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Research Article

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Land Use and Land Cover Change and Its Impact on Flood Hazard Occurrence in Wabi Shebele River Basin of Ethiopia

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Abstract

Land-use and land-cover (LULC) changes can impact the hydrological conditions such as land surface coefficient, runoff, infiltration, and hydrographic characteristics of the watersheds. This study investigates the changes in LULC and its impact on water resources of the Wabi Shebele basin using Soil and Water Assessment Tool (SWAT) and a Separation method. Surface and groundwater parameters in northwestern part of the basin; and soil and surface parameters in the eastern highland and southern lowland part of the basin are the most sensitive parameters identified for water production. Out of ten LULC types that exist in the basin, three of them (i.e., cropland, grassland, and bare land) showed growth while two LULC types (i.e., forest and woodland) shows a significant decrease in the past four decades from the 1980s to 2010s. The coverage of cropland was increased by 48.63% while forest and woodland were decreased by 49.14% and 14.76% respectively in the period. Streamflow simulated during this period indicates increases in those watersheds shows significant cropland increases and forest coverage decreases particularly in Wabi at Dodola, Maribo, Robe, and Erer watersheds. Flood indices (i.e., AMAX, SMW, SMSp, and SMSu) calculated from simulated daily streamflow under different LULC map indicates increasing in the middle and northwestern watersheds up to 1.83% and 0.44% respectively. The separation method performed to estimate the impact level of LULC change impact change on flood discharge shows that LULC change has comparable impact level with climate change on streamflow and flood values particularly in middle part of the basin.

Keywords: LULC change, Flood hazard, SWAT model, Separation method, Sensitive parameters

1. Introduction

The hydrological cycle is the phenomenon of the water recycling system on the earth, which is in the oceans, atmosphere, land surface, biosphere, soil, and groundwater systems. In this system there are several stages of cycles, including evaporation and transpiration, precipitation, run-off and watershed processes (Yulianto et al. 2020). Water contained in the sea and land surface can evaporate into the air and move up into the atmosphere directly and through vegetation as a process of evaporation and transpiration, that occurs condensation, clouds, and rain as a process of precipitation. Rainfall that falls to the ground surface becomes run-off, and also some water will be infiltrated into the ground and become ground water. The surface of the earth on which hydrological cycle process occurs continuously is a 'watershed'. It is an area that is bounded by surface topography and also drainage or river patterns. Rainfall that accumulates into the watershed will flow through drainage or river to an outlet on the surface of the earth (Marshall 2014; Yulianto et al. 2020). The characteristics and conditions of watersheds can be explained by conditions of landforms on the surface of the earth that includes the nature of landforms, genesis, processes and material composition.

Land-use/land-cover (LULC) changes can impact the hydrological conditions such as land surface coefficient, discharge and hydrographic characteristics and also can affect the related runoff and infiltration characteristics and hydrological patterns in a watershed. Land use means the use to which the land is being put or the utilization of land devoted to human activities and land cover is the physical surface of the land (Tali and Kanth 2011). Land cover is continually molded and transformed by land-use changes; for example, when a forest is converted to pasture or crop land. Land-use change is the proximate cause of land-cover change.

An understanding of LULC changes is important in supporting decisions of land planning at different scales: global, regional and local. LULC change analysis can reflect the dimensions, potential impacts and interactions of the relationship between human activity and the environment (Armenteras et al. 2019; Sutfin and Wohl 2019; Yulianto et al. 2020). The rapid increase in the human population and the activities they undertake has consequences for LULC in terms of fulfilling their needs both socially and economically. The development and the current and future conditions of water resources are very sensitive to LULC changes and the intensification of human activities (Kundzewicz et al. 2018; Liu et al. 2017; Sutfin and Wohl 2019). Various different human activities exert an influence on the hydrological cycle and water resources. These are directly related to land use for community and economic development, with LULC being an important indicator of these impacts. Indeed, LULC has a significant impact on the hydrological process and the ecology of the watershed associated with run-off, in addition to evapotranspiration. LULC in watersheds exhibit differences in hydrologic runoff response, which can be directly linked to flood events. Increased run-off as a result of LULC changes can affect the frequency of flooding, base flow and annual average flow in such a way as to alter the hydrological cycle (Sutfin and Wohl 2019; Yulianto et al. 2020). The types of LULC by itself exhibits exhibit differences in hydrologic runoff response, which can be directly linked to flood events. Loss of land floor cover, thinner forest canopies, grass lands and reduced infiltration of rainfall result in rapid hydrologic response, increased flood magnitudes and frequency (Sutfin and Wohl 2019).

Flooding is the most frequent type of natural disaster that occur in Wabi Shebele basin of Ethiopia (Admassu, Getinet, and Kirub 2010). In the basin, the magnitudes and frequency of flood events particularly in middle watersheds indicate increasing trend in recent decades (Wudineh et al. 2021). In mountainous zones, increased potential for intense convective storms, increase cultivated land and more highly confined river valleys results more rapid runoff response to precipitation and cause for flood risks. Flood events can cause problems such as the inundation of settlements, damage to infrastructure, disruption to community activities, health problems and loss of life and can create economic losses.

During the last four decades some environmental changes occurred in the studied catchments that influence the conditions of flood runoff. Land use and land cover has been changing in the northern part of Wabi Shebele River Basin. In the basin the extent of shrublands indicates significant increasing trends while grassland and cultivated area showed decreasing trend from 1984 to 2004 (MoWR 2004a.). Similarly, the extent of riparian woodland in the basin indicates decrement in the period interval. Shrubland class is the areas with extensive physical limitation; like very steep slopes, shallow soils, rock outcrops, series of deeply dissected gorges, dry and rugged areas. Due to human activities and pressures in large semi-arid areas (middle and eastern upper catchments) of the basin, most coverage of Riparian Woodland, Grassland and Perennial and seasonal Swamp and Marshland covers are changed to Shrubland in the basin in the past.

The objective of this study is to analyze land use/land cover change and relate those changes to flood occurrences in terms of magnitude and frequency in Wabi Shebele basin.

2. Materials and Methods

2.1. Study Area

The Wabi Shebele River Basin (WSRB) is a trans boundary basin in between Ethiopia and Republic of Somalia in horn of Africa. It originates from Bale Mountain ranges of the Galama and Ahmar of Ethiopia, about 4000m above sea level and drains portion of Somalia before draining to Indian Ocean. About 72% of the catchment (202,220 km2) is lying in Ethiopia. In this study, the Wabi Shebele basin is used to represent the catchment that is lying in Ethiopia within 4^o N 45' to 9^o 45' N latitude and 38^o 45' E to 45^o 45' E longitude. The watershed is divided into three geographical areas: upper valley which characterized by a mountainous area with abrupt valleys, middle valley which is wider and rainy area and lower valley is arid lowland area. The areal distribution of rainfall varies from 271 mm at lower arid portion (Gode) to 1320 mm in the upstream highlands of the basin (Seru), out of which major portion is discharged to streams as runoff. The spatial variability of temperature is significant with maximum and minimum value of 27.1 ^oC and 12.6 ^oC respectively. While having the largest area coverage, the basin water yield is only 0.43 l/s/km2 which is very low relative to other basins in Ethiopia (MoWR, 2003; Awass, 2009).

Poorly drained and shallow profile soils are distributed at upstream of the basin and highly drained soils formed from limestone and gypsum are highly distributed over flat and gently undulating lands of middle and downstream of the basin (MoWR, 2003). Geologically, the basin falls in three major categories; Precambrian crystalline basement rocks in the northern and valleys of upper tributaries main river, late – Paleozoic to Early Tertiary Sedimentary rocks in southeastern sector of the Ogaden Sedimentary Basin and Tertiary to Quaternary Volcanic rocks in the most north western fringe of the basin. The land use and land cover in the basin is highly dependent on the climatic, topography and edaphic factors (MoWR 2004). Cultivated land units are dominated in upstream part of the basin whereas, grasses and shrubs are common in the arid and semi-arid areas of the basin which cover more than 67. 8% of the basin land use/cover (MoWR 2004).

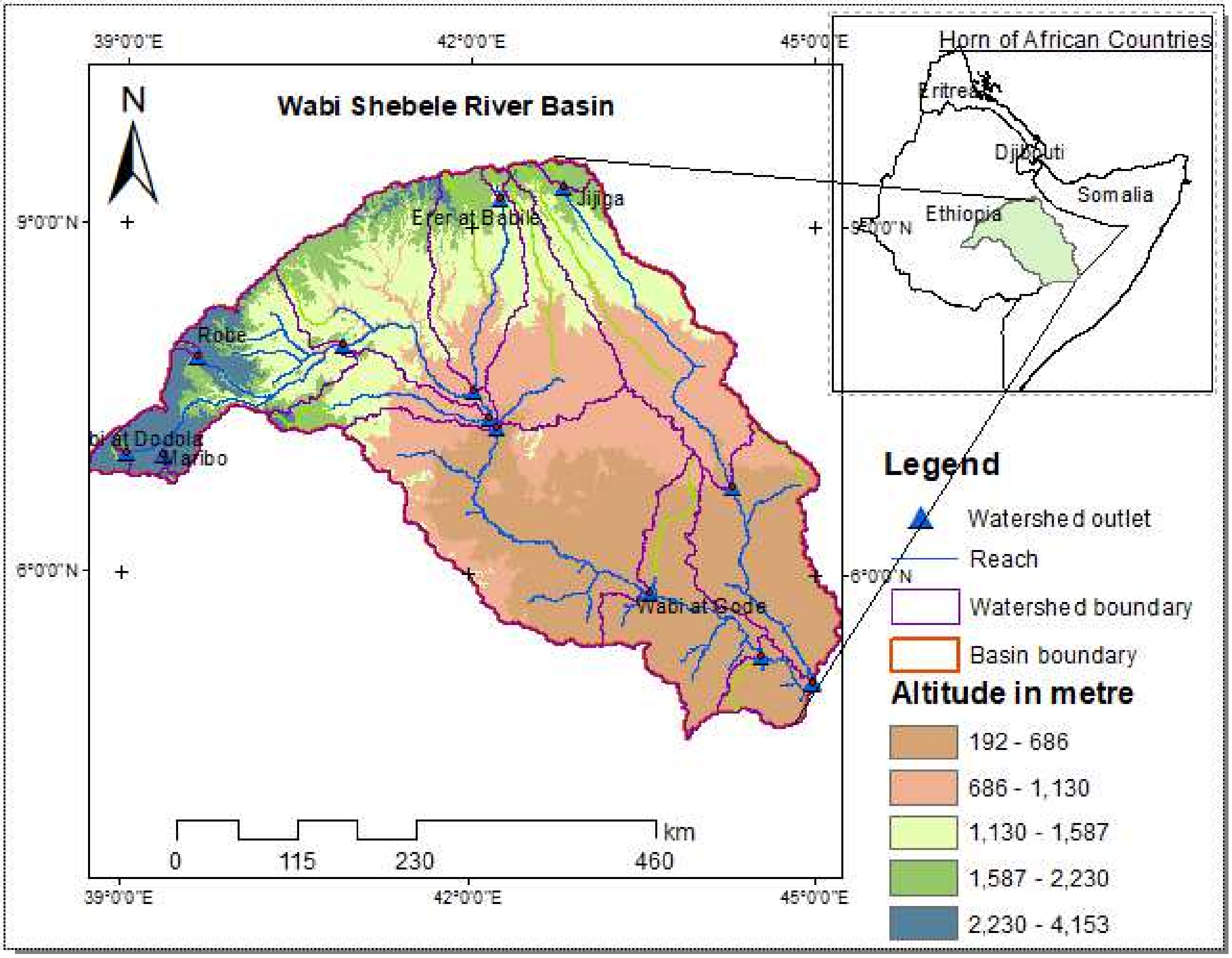


Figure 1: Study area Map

2.2.LULC Information

The input data for this study, comprising LULC maps information for 1986, 1997 and 2016 were collected from different sources (Table 1). Land Sat Image was the principal source to delineate the land use/cover map of the basin in all maps. Satellite imageries taken at a scale of 1:250,000 were used for the interpretation of land use/cover in all sources. Landsat images are medium-resolution remote sensing tools that are used for land use and land cover change analyses. There are ten major classes of LULC information identified in Wabi Shebele basin. It is found that the main categories are Shrubs, grass land and agricultural land. The maps and classes are presented in Figure 2 and Table 2, respectively.

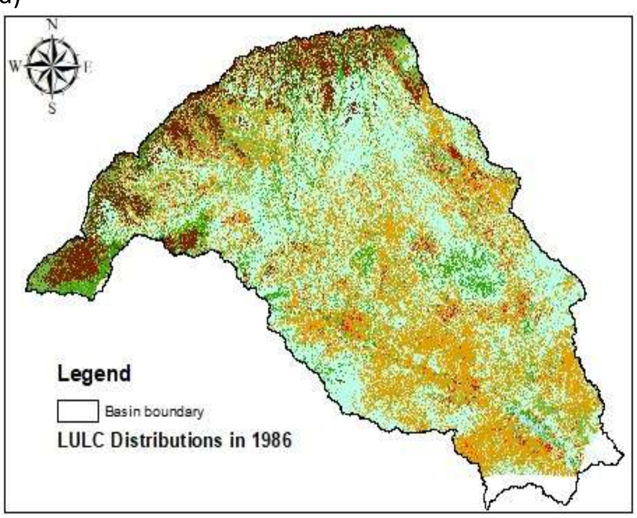
Table 1. LULC maps information, sources, and required parameter

Dataset	Resolution/ scale	Source	Required parameter
LULC map of 1986	1:250000	Water and Land Resource Center (WLRC), Addis Ababa University, Ethiopia	Area (ha), LULC classes
LULC map of 1997	1:250000	Ethiopian Ministry of Water, Irrigation and Energy (MoIE)	Area (ha), LULC classes
LULC map of 2016	1:250000	Water and Land Resource Center (WLRC), Addis Ababa University, Ethiopia	Area (ha), LULC classes

Table 2. land use/land cover classification (%) of the Wabi Shebele basin in 1986, 1997 and 2016

Year	Forest	Woodland	Shrubland	Cropland	Grassland	Bare land	Wetland	Water body	Afroalpine	Settlement
1986	5.21	43.30	31.56	8.41	9.06	1.95	0.23	0.00	0.21	0.05
1997	0.71	1.13	28.20	12.41	42.74	14.08	0.55	0.01	0.15	0.07
2016	2.65	31.69	36.90	12.50	11.40	4.49	0.10	0.02	0.17	0.08

a)



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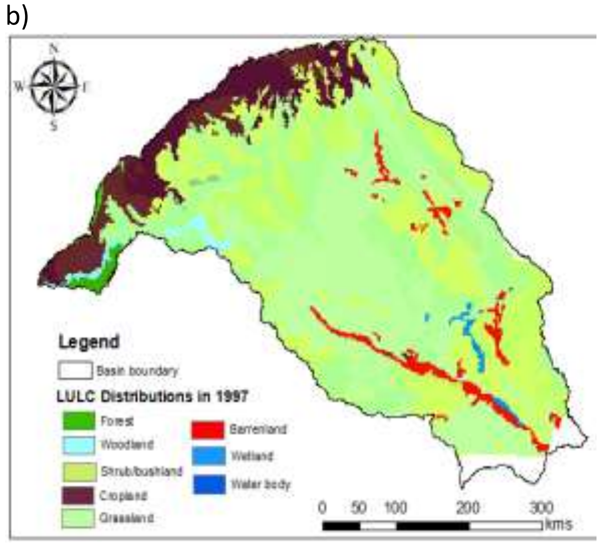


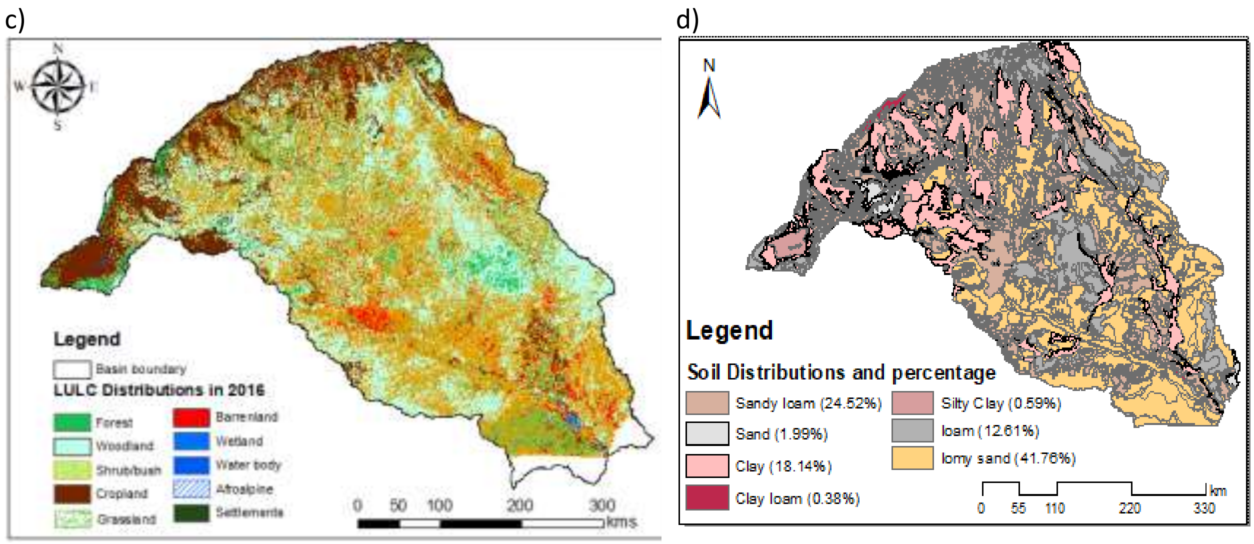


Figure 2: Distributions of land use/land cover from 1986, 1997 and 2016 (a-c) and soil distributions (d) in the Wabi Shebele River basin (Source: WLRC)

2.3.SWAT Model and Separation strategy

Soil and Water Assessment Tool (SWAT): is a physically based distributed hydrological model (Arnold et al. 1998; Neitsch et al. 2005; Abbaspour et al. 2007) that was developed by the United States Department of Agricultural Research Service to simulate the impact of land management practices on hydrology and water quality under complex watersheds with heterogeneous soil and land use conditions. In recent decades, it has been widely used for water cycle simulation and water resources management, especially for the analysis of streamflow variation under climate change and LULCC (Adamu 2014; Guo et al. 2016; Näschen et al. 2019). In addition, SWAT can also be used to predict the impact of future climate on the evolution of water resources and streamflow under different preset scenarios of climate (Camici et al. 2014; Schulze 2000; Gaur et al. 2020). The future climate conditions can be obtained from the general circulation models (GCMs) developed by the Intergovernmental Panel on Climate Change (IPCC) (Gaur et al. 2020; Schulze 2000), thus the effects of different future climate conditions can be further discussed for different drainage basins.

SWAT model proceed two steps to simulate hydrological cycle (Guo et al. 2016): runoff generation and its confluence in the river channels. To generate runoff, a watershed is firstly divided into several sub-basins, each of which is composed of one to several hydrological response units (HRUs) that consist of homogeneous land use, topographical, and soil characteristics. Threshold values for land use, soil types, and slope are setup to remove the insignificant land use, soil type, and slope in each sub-basin, thereby avoiding the generation of a large number of HRUs. Next, the river network connects the discharge produced in sub-basins on the basis of the water balance equation and water flows through the river channels and towards the basin outlet (Neitsch et al. 2005; Guo et al. 2016). The surface streamflow was calculated by a modified Soil Conservation Service (SCS) curve number method (USA_SCS 1972). The potential evapotranspiration and channel routing was estimated and simulated by the Penman-Monteith method and a variable storage method, respectively.

The optimum parameters of the SWAT model can be determined by sensitivity analysis, which assesses the sensitivity between a parameter and other parameters in different areas. Based on parameters available for water production identified by Arnold et al. (2012) and preliminary identification in SWAT model, SWAT-CUP global sensitivity analysis is conducted to identify most sensitive parameters for watersheds. The p-value and t-statistic is used to eliminate non-sensitive parameters from the calibration process. The higher the absolute value of t-stat and smaller the value of p-value, the more sensitive is the parameter (Abbaspour et al. 2007; Moreira et al. 2018).

To evaluate the errors between the simulation results and measured streamflow data that may be introduced by the initial model structure and input data, the performance of the SWAT model can be evaluated based on the visual comparison and statistical criteria such as coefficient of determination (R^2), percent bias (PBIAS) and the Nash and Sutcliffe model efficiency coefficient (NSE). R^2 is the square of the correlation coefficient between the observed and modelled data and values greater than 0.5 are considered acceptable. PBIAS range between $-\infty$ to ∞, with 0 as an optimum value. NSE is a normalized statistic, ranges from $-\infty$ to 1, used to indicate the relative value of residual variance compared to the variance of the observed data and values close to one shows a perfect match of the modeled with the observed data (Nash and Sutcliffe 1970).

$$NSE = 1 - \frac{\sum_{i=1}^{N}(X_i - Y_i)^2}{\sum_{i=1}^{N}(X_i - \bar{X})^2} \qquad 1$$

$$R^2 = \left[\frac{\sum_{i=1}^{N}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{N}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{N}(Y_i - \bar{Y})^2}}\right]^2 \qquad 2$$

$$Pbias = \frac{\sum_{i=1}^{N}(Y_i - X_i}{\sum_{i=1}^{N} X_i} * 100 \qquad 3$$

where x and y are observed and modelled streamflow, respectively, N is the number of data pairs.

Separation method: In this paper, the SWAT model is combined with a separation method which is used to separate the contributions of LULC change and climate change to the streamflow as proposed by Guo et al. (2016). Simulation results and measured data under different conditions of climate and land use can be compared using this strategy. For instance, taking two conjoint periods (defined as period I and II) and two land use conditions (defined as land use A and B) into consideration, four annual streamflow can be obtained under four conditions with different climate change and LULC change in the SWAT simulation, as following: Q_1 for period I and land use A; Q_2 for period I and land use B; Q_3 for period II and land use A; Q_4 for period II and land use B. Therefore, the difference between Q_1 and Q_2 is caused by the different conditions of land use, defined as ΔQ_L, the difference between Q_1 and Q_3 is caused by the different conditions of climate, defined as ΔQ_C, and ΔQ is used to evaluate the difference caused by both climate and land use change, here the difference between Q_1 and Q_4 is used, and yields:

$$\Delta Q_L = Q_2 - Q_1 \qquad 4$$

$$\Delta Q_C = Q_3 - Q_1 \qquad 5$$

$$\Delta Q = Q_4 - Q_1 \qquad 6$$

$$\Delta Q_m = Q_L + Q_C \qquad 7$$

Theoretically, $\Delta Q = \Delta Q_m$. Subsequently, the impact of climate change on streamflow η_C and that of land use change η_L can be separately calculated by:

$$\eta_C = \left(\frac{\Delta Q_C}{\Delta Q_m}\right) * 100\% \qquad 8$$

$$\eta_L = \left(\frac{\Delta Q_L}{\Delta Q_m}\right) * 100\% \qquad 9$$

2.4.Flood Indices

In this study separation method is applied to extreme high flows since the study focus on the impact of LULC change on flood occurrence. Six extreme high flow indices (flood indices) are extracted from simulated streamflow at different under different climate change and LULC change conditions and the impact level of climate change and LULC change are analyzed in each index. These flood indices are: Annual maximum discharge (AMAX), Peak over threshold (3rd quartile) frequency (POTF), Peak over threshold (3rd quartile) magnitude, Seasonal maximum discharge for winter (SMW), Seasonal maximum discharge for spring (SMSp) and Seasonal maximum discharge for summer (SMSu) are used to define extreme high discharges.

In extreme value analysis ensuring independence of samples is initial task. In this study the time interval approach is used to ensure the independence of flow discharges. Time intervals between 5 to 14 days between successive peaks; 5 days for catchments <10000 km^2 and 14 days for catchments ≥10000 km^2, is used. This approach is reported, a strong flood-frequency estimations approach (e.g., Keast and Ellison, 2013; Malamud and Turcotte, 2006).

3. Result and Discussion

3.1.Calibration and Validation of SWAT Model

In data-sparse watersheds, like Wabi Shebele River Basin, developing a representative hydrological model (e.g., in generating the observed streamflow) is very challenging but it is a prerequisite to accurately assess variabilities in extreme flows. In this study, we used a combination of datasets to calibrate and validate the hydrological model. In addition to the field-based ground stations, some weather data like relative humidity, solar ration and wind speed data from Climate Forecast System Reanalysis (CFSR) climate data to improve the hydrological model accuracy during both calibration and validation.

In detail, the Wabi Shebele River Basin was divided into 14 sub-basins and 311 HRUs. To define HRUs, threshold values of 10% were chosen for land use/soil type and slope, respectively. Meteorological data from the period of 1988-2000 and land use data from 2002 were used for the calibration and validation of the SWAT model with three years warming period. Seven hydrologic station was selected for calibration and validation in the basin. To evaluate the model performance, three parameters have been used, namely R^2 and NSE and P-bias are estimated as presented in Table 3.

Table 3. Evaluation of model performance

Stations	Area (km2)	Location		Average Annual Flow (Mm^3)	Calibration			Validation		
		Lat	Long		R^2	NSE	P- bias (%)	R^2	NSE	P- bias (%)
Wabi at D/Bridge	1040	7.01	39.02	230.9	0.74	0.74	-3.0	0.74	0.74	-2.1
Maribo	192	7.00	39.20	100.2	0.66	0.62	-18.5	0.55	0.47	-28.7
Robe	169	7.51	39.38	48.5	0.57	0.56	12.4	0.42	0.39	-20.8
Wabi at L/Hida	19,793	7.58	40.54	1848.5	0.64	0.61	-0.87	0.62	0.65	-0.27
Erer	494	9.14	42.15	87.5	0.43	0.42	-4.3	0.11	-0.4	-53.6
Jijiga	731	9.21	42.48	35.4	0.41	0.40	11.2	0.02	0.16	-59.1
Wabi at Gode	124,108	5.56	43.33	4523.2	0.40	0.20	-29.4	0.16	0.01	-37.6

3.2.Parameter sensitivity analysis

The sensitivity of the discharge to the model parameters was checked through global sensitivity analysis performed using SUFI-2 of SWAT-CUP. out of 20 model parameters identified for streamflow prediction in literature (Moreira et al. 2018; Narsimlu et al. 2015; Neitsch et al. 2005). Based on the results obtained from the global sensitivity analysis, the first six parameters categorized as very important and important were found to be sensitive (p-value< 0.05) in Wabi Shebele River Basin (Table 4). Griensven et al. (2006) classified parameters regarding their sensitivity based on their increasing hierarchical position of the parameters. They categorized parameters as very important (1st), important (2nd -6th), slightly important (7th -14th), and not important (15th -20th). From Table 4, it is evident that there is spatial distribution of parameters contribute for water production at three parts of Wabi Shebele basin watersheds: at northwestern highland, middle to northeastern basin and lower downstream of the basin. In north western highland of the basin surface parameters (i.e., SLSUBBSN.hru, HRU_SLP.hru, CANMX.hru) and ground water parameters (i.e GWQMN.gw, RCHRG_DP.gw and GWREVAP.gw) are the most significant parameters in water production, in middle and northeastern part of the basin soil parameters (i.e., ESCO.hru, SOL_K sol and SOL_Z.sol) and surface parameters (i.e., SLSUBBSN.hru and HRU_SLP.hru) are the most significant parameters and in lower downstream part of the basin surface parameters (i.e., SLSUBBSN.hru, HRU_SLP.hru, CANMX.hru) and soil parameters (i.e., SOL_K sol and SOL_Z.sol) are the most significant water production parameters identified in in this study.

Table 4. Sensitive parameters at watersheds.

Station	Rank of Parameter	Parameter	Fit	minimum	maximum	t-stat	p-value
Wabi at Dodola	1	V__SLSUBBSN.hru	108.68	81.81	130.52	11.03	0.00
	2	V__RCHRG_DP.gw	0.13	0.11	0.34	-6.09	0.00
	3	R__HRU_SLP.hru	0.53	0.19	0.56	-4.01	0.00
	4	V__CANMX.hru	0.05	0.00	1.57	-3.25	0.00
	5	R__SOL_K(..).sol	0.08	0.03	0.25	-3.04	0.00
	6	R__CN2.mgt	-0.07	-0.16	0.02	-2.21	0.03
Maribo	1	A__GWQMN.gw	-347.46	-659.74	21.60	-18.40	0.00
	2	V__ESCO.hru	0.99	0.71	1.00	7.65	0.00
	3	V__ALPHA_BNK.rte	0.21	0.00	0.45	7.09	0.00
	4	V__SLSUBBSN.hru	142.52	80.97	150.00	-4.06	0.00
	5	R__SOL_AWC(..).sol	-0.15	-0.16	0.01	-4.03	0.00
	6	V__CANMX.hru	2.57	1.91	7.30	-2.16	0.03
Robe	1	V__SLSUBBSN.hru	53.95	25.53	78.00	4.19	0.00
	2	V__CH_N2.rte	0.28	0.14	0.42	2.16	0.03
	3	V__ALPHA_BNK.rte	0.90	0.67	1.00	1.84	0.07
	4	V__RCHRG_DP.gw	0.02	0.00	0.28	1.56	0.12
	5	A__GWQMN.gw	-363.99	-1000.00	-324.60	-1.25	0.21
	6	A__GW_REVAP.gw	0.00	-0.01	0.02	-1.19	0.23
Wabi at Legehida	1	R__SOL_AWC(..).sol	-0.02	-0.16	0.02	23.39	0.00
	2	V__SLSUBBSN.hru	140.29	125.20	150.00	9.09	0.00
	3	V__RCHRG_DP.gw	0.00	0.00	0.15	-8.57	0.00
	4	R__SOL_K(..).sol	-0.03	-0.07	0.07	-7.73	0.00
	5	R__HRU_SLP.hru	0.05	0.00	0.16	-7.17	0.00
	6	V__ESCO.hru	0.07	0.00	0.16	-2.87	0.00
Erer	1	V__ESCO.hru	0.04	0.00	0.27	-10.46	0.00
	2	R__SOL_Z(..).sol	0.20	0.06	0.24	7.84	0.00
	3	R__HRU_SLP.hru	0.01	0.00	0.32	-5.95	0.00
	4	V__RCHRG_DP.gw	0.54	0.02	0.55	-5.22	0.00
	5	V__SLSUBBSN.hru	99.11	77.07	125.52	5.15	0.00
	6	R__SOL_AWC(..).sol	0.21	0.12	0.25	3.78	0.00
Jijiga	1	R__SOL_Z(..).sol	-0.08	-0.11	0.03	7.35	0.00
	2	V__ESCO.hru	0.13	0.09	0.27	-5.75	0.00
	3	R__SOL_AWC(..).sol	-0.14	-0.21	-0.12	4.52	0.00
	4	V__SLSUBBSN.hru	144.51	118.84	150.00	3.78	0.00
	5	V__ALPHA_BF.gw	0.39	0.28	0.53	-2.34	0.02
	6	A__REVAPMN.gw	-8.13	-28.99	11.32	1.78	0.08
Wabi at Gode	1	V__SLSUBBSN.hru	140.81	112.98	150.00	24.01	0.00
	2	R__HRU_SLP.hru	0.21	0.00	0.32	-18.34	0.00
	3	R__SOL_K(..).sol	-0.25	-0.25	-0.11	-13.25	0.00
	4	V__CANMX.hru	2.77	0.00	3.33	6.13	0.00
	5	R__SOL_Z(..).sol	0.18	-0.07	0.19	4.05	0.00
	6	R__SURLAG.bsn	-0.10	-0.19	0.01	2.20	0.03

V is the existing parameter value to be replaced by a given value. R is the existing parameter value * (1 + a given value) whereas A represent additional value to be added to existing parameter value (Abbaspour et al. 2007).

3.3.Impacts of LULC change on Flood occurrence

The effects of LUC change on streamflow were distinguished by simulations of multi-year daily catchment stream flows using 1986, 1997 and 2016 land covers respectively as presented in Table 5 and Figure 4. We used two different conditions to see effects of land use and cover changes on streamflow: condition one, stream flow change under LULC change at short period of 12 years in between 1986 and 1997 and condition two, stream flow change under LULC change long period of 31 years in between 1986 and 2016.

Condition one: Change in LULC between 1986 to 1997 and its impact on stream flow

During the 12-year period of LULC observation from 1986 to 1997 (Figure 3a and 3c), LULC was dominated by grassland, shrubland, bare land and forest entire the basin. Increases in LULC during this period occurred in grassland, cropland and barren land. Basically, these LULC increases in three watersheds Wabi at Dodola, Wabi at Legehidha and Wabi at Gode. Exceptionally, the coverage of cropland increases almost in all sub basins of Wabi Shebele river basin during this period. However, the coverage of forest and woodland and shrubland steeply decreased in this period. The coverage of forest is significantly dropping in Erer watersheds (Figure 3c). Erer watershed is one of the major sub basins which contributes large amount of annual floods to Wabi Shebele River basin (Ministry of Water Resources, MoWR 2003). From Table 5, it is evident that flow simulated under condition one indicates increases in those watersheds coverage of cropland increases and forest coverage decreases particularly in Wabi at Dodola, Maribo, Robe and Erer watersheds. In upper Wabi Shebele basin at Dodola watershed alone annual streamflow increases by 7% when LULC changed from 1986 to 1997 land use map.

Condition two: Change in LULC between 1986 to 2016 and its impact on stream flow

In long period of 31 year of LULC observation from 1986 and 2016 (Figure 3b and 3d) LULC was dominated by woodland, shrubland, cropland, grassland, bare land and forest entire the basin. Increases in LULC during this period occurred in shrubland, cropland, grassland and barren land whereas forest and woodland are LULC which shows decreases in this period. The basic change in this condition is observed on shrubland coverage. Shrubland indicates increases in long period from 1986 to 2016 while it showed decreases during short period in between 1986 and 1997. But other LULC follows similar trends as condition one.

Out of the ten LULC types analyzed in the study area, three of them namely cropland, grassland, and bare land showed growth in both conditions. The coverage of cropland was increased by 47.56% in condition one and by 48.63% in condition two. Contrarily, the coverage of forest and woodland were decreased by 86.37% and 97.39% respectively in between 1986 and 1997 (Figure 3a). Between 1986 and 2016 large areas of forest (49.14%) and woodland (14.76%) were converted to other LULC types (Figure 3b). Similarly, IWMI (2015) study report indicates forest degradation in western upper Wabi Shebele basin by average annual deforestation rate of 0.25%.

The recent data analysis in Bale Eco-Region (i.e., upper Wabi Shebele basin) indicates a reduction in forest area (forest, woodlands, Erica forest) of about 2.3% between 2010 and 2014 (IWMI 2015). It is known that the deforestation and forest degradation in Ethiopia are mainly for expansion of subsistence agriculture and grazing land. This implies that the land use and land cover change over middle and north part of Wabi Shebele basin from forest, woodland, grassland and shrubland to agricultural land (cropland) is one of the causes for streamflow increases. The reduction of forest cover amplifies flood events, as more rainfall directly turns into run-off instead of being slowed down or buffered by forests (IWMI 2015; Bradshaw et al. 2007). In north eastern and downstream of Wabi shebele basin (i.e., Erer and Wabi at Gode watersheds) simulated streamflow doesn’t show significant changes with land use change in both conditions as presented in Table 5 and Figure 4. Flood indices calculated from simulated daily streamflow under different land use and cover map indicates similar situation with annual average flow variations in the basin. In middle and northwestern basin flood indices like AMAX, SMW, SMSp, SMSu and volume of discharge indicates increasing as forest coverage indicates decreasing trends (Table 6).

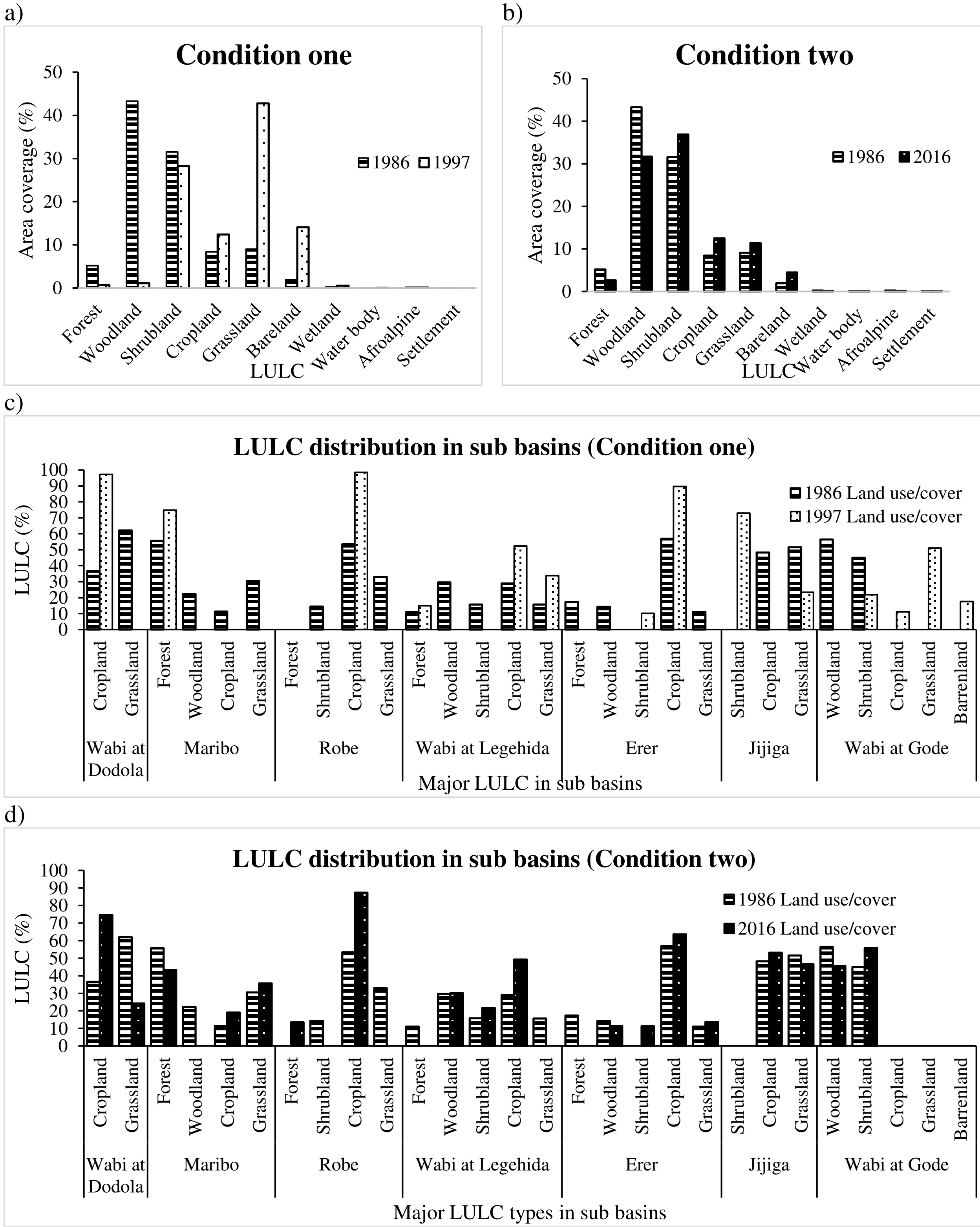


Figure 3: Major LULC distribution in Wabi Shebele basin and its sub basins at two different conditions: condition one (a and c) in short period between 1986 and 1997 and condition two (b and d) in long period between 1986 and 2016.

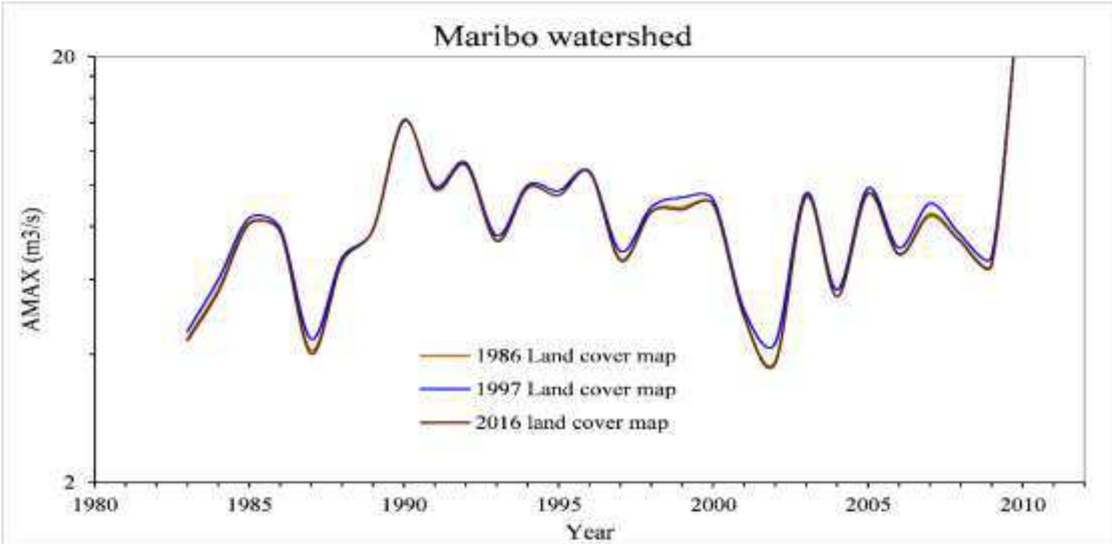
Table 5. Simulated average annual surface run-off (m^3/s) from 1986, 1997 and 2016 land use/land cover and changes under two conditions: condition one (in between 1986 and 1997) and condition two (in between 1986 and 2016).

S. No	**Sub-basin**	**Condition one**		**Change (m^3/s)**	**Percentage change (%)**	**Condition two**		**Change (m^3/s)**	**Percentage change (%)**
		1986	1997			1986	2016		
1	Wabi at Dodola	3.76	4.04	0.28	7%	3.76	3.82	0.06	2%
2	Maribo	2.59	2.68	0.09	3%	2.59	2.58	-0.01	0%
3	Robe	1.59	1.61	0.02	1%	1.59	1.6	0.01	1%
4	Wabi at Legehida	65.56	65.77	0.21	0%	65.56	67.18	1.62	2%
5	Erer at Babile	3.07	3.10	0.03	1%	3.07	3.07	0.00	0%
6	Jijiga	3.90	3.90	0.00	0%	3.90	3.91	0.01	0%
7	Wabi at Gode	1215	1197.05	-17.95	-1%	1215	1214.67	-0.33	0%

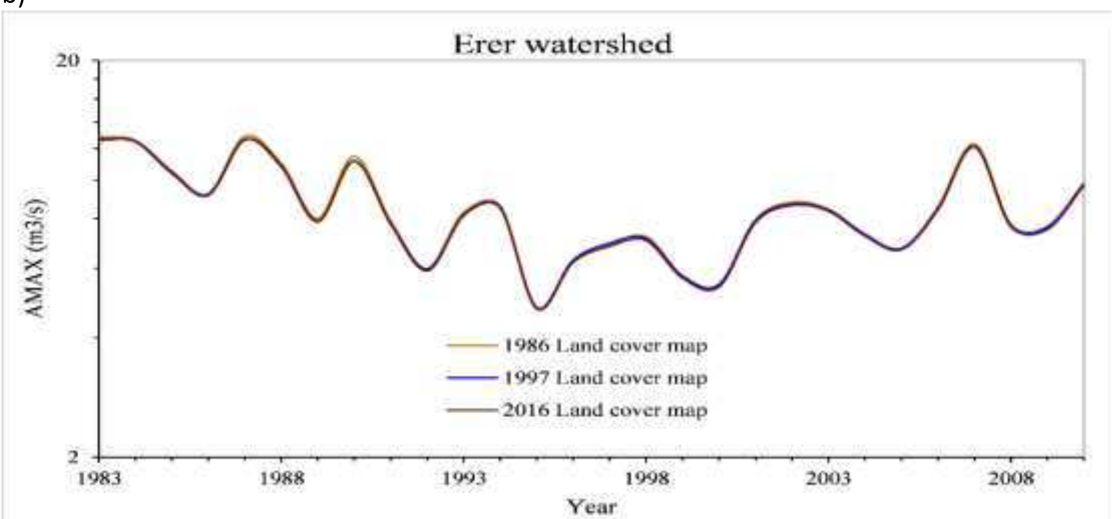
Table 6. Flood indices obtained from daily simulations for 1986, 1997 and 2016 land cover

Item	***Maribo watershed***			***Wabi at Legehida watershed***			***Erer watershed***			***Wabi at Gode watershed***		
	1986	1997	2016	1986	1997	2016	1986	1997	2016	1986	1997	2016
Maximum daily flow (m3/s)	8.9	9.1	8.8	281	273	286	8.59	8.53	8.47	4181	4120	4176
Seasonal maximum discharge for Winter (m3/s)	2.7	2.8	2.7	68.1	70.5	70.8	3.20	3.23	3.22	1459	1454	1462
Seasonal maximum discharge for Spring (m3/s)	1.8	1.9	1.9	60.5	59.5	60.9	3.38	3.36	3.34	786	671	680
Seasonal maximum discharge for Summer (m3/s)	5.9	6.2	5.9	161	158	164	5.96	5.97	5.91	2782	2828	2881
Frequency of Peak over threshold (3rd quartile) (POTF)	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.00	95.0	95.0	95.0
Volume of discharge (BMC)	0.8	0.9	0.9	2.1	2.1	2.2	0.96	0.98	0.97	38.3	37.8	38.3

a)


Maribo watershed
AMAX (m3/s)
20
2
1980
1985
1990
1995
2000
2005
2010
Year
1986 Land cover map
1997 Land cover map
2016 land cover map

b)


Erer watershed
AMAX (m3/s)
20
2
1983
1988
1993
1998
2003
2008
Year
1986 Land cover map
1997 Land cover map
2016 Land cover map

c)

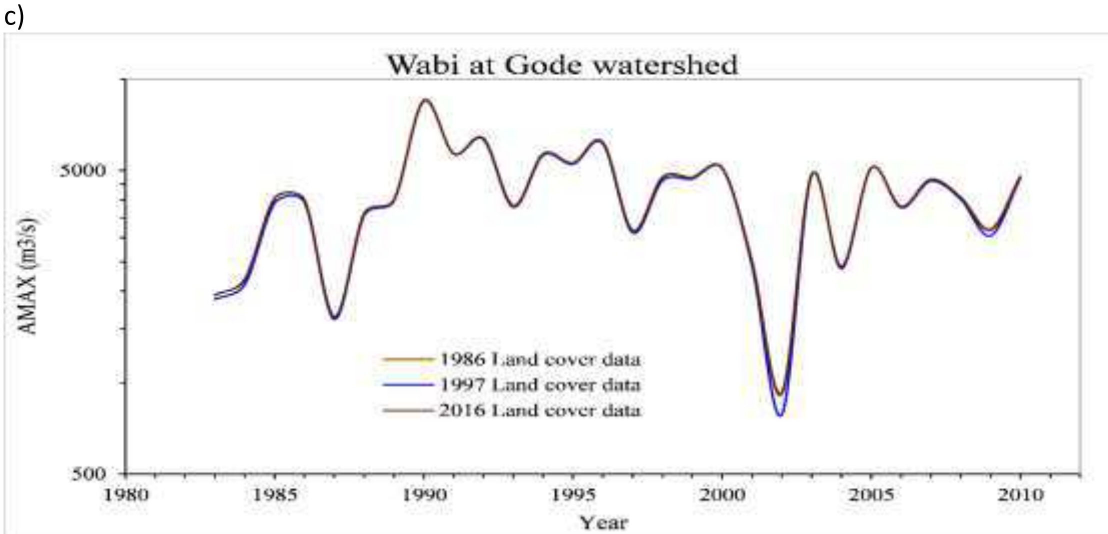

Wabi at Gode watershed
AMAX (m3/s)
5000
500
1980
1985
1990
1995
2000
2005
2010
Year
1986 Land cover data
1997 Land cover data
2016 Land cover data

Figure 4: Comparison of simulated maximum daily discharges for 1986, 1997 and 2016 land cover data at three gauging stations: a) western upper basin (Maribo watershed), b) eastern upper basin (Erer watershed) and c) downstream lower basin (Wabi at Gode watershed).

3.4.Quantitative measure of influence of LUCC change and Climate Change on Flood occurrence

The influence level of LULC change and climate change on stream flow of Wabi Shebele basin is estimated using separation method. As presented in Table 7, the response of the streamflow to climate change is higher than that of LULC change in Wabi Shebele basin. However, LULC change also has significant impact in watersheds like Wabi at Legehida, Wabi at Dodola, Maribo and Robe. Annual maximum discharge (AMAX) decreases in watersheds where forest and shrubland coverage increase in study period. For instance, in Wabi at Legehida and Erer watersheds the magnitude of floods decreases while the coverage of forest increases in condition one. In north western watersheds like Wabi at Dodola, Maribo, Robe and Wabi at Legehida flood discharge estimated using LULC of 2016 is greater than flood estimate using LULC of 1986 by 3.91, 2.33, 1.92 and 128.66 m^3/s and as a result, flood magnitude increases by 0.18%, 1.83%, 0.57% and 0.44% in watersheds respectively. In Wabi at Gode watershed flood magnitude under condition one is greater than flood magnitude in condition two by a value of 1285.18 m3/s which is contributed by both climate change and LUCC, accounting for 105.12% and 5.12%, respectively. The results indicated that climate change is the major factor influencing the streamflow and flood values in Wabi Shebele River Basin in the period from 1980–2010 which is similar to conclusion drawn by (Akola et al. (2018).

Table 7. Impact of LULC and Climate change on annual maximum streamflow in Wabi Shebele River Basin under two different conditions of climate and land use defined by the preset scenario. **Bold** number indicates the significancy of drivers influence on streamflow

Subbasin	Condition one (1980-1999)			Condition two (1980-2010)		
	Variation in AMAX (m3/s)	Impact of LULC change (ηL) (%)	Impact of Climate change and others (ηc) (%)	Variation in AMAX (m3/s)	Impact of LULC change (ηL) (%)	Impact of Climate change and others (ηc) (%)
Wabi at Dodola	1.86	2.55	**97.45**	3.91	0.18	**100.18**
Maribo	1.94	**6.45**	**93.46**	2.33	1.83	**101.83**
Robe	0.95	0.66	**99.34**	1.92	0.57	**100.57**
Wabi at Legehida	-14.37	**45.95**	**54.05**	128.66	**0.44**	**99.56**
Erer	-4.51	**3.07**	**96.63**	-2.71	**6.44**	**93.56**
Jijiga	-18.57	0.54	**100.54**	-12.31	0.11	**99.89**
Gode	1285.18	5.12	**105.12**	-115.08	**3.37**	**96.63**

4. Conclusion and Recommendations

Land-use/land-cover (LULC) changes can impact the hydrological conditions such as land surface coefficient, discharge and hydrographic characteristics and also can affect the related runoff and infiltration characteristics and hydrological patterns in a watershed. To identify the most sensitive parameters to water production hydrological model is performed in this study. The impact of land use and land cover on flood occurrence is investigated. Furthermore, to which share LULC and/or climatic changes cause the increase of flooding in the Wabi Shebele basin is answered partly by this study.

In Wabi Shebele basin parameters contribute for water production is spatially distributed over the basin at three different parts: at northwestern highland, surface and ground water parameters (i.e., SLSUBBSN.hru, HRU_SLP.hru, CANMX.hru, GWQMN.gw, RCHRG_DP.gw and GWREVAP.gw); at north eastern and southern lowland part of the basin, soil and surface parameters (i.e., ESCO.hru, SOL_K sol and SOL_Z.sol, SLSUBBSN.hru and HRU_SLP.hru) are the most sensitive parameters identified for water production. These parameters are directly and indirectly based on land use and land cover on the watersheds. For instance, CANMX.hru is maximum canopy storage (mm H_20) which can significantly affect infiltration, surface runoff and evapotranspiration. The influence the canopy exerts on these processes is a function of the density of plant cover and the morphology of the plant species (Neitsch et al. 2005).

Out of the ten LULC types analyzed in the study area, three of them namely cropland, grassland, and bare land showed growth in both conditions. The coverage of cropland was increased by 47.56% in condition one and by 48.63% in condition two. Contrarily, the coverage of forest and woodland were decreased by 86.37% and 97.39% respectively in between 1986 and 1997. Between 1986 and 2016 large areas of forest (49.14%) and woodland (14.76%) were converted to other LULC types. Streamflow simulated under condition one indicates increases in those watersheds shows significant cropland increases and forest coverage decreases particularly in Wabi at Dodola, Maribo, Robe and Erer watersheds. In upper Wabi Shebele basin at Dodola watershed alone annual streamflow increases by 7% when LULC changed from 1986 to 1997 land use map. Flood indices (i.e., AMAX, SMW, SMSp and SMSu) calculated from simulated daily streamflow under different land use and land cover map indicates increasing in watersheds located in middle and north western part of the basin where most of forest coverage decreases.

The separation method conducted to quantify the influence level of LULC change and climate change on stream flow reveals that, the response of the streamflow to climate change is higher than that of LULC change in Wabi Shebele basin.

The influence level of LULC change and climate change on stream flow analyzed using separation method indicate that climate change is the major factor influencing the streamflow and flood values in Wabi Shebele River Basin. However, LULC change has also significant impact in middle and upper watersheds like Wabi at Legehida, Wabi at Dodola, Maribo and Robe. Annual maximum discharge (AMAX) decreases were forest and shrubland shows increments. In north western watersheds like Wabi at Dodola, Maribo, Robe and Wabi at Legehida flood discharge estimated using LULC of 2016 is greater than flood estimate using LULC of 1986 by 3.91, 2.33, 1.92 and 128.66 m^3/s and as a result, flood magnitude increases by 0.18%, 1.83%, 0.57% and 0.44% in watersheds respectively.

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