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ORGINAL ARTICLE

The Response of Water Balance Components to Land Use and Land Cover Change Based on Hydrologic Modeling in Bogena Watershed, Upper Blue Nile Basin, Ethiopia

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ABSTRACT

This study investigates the effects of land cover change on the water balance components using an integrated hydrologic modeling approach. Hydrologic modeling and water resources management studies is strongly interrelated to the spatial processes of the hydrological cycle. These rotations are showy by various factors like land use / land cover and climate changes. Deforestations are day to day movement of the people presented in the Bogena watershed; the area is facing high erosion due to forceful rainfall that intensifies the land cover change of the watershed. This study aimed to assess the effects of land use/land cover (LULC) changes on the streamflow of the Bogena Watershed using Geographic Information System (GIS), the Soil and Water Assessment Tool (SWAT), and SWAT-CUP. Input data for SWAT are climate data, soil, Land use and land covers data, and DEM. The land cover maps were produced using the Maximum Likelihood Classifiers of Supervised Classification. The model was calibrated using stream flow data from 1991 to1997, validated from 1998 to 2003 and from 1989-1990 used for warm up period. The R^2 and NSE values were used to evaluate the model performance. The results indicated that the R^2 values were 0.997 and 0.988, while the NSE values were 0.86 and 0.79 during the calibration and validation periods, respectively. The results showed that land use/land cover (LULC) changes had significant effects on runoff production, infiltration rates, water yield, sediment loading, evapotranspiration, and the soil's water preservation capacity. The analysis also indicated that streamflow during the wet season increased, whereas streamflow during the dry season decreased. Between 1990 and 2015, surface runoff increased from 33.13 mm to 245.90 mm, representing an increase of 642.2%, while groundwater contribution decreased from 160.61 mm to 29.92 mm, representing a decrease of 81.4%. These changes were primarily attributed to the expansion of agricultural land and the legal and illegal extraction of groundwater for small-scale irrigation and other purposes. Overall, the hydrological regime of the watershed changed substantially during the 1990–2015 period as a consequence of LULC changes.

Keywords: GIS; LULC; SWAT model; SWAT-CUP; Bogena watershed

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1. INTRODUCTION

Water is mainly vital natural resources for alive species. While the accessible quantity of water is insufficient, restricted, and not spatially dispersed in family member to the populace requests (Del Castillo, E. M. et al., 2015). The land management practices and the hydrologic responses of Land use / land cover changes are the integrated indicators of the watershed condition (Worku, Khare et al., 2017). The calibrated and validated SWAT model was used to simulate the watershed water balance and assess the hydrological responses to land use/land cover changes at the sub-basin level across multiple temporal scales. Appropriate management of water resource is significant to satisfy the present demands as well as to conserve sustainability. According to (Denboba, 2005) Land use / land cover change (LU/LCC) is an extremely critical problem considering worldwide dynamics and their responses to environmental drivers and socio-economic (Koch J , 2012). Land use management and planning is strongly related to the sustainability of water resources as changes of land use is related with amount of water throughout pertinent hydrological processes (Guo, 2008). Land use/land cover (LULC) change is one of the most important human-induced factors altering the hydrological system (Hadgu, 2008). Human induced activities in the Bogena watershed pressure the catchment hydrology, which change the surface runoff and minimizing the ground water flow, i.e. percolation, infiltration (Pokhrel, Burbano et al., 2018). These are occurred due to the development of agricultural lands and minimizing of shrub lands, grasslands, and forest (Shiferaw and Singh, 2011) and is short of consciousness and poor management (Bewket, 2005). High population growth, customary agriculture techniques, land use/ land cover change, deforestation, and unacceptable use of land have consequence in huge land degradation with water shortage (Kidanu, 2004).

The rising water demand in the bogena watershed due to the increasing population growth rate and the socio-economic developments are rising the struggle among a variety of water users (Cheng, Li et al., 2014). Degraded watersheds be liable to speed up the overland flow, which decrease the groundwater recharge and soil moisture. Various studies used land cover mapping tools and methods to understand LC changes, discovery of forest and natural resources as well as recognize the changes in the hydrologic behavior of watersheds (Shawul, Chakma et al., 2019)

In general, the response of water balance components to Land use /land cover change acting a vital accountability in powerful hydrological cycles within a watershed (Wassie, 2020). These consist of alter water demands such as changes in water supply from changed hydrological processes of irrigation, runoff, infiltration, changes in water quality from agricultural runoff, and groundwater recharge (Getachew and Melesse, 2012). The Bogena watershed experiences severe soil erosion as a result of intense rainfall and land use/land cover changes, which together accelerate land degradation and adversely affect the watershed's hydrological processes (Kidanu, 2004). These nonstop change in land cover have impacts on the water sense of the balance of the watershed by changing the pattern and magnitude of the elements of stream flow (ground water flow and surface runoff), that consequence arising the degree of the water management dilemma (Solomon 2005). To ensure sustainable water resource management, hydrological models are effective tools for representing and analyzing the hydrological characteristics of a watershed (Surur A, 2010). Hence, in addition a far improved considerate of land use /land cover change, its effect, and interface to the hydrology of a watershed are greatly essential (Pokhrel, Burbano et al., 2018). Therefore main objective of this study is to the water balance response components to land use/land cover change based on hydrologic modeling in bogena watershed (Dogan and Karpuzcu, 2022).

2. Materials and Methodology

2.1 Description of the Study Area

The Bogena watershed originates in the Bibugn District near Choke Mountain at an elevation of 3,687 m above mean sea level (amsl) and drains into the Abbay River in the Upper Blue Nile Basin, Ethiopia. It was about 259 km far from the North West of Addis Ababa in the Northern highlands of Ethiopia, within 10.25° and 10.75° North latitudes and 37.95° and 38.42° East longitudes.

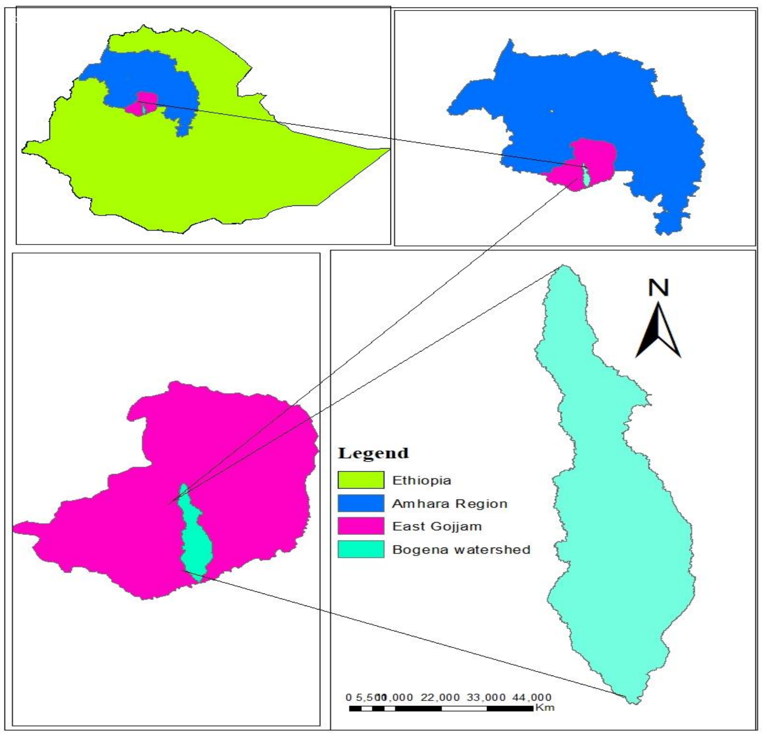


Fig. 1. Location Map of Bogena Watershed

2.2 Climate

The meteorological data collected were minimum and maximum temperature, precipitation, sunshine hours, relative humidity, and wind speed, collected mainly the National Meteorological Service Agency of Ethiopia (NMSA) for station to be found within the study basin. The study area has a mean annual rainfall of 1350 mm, and the minimum and maximum temperature of 5°C and 26°C respectively. The dry season occurs between October and May while the wet season occurs mostly between June and September when the Inter Tropical Convergence Zone (ITCZ) is to the North of the country.

2.3 Hydrological data

We acknowledge that the use of more recent streamflow data would strengthen the study. However, the analysis was limited by the availability of consistent and continuous observed streamflow records for the Bogena watershed. The period from 1989 to 2003 was the most complete and reliable dataset available from the Ministry of Water and Energy of Ethiopia for model calibration and validation

2.4 Data Collection

For this study, various datasets were collected, including topographic data (DEM), streamflow data, land use/land cover (LULC) data, soil data, and daily climatic variables, including precipitation, relative humidity, wind speed, minimum and maximum air temperature, and solar radiation. Landsat images (TM, ETM+ and OLI/TIRSC1) were also used to differentiate changes in LULC of the watershed from 1990-2015 using GIS 10.3 software that obtained from (http://glovis.usgs.gov/). The images were particularly taken during dry season to get clear and cloud free images for the study area.

Table 1: Profiles of Satellite Image

Satellite Image	*S/resolution*	*D/Acquisition date*	*Path/row*	*Sensor*	*Source*
Landsat 4-5TMC1 (1990)	*30m*30m*	*Mar-12/1990*	*169/53*	*TM*	*USGS*
Landsat- 7 (2001)	*30m*30m*	*Feb-22/2001*	*169/53*	*ETM+*	*USGS*
Landsat-8(2015)	*30m*30m*	*Feb-05/2015*	*169/53*	*OLI/TIRSC1*	*USGS*

2.5 Digital elevation model (DEM)

DEM was essential to determine the stream networks, slope, flow direction, flow accumulation, and watershed delineation using SWAT watershed Delineators or apparatus. A 30m-by-30m resolution ASTER Global Digital Elevation Model is obtained from the NASA website. It was in raster format to fit into the model requisite. A digital contour was interpolated and processed to derive a DEM of the study area.

Meteorological data was required by the SWAT model to simulate the hydrological situation of the catchment. The meteorological data essential for this study were gathered from the National Meteorological Service Agency of Ethiopia (NMSA). The meteorological data collected were minimum and maximum temperature, precipitation, relative humidity, sunshine hours, and wind speed, which cover from 1989 to 2015.

2.6 Soil data

The soil data used in this study were obtained from the Ministry of Water and Energy of Ethiopia. The soil dataset included both the physical (textural) and chemical properties required for SWAT model parameterization. To integrate the soil information into the SWAT model, a user-defined soil database was developed by organizing the physical and chemical properties for each soil layer and importing the database into the SWAT user soil database using the Data Management tools in ArcGIS. The dominant soil types within the Bogena watershed are Vertisols and Leptosols. The Vertices are dominated by the montomorillonite clay mineral. This clay mineral wide when there are wet conditions and shrinks when there are dry conditions, causing cracks at the surface in the dry season.

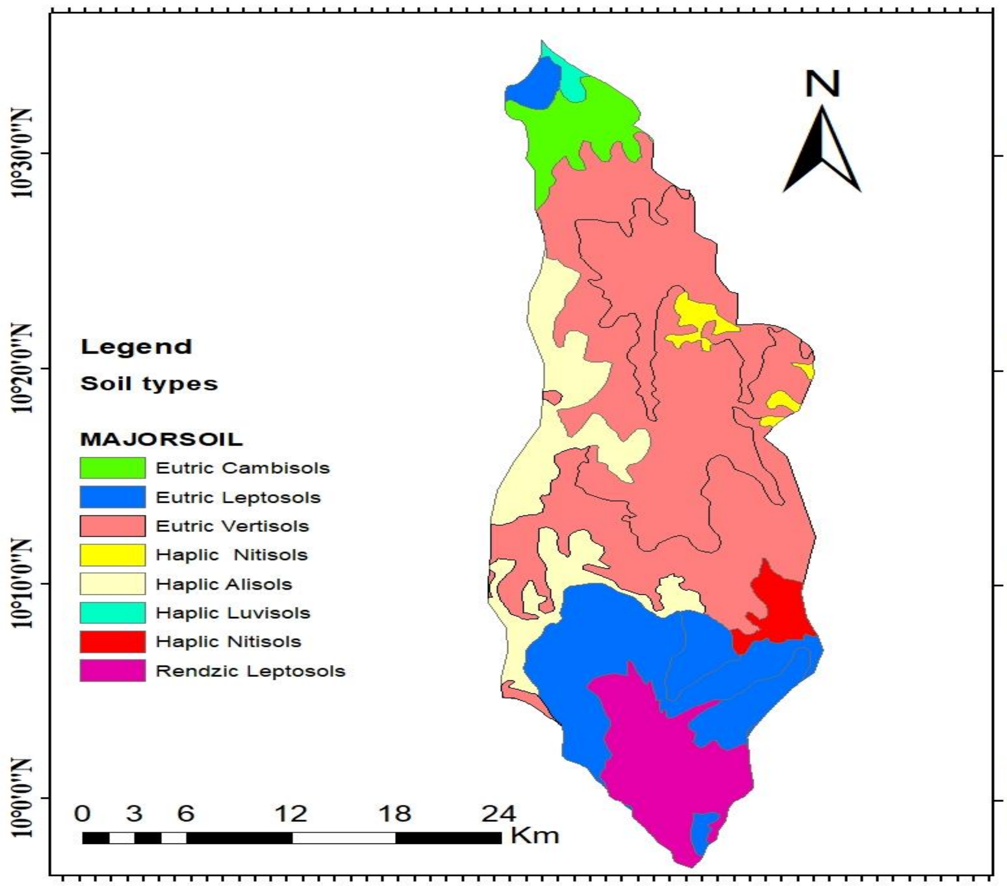


Fig. 2. Soil map of Bogena watershed

2.7 Land use /land cover data

Landsat images (TM, ETM+ and OLI/TIRSC1) are also important to differentiate changes in LULC of the watershed from 1990-2015 using GIS 10.3 software that obtained from (http://glovis.usgs.gov/). The supervised classification method was practicing using the Maximum Likelihood Classification system. Land use/land cover (LULC) maps were produced using a supervised classification approach based on the Maximum Likelihood Classification (MLC) algorithm in ArcGIS 10.3. Representative training samples for each LULC class were selected from the Landsat images using field observations, Google Earth imagery, and visual image interpretation. The MLC algorithm classifies each pixel into the class with the highest probability based on the statistical characteristics of the training samples (Patil, Desai et al., 2012). The LC classification method was purposeful by defining signature files and conveying the number of LC classes. Post-classification analyses were voted for using ArcGIS toolboxes (https://www.esri.com). The LC dataset were summarized to eight different LC classes with its respective four-letter SWAT code, namely, Cultivated land (AGRR), forest (FRST), Shrub land (RNGB), bare land (PAST), grass land (RNGE) and Water body (WATR) Artifical surface (POPL), and wet land (WETF).

The response of water balance elements to land use/ land cover change was one of the extremely affect the hydrological property of the watersheds. It was one of the major input data of the SWAT model to explain the Hydrological Response Units (HRUs) of the watershed.

The SWAT model has predefined four letter codes for each land use group. These codes were important to relate or connect the land use map of the study area to SWAT land use databases. Whereas preparing the lookup-table, the land use type was made companionable with the input wants of the model.

2.8 Hydrologic model setup and simulation

The major hydrological elements simulated in the land phase of the hydrologic cycle are lateral surface, evapotranspiration, flow, surface runoff, groundwater flow, canopy, ponds, infiltration, storage, and tributary channel (Sajikumar and Remya, 2015). The HRU analysis in SWAT considers the delineation of HRUs by overlaying the spatial map of slope classes, soil data, and land use. The delineation of watershed and sub watershed were done using 30 m resolution DEM data using Arc SWAT model watershed delineation function. First, the SWAT projects set up were formed. The delineation of watershed process consists of five major steps, stream definition, DEM setup, watershed outlets selection, outlet and inlet definition, definition and calculation of sub basin parameters. Once, the DEM setups were finished and the locations of outlet were specified on the DEM, the model automatically calculates the flow accumulation and flow direction. Subsequently, sub watersheds, stream networks, and topographic parameter was done using the respective tools. The stream definition and the size of sub basins were vigilantly calculated by selecting threshold area or smallest amount drainage area requisite to form the origin of the streams. The Bogena watersheds were delineated in to 19 sub watersheds having a predictable total area of 636.59 km^2. The difference in the total area among the delineated and the database may be due to the difference in the DEM Resolution or the watershed delineate or model used.

The response of water balance to land use land cover change detection analysis is lead to evaluate and temporal and list spatial changes in land use and land cover in Bogena watershed. Suitable satellite imagery was done with an advanced thought of cloud cover, the phonological and seasonality effects. Clouds free satellite images with a smaller amount than 10% clouds cover were chosen for this study. Supervised image classifications using maximum Likelihood Classifier (MLC) were considered to generate a base map.

To isolate the hydrological effects of land use/land cover (LULC) change, the calibrated SWAT model was applied using identical climatic forcing and the same calibrated parameter set for all simulation scenarios. Independent simulations were performed using the 1990, 2001, and 2015 LULC maps, while meteorological inputs (daily precipitation, maximum and minimum temperature, solar radiation, relative humidity, and wind speed), soil data, DEM, and calibrated model parameters were kept unchanged. Therefore, differences among the simulated hydrological responses are attributable solely to changes in LULC. A factorial experiment designed to independently evaluate climate variability and LULC change was beyond the scope of the present study and has been acknowledged as a limitation.

Potential evapotranspiration (PET) was estimated in SWAT using the FAO Penman–Monteith method, which utilizes daily maximum and minimum temperature, precipitation, solar radiation, relative humidity, and wind speed. Daily meteorological data were obtained from the National Meteorological Agency of Ethiopia for stations located within and surrounding the Bogena watershed. Prior to model implementation, the climatic records were subjected to quality control, and missing observations were filled using standard interpolation procedures based on neighboring stations. Within SWAT, climatic variables were spatially assigned using the nearest-station approach, whereby each sub-basin was linked to the closest meteorological station and all HRUs within that sub-basin inherited the corresponding climate inputs.

2.9 Model calibration and validation

The Consequence of sensitivity analysis is; model calibrations were done to get optimum values for sensitive parameters. SWAT – CUP provide an auto-calibration method. In this progress, the value of parameters was in step by altering one or two parameters at a time within the acceptable ranges either by the substitute of the first value or addition or by multiplication of the first value as per intended in the interface. Then, auto calibration progresses were used.

Daily streamflow data for the period 1989–2003 were collected for the Bogena watershed. However, model calibration and validation were performed using monthly streamflow because monthly aggregation reduces the effects of uncertainties in daily rainfall and streamflow observations and provides a more reliable assessment of the watershed's long-term hydrological response. A two-year warm-up period (1989–1990) was used to initialize the model, while the calibration period covered January 1991 to December 1997. The multi objective SWAT-CUP includes , automated calibration progress that was urbanized by (Van Griensven, et al., 2006). Based on a Shuffled Complex Evolution Algorithm (SCE-UA) and a single objective function The calibration procedure was done.

The auto calibration tool in SWAT – CUP can be run in the GLUE, SUFI-2, McMc, Parasol, and Pso. The SUFI-2 was selected For this study (Abbaspour, 2007). It was applicable to both simple and complex hydrological models. The simulation of SWAT-CUP was specified for the auto-calibration performing and the sub basin location where observed data could be compared against simulated output. After that, the preferred parameter for optimization and observed data file was chosen. For this reason, 13 flow parameter was considered in the calibration progress.

To compare the model outputs with an independent data set values Validation was also done. The model validation process was used the measured data of average monthly stream flow data of 5 years from January 1998 to December 2003.

The observed data, and model performance evaluation is necessary to evaluate the model simulation outputs in relative. To evaluate the model performance during the calibration and validation periods various methods needed.

The Coefficient of determination (R^2) and Nash and Sutcliffe simulation efficiency (ENS) was used for this study. The coefficient of determination (R^2) describes the fraction the variance in measured data by the model. It is the degree line relationship between the observed and the simulated values. R^2 ranges from 0 (which indicates the model is weak) to 1 (which indicates the model is good),with higher values indicating fewer error variance, and typical values greater than 0.6 are considered acceptable (Santhi, et al., 2001). The R^2 was determined using the following equation:

$$R^2 = \frac{\sum[\mathrm{Xi} - \mathrm{Xav}][\mathrm{Yi} - \mathrm{Yav}]}{\sqrt{\sum[\mathrm{Xi} - \mathrm{Xav}]2} \;\; \sqrt{[\mathrm{Yi} - \mathrm{Yav}]}^2} \qquad 2.1$$

Where; Xi is measured value (m^3/s), Xav is average measured value (m^3/s), Yi is simulated value (m^3/s) and Yav is average simulated value (m^3/s)

The Nash –Sutcliffe simulation efficiency (ENS) indicates that how well the plots of

Observed versus simulated data fits the 1:1 line. ENS is computed using the following equation:

$$\text{ENS} = 1 - \frac{\sum(\text{Obesrved value} - \text{simulated})2}{\sum(\text{Observed value} - \text{average obesrved value})2} \quad \text{--------------------- 2.2}$$

The ENS value of ranges from negative infinity to 1 (best) i.e., (-∞, 1]. <0 ENS value indicates the mean observed value is better forecast or than the simulated value, that indicates unacceptable performance. While greater than 0.5 ENS values, the simulated value is better predictor than mean measured value and generally viewed as acceptable performance (Santhi, et al., 2001). The selection of Coefficient of determination (R^2) and Nash and Sutcliffe simulation efficiency (ENS) for the Reason Very good model performance (Moriasi, et al., 2007)

Table 2: The recommended Overall performance ratings of statistics for stream flow on a monthly time step adapted from (Moriasi et al., 2007; Ayele et al., 2017).

Performance	ENS	R^2
Very good	0.7<ENS<=1	0.7< R^2 <=1
Good	0.65<ENS<=0.75	0.6< R^2 <=0.7
Satisfactory	0.5<ENS<=0.65	0.5< R^2 <=0.6
Unsatisfactory	ENS<0.5	R^2 <0.5

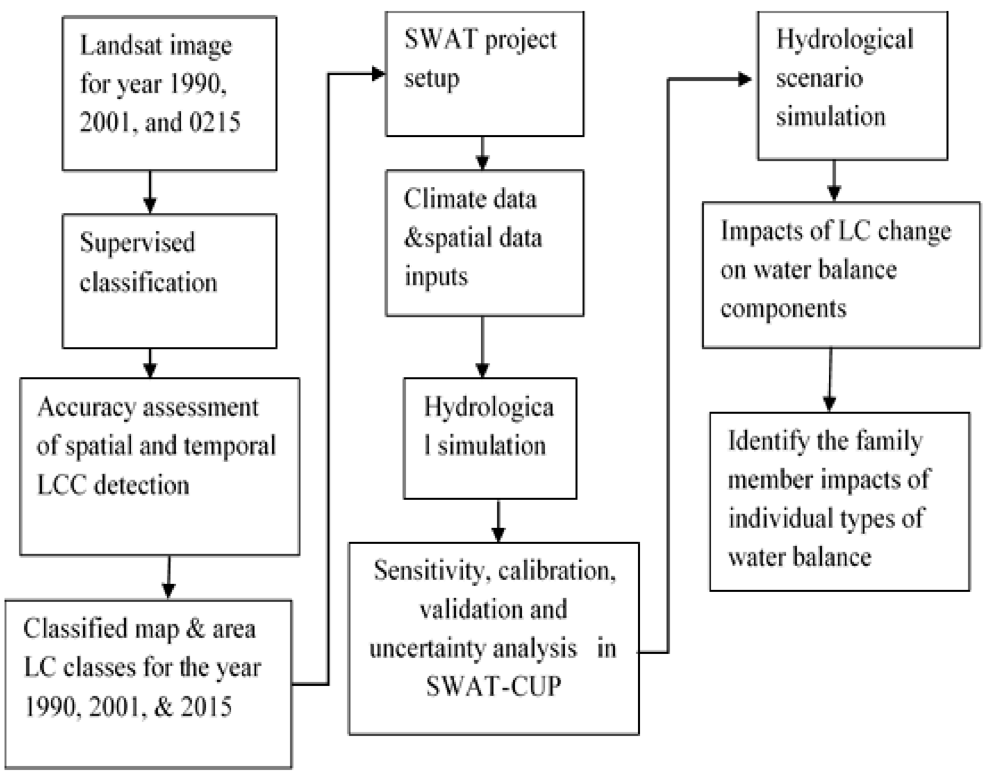


Fig.3. Methodological framework

3. Results and Discussion

3.1 Land Cover Change detection and analysis

In this study, 26 years ‘time duration, and three periods, detection change had been made; (1990-2001, 2001-2015, and 1990-2015 which is fairly enough in showing long history of land use land cover change).

The statistics changes were calculated by comparing values of the area of one data set to the equivalent value of the second data set in each period. The values were presented in terms of percentage and hectare. The method used for LULC detection change in this study is the comparison statics. Percentage area for each land cover classes were derivative from the classified images for each data (1990, 2001, and 2015) separately using Arc GIS 10.3 soft wares. Lastly the area coverage for each land cover for different time was compared. The quantification of the rate of change has been applied to create information about the land use/land cover change of the study area.

The total cultivated land coverage of the land use and land cover map of 1990 indicated that was about 50.50 % of the total area of the watershed. It augmented quickly and became 77.61% of the watershed in 2001 and 85.11% of the watershed in 2015. These are great for the reason that of the population growth that augmented in need for new cultivation land and settlement which in turn resulted decrease on other types of land use and land cover of the area.

The year 1990 land use and land cover map as indicated in figure 4 below the total forest coverage was about 1.43% of the form whole area of the watershed and the year 2001 the land use and land cover map of minimized to almost 1.12% of from the whole area and it minimize to approximately 0.51% of the whole area for 2015 year. These are for the reason that deforestation activities commonly took place for the function of agriculture. Generally, for the period of the 26 years’ period the cultivated land augmented almost 34.61% whereas the forest land minimized to 0.92%. There is a high expansion of cultivated lands in the expenses of other lands (bush land, forest land, and grazing land) for the study periods was considered.

Land use/land cover classification was performed using a supervised Maximum Likelihood Classification (MLC) algorithm in ArcGIS 10.3. Representative training samples were manually selected based on prior knowledge of the study area, field observations, and interpretation of false-color composite Landsat imagery. A total of 127, 147, and 156 training sites were selected for the 1990, 2001, and 2015 images, respectively, covering all eight land-use/land-cover classes. Classification accuracy was assessed using independent Ground Control Points (GCPs) interpreted from Google Earth imagery and temporally unchanged reference locations. Separate validation datasets consisting of 127, 147, and 156 GCPs were used for the 1990, 2001, and 2015 classifications, respectively. Confusion matrices were generated to compute Producer's Accuracy, User's Accuracy, Overall Accuracy, and the Kappa coefficient. The resulting Overall Accuracies were 83.5%, 85.03%, and 87.12%, while the corresponding Kappa coefficients were 0.731, 0.820, and 0.851 for the 1990, 2001, and 2015 classifications, respectively.

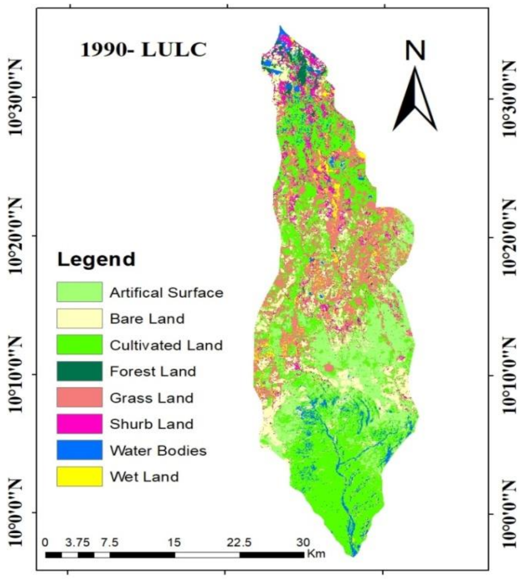
3.2 Sensitivity, calibration and validation of SWAT model

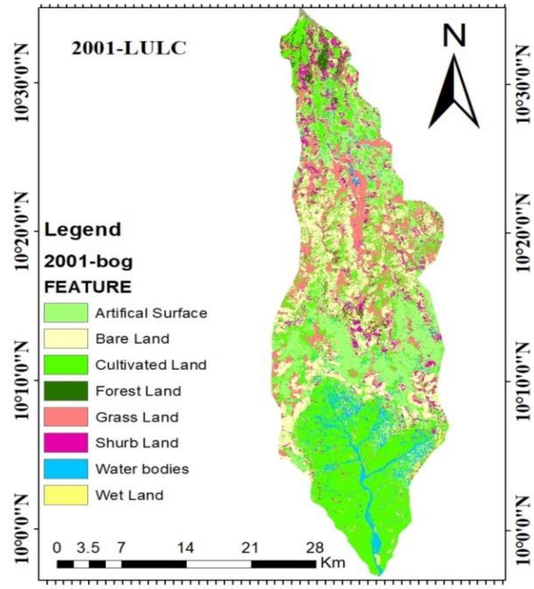
The analyses sensitivity was executed by SWAT with flow parameters of monthly instance steps with observed data of the gauge station of Bogena River (1989-2003). During the analysis 26 parameter was bethink and only 10 parameter was recognized to have important weight in preventing the stream flow in the watershed, such as, saturated hydraulic conductivity (SOL_K), total soil depth (SOL_Z), Curve number (CN2), moisture bulk density (SOL_BD), Crack volume potential of soil (R__SOL_CRK.sol) snowfall temperature (SFTMP), We agree that the snowfall temperature parameter (SFTMP) is not appropriate for the Bogena watershed because the study area does not experience snowfall under its prevailing climatic conditions. The inclusion of SFTMP resulted from the initial automatic parameter list generated during the SWAT-CUP sensitivity analysis and was not intended to imply that snow processes influence the watershed hydrology. Groundwater delay (GW_DELAY), threshold depth of water in the shallow aquifer required for return flow (GWQMN), surface lag (SURLAG), leaf area index at which no evaporation from water surface (EVLAI), and Soil evaporation compensation (return) factor (REVAPMN).

Parameter grading is depending on the t-stat and the p-value in the SUFI-2 program. The result of T-test gave a measure of the sensitivity which means that the larger the t-stat in absolute value, the more sensitive the parameter are, while the p-value calculated the importance of the sensitivity and P-values close to zero are further sensitive which means that the smaller the p-value, the further sensitive the parameter is (Abbaspour, 2013) .

By the sensitive flow parameters of SWAT with observed average monthly stream flow data Calibrations were done. The result of calibration for monthly flow shown that there are a good accord between the simulated average and measured monthly flows with coefficient of determination (R^2) of 0.997and Nash-Sutcliffe simulation efficiency (ENS) of 0.86. The validation simulation also shown that a good accord between the measured and simulated monthly flow with the R^2 of 0.988 and ENS value of 0.79.

Because the objective of this study was to evaluate the long-term hydrological impacts of LULC change, the SWAT model was calibrated and validated using monthly streamflow observations**.** Monthly calibration reduces the influence of short-term measurement errors and is commonly adopted in watershed-scale LULC impact studies. Daily calibration and validation were therefore not conducted. The future work will consider daily simulations to further evaluate flow timing, peak flows, and recession characteristics. The SWAT model demonstrated satisfactory predictive capability during both calibration and validation. The calibration produced NSE, R^2, KGE, and PBIAS values of 0.86**,** 0.997**,** 0.84**,** and 4.6%**,** respectively, while validation yielded corresponding values of 0.79**,** 0.988**,** 0.76, and 7.3%**.** The SUFI-2 uncertainty analysis resulted in a P-factor of 0.82 and an R-factor of 0.94 during calibration, indicating that more than 80% of the observed streamflow was enclosed within the 95% prediction uncertainty with a relatively narrow uncertainty band. Validation produced a P-factor of 0.79 and an R-factor of 1.08**,** confirming that the calibrated model maintained acceptable predictive uncertainty during the independent validation period.





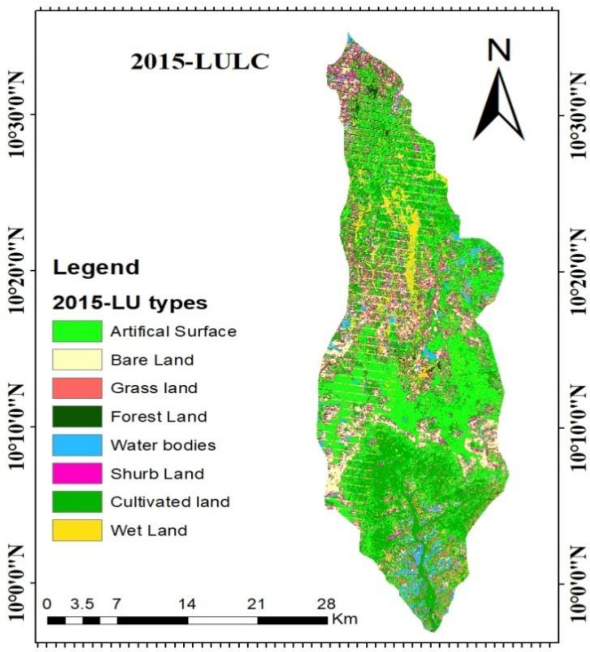


Fig. 4. Map of the Land use types of Bogena watershed in different years

Table 4**:** Input parameters and bounds, sensitivity ranking and calibrated values by the SWAT model for the Bogena watershed

Parameters	Description	t-Stat	p-value	Lower & upper bound	Fitted value	Rank
R_CN2	SCS runoff curve number (%)	4.53	0.0027	-0.2 to 0.4	0.306	1
R_SOL_BD	Moisture bulk density	4.17	0.004	-0.057to 0.29	0.286	2
R_SOL_K	Saturated hydraulic conductivity	2.41	0.047	-0.702to 0.09	-0.004	3

R__SOL_CRK.sol	Crack volume potential of soil	1.04	0.33	0.164 to 1.44	0.87	4
R_SOL_Z	Saturated hydraulic conductivity	-1.97	0.09	-0.2 to 0.2	0.686	5
V_GW_DELAY	Ground water delay (days)	1.57	0.159	46.4to458.12	264.02	6
V_GWQMN	Threshold depth of water in the shallow aquifer required for return flow (mm)	1.33	0.226	0.08 to 2.56	0.257	7
R_EVLAI	Leaf area index at which no evaporation occurs from water surface	-1.28	0.243	0.336 to 1.16	0.772	8
R_SURLAG	Surface lag	1.23	0.259	0.04 to 1.06	0.055	9
R_REVAPMN	Threshold depth of water in the shallow aquifer for "revap" to occur	-1.21	0.264	0.12 to 0.707	0.329	10

A r_parameter = multiplies the existing value (1+ the new value); a parameter = adds the given value to existing value; v_paramater = replaces the existing value with the given value.

Hydrologic Response Units (HRUs) were generated by overlaying the land use/land cover, soil, and slope maps within each sub-basin. HRU definition employed threshold values of 5% for land use, 10% for soil, and 10% for slope, thereby excluding minor spatial units while maintaining the dominant watershed characteristics. The SWAT model assigns Curve Number (CN2) values automatically using the USDA Soil Conservation Service (SCS) Curve Number method based on unique combinations of land use, hydrologic soil group, and slope. During model calibration, CN2 was included among the sensitive parameters and optimized using the SUFI-2 algorithm implemented in SWAT-CUP.

The basin-average Curve Number increased with progressive land use change, indicating a reduction in infiltration capacity and an increase in runoff potential. The observed increase in CN2 between the 1990 and 2015 LULC scenarios is consistent with the expansion of agricultural and built-up areas and the decline of forest and shrub land. This increase in runoff potential explains the corresponding increases in simulated surface runoff and reductions in groundwater recharge and base flow.

Table 5**:** Model efficiency criteria for monthly calibration and validation period at main gauged sub basins in Bogena watershed the Upper Blue Nile

Period	Average monthly flow(m^3/s)		ENS	R^2
	Measured	Simulated		
Calibration(1991-1997)	17.45	16.87	0.86	0.997
Validation(1998-2003)	18.77	19.87	0.79	0.988

As indicated in the Table 5, the model performance values for validation and calibration of the flow simulations are adequately acceptable. These indicate which the physical progress participates in the creation of stream flows in the watershed was sufficiently caught by the model. For this reason, the simulations of model can be used for various water resource development and management situation.

3.3 Hydrological impact of LC change at the Bogena watershed in Upper Blue Nile Basin

The effects of land cover (LC) change on the hydrologic elements, mainly GWQ and SURQ components of the stream simulated using the 1990 and 2001 land use and land cover map were160. 61 mm and 33.13 mm, and156. 53 mm and 45.15mm, respectively, whereas using 2015 land use and land cover map were 29.92 mm and245. 90, respectively. The involvement of surface runoff has augmented from 33.13 mm to 245. 90 mm while the groundwater flow has reduced from 160.61 mm to 29.92 mm owing to the land use and land cover change took place between the periods of 1990 to 2015. These are for the reason that of the growth of agricultural land over forest that results in the augment of surface runoff following rainfall events. It describes this in terms of the soil moisture crop demands

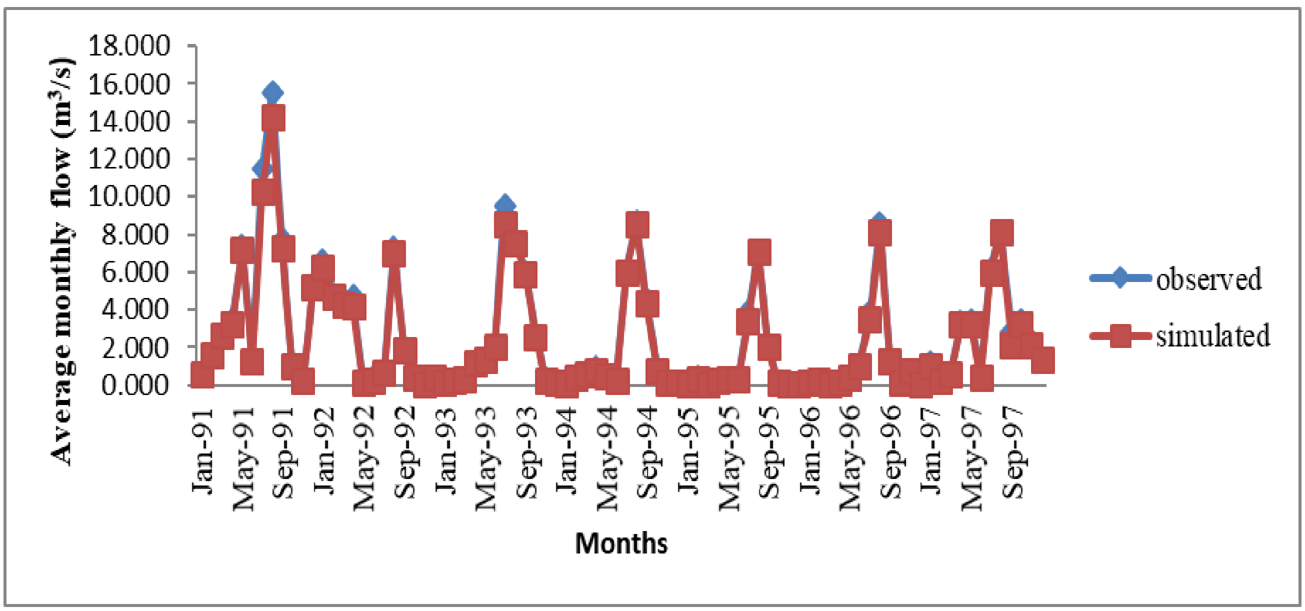


Fig. 5. The result of calibration for average monthly stream flow

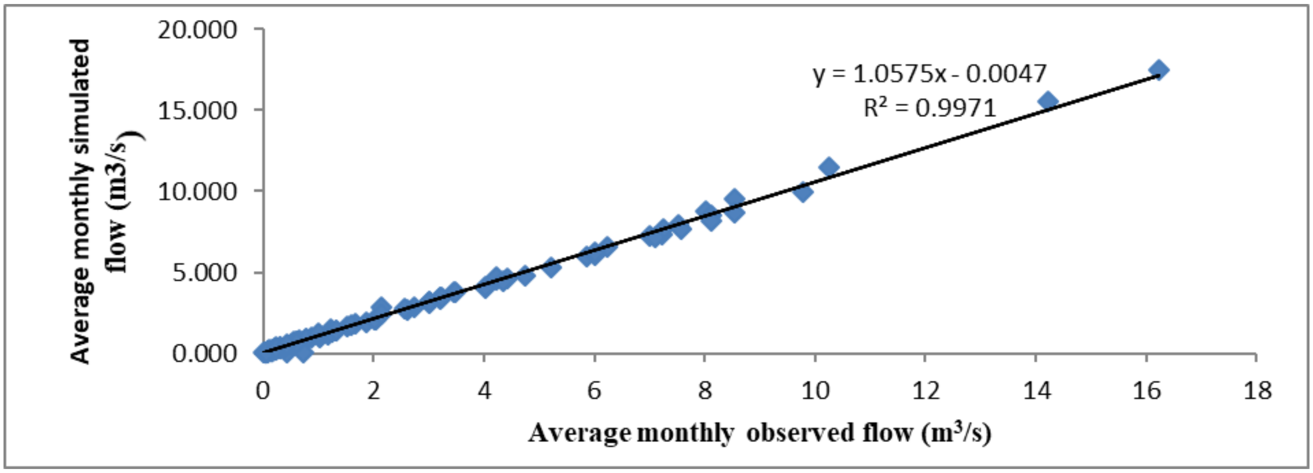


Fig. 6. Average observed vs. simulated monthly flow calibration

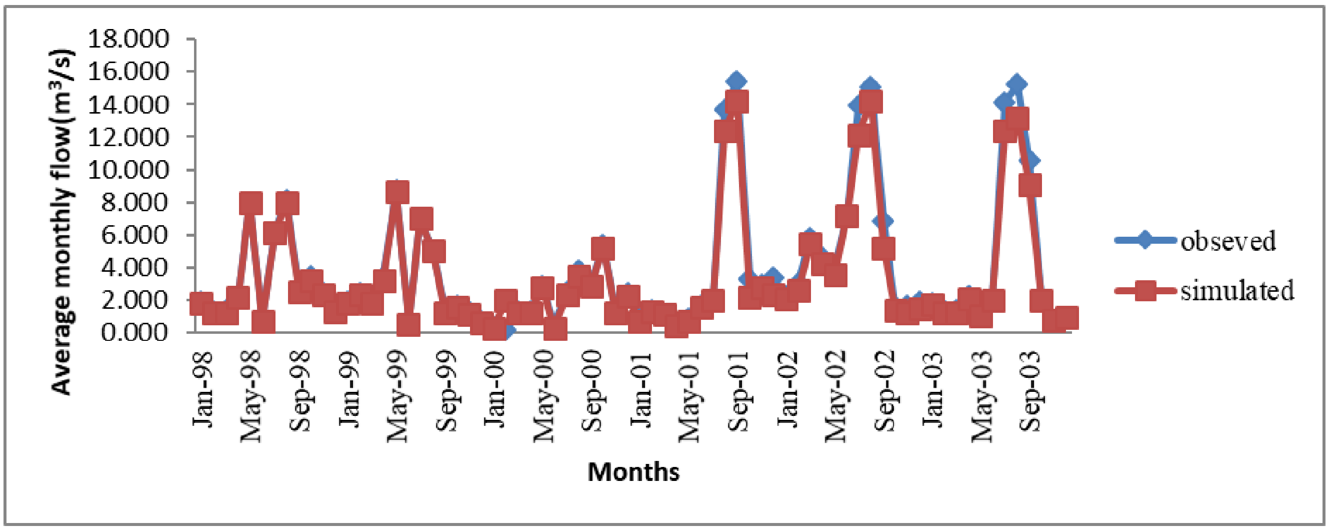


Fig. 7. The result of validation for average monthly stream flow

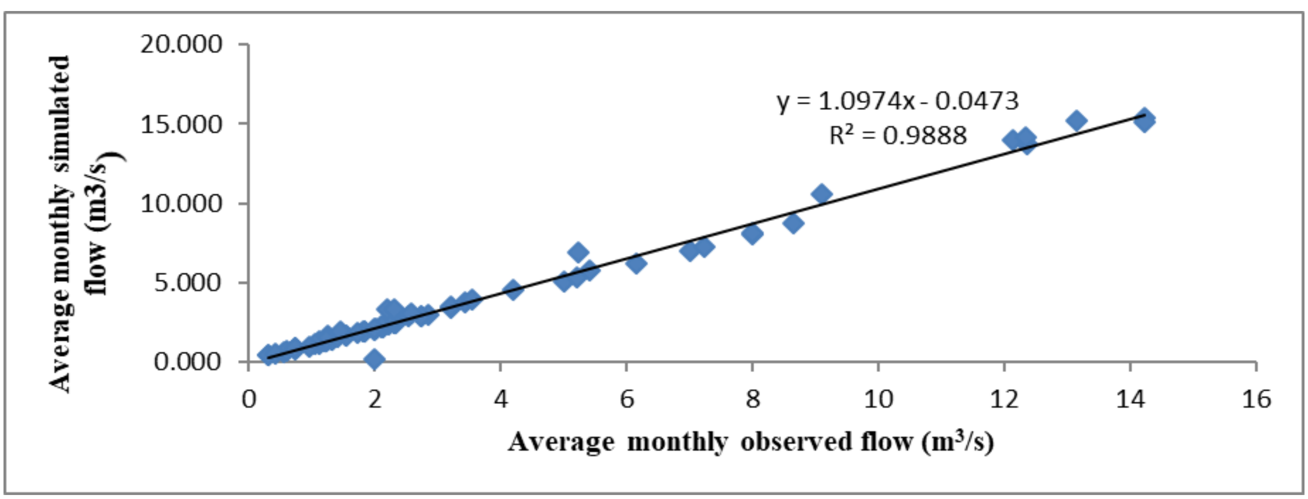


Fig. 8. Average observed vs. simulated monthly flow validation

The measured and simulated average monthly stream flow in Bogena watershed was gained for the period of the calibration period (17. 45 and 16. 87m^3/s) correspondingly. The simulated and measured average monthly stream flow for the validation period was 19. 87 and 18. 77 m^3/s, correspondingly. These indicated that there is agreeable between the measured and the simulated values in both calibration and validation periods.

Table 6: Area of LC types and change statistics of Bogena watershed

Land cover type	1990		2001		2015		1990-2015	
	Ha	%	Ha	%	Ha	%	Ha	%
Cultivated land	32148.45	50.50	49406.69	77.61	54182.09	85.11	22033.64	34.61
Forest	911.09	1.43	711.33	1.12	324.51	0.51	-586.58	-0.92
Shrub land	5246.82	8.24	2009.74	3.16	2177.60	3.42	-3069.22	-4.82
Grass land	14302.26	22.47	10052.26	15.79	5626.81	8.84	-8675.45	-13.63
Artifical surface	142.92	0.22	147.97	0.23	682.15	1.07	539.23	0.85
Bare land	10829.25	17.01	1273.23	2.00	613.75	0.96	-10215.50	-16.05
Water bodies	55.09	0.09	44.34	0.07	42.35	0.07	-12.74	-0.02
Wet land	23.84	0.04	13.77	0.02	10.23	0.02	-13.61	-0.02

Table 7**:** Annual average SURQ, and GWQ

Hydrological Component	1990 LULC	2001 LULC	2015 LULC	Correct Change (1990–2015)
Surface Runoff (SURQ, mm)	33.13	45.15	245.90	+642.35%
Lateral Flow (LATQ, mm)	9.23	9.00	2.22	−75.95%
Groundwater Flow (GWQ, mm)	160.61	156.53	29.92	−81.37%
Evapotranspiration (ET, mm)	520.52	519.57	461.25	−11.39%
Soil Water (SW, mm)	412.19	405.33	389.30	−5.55%
Water Yield (WYLD, mm)	11.32	12.62	91.01	+703.80%

The simulated annual evapotranspiration decreased from approximately 520.52 mm in 1990 to 461.25 mm in 2015, representing an overall reduction of about 11.4%**.** This reduction is consistent with the observed land-use change in the watershed, where forest and shrub land decreased while cultivated land expanded, altering vegetation water use and watershed water balance. The study also reported that LULC change affected hydrological processes including runoff and groundwater response.

3.4 Impacts of LU/LC Changes on stream flow

For this study one of the most considerable things was to evaluate the impact of land use and land cover changes on Bogena watershed. For This evaluation were performed in situations of the effects of land use and land cover changes

on the repeated stream flow and changes on the main components of stream flow, such as surface runoff and groundwater flow for the period of the study periods (1990-2015).
In order to evaluate the variety of stream flow due LULC change from 1990 to 2015, three self-sufficient simulation periods of LU/LC were management on a yearly basis for the period of 1990-2015 keeping the most sensitive input parameters unchanged (precipitation, soil, maximum and minimum temperature). The changeability of Seasonal stream flow of 1990, 2001 and 2015 due to the LULCC was evaluated and compares was prepared on stream flow based on observed data, ground water flow and surface runoff assistance to stream flow based on SWAT output data after simulation using SWAT viewer.

This process gained the discharge results for all land use and land cover patterns. Afterward, these consequences were contrasted and the discharge changed for the period of the wettest seasons of stream flow taken as June, July and August and dry seasons stream flow was suggested in the months of January, February and March was calculated and used as shows to estimate the impacts of land use and land cover changes on the stream flow. The results demonstrate that land use/land cover (LULC) changes substantially altered the hydrological response of the Bogena watershed between 1990 and 2015. The expansion of cultivated land and the reduction of forest and shrub cover increased wet-season streamflow while reducing dry-season streamflow. Specifically, the average wet-season streamflow increased from 59.551 m³/s in 1990 to 163.178 m³/s in 2015, whereas the average dry-season streamflow declined from 9.978 m³/s to 2.286 m³/s over the same period. These changes indicate that the watershed now responds more rapidly to rainfall events but has a reduced capacity to sustain streamflow during the dry season.

The simulated hydrological components further support these findings. Surface runoff increased from 33.13 mm in 1990 to 245.90 mm in 2015 (642.2%), while groundwater contribution decreased from 160.61 mm to 29.92 mm (81.4%). These changes suggest that the conversion of natural vegetation to cultivated land reduced infiltration and groundwater recharge while increasing direct runoff. Consequently, more rainfall was converted into immediate surface flow during the rainy season, resulting in higher peak flows and lower base flow during the dry season.

These findings are consistent with previous studies reporting that the conversion of forest and shrub land to agricultural land increases surface runoff and reduces groundwater recharge and dry-season streamflow. The observed hydrological changes highlight the importance of implementing sustainable land management and watershed conservation practices to reduce runoff, enhance groundwater recharge, and maintain streamflow during dry periods.

Table 8. Changes in Seasonal Streamflow under Different LULC Conditions

Season	1990 (m³/s)	2001 (m³/s)	2015 (m³/s)	Change (1990–2001)	Change (2001–2015)	Overall Change (1990–2015)
Wet season streamflow	59.551	101.093	163.178	+69.76%	+61.41%	+103.627 m³/s (+174.0%)

Dry season streamflow	9.978	4.789	2.286	−52.01%	−52.27%	−7.692 m³/s (−77.09%)

Table 9. Changes in Simulated Hydrological Components under Different LULC Scenarios

Hydrological Component	1990 (mm)	2001 (mm)	2015 (mm)	Overall Change (1990–2015)
Groundwater contribution (GWQ)	160.61	156.53	29.92	−130.69 mm (−81.4%)
Surface runoff (SURQ)	33.13	45.15	245.90	+212.77 mm (+642.2%)

The hydrological responses simulated for the Bogena watershed are consistent with numerous SWAT-based investigations conducted in the Upper Blue Nile Basin and other Ethiopian highland watersheds. Similar to the present study, previous research has shown that the expansion of cultivated land and settlement areas at the expense of forests, shrub lands, and grasslands generally increases surface runoff while reducing infiltration, groundwater recharge, and base flow. These hydrological changes are primarily attributed to reduced vegetation cover, increased soil disturbance, lower interception losses, and reduced infiltration capacity, all of which promote more rapid surface runoff generation. Several studies in the Upper Blue Nile Basin have reported that conversion of forest and natural vegetation to agricultural land leads to increased annual streamflow during the rainy season, accompanied by reductions in dry-season base flow. Comparable responses have been documented in watersheds such as the Gilgel Abay, Gumara, Ribb, Chemoga, and other sub-basins of the Upper Blue Nile, where SWAT simulations consistently demonstrated increases in surface runoff and water yield together with decreases in groundwater recharge following agricultural expansion. These findings closely agree with the hydrological behavior observed in the Bogena watershed. The observed reduction in groundwater flow and soil water storage in the present study is also consistent with previous studies indicating that land-cover conversion decreases infiltration opportunities and reduces groundwater recharge. As cultivated land expands and natural vegetation declines, rainfall is partitioned increasingly toward direct surface runoff rather than subsurface flow pathways. Consequently, dry-season flows become increasingly dependent on diminished groundwater storage. Although the general trends are consistent with previous investigations, differences in the magnitude of the simulated hydrological responses are expected because of variations in watershed size, elevation, soil characteristics, climatic conditions, topography, LULC composition, simulation period, and calibration methodology. In addition, differences in HRU discretization, parameter calibration, and the spatial resolution of input datasets may also contribute to variations among published studies. Nevertheless, the overall agreement between the present results and previous SWAT applications increases confidence in the reliability of the simulated impacts of LULC change on watershed hydrology. The findings therefore reinforce the growing body of evidence that continued conversion of natural vegetation to agricultural and built-up land within the Ethiopian Highlands is likely to increase runoff generation while reducing groundwater recharge and base flow. These changes have important implications for sustainable watershed management, soil and water conservation planning, groundwater resource development, and climate-resilient water resources management in the Upper Blue Nile Basin.

4. Conclusion

The impact of land cover (LC) change assessment on the hydrologic variableness at temporal and multiple spatial balance emphasize to expose watershed, which are essential for watershed management and planning sound interventions. Integrated approaches of remote sensing, hydrologic modeling show the influence of LC change on the water balance components, in the Upper Blue Nile basin. The SWAT model simulation effectiveness was assessed at Bogena watershed, and it was talented of showing the variability of hydrologic in the Upper Blue Nile basin. The analysis of LC change during the past century, mainly bared a significant turn down in the coverage of pasture, forest, and shrub land due to the growth of settlement and agriculture areas. Consequently, the replacement of cropland to nearby slightly appropriate elevated incline terrains and removal of the shrub and forest land could pretense an unpleasant effect that activate an unevenness in the hydrologic elements of the basin. The LC change impact is highly introduced at small scale sub basins in the Bogena watershed. The LC change assessment effects on hydrologic progress would be completed in a sufficient temporal and spatial detail at sub basins level to recognize the more affected areas. The change from the pasture, shrub land, and indigenous forest to cultivation significant boost in the total water yield and surface runoff and diminishing leaning in groundwater flow, and lateral flow. The altering in forest and cropland area has unhelpful pressure on the groundwater flow, but the boost in the forest area should notably improve groundwater flow. The investigation of the research given precious ideas on the comparative pressure of exacting land use to develop a specific water balance component that are essential for sustainable planning and management of water resources interventions. A forestation of ruined elevated angle terrains should reduce surface runoff and, improve groundwater recharges in that way enhance the water balance of the basin. Upcoming researchers could think about the enhancement of the SWAT model̓s ability to simulate evapotranspiration and peak runoff mainly in tropical areas. Through the regulation of unplanned urban and agricultural expansions are occurred due to the high level of land rivalry among dissimilar sectors should be managed. Additionally, suitable strategy actions would be implemented to guarantee water resources sustainable management, and to enhance the excellence of hydrologic services in the Upper Blue Nile river basin

Conflict of Interest

The authors declare that they have no competing of interests.

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Ethics and Consent to Participate Declarations

Not applicable.

Data Availability Statement

Data will be made available upon reasonable request

Reference

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Satellite Image	***S/resolution***	***D/Acquisition date***	***Path/row***	***Sensor***	***Source***
Landsat 4-5TMC1 (1990)	*30m*30m*	*Mar-12/1990*	*169/53*	*TM*	*USGS*
Landsat- 7 (2001)	*30m*30m*	*Feb-22/2001*	*169/53*	*ETM+*	*USGS*
Landsat-8(2015)	*30m*30m*	*Feb-05/2015*	*169/53*	*OLI/TIRSC1*	*USGS*