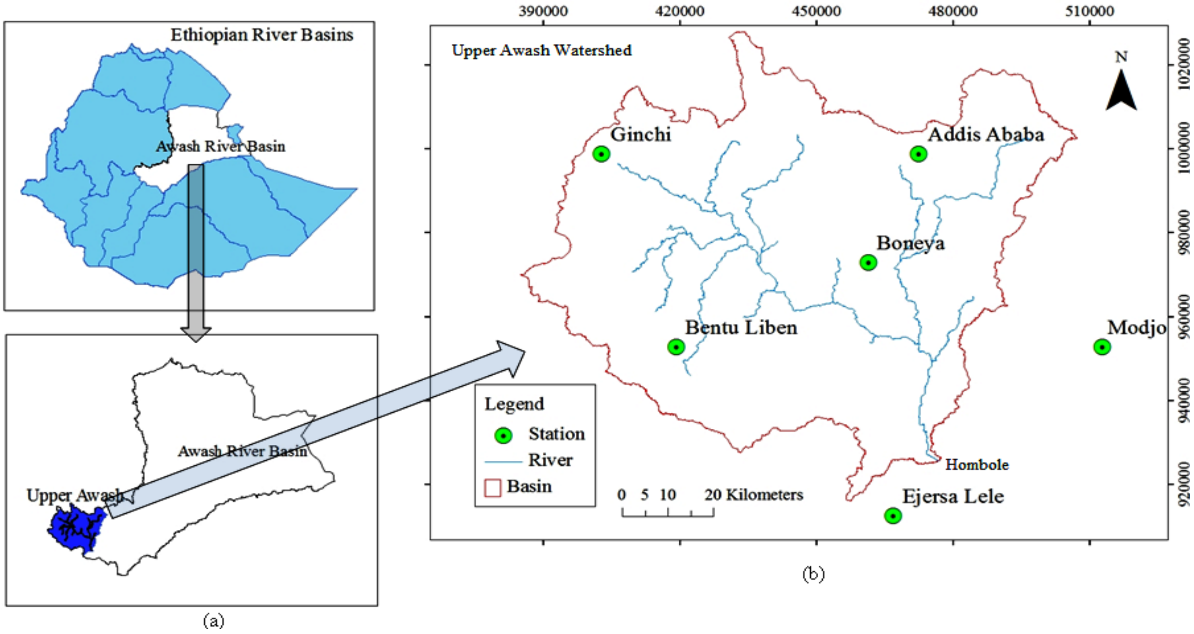


Figure 1. Location of Upper Awash watershed

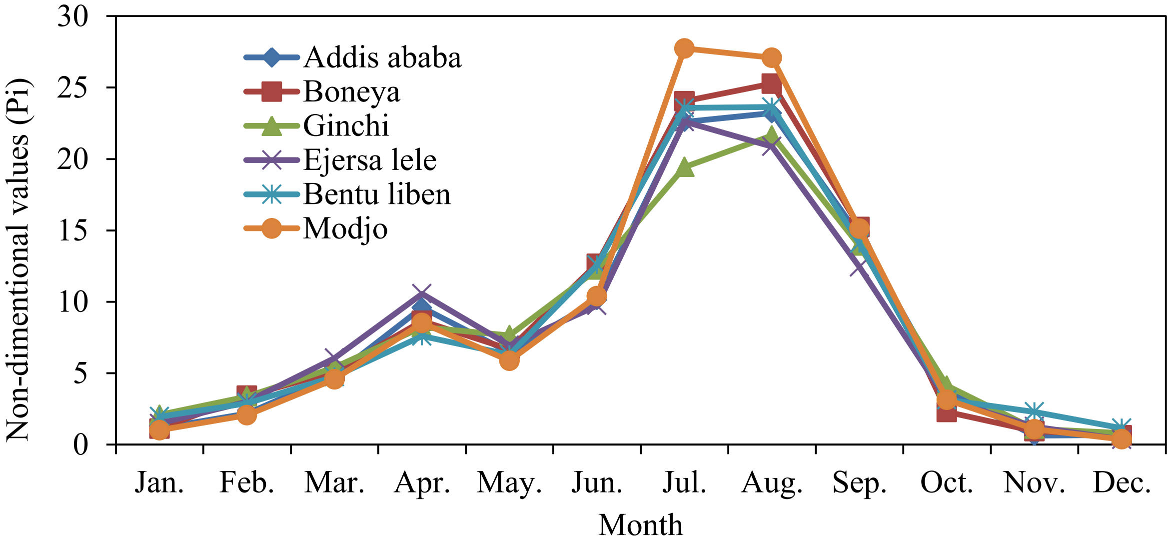
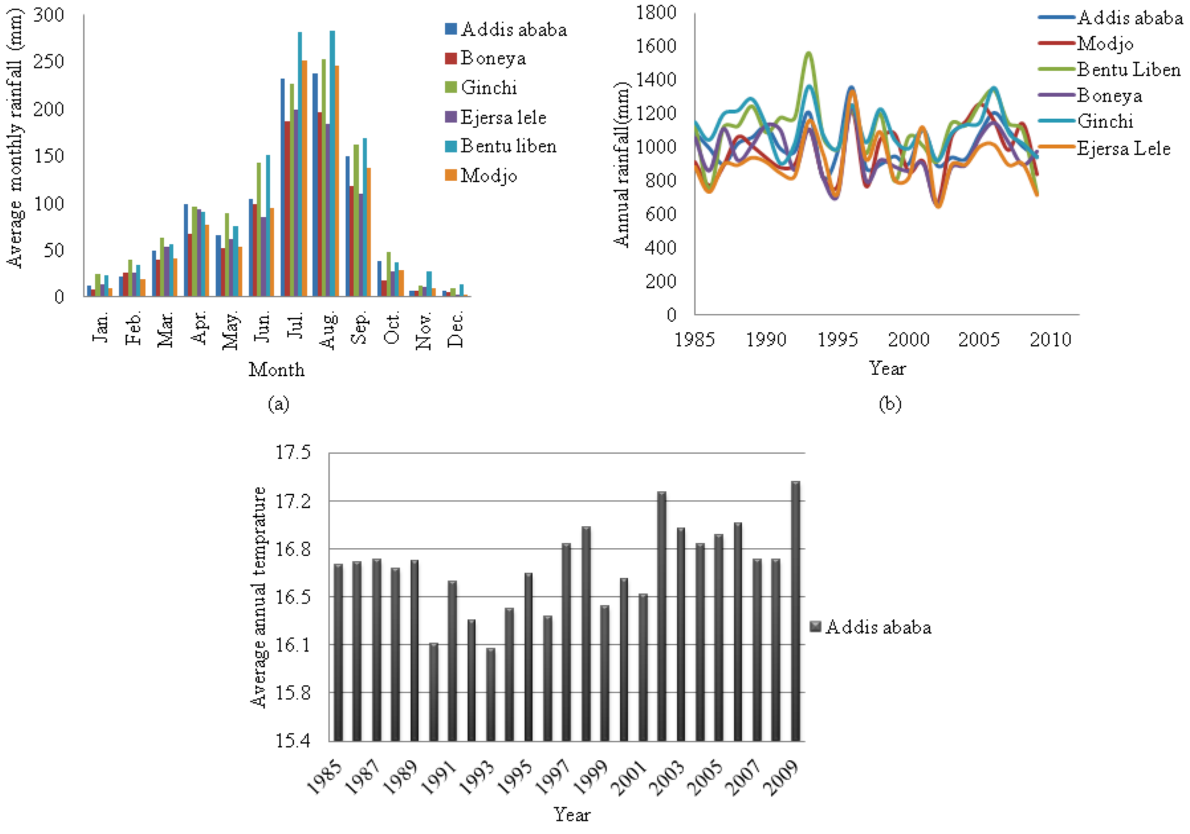


Figure 2. Homogeneity test of selected stations within and around the Upper Awash watershed



(a)

(b)

(c)

Figure 3. Average rainfall patterns of the stations at a) monthly, b) annual scale, and c) average annual temperature at Addis Ababa station

2.2 Data used

The digital elevation model [DEM (30*30 m)] and soil data were obtained from the Ministry of Water, Irrigation, and Energy (MoWIE) of Ethiopia (Figure 4). DEM is used to analyze the drainage pattern of the watershed, slope, stream length and width of channels of the watershed. The LULC data was downloaded from http://glovis.usgs.gov/website. This data was used to identify changes in LULC change in the Upper Awash watershed from 1986 to 2009. Landsat Thematic Mapper (L4-5 TM) was selected for data acquisition. The imageries utilized in this study were ortho-rectified to a Universal Transverse Mercator (UTM) projection system using datum World Geodetic System (WGS) 84, zone 37 N. The more details of the satellite imageries are presented in Table 1. The daily streamflow data from the year 1985 to 2009 at Hombole station was collected from MoWIE. The long-term mean monthly river discharge of Upper Awash watershed at Hombole station is shown in Figure 5. The wettest months are from July to September while driest months are from December to March.

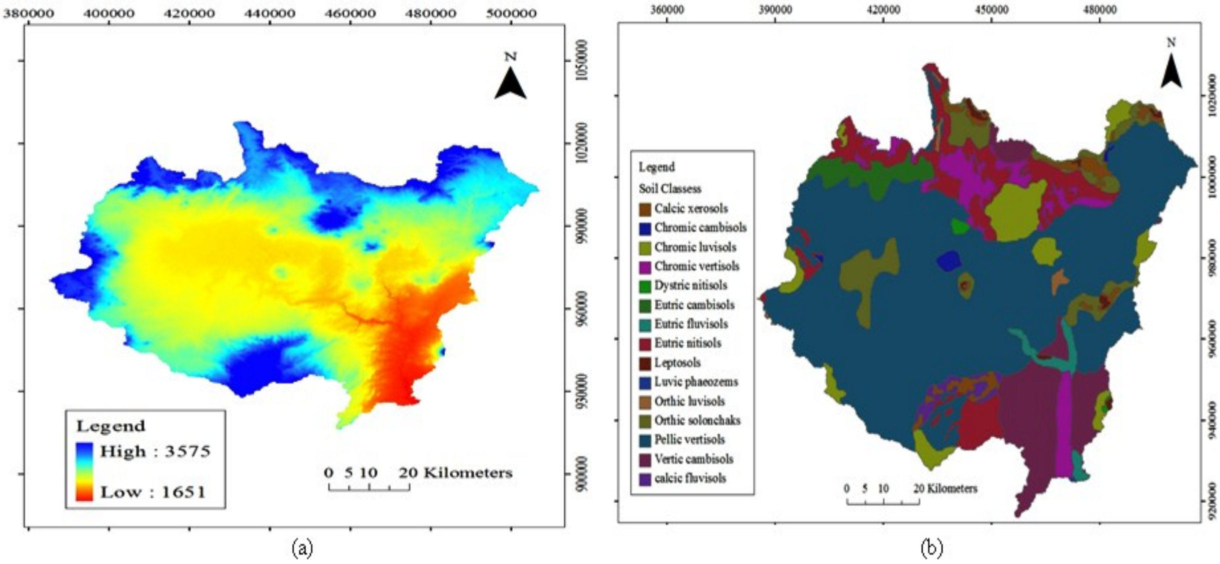


Figure 4. a) DEM and b) Soil map of Upper Awash watershed

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

Path/Raw	Acquisition date	Sensor	Resolution(m)	Producer
168/054	17-Aug-1986	TM	30	USGS
169/054	8-Aug-1986	TM	30	USGS
168/054	22-Jul-2000	TM	30	USGS
169/054	11-Jun-2000	TM	30	USGS
168/054	14-Sep-2009	TM	30	USGS
169/054	5-Oct-2009	TM	30	USGS

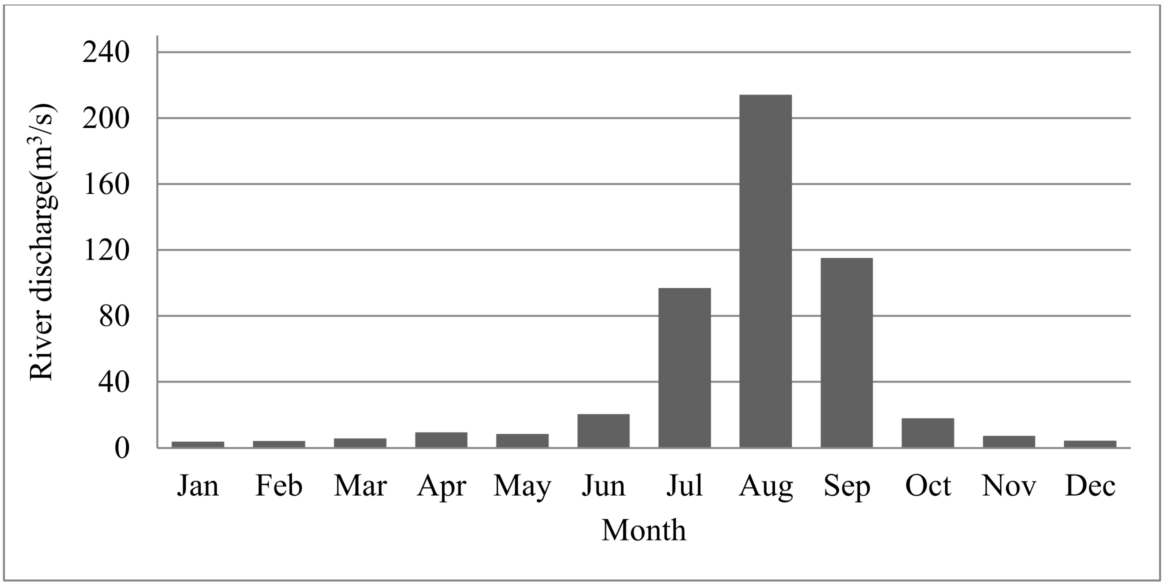


Figure 5. Long-term mean monthly river discharge of Hombole station

The climatic data (i.e. daily rainfall, maximum and minimum temperature, relative humidity, wind speed and solar radiation) were collected from the National Meteorological Services Agency. This data was collected for six meteorological stations in and around Upper Awash watershed for the 25 years (January 1985 to December 2009) (Figure 1b). Addis Ababa is the first class station which contains all meteorological variables required for SWAT (Table 2). This station was used as weather generator station so as to generate weather variables for missing records assigned with no data code value (-99) in SWAT database. Basic data quality checks (i.e. homogeneity, consistency, filling missing data, the location of the station etc.) were performed for selected stations. The inconsistency of the record was performed by the double-mass curve technique (Subramanya 1998) (Figure 6).

Table 2 Meteorological station names, locations, and variables

ID	Station	Lat(Deg)	Long(Deg)	Rainfall	Temperature	Relative humidity	Sunshine hours	Wind speed
1	Addis Ababa	9.03	38.75	✓	✓	✓	✓	✓
2	Boneya	8.78	38.64	✓				
3	Ginchi	9.02	38.13	✓				
4	Ejersa Lele	8.24	38.68	✓				
5	Bentu Liben	8.62	38.36	✓				
6	Modjo	8.61	39.11	✓				

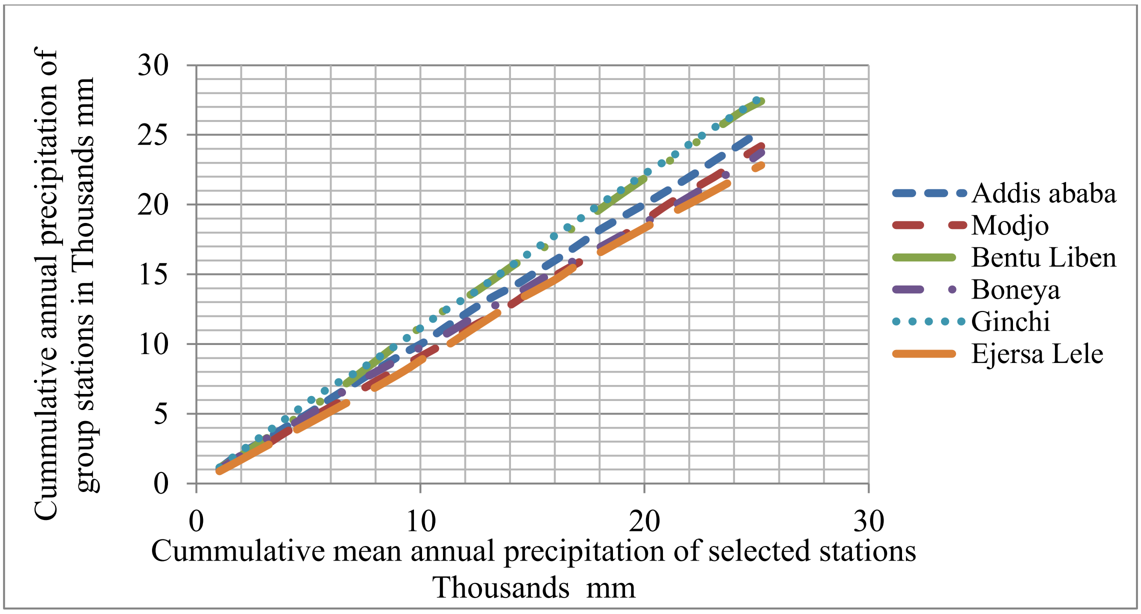


Figure 6. Double mass curves for selected stations

3. Methodology

3.1. SWAT Model Description

SWAT model (i.e. ArcSWAT) is an extension of ArcGIS, which is developed by the United States (US) Department of Agricultural Research Service (ARS). SWAT is a physically based semi-distributed continuous time-scale hydrological model, which works on a daily time step. This model can simulate runoff, sediment, nutrients, pesticide and bacteria transport from agricultural watersheds (Arnold et al. 1998). The hydrological response units (HRU's) are utilized to consider spatial heterogeneity in terms of land cover, soil type and slope class within a watershed. It simulates the hydrological cycle parameters based on the water balance represented in equation 1 within the watershed (Neitsch et al. 2005). More details information about SWAT model can be found in SWAT user manual (Neitsch et al. 2005).

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

where

SW_t is the final soil water content (mm)

SW_o is the initial water content (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 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).

3.2 Model Setup

The detail conceptual framework adopted in the present study has been presented in Figure 7.

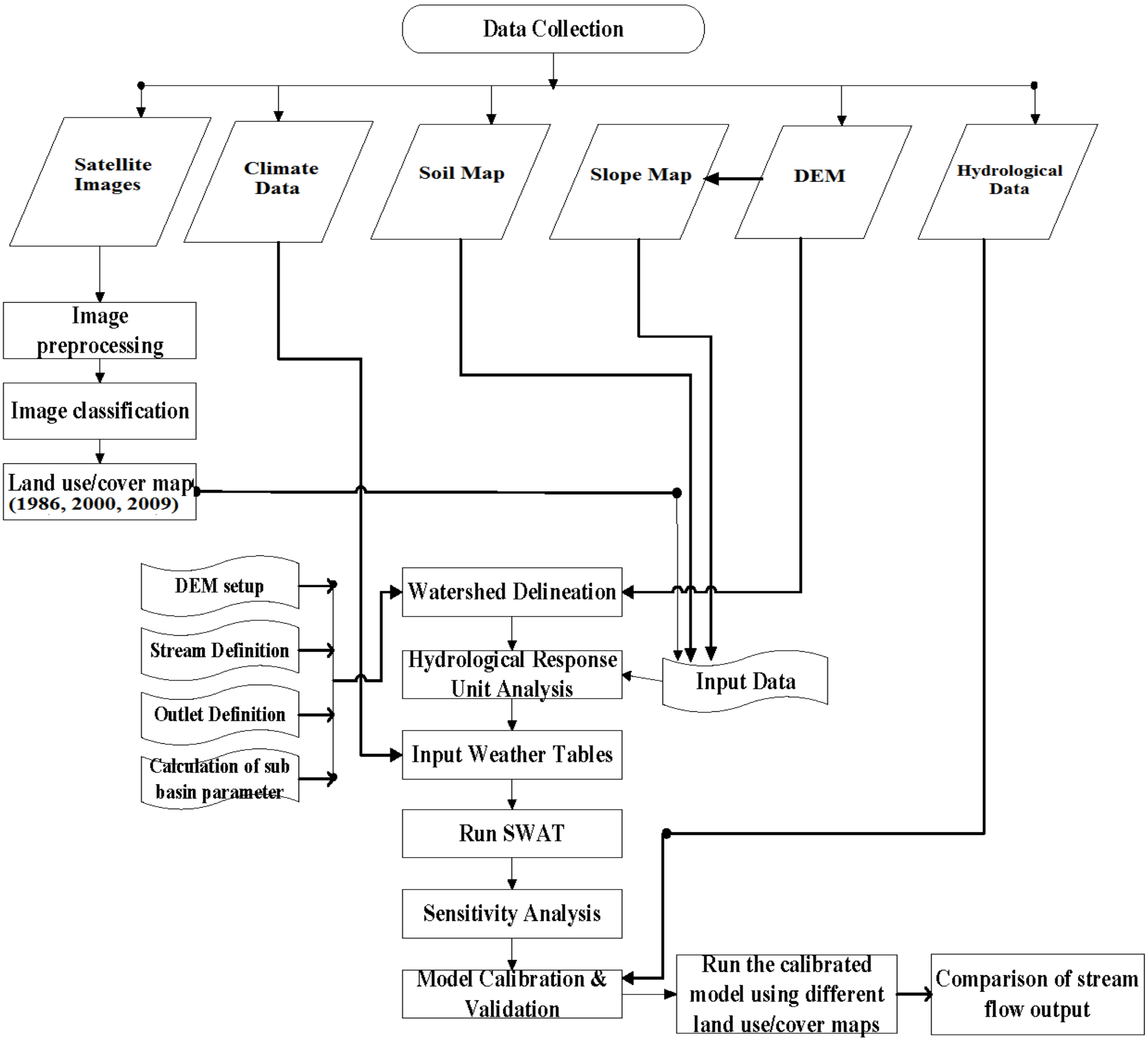


Figure 7. The conceptual framework of the study

The watershed and subwatershed delineation were carried out using 30 m DEM using ArcSWAT version 2.3.4 and SWAT version 2005 on ArcGIS 9.3 platform. The watershed delineation process consists of five major stages such as DEM setup, stream definition, outlet and inlet definitions, watershed outlets selection, definition and calculation of sub-basin parameters. The size of sub-basin in the watershed will affect the assumption of homogeneity. Hence, the definition of a watershed, sub-basin boundaries and streams is decided based on a threshold area to define streams. Using a threshold value, the Upper Awash basin was delineated into 27 sub-watersheds, which is having a total area of 7256 km^2 (Figure 8).

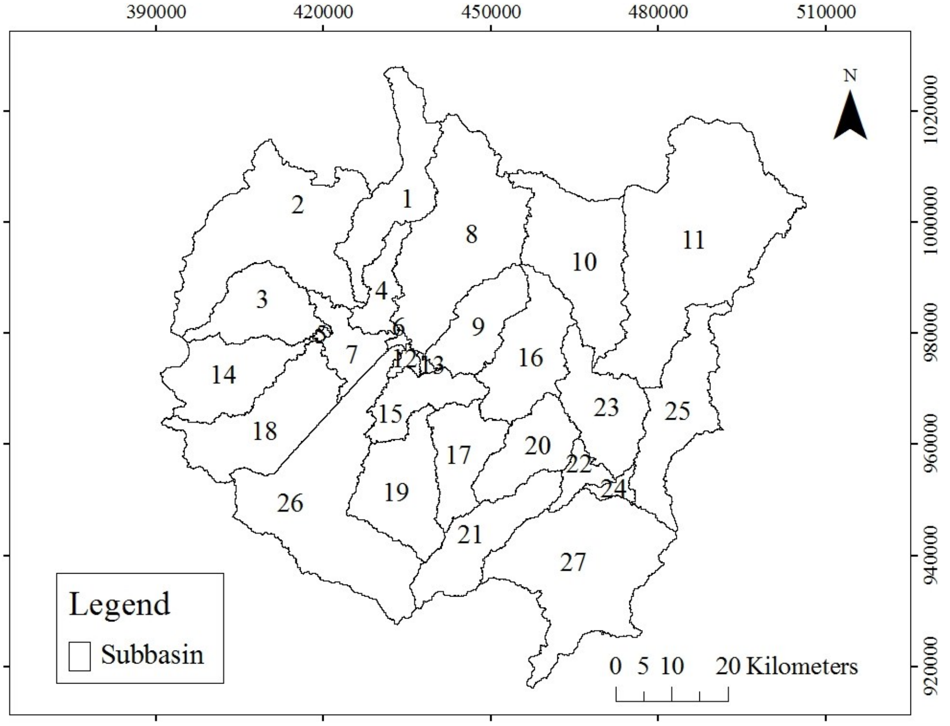


Figure 8. Sub-watersheds map of the Upper Awash watershed

The model requires the creation of HRUs, which consists of unique combinations of LULC, soil and slope classes within each sub-basin. HRU analysis includes classification of HRUs based on slope classes in addition to LULC and soils classes. The multiple slope option was selected for this study, which were reclassified into four classes (namely 0-2 %; 2-5 %; 5-10 %; >10). In this study, threshold combination of 5 % land use, 6 % soil and 10 % slope were used to get better results. Therefore, the Upper Awash watershed was divided into 454 HRUs, each has a unique LULC, slope and soil combinations.

SWAT requires long-term daily records of meteorological data which includes precipitation, maximum and minimum temperature, solar radiation, relative humidity and wind speed. These data records were prepared according to the SWAT model table format. In this study, weather generator parameters were estimated using more than 20 years of measured records. The weather generator model called WXGEN (Shapley and Williams 1990) was used in the SWAT to generate climatic data or to fill missing data using monthly statistics.

3.3 Sensitivity analysis

In this study, parameter sensitivity method has been used to identify the sensitive parameters. The sensitivity is used to estimate the rate of change of model outputs with respect to the change of model inputs. It is also useful to understand how the model depends on the information fed into it (Willems 2000). Initially, the SWAT simulation was specified to carry out the sensitivity analysis and location of the sub-basin where observed data was compared against simulated output. Further, selected parameters were entered for the sensitivity analysis with the default lower and upper parameter bounds. Thus, 27 flow parameters were included for the analysis with default values (Van Griensven et al. 2006). Finally, the mean relative sensitivity (MRS) values of the parameters were used to rank the parameters and their category of classification. The category of sensitivity was defined based on the classification presented in Table 3 (Lenhart et al. 2002).

Table 3 SWAT parameters sensitivity classes

Class	MRS	Sensitivity category
I	$0.00 \leq MRS < 0.05$	Small to negligible
II	$0.05 \leq MRS < 0.2$	Medium
III	$0.2 \leq MRS < 1$	High
IV	$MRS > 1$	Very high

3.4 Model calibration and validation

In this study, manual calibration was used to calibrate the SWAT Model. The parameter values were adjusted by changing one or two parameters at a time within the allowable ranges either by replacing the initial value or addition or by multiplication of the initial value. The calibration was done on monthly time steps using the average observed streamflow data of the Upper Awash watershed from January 1986 to December 1999. In this study, 10 flow parameters were considered in the calibration process. The model was run using the best parameter output values and the simulations were carried out. Further, observed data of average monthly streamflow from January 2000 to December 2009 was used for the model validation process.

The model performance during calibration and validation process was carried out using performance indicators such as Nash and Sutcliffe coefficient of efficiency (ENS) and coefficient of determination (R^2). Determination coefficient ranges from 0 (which indicates the model is poor) to 1 (which indicates the model is good), with higher values indicating less error variance, and typical values greater than 0.6 are considered as acceptable (Santhi et al. 2001). The R^2 is calculated using equation 2:

$$R^2 = \frac{\sum[X_i - X_{av}]*[Y_i - Y_{av}]}{[\sqrt{\sum[X_i - X_{av}]^2} * \sqrt{\sum[Y_i - Y_{av}]^2}]} \qquad (2)$$

where

X_i is a measured value (m^3/s)

X_{av} is an average measured value (m^3/s)

Y_i is a simulated value (m^3/s) and

Y_{av} is an average simulated value (m^3/s)

The ENS indicates that how well the plots of observed versus simulated data fit the 1:1 line. This is computed using equation 3:

$$ENS = 1 - \frac{\sum[X_i - Y_i]^2}{\sum[X_i - X_{av}]^2} \qquad (3)$$

The value of ENS ranges from negative infinity to 1 (best). ENS value ≤0 indicates the mean observed value is a better predictor than the simulated value, which indicates unacceptable performance. While ENS values greater than 0.5, the simulated value is a better predictor than mean observed value and generally viewed as acceptable performance (Santhi et al. 2001).

3.5 Evaluation of streamflow variability due to LULC change

Initially, satellite imageries (1986, 2000 and 2009) were classified by means of unsupervised classification using an Iterative Self-Organizing Data Analysis Techniques (ISODATA) algorithm with ERDAS imagines version 2014 software. Using this method, 30 classes were identified according to their reflectance values. In labeling the spectral class into information classes the image with approximately similar values was merged together. After the image was merged, Google earth was used to identify information classes. Further, the impact of LULC on the variability of streamflow was evaluated for the year 1986 to 2009. Three independent SWAT runs were carried out on a monthly time step for the year 1986, 2000 and 2009 LULC, keeping other input parameters unchanged. Finally, seasonal streamflow variability due to LULC change was assessed based on the simulation outputs. The comparison was made on surface runoff and groundwater flow contributions to streamflow.

4 Results and discussion

4.1 Streamflow modeling

4.1.1 Sensitivity analysis

Sensitivity analysis was performed on SWAT flow parameters at monthly time step using observed streamflow of Hombole gauging station. All flow parameters were considered to identify which parameters were more sensitive in Upper Awash watershed. The result shows that 10 flow parameters have a significant influence on streamflow of the watershed (Table 4). Total soil depth (SOL-Z), Threshold depth of water in the shallow aquifer required for return flow (GWQMN), SCS runoff curve number (CN2) and maximum canopy storage (CANMX) were identified to be highly sensitive parameters and retained rank 1 to 4, respectively. While parameters like soil evaporation compensation factor (ESCO), Groundwater "revap" coefficient (GW_REVAP), Maximum potential leaf area index (BLAI), Soil available water capacity (SOL_AWC), Effective hydraulic conductivity of the main channel (CH_K2) are identified as slightly important parameters that were retained rank 3 to 9, respectively. Base flow alpha factor (ALPHA_BF) was found least sensitive parameter (ranked 10). The remaining flow parameters were not considered during calibration process as the model simulation result was not significantly affected by these parameters in the watershed.

Table 4 List of parameters and their ranking with MRS values for monthly flow

Parameters		MRS	Rank	Category
Name	Description			
SOL-Z	Total soil depth (mm)	0.6060	1	High
GWQMN	Threshold depth of water in the shallow aquifer required for return flow (mm)	0.3370	2	High
CN2	SCS runoff curve number (%)	0.3020	3	High
CANMX	Maximum canopy storage (mm)	0.2830	4	High
ESCO	Soil evaporation compensation factor	0.1110	5	Medium
GW_REVAP	Groundwater "revap" coefficient	0.0844	6	Medium
BLAI	Maximum potential leaf area index	0.0809	7	Medium
SOL_AWC	Soil available water capacity (water/mm soil)	0.0643	8	Medium
CH_K2	Effective hydraulic conductivity of the main channel (mm/hr)	0.0611	9	Medium
ALPHA_BF	Base flow alpha factor (days)	0.0025	10	Small

4.1.2 Calibration and validation

Simulation results of default parameters indicated that observed flow was poorly matched with the simulated flow. Therefore, calibration was done for the sensitive parameters of SWAT model in the watershed using observed streamflow. All sensitive parameters were identified using calibration procedure. The results of calibrated flow parameters are presented in Table 5. The model was run for the years 1985 to 1999 including one year for the warm-up period. The calibration was done for the period 1986 to 1999 (Figure 9a). The calibration results showed that there is a good agreement between observed and simulated streamflow (ENS=0.77 and R^2=0.86). The model validation was done for a period of 10 years from 2000 to 2009 (Figure 9b). The result of validation for monthly flow showed a good agreement between observed and simulated streamflow (ENS= 0.76 and R^2=0.84). The validation revealed that model adequately captured streamflow except for peak flow (Figure 9b). This probably is a limitation of the SWAT model. Since the model performance values are satisfactory for calibration and validation periods, the model can be used for further study of the watershed. Similar, calibration and validation results were reported by different studies that conducted in Ethiopian region. For e.g. Haile and Assefa 2012 reported that the SWAT model showed a good agreement between observed (ENS=0.76 and R^2=0.85) and simulated (ENS=0.72 and R^2=0.79) streamflow for calibration and validation in Angereb watershed.

Table 5 List of parameters with calibrated values for average monthly streamflow

Parameters		Range	Calibrated value
Name	Description		
SOL-Z	Total soil depth (mm)	± 25	20
GWQMN	Threshold depth of water in the shallow aquifer required for return flow (mm)	0-5000	100
CN2	SCS runoff curve number (%)	± 25	-15
CANMX	Maximum canopy storage(mm)	0-10	6
ESCO	Soil evaporation compensation factor	0-1	0.6
GW_REVAP	Groundwater “revap” coefficient	0.02-0.2	0.19
BLAI	Maximum potential leaf area index	0-1	0.5
SOL_AWC	Soil available water capacity (water/mm soil)	± 25	12
CH_K2	Effective hydraulic conductivity of the main channel (mm/hr)	0-150	3
ALPHA_BF	Base flow alpha factor (days)	0-1	0.85

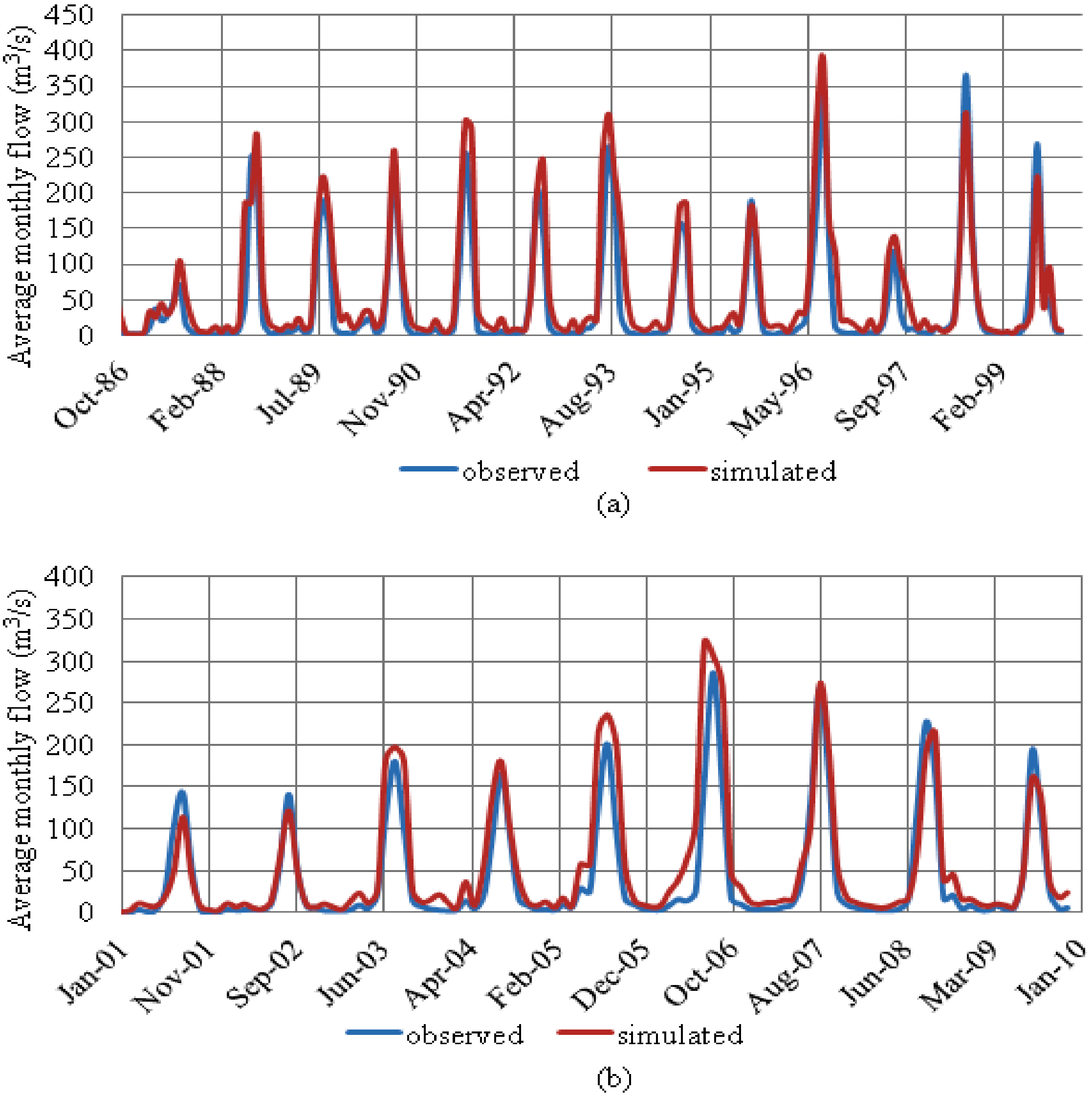


Figure 9. The results of average monthly streamflow for a) calibration and b) validation

Yacob (2010) also found a good agreement between observed and simulated (ENS=0.60 and R^2=0.75) and simulated (ENS=0.74 and R^2=0.85) streamflow in Tikur Wuha watershed, respectively. The average monthly flow indicates reasonable agreement between observed and simulated flow during calibration (43.16 and 58.76 m^3/s) and validation (40.93 and 50.89 m^3/s), respectively. There is a good linear correlation between observed and simulated flows with a percentage fit greater than 80 [Figure 10 (a & b)]. Further, the relationship between rainfall and runoff was investigated for the Upper Awash watershed (Figure 11a). The results indicated that the surface runoff has the same pattern with rainfall of the watershed. There is a fair linear correlation between rainfall and runoff in the watershed with percentage fit greater than 60 (Figure 11b).

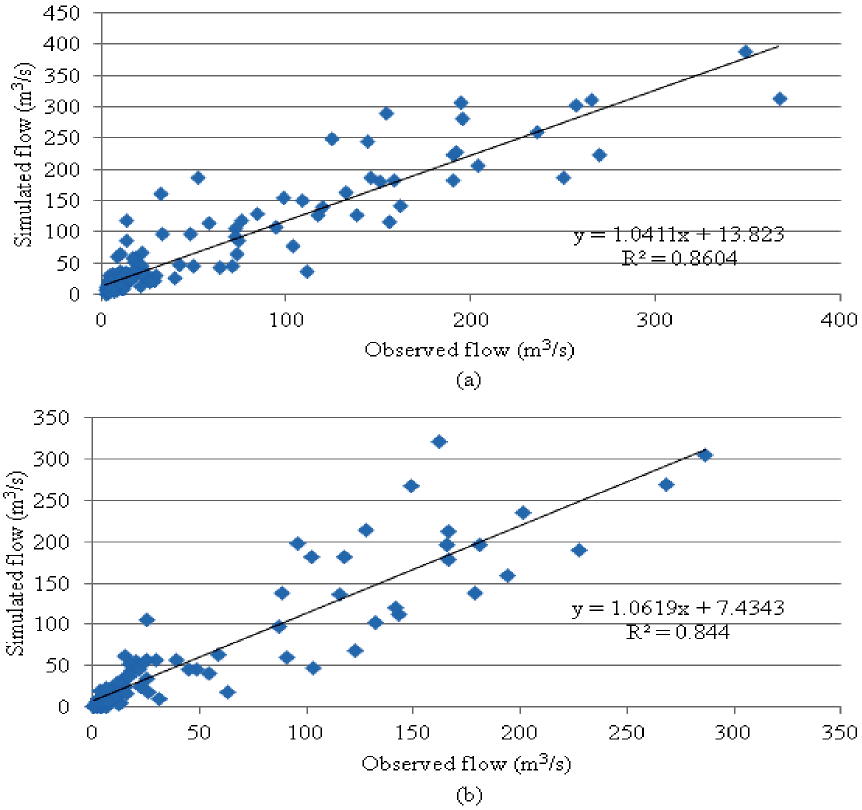


Fig. 10 The observed versus simulated flow during a) calibration and b) validation

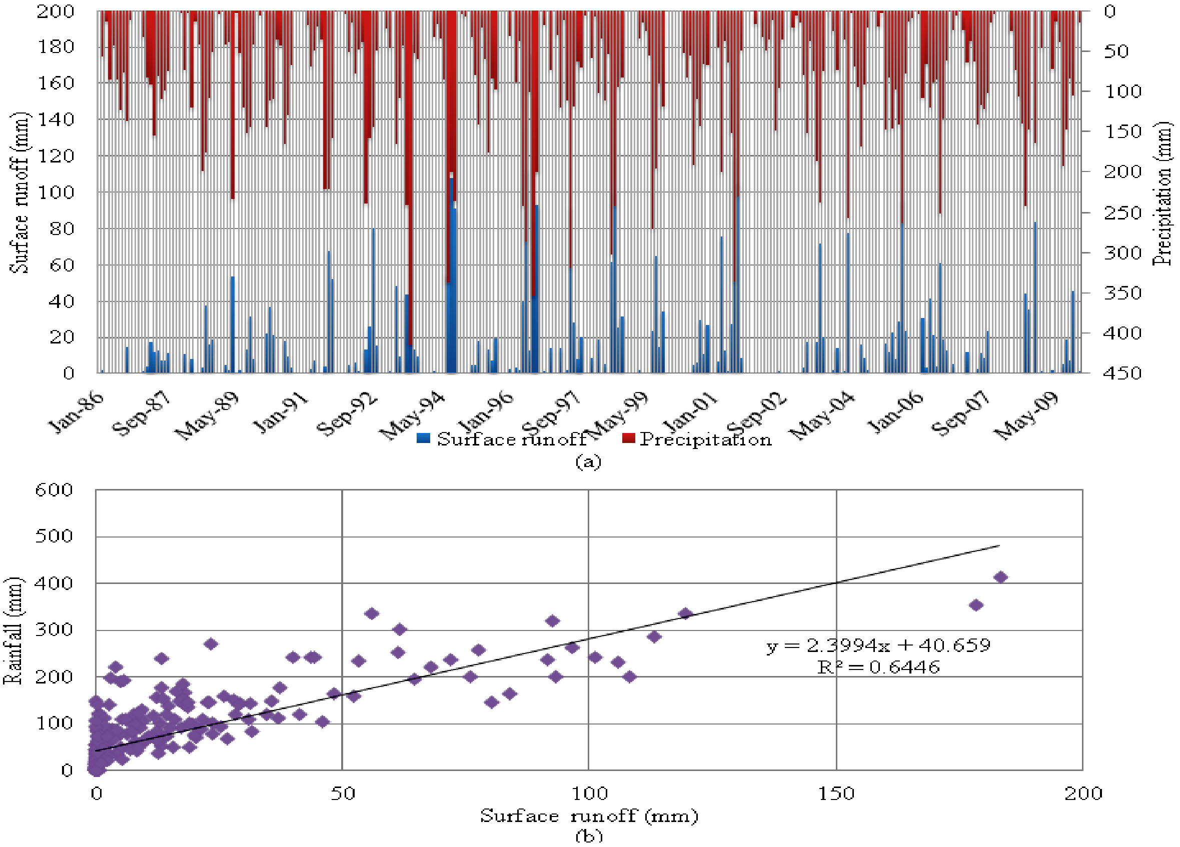


Fig. 11 The rainfall-runoff relationship in Upper Awash watershed

4.2 LULC Change

The satellite imageries were classified using unsupervised classification method and LULC map was prepared for Upper Awash watershed of the years 1986, 2000 and 2009 (Figure 12). The study result revealed that the watershed has undergone significant LULC change. It shows that increase in the agriculture, bare land, urban and shrubland, whereas the decrease of the forest, grassland, water, and wetland. Land area under agriculture increased by 39.55 % during the study period. This is due to increase of population growth that causes the increase in demand for cultivation land for different agricultural products like sugarcane, whereas the forest area was decreased to 42.76 %. This might be because of the deforestation activities that have taken place for the purpose of agriculture and urban expansion. The urban area was increased by 0.73 %. Moreover, bare land increased by 0.13 % which indicates the degradation of the watershed. This attributed to declining of forest land in the watershed. From years 2000 to 2009, there was further expansion of the land under agriculture and urban at the expense of other land covers (Table 6).

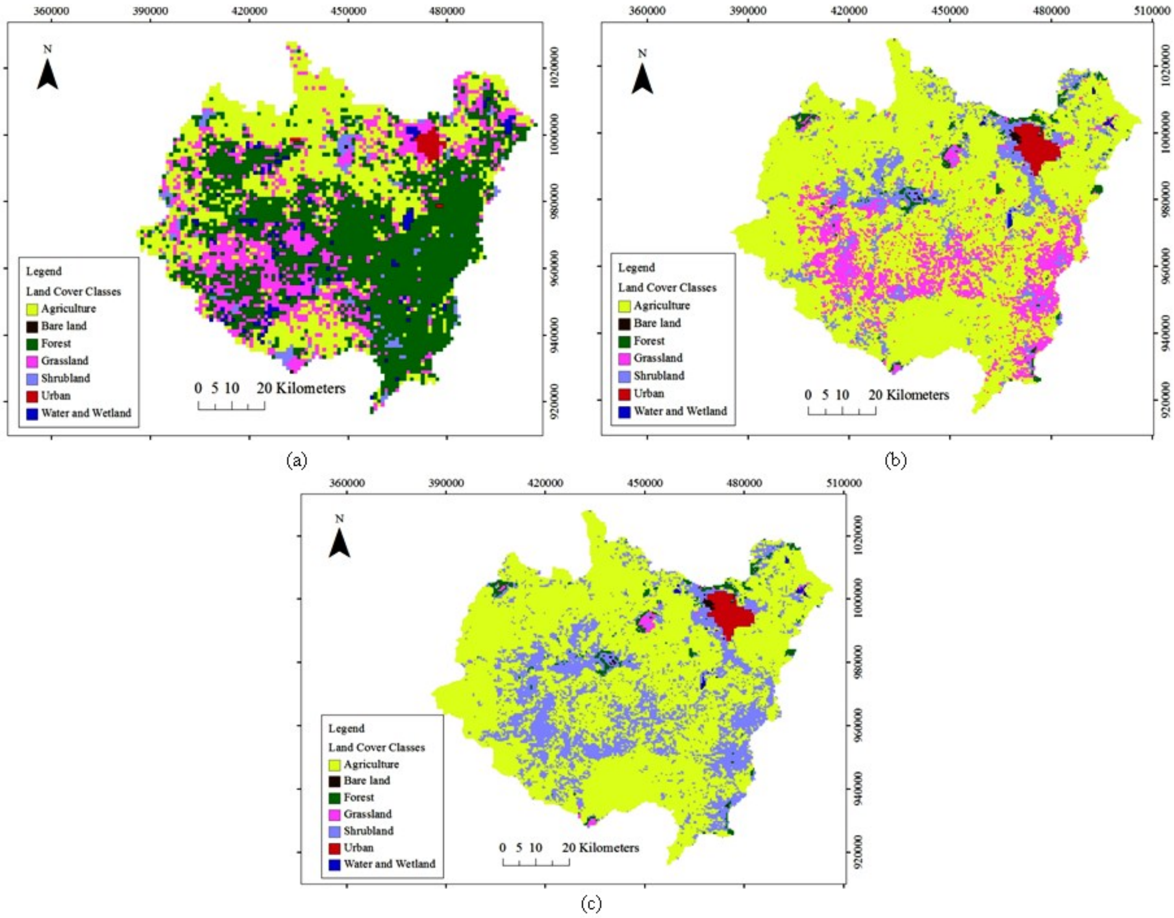


Figure 12. Land cover map of Upper Awash watershed in the year a) 1986, b) 2000 and c) 2009

The comparison of LULC change in the Upper Awash watershed are presented for the year 1986, 2000 and 2009 (Figure 13). This indicates that the major portion of the watershed was covered by forest in the year 1986. While a major portion of the watershed was dominated by agriculture in the year 2000 and 2009. This shows there was deforestation of forest land and expansion of agricultural land. Similar, observation was also reported that cultivated land was expanded at the expense of natural forest cover between 1957 and 1982 in Dembecha area,

Table 6 LULC change of Upper Awash watershed for the period 1986 to 2009

LULC	1986		2000		2009		LULC change			
							2000 to 1986		2009 to 2000	
	Km^2	%	Km^2	%	Km^2	%	Km^2	%	Km^2	%
Agriculture	2257	31.11	5126.8	70.66	5159.15	71.10	2869.81	39.55	32.28	0.445
Bare land	2.0	0.03	11.35	0.16	11.31	0.16	9.33	0.13	-0.04	-0.001
Grassland	1359.6	18.74	37.31	0.51	37.20	0.51	-1322.29	-18.23	-0.11	-0.002
Forest	3218.8	44.36	115.84	1.60	113.47	1.56	-3102.95	-42.76	-2.37	-0.033
Shrubland	208.8	2.88	1840.78	25.37	1807.52	24.91	1631.95	22.49	-33.26	-0.458
Urban	60.7	0.84	114.07	1.57	117.64	1.62	53.35	0.73	3.56	0.049
Water and Wetland	149.0	2.05	9.820	0.140	9.750	0.134	-139.21	-1.92	-0.066	-0.001

Note: Negative and positive signs indicate the decrease and increase of LULC class, respectively.

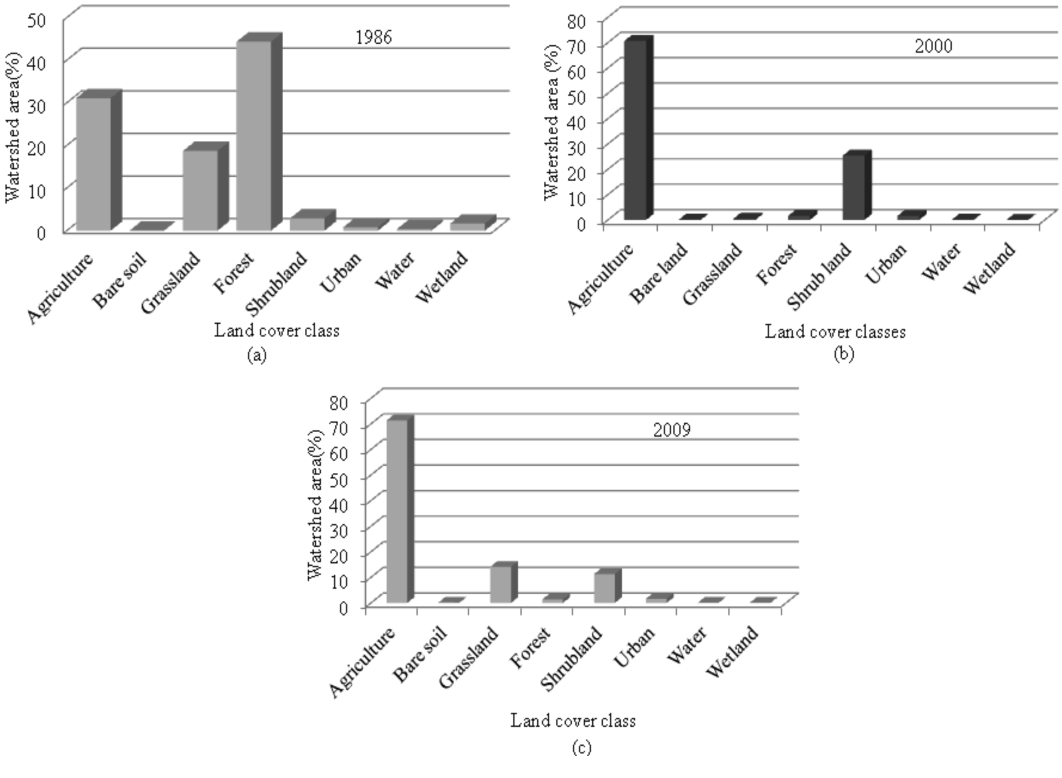


Figure 13. Comparison of LULC classes of the year a) 1986, b) 2000 and c) 2009

north-western Ethiopia (Zeleke and Hurni 2001). Amsalu et al. 2007 showed that there was a decrease in natural vegetation cover and increase of plantation in Beressa watershed, in the central highlands of Ethiopia between 1957 and 2000.

4.3 Impact of LULC change on streamflow

This study assessed the impact of LULC change on streamflow in Upper Awash 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 1986, 2000 and 2009 LULC maps are shown in Figure 14(a). The wet and dry mean monthly streamflow of 1986, 2000 and 2009 LULC and its variability during the study period are presented in Table 7. The results indicated that mean monthly streamflow was increased in the wet months (16.13 %) and decreased in dry months (20.8 %) in the year 1986 and 2000 (Table 7). This was attributed to increase in the area under agriculture and decrease of forest land in the Upper Awash watershed. This is due to rainfall satisfies soil moisture deficit more quickly in the agricultural land than forest thereby generating more runoff in agricultural land. As a result, more runoff was generated due to streamflow in the year 2000 than 1986 (Figure 14b). Moreover, expansion in agricultural land decreased rainfall infiltrated into the

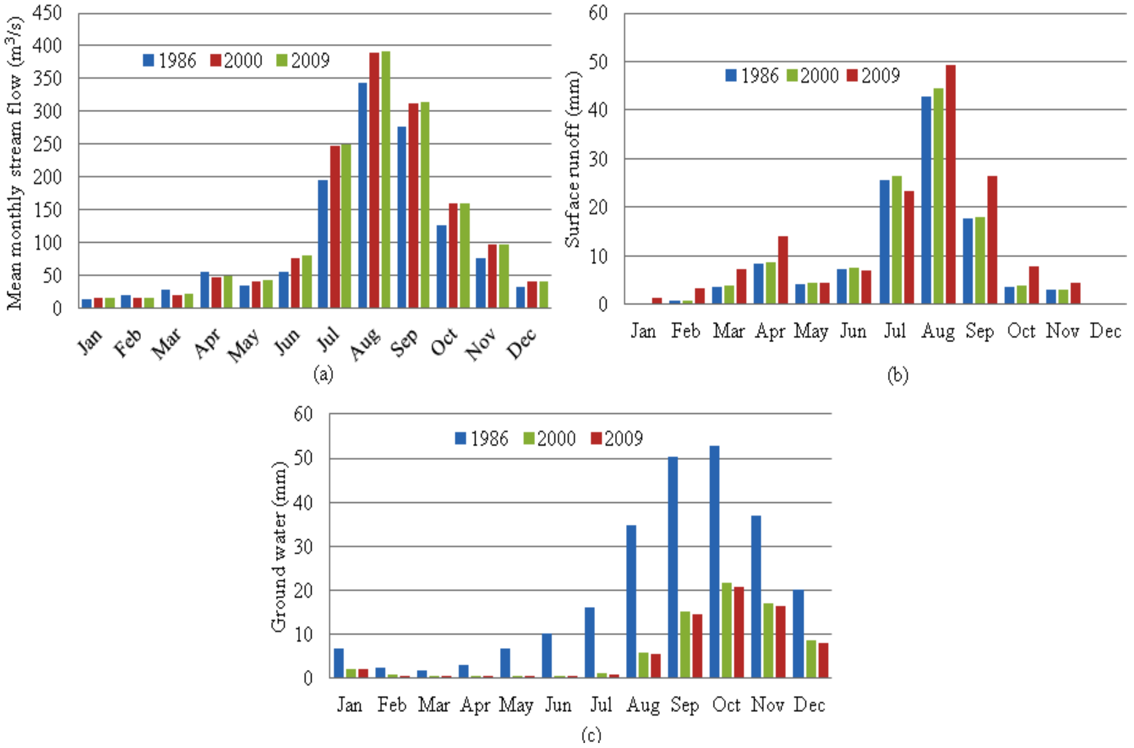


Figure 14. Comparison of mean monthly a) flow, b) surface runoff and c) groundwater for the years 1986, 2000 and 2009 LULC

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 2009 both in wet (0.92 %) and dry (5.82 %) seasons as compared to 2000 due to LULC change (Figure 14a). Besides, a slight decrease in land under grassland and bare land which contributed to increases of groundwater in the watershed. It generates more surface runoff in grassland and bare land due to less infiltration.

The result indicates that mean monthly streamflow was increased by 15.84 % in the year 1986 to 2000 and 1.82 % between the years 2000 to 2009 (Table 8). The dominant land cover in the year 2000 was agriculture and there was high agricultural expansion at the expense of other land use from the year 1986 to 2000. As a result, high runoff was generated during this period; this increases streamflow of 2000 as compared to 1986. In the year 2009, there was a further expansion of the land under agriculture and decrease of the forest. Therefore, for the same reason, the streamflow was increased in 2009 as compared to 2000. Generally, during the study period, Upper Awash watershed experienced an increase of streamflow due to drastic LULC change.

The change in monthly streamflow [i.e. surface runoff (SURQ) and groundwater flow (GWQ)] due to LULC change was assessed for years 1986, 2000 and 2009 (Figure 14b & c). It was found that the mean monthly surface runoff was increased to 9.81mm to 10.14mm from 1986 to 2000 (Figure 14b and Table 9). Therefore, high surface runoff was generated in the year 2000 as compared to 1986 due to increment in the area under agriculture. In the year

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

Mean monthly streamflow (m^3/s)						Mean monthly streamflow change			
LULC						2000 to 1986		2009 to 2000	
1986		2000		2009					
Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
815.63	61.43	947.18	48.65	955.88	51.49	131.55	-12.78	8.70	2.83

Table 8 Streamflow simulation on monthly basis for 1986, 2000 and 2009 LULC

Mean monthly streamflow (m^3/s)			Mean monthly flow change			
LULC map			2000-1986		2009-2000	
1986	2000	2009	m^3/s	%	m^3/s	%
104.53	121.08	122.9	16.55	15.84	1.82	1.51

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

LULC map						Change of SURQ and GWQ			
1986		2000		2009		2000 to 1986		2000 to 2009	
SURQ(mm)	GWQ(mm)	SURQ(mm)	GWQ(mm)	SURQ(mm)	GWQ(mm)	SURQ(mm)	GWQ(mm)	SURQ(mm)	GWQ(mm)
9.81	20.17	10.14	6.2	12.5	5.94	0.33	-13.97	2.36	-0.26

2009, there was a slight increase of agriculture and urban at the expense of other land covers, this result increase of surface runoff. While groundwater was decreased from 20.17 mm to 6.2mm in 2000 as compared to 1986 due to LULC change (Figure 14c). This attributed to the decline of forest land because forest increases groundwater by infiltrating the precipitation and reducing surface runoff. In the year 2009, there was a further decrease of forest and shrubland that result decrease of groundwater (6.2 mm to 5.94 mm) as compared to 2000. Whereas, surface runoff was increased from 10.14 mm to 12.5 mm (Figure 14c). Similar, studies were also conducted in Ethiopian region to evaluate the impact of LULC change on streamflow. Haile and Assefa (2012) reported that the mean wet monthly streamflow 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. Also, Geremew (2013) revealed that the mean monthly streamflow 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. 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 etc (Setyorini et al. 2017).

5 Conclusions

In the present study, the impact of LULC change on the hydrology of Upper Awash watershed was evaluated using remote sensing and GIS. SWAT model was calibrated and validated to assess the impact of LULC change on streamflow in this watershed. The study results indicated that the model simulates observed streamflow satisfactorily. The performance and evaluation of the model were found good (ENS= 0.77 and R^2=0.86 for calibration) and (ENS = 0.76 and R^2=0.84 for validation).

From this study, it can be concluded that a significant LULC change during the study period. Land area under agriculture increased by 39.55 % in expenses of other land cover classes while the land area under forest decreased by 42.76 % during 1986 to 2000. Between the year 2000 and 2009, further decrease of the land under agriculture and urban in the expense of other land cover was observed in the Upper Awash watershed. The impact of LULC dynamics showed that mean monthly streamflow was increased by 16.13 % in wet months and decreased by 20.8 % in dry months between the years 1986 and 2000. While in 2009, it was increased by 0.92 % and 5.82 % for wet and dry, respectively as compared to 2000 due to LULC change. This change (increase or decrease) in streamflow may occur due to rainfall variability as well as a change in LULC over a period of time.

Surface runoff was increased from 9.81 mm to 10.14 mm while groundwater was decreased from 20.17 mm to 6.2 mm in the years 1986 and 2000. Also, surface runoff was increased from 10.14 mm to 12.5 mm while groundwater was decreased from 6.2 mm to 5.94 mm in the year 2000 and 2009. This is mainly attributed to conversion of forest cover to agricultural land, which in turn increased surface runoff during the wet season and decreased groundwater during the dry season. In 2009, a minor decrease of the land under grassland and bare land which contributed to increases in groundwater which in turn increase dry season streamflow in the watershed from the year 2000 to 2009. 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 Upper Awash watershed as well as in other regions of Ethiopia.

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