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# Assessing the Impacts of Land use and Land Cover Change on Stream flow in Mille Watershed, A wash Basin, Ethiopia

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## Abstract

Land use and land cover change is one factor which has impact on watershed hydrology by changing the magnitude and pattern of stream flow. The main objective of this study is to assess the impact of land use and land cover change on stream flow in mille watershed of a wash basin. In this study, the stream flow in the mille watershed was simulated using the semi-distributed hydrologic model, Soil and Water Assessment Tool (SWAT). The sensitive parameters analysis, SWAT output calibration, and validation for stream flow in the watershed were done using SWAT-CUP (SUFI-2-algorithm). The stream flow was calibrated for 1994, 2004 and 2014 land use land cover data, and results from calibration for three different periods land use show acceptable range (0.79, 0.82 and 0.85 for $R^2$ and 0.75, 0.78 and 0.81 for NSE) between observed and simulated stream flow respectively. The results of validation were also acceptable range (0.83, 0.84 and 0.86 for $R^2$ and 0.78, 0.84 and 0.86 for NSE) for three land uses/cover scenario. Land use and land cover changes; climatic characteristics and slope variation of the topography were having an impact on the stream flow of the mille watershed. However, agricultural land, urban, dispersed shrub, and rocky bare land increased by 3.98%, 0.85%, 21.2%, and 41.76% respectively. The amount of forest, shrub lands, acacia, and grassland in the watershed decrease by 44.7%, 2.56%, 23.25%, and 0.92% respectively.

**Keywords:** Land use land cover change • SWAT model • GIS • Mille watershed • Stream

## Highlights

- The impact of land use and land cover change on stream flow is assessed in the mille watershed.
- The study result indicates land use and land cover changes had an impact on the stream flow of the mille watershed.
- The study gives information for various stakeholders and decision-maker for appropriate watershed planning and management in mille watershed.

## Introduction

Water is the most essential natural resources for living species. Since the available amount of water is limited, scarce and not spatially distributed in relation to the population needs, proper management of water resources is essential to satisfy the current demands as well as to maintain sustainability [1]. Land use planning and management are closely related to the sustainability of water resources as changes of land use are linked with amount of water through relevant hydrological processes [2]. To maintain water sustainability, effective methods and mechanisms should be used. In nowadays, the hydrological models are good to represent the hydrological characteristics [3]. Hydrologic modeling and water resources management studies are closely related to the spatial processes of the hydrologic cycle [4].

The primary natural resource used for economic, social, infrastructure, and other human activities is land. The word "land change," which also refers to changes is a general term for the human modification of earth's terrestrial surface. Land use/cover changes is a widespread and accelerating process, mainly driven by human activities, which in turn produce changes that would impact humans and alter the availability of different biophysical resources including water, soil, vegetation and animal feed. There are very few landscapes left on the planet that have not undergone major human influence in some form [5].

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The main reasons of land use change leading to deforestation and land degradation have been identified as population growth, rapid economic development, and poverty [6]. The growing population and increasing socio-economic necessities creates a pressure on land use land cover. This pressure results in unplanned and uncontrolled changes in land use land cover change. The relationship between land use land cover change and hydrology is complicated, with linkages existing at a wide variety of spatial and temporal scales; but, land use change indisputably has a strong influence on global water yield [7]. Land use/land cover directly impact the amount of evaporation, groundwater infiltration and overland runoff that occurs during and after precipitation events. These factors control the water yields of surface streams and groundwater aquifers and thus the amount of water available for both ecosystem function and human use [8]. Changes in land cover and use change both runoff behavior and the balance that exists between evaporation, groundwater recharge and stream discharge in specific areas and in entire watersheds, with considerable consequence for all water users [9].

The land use and land cover changes are caused by a number of natural and human driving forces [10]. The effect of natural forces such as climate change has seen after a long period of time, whereas the human effects are immediate and often direct. Out of the human factors, population growth is the most important in Ethiopia, as it is common in developing countries. The dynamic nature of land use arising from an increasing population at alarming rate in Ethiopia [11]. People demand land for different purpose such as agriculture, housing. These anthropogenic activities result expansion of agricultural land and urbanization thereby deforestation. In such a way, land use and land cover change is inevitable which affects stream flow of the watershed. Satellite data help to investigate land use and land cover change by providing paramount information for rainfall runoff simulation aimed in studying land use and land cover impact on watershed stream flow [12]. Although there are various researches on a hydrologic model using land use data, only a small number of these have focused on describing how land use change affects river flow [13]. Therefore, it is essential to provide a scientific understanding of how changes in land use and land cover impact the stream flow of watersheds.

Generally, in this study a physically-based hydrological model, Soil and Water Assessment Tool (SWAT) was used to for assessing the effect of land use land cover change on stream flow in the study area.

## Materials and Methods

### Description of the study area

The Mille River is a river of Ethiopia and a tributary of the Awash. It drains parts of the Semien (North) Wollo and Debub (South) Wollo Zones of the Amhara Region, as well as Administrative Zone 4 of the Afar Region. The explorer L.M. Nesbitt, who travelled through the area in 1928, was impressed by its size, and described the Mille as "probably the only real river which joins the Awash". The Ala River (A'ura) and Golima River (Golina) are small Tributaries of the Mille. The Mille River rises in the Ethiopian highlands west of Sulula in Tehuledere woreda. It flows first to the north, and then curves to run east to its confluence with the Awash at 11°25′N 40°58′E.

The mille watershed is located below 2400 meters above sea level; its climate is classified as cola (hot) zone. Two distinct periods dominate it. There are dry and wet times here. The dry season begins in November and lasts until April, whereas the wet season begins in June and ends in September. May and October, the latter two months, are transitional months. While October marks the change over from the wet to the dry season, may marks the change over from the dry to the rainy season. The first rainy season, the shorter of the two, lasts from mid-March to April, while the second usually starts around June/July. Based on results of the ArcGIS software's soil type of mille watershed classified as water bodies, chromic luvisols, chcambisols; eutric regosols; haplic xerosols; calcaric flubisols; orthic solonchacks; eutric cambisols; leptosols; dystric nitisols; verticcambisols and eutric cambisols. But Eutric regosls makes up the majority of the watershed (Figure 1).

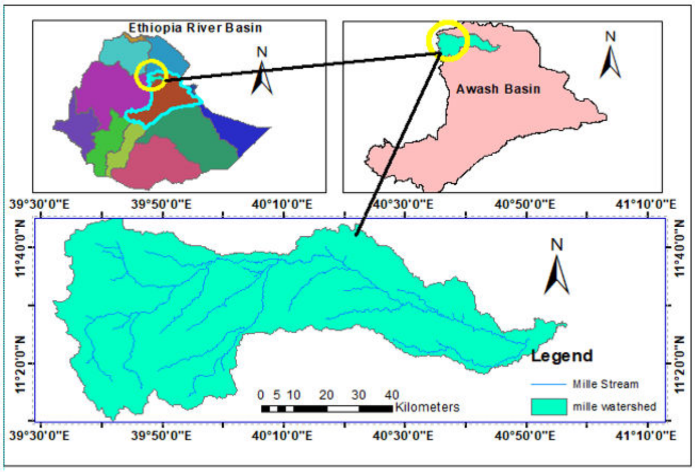


**Figure 1.** Location of the study area.

### Description of SWAT model

The Soil and Water Assessment Tool (SWAT) watershed model is one of the most recent models developed at the USDA-ARS Arnold, et al, during the early 1970's. SWAT model is semi-distributed physically based simulation model and can predict the impacts of land use change and management practices on hydrological regimes in watersheds with varying soils, land use and management conditions over long periods and primarily as a strategic planning tool [14]. The interface of SWAT model is compatible with ArcGIS that can integrate numerous available geospatial data to accurately represent the characteristics of the watershed. In SWAT model, the impacts of spatial heterogeneity in topography, land use, soil and other watershed characteristics on hydrology are described in subdivisions. There are two scale levels of subdivisions; the first is that the watershed is divided into a number of sub-watersheds based upon drainage areas of the attributes, and the other one is that each sub-watershed is further divided in to a number of Hydrologic Response Units (HRUs) based on land use and land cover, soil and slope characteristics.

The SWAT model simulates eight major components: Hydrology, weather, sedimentation, soil temperature, crop growth, nutrients, pesticides, and agricultural management [15]. Major hydrologic processes that can be simulated by this model include evapotranspiration, surface runoff, infiltration, percolation, shallow aquifer and deep aquifer flow and channel routing [16]. Stream flow is determined by its components (surface runoff and ground water flow from shallow aquifer).

In the land phase of the hydrologic cycle, SWAT simulates the hydrological cycle based on the water balance equation [17].

$SWt=SWo+\sum_{i=1}^{t}(Rday-Qsurf-Ea-Wseep-Qgw)$ Where,

SWt: Is the final soil water content (mm),

SW: 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)

Ea: 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).

## SWAT model input data and analysis

**Digital elevation model:** DEM is used to examine the drainage pattern of the watershed, stream length and slope, and width of channels of the watershed. This study used DEM that was a processed shuttle Rader Topographic Mapping (SRTM) 30 × 30 m Resolution topography map obtained from Ethiopia ministry of water, irrigation and energy, GIS and Remote sensing department.

**Meteorological data:** The meteorological input data for SWAT model calibrating and validating includes daily precipitation, maximum and minimum temperature. The data were obtained from Ministry of Water, Irrigation and Energy (MoWIE) and National Meteorological Agency (NMSA). In this study Mille, Wuchala, Tita, Sirinka, Werebabo, Haike, Kombolcha, Bati and Meresa stations data were used. Except Mille station, all meteorological stations are found out of the Mille watershed (Table 1).

| No | Station | Data type | Latitude | Longitude | Record period | Mean annual rainfall (mm) |
|---|---|---|---|---|---|---|
| 1 | Mille | Precipitation, temperature | 11.4167 | 40.75 | 1994-2014 | 323.9622 |
| 2 | Wuchal | Precipitation only | 11.5176 | 39.60575 | 1994-2014 | 553.864 |
| 3 | Tita | Precipitation only | 11.1658 | 39.67108 | 1994-2014 | 1099.76 |
| 4 | Sirinka | Precipitation, temperature (Wind-speed, solar radiation humidity) | 11.751 | 39.61428 | 1994-2014 | 1074.3 |
| 5 | Werebabo | Precipitation only | 11.3167 | 39.75 | 1994-2014 | 1155.72 |
| 6 | Haike | Precipitation only | 11.3053 | 39.68021 | 1994-2014 | 1225.8 |
| 7 | Kombolcha | Precipitation only | 11.084 | 39.71763 | 1994-2014 | 1032.98 |
| 8 | Bati | Precipitation, temperature wind speed, solar radiation, relative humidity | 11.1967 | 40.01539 | 1994-2014 | 912.179 |
| 9 | Meresa | Precipitation only | 11.6638 | 39.6605 | 1994-2014 | 1055.89 |

**Table 1.** Statistical properties of meteorological station.

Filling missing rainfall data: Filling the missing data is very important for hydrological analysis. In this study, the Variation of normal annual rainfall and temperature of the surrounding stations exceed 10% of the values of the station under consideration, missing daily rainfall and temperature data has been filled using normal ratio method. The general formula for computing the rain fall at missing station (PX) using normal ratio method is as follows:

$PX=(NX)/n(P_1/N_1+P_2/N_2+P_n/N_n)$

Where PX is missing value of precipitation or temperature to be computed, $P_1$, $P_2$….. $P_n$ are Rainfall or temperature of at the surrounding station, Nx is the normal annual rainfall or temperature at station, $N_1$, $N_2$…. $N_n$ are annual rainfall or temperature at the n surrounding stations and n is the Number of stations used in the computation. After the missing data filled, the consistencies and the homogeneity of the data were checked by using double mass curve and Non dimensional Value respectively. From the result, the rainfall record in each meteorological station were consistence and homogenous (Figures 2 and 3).

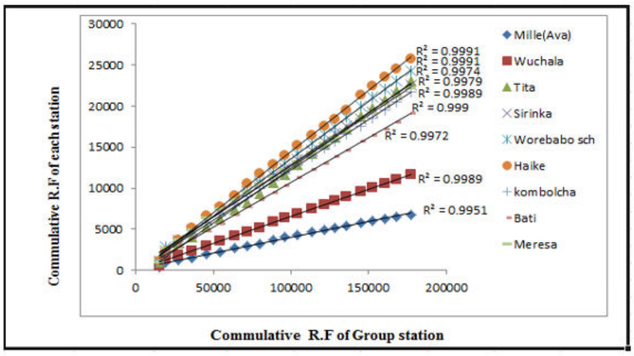


**Figure 2.** Double mass curve of selected meteorological station.

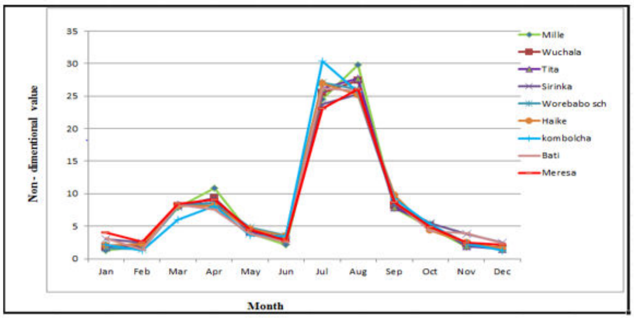


**Figure 3.** Homogeneity test for selected meteorological station.

**Areal rainfall computation:** Rain gauges represent point sampling of the areal distribution of a storm. But in practice, hydrological analysis requires knowledge of the rainfall over an area. For this study Thiessen polygon method was used to convert point rainfall to areal. The average rainfall over the watershed is given by equation.

$$P_{av}= (P_1A_1+P_2A_2+P_3A_3 \text{ ----} +P_nA_n)/(A_1+A_2+A_3 \text{ -----} +An)$$

Where, $P_{av}$ average areal rainfall (mm), $P_1$, $P_2$, $P_3$........$P_n$ are the precipitation of stations 1, 2, 3…n, respectively and $A_1$, $A_2$, $A_3$….$A_n$ are the area coverage of stations 1, 2, 3…n respectively in the Thiessen polygon. Accordingly, this method was used to determine areal rainfall for intervening watershed (Figure 4).

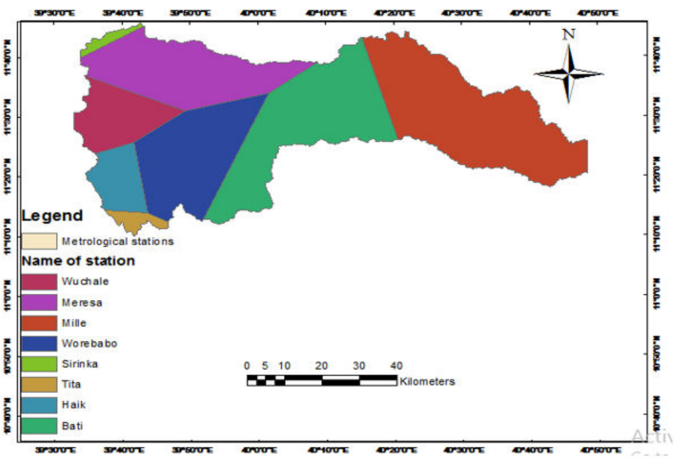


**Figure 4.** Thiessen polygons for intervening basin.

**Hydrological data:** Hydrological data includes stream flow data that used to calibrate and validate the soil and water assessment tools model. The observed daily stream flow data is the required data for calibration and validation of the simulated stream flow from the watershed. The available observed daily stream flow data recorded at mille gauging station from 1994-2014 years was collected from the Ministry of Water, Irrigation, and Energy.

**Soil data:** One of the main inputs to the SWAT model of the watershed is data on the soil properties. Physical characteristics (required) and chemical characteristics can be used to separate the necessary soil data (optional). Based on results of the ArcGIS software's soil type classification twelve varieties of soil can be found in the Mille watershed. These include the following: Waterbodies, chromicluvisols, chcambisols; eutricregosols; haplicxerosols; calcaric flubisols; orthic solonchacks; eutric cambisols; leptosols; dystricnitisols; verticcambisolsand eutric cambisols. Eutric regosls, which makes up the majority of the watershed, is the most common form of soil there (Figure 5).

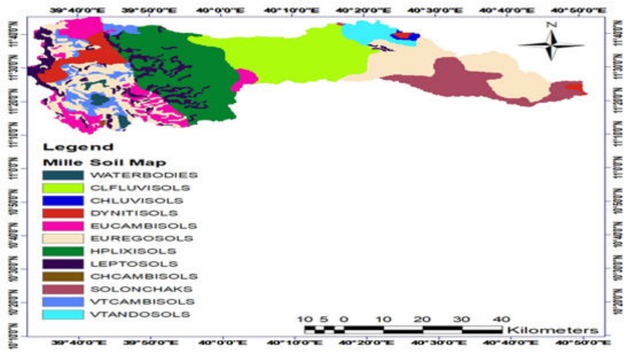


**Figure 5.** Soil map of mille watershed.

**Land use land covers data:** Land cover in a watershed can often be correlated with the amount of interception storage/loss and actual evapotranspiration in a watershed. Land use/cover data is used for comparison of impacts on hydrology. The land use and land cover classification was made using ministry of water resource, irrigation (Figure 6).

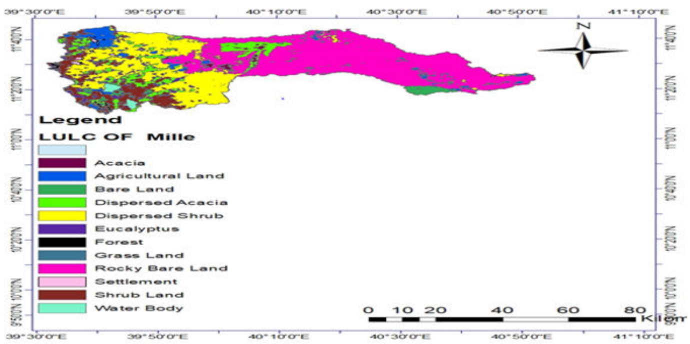


**Figure 6.** Land use land cover map of mille watershed.

## Hydrological modeling using SWAT

**Sensitivity analysis:** Sensitivity analysis is used to estimate the rate of change of model outputs with respect to change of model inputs.

It is also useful to recognize how the model depends on the information fed into it [18]. SWAT model have large number of parameters and a number of outputs, thus, an initial parameter selection makes the calibration process easier and reduces the uncertainties related to diverse parameters. In the sensitivity process, by using the Arc SWAT interface sensitivity analysis window, first the SWAT simulation was specified to perform the sensitivity analysis and the location of the sub basin where observed data was compared against simulated output. Thus, 27 flow parameters were incorporated for the analysis with default values as recommended by [19]. Following the completion of sensitivity analysis, the Mean Relative Sensitivity (MRS) values of the parameters were used to rank the parameters, and their category of classification.

**Model calibration and validation:** Model calibration is the process of fine-tuning or adjusting model parameters to match observable data as closely as possible while accepting a small amount of variation. Similar to that, model validation involves testing calibrated model results using other data sets without any additional adjustments at different temporal and spatial scales. SWAT provides three options for calibration: Auto-calibration, manual calibration and combination of these two methods [20]. For this study the measured stream flow data were calibrated using SWAT-Cup model from Soil and Water Assessments Tool (SWAT) model output, automatic calibration period. The automatic calibration was done on monthly time steps using the average observed stream flow data of the mille Basin the first two years (1994-1995) was consider for model warm up period and covering from January 1996 to December 2007. The observed data of average monthly stream flow data of 7 years from January 2008 to December 2014 were used for the model validation process. The model performance values were checked to confirm that the simulated values are still within the allowable range.

**Model performance evaluation:** To evaluate the model simulation outputs in relation to the observed data, model performance evaluation is required. There are various measures to evaluate the model performance during the calibration and validation periods. For this study, the following two methods were used Coefficient of determination ($R^2$) and Nash, Sutcliffe Simulation Efficiency (NSE).

**Correlation of determination ($R^2$)**

$$\mathbf{R}^2 = \frac{\sum[Xi - Xav] * [Yi - Yav]}{\left[\sqrt{\sum[Xi - Xav]^2}\right] * \left[\sqrt{\sum[yi - yav]^2}\right]}$$

Where, $X_i$=measured value ($m^3/s$), $X_{av}$=average measured value ($m^3/s$), $Y_i$=simulated value ($m^3/s$) and $Y_{av}$=average simulated value ($m^3/s$)

**Nash and Sutcliffe simulation efficiency (NSE)**

NSE is calculated as:

$$NSE=1-(\sum(X_i-Y_i)^2)/(\sum(X_i-X_{ave})^2)$$

Where, $X_i$=measured value, $Y_i$=simulated value and $X_{av}$=average observed value.

**Evaluation of stream flow due to land use/land covers changes:** To evaluate the variability of stream flow due to land cover dynamics from 1994 to 2014, three independent SWAT runs were carried out on a monthly time step using 1994, 2004 and 2014 land use and land cover maps for the period of 1994 to 2014 keeping other input parameters unchanged. Based on the simulation output, seasonal stream flow variability caused by land use and land cover change was assessed and comparison was made on surface runoff and ground water flow contributions to stream flow for period from 1994 to 2014.

## Result and Discussion

### Stream flow modeling

**Sensitivity analysis:** Twelve hydrological parameters related to stream flow were tested using the SUFI-2 algorithm. For the simulation of the stream flow average criteria option, the parameter was examined for sensitivity analysis and the output was chosen. The mille watershed is considerably impacted by 12 flow parameters for the SWAT model. After identified as being parameter to which the flow has Medium, high or vary high sensitivity the ranking of parameter is presented in Table 2. The Curve Number ($CN^2$) was the main sensitivity parameter. Because the curve number depends on several factors including soil types, soil textures and land use properties. Global sensitivity analysis was used to identify sensitive parameters based on their p-value. Parameters corresponding to p-value less or equal to 0.05 are categorized as more sensitive parameters in their degree of sensitivity (Table 2).

| Parameter name | t-state | p-value | Rank |
|---|---|---|---|
| R_CN$^2$.mgt | -0.5 | 0.62 | 1 |
| V_GWQMN.gw | -0.26 | 0.795 | 2 |
| R_SOL_K (..).sol | 0.37 | 0.717 | 3 |
| R_SOL_AWC (..).sol | 0.38 | 0.7 | 4 |
| V_GW_DELAY.gw | 0.46 | 0.648 | 5 |
| R_GW_REVAP.gw | 0.47 | 0.645 | 6 |

| | | | |
|---|---|---|---|
| V_ALPHA_BF.gw | 0.48 | 0.63 | 7 |
| R_CANMX.hru | 0.83 | 0.41 | 8 |
| R_ESCO.bsn | 0.96 | 0.344 | 9 |
| R_RCHRG_DP.gw | 0.99 | 0.324 | 10 |
| R_REVAPMN.gw | 1.012 | 0.318 | 11 |
| R_CH_K$^2$.rte | 1.11 | 0.27 | 12 |

**Table 2.** Sensitivity analysis rank for stream flow using p-value.

## Model calibration and validation

**Model calibration:** The simulated stream flow at the mille watershed outlet was calibrated in SWAT-CUP using the SUFI2-algorithm for each of three periods land use/land cover scenarios. The calibration was carried out by adjusting the parameters until there was good agreement between the simulated and observed result. Based on the execution of the SUFI-2 optimization function, $R^2$ and NSE values were used to assess the model's performance for the provided observed data. From 1994 to 2007, stream flow that was observed was used for calibrating each land use land cover scenario's simulated stream flow, as indicated (Figures 7-12). As a result, the coefficient of determination of model performances for the LULC in 1994 was $R^2$=0.79 and NSE=0.75, while for the LULC in 2004, $R^2$=0.82 and NSE=0.78. $R^2$ is 0.85 and NSE is 0.81 for 2014-LULC. $R^2$>0.6 and NSE>0.5 values for the calibration of the daily and monthly simulated stream flow are typically regarded as sufficient for an acceptable calibration, according to Santhi et al., values. According to the findings, in the case of land use and land cover data for the 1994, 2004, and 2014 scenarios, the estimated value from the models is highly correlated with the observed value.

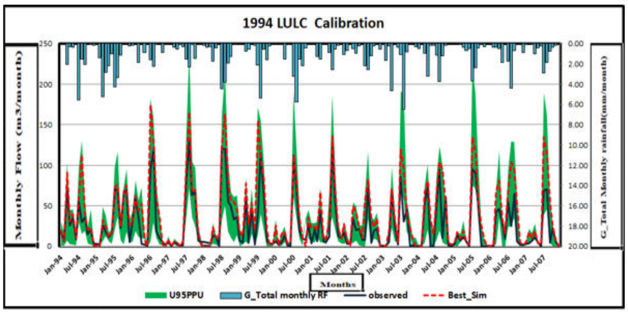


**Figure 7.** The calibration result of average monthly flow 1994.

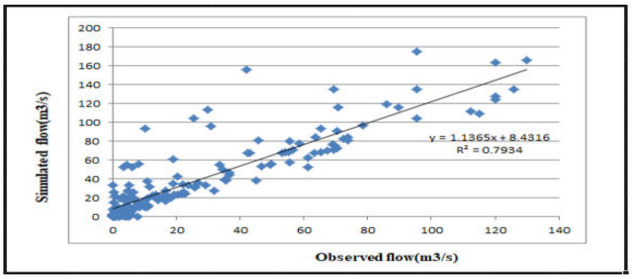


**Figure 8.** Scatter plot of simulated versus observed flow during calibration in 1994.

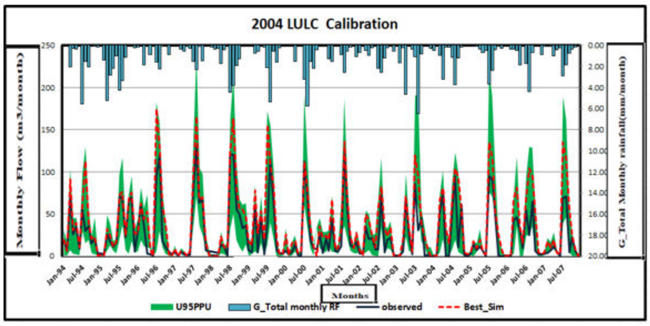


**Figure 9.** The calibration result of average monthly flow 2004.

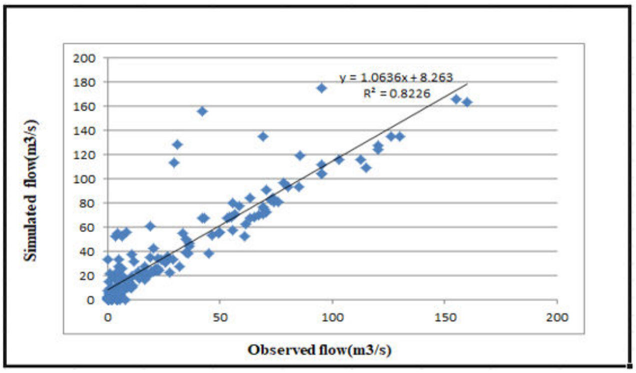


**Figure 10.** Scatter plot of simulated versus observed flow during calibration in 2004.

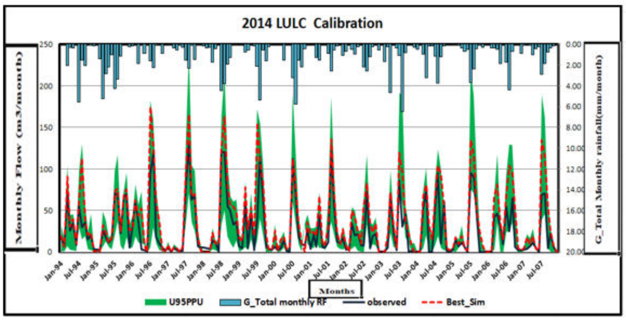


**Figure 11.** The calibration result of average monthly flow 2014.

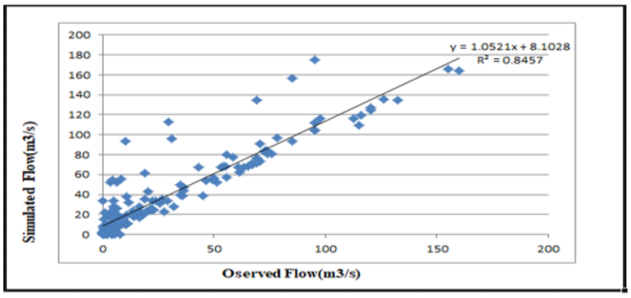


**Figure 12.** scatter plot of simulated versus observed flow during calibration in 2014.

**Model validation:** Applying maps of land use and land cover from 1994, 2004 and 2014, the model was validated during a seven-year period from 2008 to 2014 without further adjusting the calibrated parameters. According to the validation results for monthly flow, there is a good agreement between observed and simulated stream flow for the years 1994, 2004, and 2014, with coefficients of determination ($R^2$) and Nash-Sutcliffe Simulation Efficiency (NSE) values of 0.83, 0.84 and 0.86 and 0.78, 0.81, 0.83 respectively (Figures 13-18)

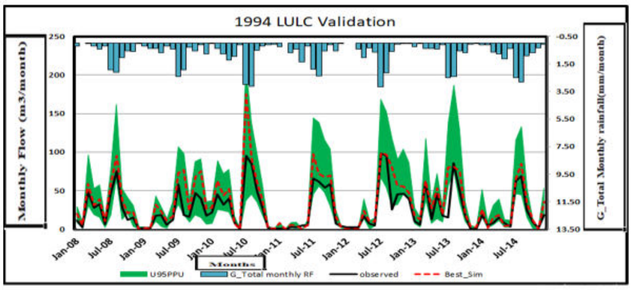


**Figure 13.** The validation result of average monthly flow 1994.

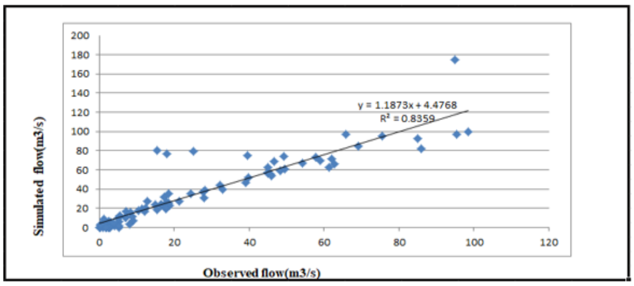


**Figure 14.** Scatter plot of simulated versus observed flow during validation in 1994.

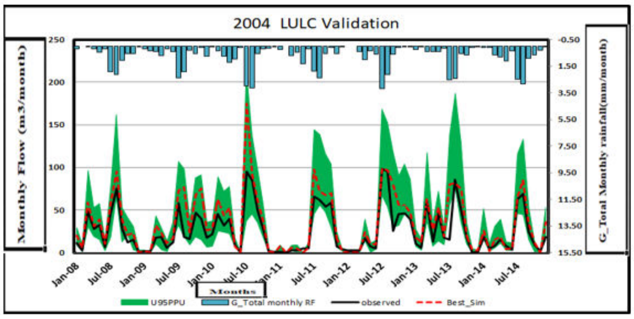


**Figure 15.** The validation result of average monthly flow 2004.

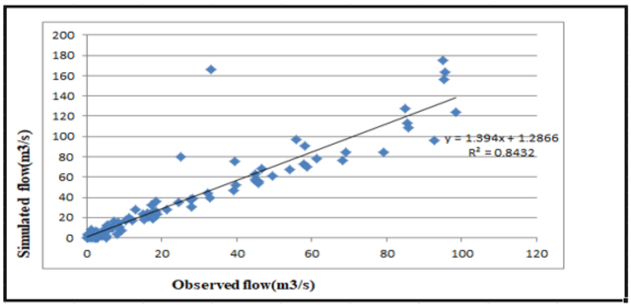


**Figure 16.** Scatter plot of simulated versus observed flow during validation in 2004.

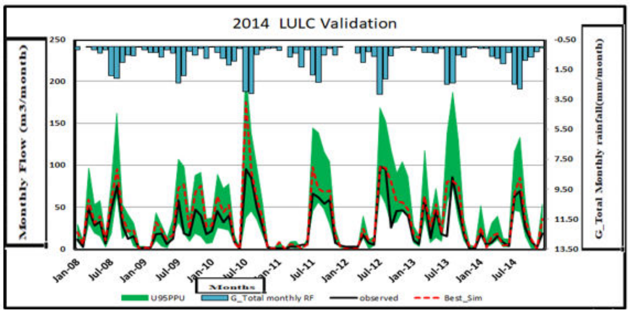


**Figure 17.** The validation result of average monthly flow 2014.

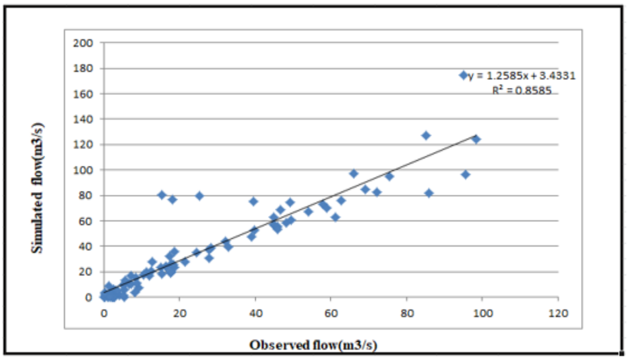


**Figure 18.** Scatter plot of simulated versus observed flow during validation in 2014.

## Land use land cover map

Mille watershed undergone significant land use land covers change from period of 1994 to 2014. It shows that the increase of agriculture land, rocky bare land, Eucalyptus and settlement (urban) and whereas the decrease of forest, grassland and acacia, during the period from 1994 to 2014. Land area under agriculture increased by 3.98% of total area during this period. This is due to the increase of population growth that causes the increase in demand of cultivation land for different agricultural production. On the other hand, land area under forest decreased by 44.7% of total area. 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 0.85% of total area due to expansion of urban areas within the watershed. Moreover, rocky bare land increased by 41.76% of total area which indicates the degradation of the watershed. This attributed to decline of forest land in the watershed (Figures 19-21).

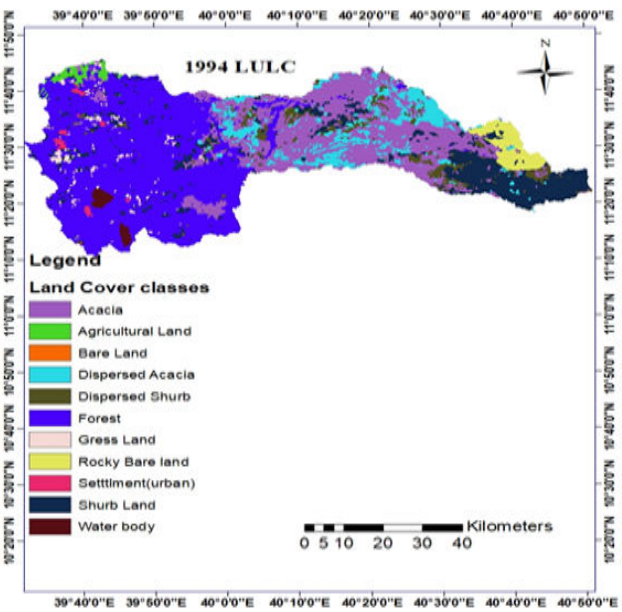


**Figure 19.** Land cover map of mille watershed in 1994.

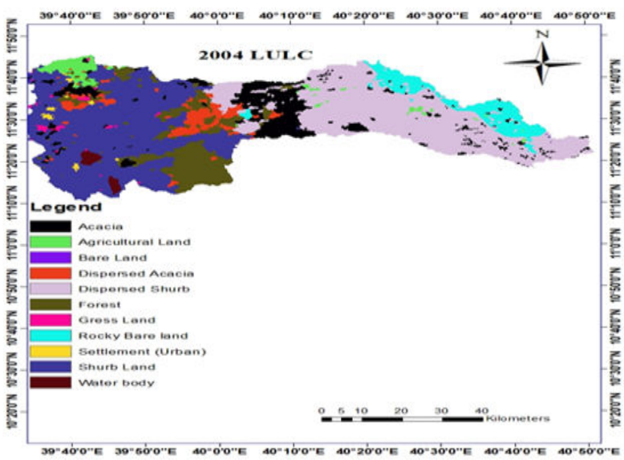


**Figure 20.** Land cover map of mille watershed in 2004.

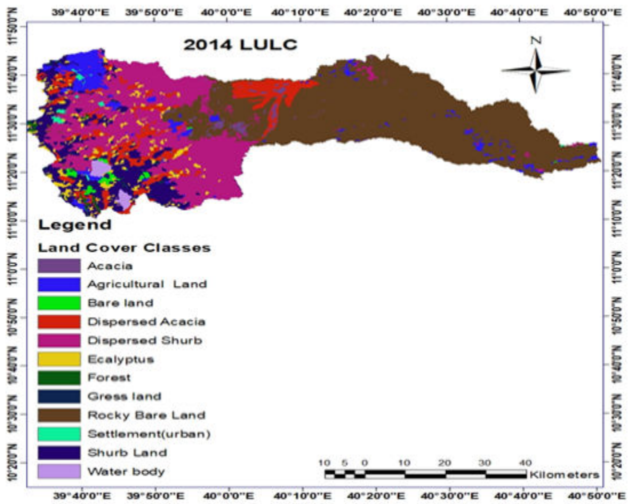


**Figure 21.** Land cover map of mille watershed in 2014.

## Land use land cover change in Mille Watershed

Between 1994 and 2004 there was an increase in agricultural land, dispersed shrub, rocky bare land, urban land, and shrub land, but a decrease in forest, acacia, dispersion acacia, and water bodies. Between 2004 and 2014, agricultural land, bare land, dispersed acacia, rocky bare land, water bodies and urban land increased while forest, acacia, grassland, dispersed shrub and shrub land decreased (Figures 22 and 23). The agricultural land, urban, dispersed shrub and Rocky bare land increased by 189.65 km$^2$ (3.98%), 123.05 km$^2$ (0.85%), 1,008.9 km$^2$ (21.22%) and 1987.62 km$^2$ (41.76%) respectively. But forest land, shrub land, Acacia and grass land decreased by 2,127.79 km$^2$ (44.7%), 121.1 km$^2$ (2.56%), 1106.55 km$^2$ (23.25%) and 44.08 km$^2$ (0.92%) respectively in the watershed. This indicates that grass land and forest land shrinkage mainly due to expansion of agricultural land and urban land in the watershed. According to Bekele, the main factor of this land use change was population growth, lack of appropriate land management policy, legislation and institutions and lack of awareness (Tables 3 and 4).

| LULC | 1994-LULC area | | 2004-LULC area | 2014-LULC area | | |
|---|---|---|---|---|---|---|
| | KM$^2$ | % | KM$^2$ | % | KM$^2$ | % |
| Agricultural land | 49.33 | 1.04 | 125.84 | 2.64 | 238.98 | 5.02 |
| Acacia | 1168.34 | 24.55 | 473.42 | 9.95 | 61.79 | 1.3 |
| Bare land | 0.24 | 0.01 | 0.25 | 0.011 | 32.26 | 0.68 |
| Dispersed Acacia | 359.77 | 7.56 | 194.65 | 4.09 | 391.85 | 8.23 |
| Dispersed Shrub | 186.88 | 3.9 | 1444.43 | 30.35 | 1195.78 | 25.12 |
| Forest | 2148.2 | 45.13 | 368.64 | 9.58 | 20.41 | 0.43 |
| Grassland | 66.74 | 1.4 | 28.3 | 0.59 | 22.66 | 0.48 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Rocky Bare land | 137.93 | 2.9 | 298.41 | 6.27 | 2125.55 | 44.66 |
| Urban | 25.21 | 0.53 | 143.31 | 1.17 | 148.26 | 1.38 |
| Shrub land | 576.36 | 12.12 | 1642.18 | 34.5 | 455.25 | 9.56 |
| Water body | 40.78 | 0.86 | 40.32 | 0.85 | 41.85 | 0.88 |
| Eucalyptus | - | - | - | - | 25.14 | 2.26 |
| Total | 4,759.80 | 100 | 4,759.80 | 100 | 4,759.80 | 100 |

**Table 3.** Land use and land covers types and area in 1994, 2004 and 2014 in the mille watershed.

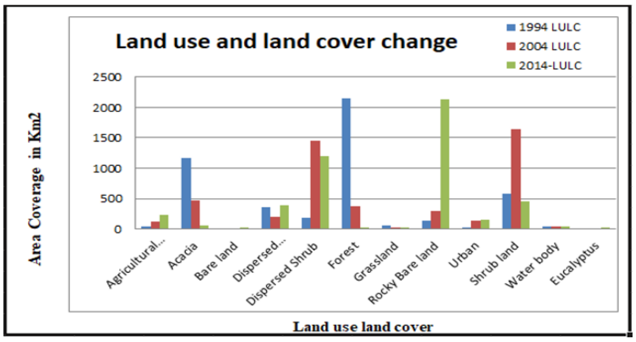


**Figure 22.** Land uses Land covers and their Area coverage in 1994, 2004 and 2014 in the mille watershed.

| LULC | 1994-2004 | 2004-2014 | 1994-2014 |
|---|---|---|---|
| Agricultural land ($km^2$) | 76.51 | 113.14 | 189.65 |
| Acacia ($km^2$) | -694.92 | -411.63 | -1106.55 |
| Bare land ($km^2$) | 0.01 | 32.01 | 32.02 |
| Dispersed Acacia ($km^2$) | -165.12 | 197.2 | 32.08 |
| Dispersed Shrub ($km^2$) | 1257.55 | -248.65 | 1008.9 |
| Forest ($km^2$) | -1779.56 | -348.23 | -2127.79 |
| Grass Land ($km^2$) | -38.44 | -5.75 | -44.08 |
| Rocky Bare land ($km^2$) | 160.48 | 1827.14 | 1987.62 |
| Urban ($km^2$) | 118.1 | 4.95 | 123.05 |
| Shrub land ($km^2$) | 1065.82 | -1186.93 | -121.11 |
| Water body ($km^2$) | -0.46 | 1.53 | 1.07 |
| Eucalyptus ($km^2$) | - | 25.14 | 25.14 |

**Table 4.** Land use land covers difference in area $km^2$.

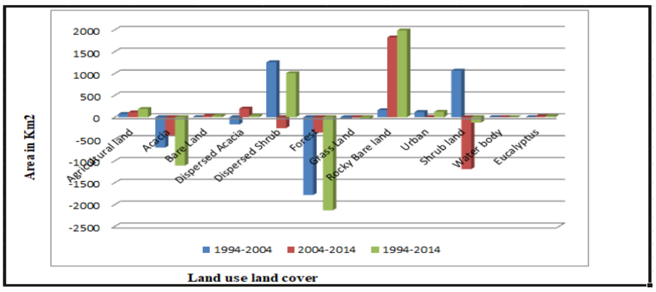


**Figure 23.** Land use and land cover change between 1994 and 2004, 2004 and 2014, 1994 and 2014 in mille watershed.

## Model responses for land use land cover change

Stream flow change was evaluated with the land use and land cover change observed in the period 1994-2014. Here, the rate of change in stream flow doesn't considers the climate and slope factor (mainly precipitation, climate and slope). For this case to reduce the impact of other factors on stream flow, only land use/cover parameter were changed while the other factors like rainfall, temperature and slope held constant during simulation. The mean annual surface flow of 2004 land use land cover decreased by 37.6% compared to 1994 land use land cover and on the other hand, the mean surface flow at 2014 land use increased by 8.6% compared to 2004 and land use decreased by 25.79% in 1994 land use. This is due to the increment of agricultural land from 1994 up to 2014 and the decreasing of grassland and forest coverage in the watershed. Generally, watershed hydrological response with respect to change in land use land cover within mille watershed indicated that the river flow regime has changed, with decrease in mean annual stream flow from 119.82 mm/year to 94.82 mm/year throughout the selected periods of this study (Tables 5 and 6).

| Flow | LULC of 1994 | LULC of 2004 | LULC of 2014 |
|---|---|---|---|
| Mean annual SURQ (mm) | 119.28 | 86.66 | 94.82 |
| Mean annual GWQ (mm) | 137.68 | 149.78 | 113.86 |
| Total water yeld (mm) | 367.24 | 341.43 | 329.99 |

**Table 5.** Annual surface runoff and ground water flow using 1994, 2004 and 2014 land use land cover maps.

| SURF (mm/month) | | | |
|---|---|---|---|
| **Month** | **LULC 1994** | **LULC 2004** | **LULC 2014** |
| Jan | 2.43 | 1.7 | 2.07 |
| Feb | 2.46 | 1.79 | 1.78 |
| Mar | 10.94 | 7.9 | 7.2 |
| Apr | 9.22 | 6.24 | 6.33 |
| May | 5.71 | 3.97 | 4.09 |
| Jun | 2.34 | 1.61 | 1.64 |
| Jul | 34.09 | 25.27 | 27.96 |
| Aug | 32.15 | 23.57 | 27.17 |
| Sept | 8.79 | 6.31 | 7.28 |
| Oct | 5.27 | 3.91 | 4.38 |
| Nov | 3.65 | 2.78 | 3.09 |
| Dec | 2.23 | 1.61 | 1.83 |

**Table 6.** Monthly stream flows for 1994, 2004, and 2014 period LULC SURF (mm/month).

## Evaluation of stream flow due to land use and land cover change

Mean monthly stream flow increased in the wet months and decreased in dry months during the study period. This was attributed to the increase in area under agriculture and decrease of forest land in the mille. Because rainfall satisfies soil moisture deficit more quickly in agricultural land than forest thereby generating more runoff in agricultural land. As a result, more runoff was generated in 2004 that 1994 there by stream flow. Moreover, expansion in agricultural land increase rainfall infiltrated into the soil and decrease surface runoff, therefore, the stream flow was increased in wet months and decreased in dry months. Because in wet months the stream flow was contributed more from surface runoff while in dry months it was contributed more from ground water. On the other hand, in 2014 stream flow was increased in dry and decrease in wet seasons as compared to 2004 due to further expansion of the land under agriculture and urban. Besides, slight decrease of the land under grassland and bare land which contributed for increases of ground water in the watershed. Because in grassland and bare land there is less infiltration due to compaction of soil, it generates more surface runoff. Mean monthly stream flow was decreased by 40.16 $m^3/s$ (13.43%) in wet months and decreased by 45.91 $m^3/s$ (69.64%) in dry months between the year 1994 and 2004. In 2014 it was decreased by 31.7 $m^3/s$ (11.85%) in wet and increased by 15.58 $m^3/s$ (19.12%) for dry month as compared to 2004 (Tables 7 and 8).

| Mean monthly stream flow ($M^3/s$) | Mean monthly stream flow change | |
|---|---|---|
| **Land use land cover map** | **From (1994-2004)** | **From (2004-2014)** |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1994 | 2004 | 2014 | $M^3/s$ | % | $M^3/s$ | % |
| 37.58 | 30.41 | 29.07 | 7.17 | 19.08 | 1.34 | 4.41 |

**Table 7.** Stream flow simulation on monthly basis for 1994, 2004 and 2014 land use land cover map.

| Land use land cover map | | | | | | Change of SURQ and GWQ | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1994 | | 2004 | | 2014 | | From (1994-2004) | | From (2004-2014) | |
| SURQ (mm) | GWQ (mm) | SURQ (mm) | GWQ (mm) | SURQ (mm) | GWQ (mm) | SURQ (mm) | GWQ (mm) | SURQ (mm) | GWQ (mm) |
| 119.28 | 137.68 | 86.66 | 149.78 | 94.82 | 113.86 | 32.62 | -12.1 | -8.16 | 35.92 |

**Table 8.** Surface runoff and ground water flow of the stream simulated using 1994, 2004 and 2014 land use/cover map.

## Conclusion

This study used a distributed hydrological modal soil and water assessment tool to assess the impacts of land use and land cover changing on the stream flow of a mille watershed between the years of 1994 to 2014. In order to evaluate the effects of land cover dynamics on stream flow in this watershed, the SWAT-CUP model was calibrated and validated primarily for hydrological modeling. The stream flow was calibrated for 1994, 2004 and 2014-LULC data. The results from calibration for three periods land use show vary good range (0.79, 0.82 and 0.85 for R2 and 0.75, 0.78 and 0.81 for NSE) between observed and simulated stream flow respectively. The results of validation were also very good range (0.83, 0.84 and 0.86 for $R^2$ and 0.78, 0.81 and 0.83 for NSE) respectively. It can be concluded from the land cover analysis done for the land use and land cover maps produced that there were significant changes in land use and land cover in the study watershed from 1994 to 2014. During the years from 1994 to 2014, land area under agricultural increased by 3.98% of total area because of the costs of other land cover classes, while land area under forest decreased by 44.7% of total area. Particularly the expansion of agricultural land was lead to deforestation of forest cover in the mille watershed during period from 1994 to 2014. This might be due to the population demand for cultivated lands were increased during the study period. Generally; Agricultural land, urban, dispersed shrub, and rocky bare land increased by 3.98%, 0.85%, 21.22%, and 41.76% respectively, according to analyses of changes in land use and cover. However, the amount of forest, shrub, acacia, and grassland in the watershed decrease by 44.7%, 2.56%, 23.25%, and 0.92% respectively.

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## Author Contributions

Abdu Mohammed and Hussen Ali designed the technical route of the study, analyzed the data and wrote the manuscript. Abdela yimer and Yonatan Tibebu proposed suggestions to improve the quality of the manuscript. The author has read and agreed to the published version of the manuscript.

## Conflict of Interest

The authors declare no conflict of interest.

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