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Impact of Land Use Land Cover Dynamics on Water Balance, Lake Ziway Watershed, Ethiopia

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Abstract

Quantification of Land Use Land Cover (LULC) change influence on river basin hydrology will enable local government and policy makers to formulate and implement effective and appropriate strategies to minimize the effect of future LULC change. In this research Soil and Water Assessment Tool (SWAT) with Sequential Uncertainty Fitting Intervals (SUFI-2) was used for analyzing the LULC changes on the Water balance of Katar and Meki River Basins, in the Rift Valley of Ethiopia. LULC map of 1996 and 2014 was used for the change analysis and the results revealed that the reduction of Forest and expansion of Agriculture and Built-up areas have an influence on the surface water spatial distribution and the water balance components. During the land use change periods, the increment of annual surface runoff from 67.54 mm to 129.14 mm has resulted from Katar river basin and 40.64 mm to 59.56 mm has resulted from Meki river basins. This result has revealed that the above land use changes are the main contributors to the increment of surface runoff on both river basins. With this regard, major changes from the Forested region on both river basins have resulted in runoff depth increment. Forexample, runoff depth increment of 4-53 mm to 10-65 mm on Katar river basin and 2-34 mm to 23-60 mm range from Meki river basin mainly from forested regions resulted. Therefore, LULC change is becoming a serious threat to Katar and Meki river basin, hence appropriate measures should have to be taken for the stabilization of the land cover change with the regional development plan. Furthermore, the outcome of this study serves for policymakers as a valuable information for the planning of best land management strategies and priorities for the region.

Keywords: LULC; SWAT; Water balance; Lake Ziway watershed

Introduction

Land use change is an undeniable and significant global ecological trend which is briefly noted by Agarwal [1,2] and included under the "three global changing effects: increasing concentrations of carbon dioxide in the atmosphere, alterations in the biochemistry of the global nitrogen cycle, and the on-going LULC change".

As per Abbaspour et al. LULC changes are highly pronounced in the developing countries that are characterized by agriculture-based economics and rapidly increasing human population caused by a number of natural and human driving forces [3]. Whereas natural effects such as climate change [4] are only over a long period of time, the effects of human activities are immediate and often direct. From human factors, population growth is the most important in Ethiopia as it is common in developing countries [5]. More than 85% of the population in Ethiopia lives in rural areas and directly depend on the land for its livelihood which insight that the demands of lands are increasing as population increases.

Assessing the effect of land use dynamics on the water is an imperative and challenge in hydrological studies. The exchange of energy and water through soil-vegetation-atmosphere system is impacted by land use change [6].

Land use and land cover changes may have immediate and long-lasting impacts on terrestrial hydrology and, alter the long-term water balance between rainfall and evapotranspiration and the resultant runoff [7]. In the short-term, destructive land use change may affect the hydrological cycle either through increasing the water yield or through diminishing, or even eliminating the low flow in some circumstances [8]. Savenije [9] suggested that in the long-term reduction in evapotranspiration and water recycling arising from land cover changes may initiate a feedback mechanism that results in the reduction of rainfall.

Due to localized and global climatic change and persistent land degradation, the region undergone in the change of evapotranspiration and runoff component of the hydrologic cycle which resulted in recurrent failure on crop production [3,8,10-12].

Low soil fertility coupled with a temporal imbalance in the distribution of rainfall and the substantial non-availability of the required water at the required period is the principal contributing factors to the low and declining agricultural productivity. Hence, proper utilization of the available soil and water resources is essential to Ethiopia's agricultural development and achievement of food security [13]. Poor land use practices and improper management systems have played a significant role in causing high soil erosion rates, sediment transport and loss of agricultural nutrients. Furthermore, limited measures have been taken to combat these problems [14].

The Impact of LULC changes on hydrology is vital for watershed management and development. These LULC changes have potentially large impacts on the relations between rainfall and run-off, however, a greater challenge is to quantify these impacts for large basins, where the interaction between LULC, climate characteristics, and the underlying hydrological processes are complex and non-static.

Depending upon the conceived output, the existing database, input variables and required analysis a semi-distributed physically based SWAT model is adopted for this study for modeling Water balance of the study area under the changing LULC.

The study regions contain two perennial Rivers (Meki and Katar river) that are flowing into Lake Ziway. But recently the rapid LULC changes caused by the clearing of the forest for agriculture production are presumed adversely affected the hydrological response of the Meki and Katar river basins [12]. In order to reduce onsite and offsite negative impacts of runoff as a result of a change in LULC, effective land and water development and management interventions need to be done. However, there is a lack of information on detailed analysis of land use and cover changes and its impact on the spatial distribution of runoff on Katar and Meki river basins so far. Therefore, evaluation of LULC change impacts on surface water spatial distribution would give insights for policymakers and a priority of order on watershed management plans.

Materials and Methods

Study area

Katar and Meki river basins drain to Lake Ziway which has an open water area of 434 km^2 with an average depth of 4 m and an elevation of 1636 m.a.s.l (Figure 1).

Meki River originates from the western plateau or highlands with elevation ranging from 3500 to 3600 m.a.s.l. by covering a total area of 2033 km^2. Meki River drains from the western mountains and escarpments including a vast swampy area as indicated on the 1996 LULC map. On the other side, Katar River starts flowing from the eastern volcanic chains ranging in altitude from 4000-4250 m.a.s.l. covering a total area of 3241 km^2.

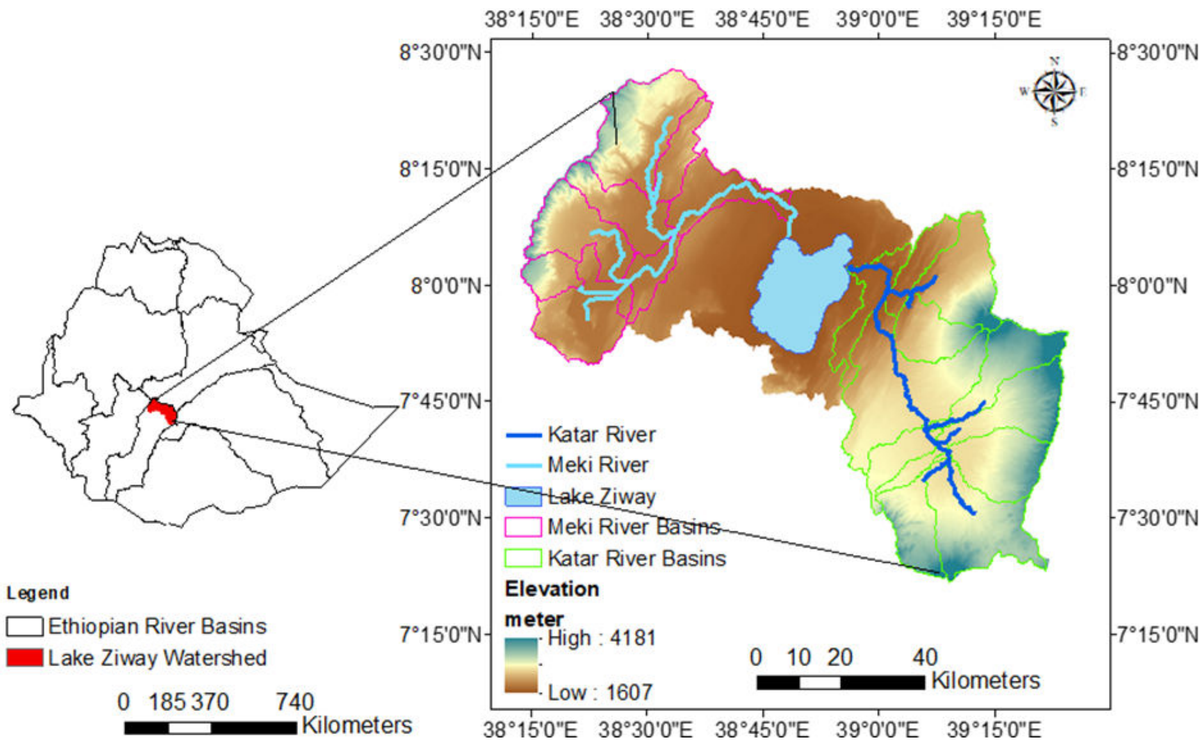

Figure 1: Location map of the study area shown in Ethiopia containing Katar and Meki River basins, Lake Ziway watershed its topography and the Lake.

Modeling river basins with SWAT

For this study, a Soil and Water Assessment Tool (SWAT) which is a physically distributed one is selected. The model was designed in the 1990s to predict the impact of land management practices such as LULC changes on water balance and spatial distribution of surface runoff in large complex watersheds over long periods of time [3,15,16].

The model spatially predicts the impacts at the subbasin even at the Hydrologic Response Units (HRUs) level [17]. Where HRUs represent the portion within the sub-basin that is comprised of a unique land cover, soil and slope combinations. HRUs categorizing within the sub-basins increases modeling accuracy and provides a better physical representation. The predicted values from each HRU are routed to obtain the total value for the watershed. SWAT requires spatial (soil, topography and land use) and temporal data (weather, hydrology) to set up and run the model [3,16,18]. SWAT simulates the hydrological cycle based on the water balance equation [15] as shown in Equation (1).

$$SWt = SWo + \sum_{i=1}^{t} (Rday - Qsur - Ea - Wseep - Qgw) \quad Eq(1)$$

Where: SWt - is the final soil water content (mm);

Swo- the initial soil water content,

Rday- the amount of precipitation,

Qsur- the amount of surface runoff,

Ea- the amount of evapotranspiration,

Wseep - and the amount of water entering the vadose zone from the soil profile and Qgw -the amount of return flow on day i (mm); and

t - is the time (days).

Runoff in SWAT in this study was estimated using the Soil Conservation Service (SCS) curve number (CN) method [19]. This method showed efficiency during computation and prediction of runoff depth with a given rainfall event [20] and mainly based on land use types, soil distribution, and hydrologic conditions. The SCS CN method computes runoff using Equation (2).

$$Qsurf = \frac{(Rday - 0.2S)^2}{(Rday + 0.8S)} \quad Eq(2)$$

Where Qsurf is the daily surface runoff (mm), Rday is the rainfall depth for the day (mm), and S is the retention parameter (mm). The retention parameter (S) is given in Equation (3).

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

Where S is the drainable volume of soil water per unit area of saturated thickness (mm/day), CN is curve number.

SWAT-CUP model and SUFI-2 algorism

According to Niraula et al. [21] the hydrological model has to be calibrated spatially to assess the impacts of LULC change. In this study, the SWAT model was calibrated spatially at Meki and Katar discharge gauging station by using SWAT Calibration and Uncertainty Procedures (SWAT-CUP) to assess the model uncertainty by performing calibration, validation, and sensitivity analysis. SWAT-CUP is selected due to the flexibility offered towards the limitations of the ArcSWAT calibration process.

SWAT CUP uses different algorithms for the sensitivity and uncertainty analysis. Some of them are Sequential Uncertainty Fitting version 2 (SUFI-2), Generalized Likelihood Uncertainty Estimation (GLUE) and Parameter Solution (PARASOL). In this study, the SUFI-2 strategy is used since it can provide wide marginal parameter uncertainty intervals in the model than the other techniques. SUFI-2 operates based on a Bayesian framework and identifies the parameter uncertainties through the sequential and fitting process. In SUFI-2, parameter uncertainty could emerge from the model itself and from its input, and from model parameters. SUFI-2 executes a combined optimization and uncertainty analysis of parameters using a global search method by optimizing many parameters through the Latin Hypercube sampling technique [22]. The detailed procedure of the SUFI-2 algorithm is shown below.

First, the objective function g(b) and the initial uncertainty ranges [bj, $_{abs\_mean}$, bj, $_{abs\_max}$] for the parameters are defined by choosing the a value of 0.5 Nash-Sutcliffe efficiency (NSE) criteria. where bj is the jth parameter; j=1,..., m; and m is the number of parameters selected for Katar and Meki river discharge. Then a Latin Hypercube sampling is carried out in the hypercube range [b_{min}, b_{max}] to assess the corresponding objective functions, and the sensitivity matrix J and the parameter covariance matrix C are estimated as shown on Equation (4) and (5).

$$J_{ij} = \frac{\Delta gi}{\Delta bj} i = 1....,C_2^n; j = 1,...,m \quad Eq(4)$$

$$C = S_g^2 (J^T J)^{-1} \quad Eq(5)$$

Where S_g^2 is all combinations of two simulations, S_g^2 is the variance of the selected objective function values resulted for the n runs. Then the 95% percent prediction uncertainty (95PPU) is calculated with two indices, such as r-factor and p-factor. The R-factor measures the quality of the calibration process by measuring the thickness of the 95PPU bracketing the observed data. Whereas the P-factor is the percentage of the observed data bracketed within the 95PPU. This index indicates a measure of the model's performance to capture possible uncertainties. In an ideal situation the, P-factor should have a value of 1 but, the R-factor value should be closer to zero, which implies the thinner graph of 95PPU overlaping with measured river flow data as shown in Equation (6).

$$r - factor = \frac{\overline{d}x}{\sigma x} \quad Eq(6)$$

Where σx is the standard deviation of the measured variable x; and is the average distance between the upper and lower boundary of 95PPU, as shown in Equation (7):

$$\overline{d}x = \frac{1}{k}\sum_{i=k}^{k}(Xu - XL)l \quad Eq(7)$$

Where l is a counter; k is the number of measured data points and the lower and upper boundary of the 95PPU are marked by QL (2.5 th) and QU (97.5th). Finally, to correct the initially large parameter uncertainties, parameter ranges updating was done which would reduce the value of which is quite large during the first sampling. Later the performance of SUFI-2 is evaluated by the coefficient of linear correlation (R^2), the coefficient of Nash-Sutcliffe Efficiency (NSE) [23] and the coefficient of Percent bias (PBIAS) between the measured and best-simulated data as shown in Equation (8-10):

$$R^2 = \frac{\left(\sum[Qsi - Qsi_{av}][Qob - Qob_{av}]\right)^2}{\sum[Qsi - Qsi_{av}]^2 \sum[Qob - Qob_{av}]^2} \quad Eq(8)$$

$$NSE = 1 - \frac{\sum(Qob - Qsi)^2}{\sum(Qob - Qob_{av})^2} \quad Eq(9)$$

$$PBIAS = \frac{\left(\sum_{i=1}^{n} Yi^{obs} - Yi^{sim}\right)\times 100}{\sum_{i=1}^{n}(Yi^{obs})} \quad Eq(10)$$

Input Data

The input data required by the SWAT model include climate, stream flow, and spatial data. The detail data period and the source are discussed below.

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Climate and streamflow

Daily climate data for the periods 1993-2013 were collected from Lake Ziway watershed meteorological stations, which were obtained from the Ethiopian National Meteorological Agency. The mean monthly rainfall (1993-2013) characteristics of the stations are shown in Figure 2.

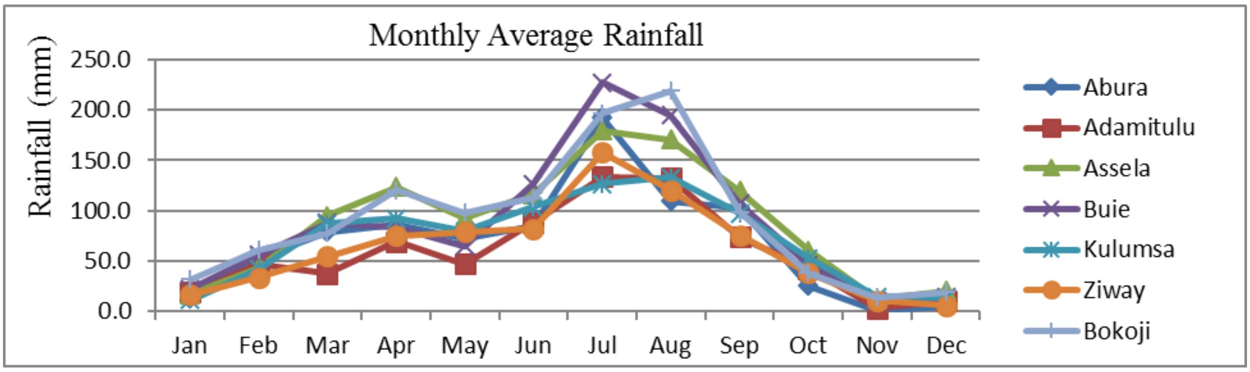

Figure 2: Mean monthly rainfall of selected station at Lake Ziway watershed (1993-2013) source NMSA.

SWAT requires daily streamflow data for baseline period calibration of the model to generate simulated inflows to the Lake under LULC change. The inflow data to lake Ziway were obtained from Katar and Meki rivers from the Hydrology Department of the Ministry of Irrigation Water and Energy of Ethiopia (MoIWE).

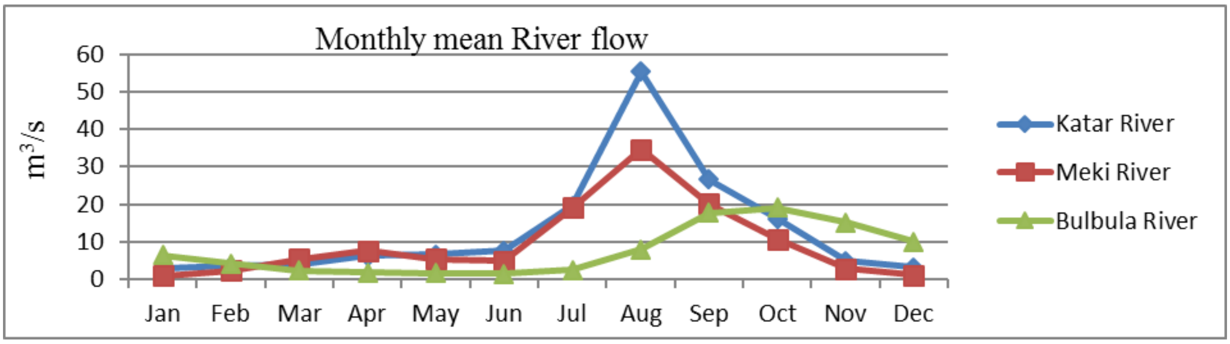

Figure 3: Mean monthly River flow of gauged stations at Lake Ziway Watershed (source MoIWE).

Digital elevation model and land cover

A 20 m × 20 m resolution Digital Elevation Model (DEM) was taken in this study to delineate the watershed and to analyze the drainage patterns of the land surface terrain. Sub-basin parameters such as slope gradient, slope length of the terrain, and the stream network characteristics such as channel slope, length, and width were derived from the DEM. Elevation of the study area ranges from 1607 masl and 4181 masl on both river basins as shown in Figure 1. Land use land cover map of the year 1996 and 2014 were also used to assess the responses of water balance components and surface runoff spatial variation on the region. Figure 4 shows the LULC map of both Meki and Katar River basins during 1996.

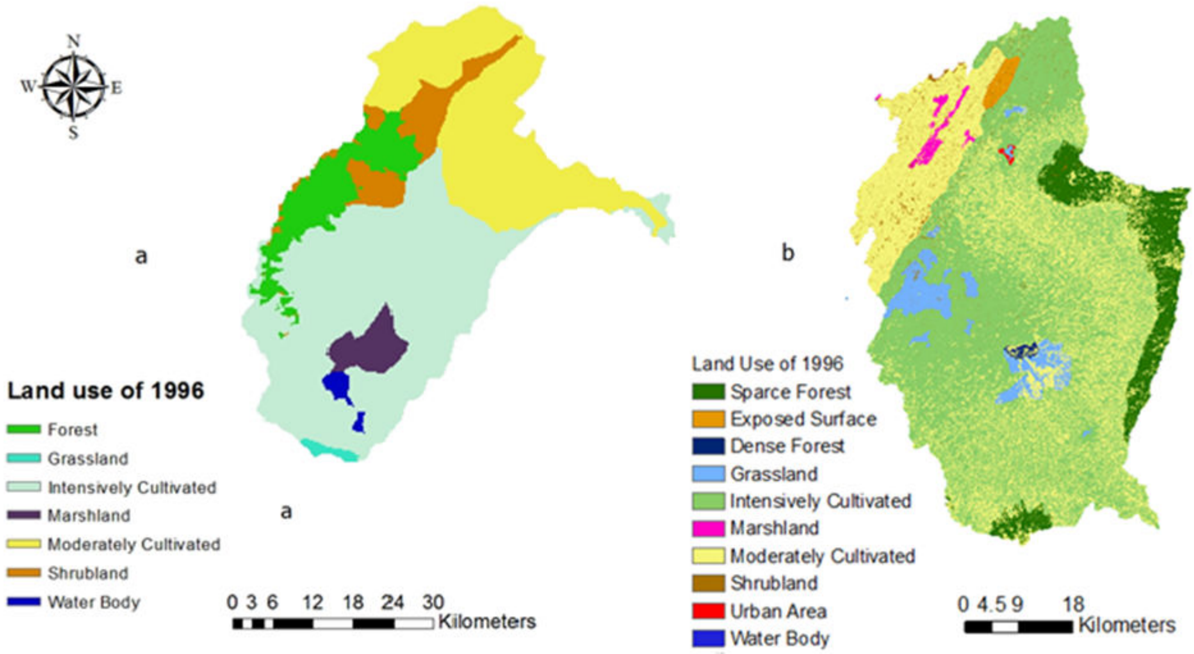

Figure 4: Land use land cover map Meki River Basin (a) and Katar River Basin (b) during the 1996 LULC.

Soil map: Soil data is also used as an input associated with all the information describing the physical and chemical properties such as soil texture, available water content, hydraulic conductivity, bulk density, and organic carbon content for different layers of each soil type. This map is also obtained from the Hydrology Department of the Ministry of Irrigation Water and Energy of Ethiopia (MoIWE) (Figure 5).

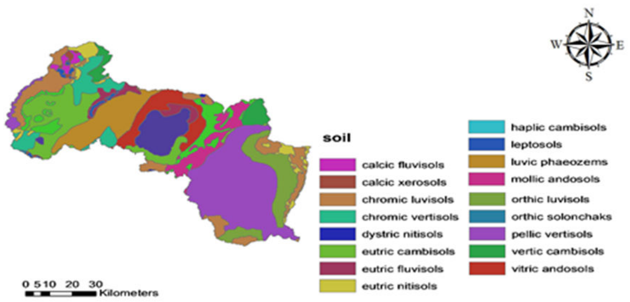

Figure 5: Soil type distribution over Lake Ziway watershed.

Basin delineation and HRU definition

Lake Ziway watershed was delineated with an outlet point at the downstream sites of Katar and Meki rivers. The overall watershed was further broken down into sub-basins based on the Algorithms provided by the SWAT model. With this information, the model automatically delineates the Katar river basin area of 3241 km^2 into 13 sub-basins and Meki river basin having area of 2033 km^2 into 9 subbasins (Figure 1).

On the other hand, analysis of the watershed is allowed by SWAT as a whole or by subdividing it into sub-basins containing the same portions of Hydrological Response Units (HRU) where the dominant land use, soil, and slope within the basin are regarded to be the land use, soil and slope in each sub-basin. A better estimation of stream flow and surface runoff distribution is given by the multiple scenarios that account for 5% land use, 10% soil and 10% slope threshold combination. With this threshold, Katar river basin resulted in 75 HRUs and Meki river basin resulted in 73 HRUs. This scenario results in the detailed land use, soil and slope database containing many HRUs, which in turn represent the heterogeneity of Katar and Meki River basins.

Results and Discussion

Sensitivity analysis

For the two river basins, sensitivity analysis was carried out for the period of 1993-2007 where the gauged data is found for flow calibration and validation. This was done from January 1993 to December 2007, which includes one year for the model warm-up period and nine years for model calibration period from 1993-2001 for Kater and Meki river flow. SWAT sensitivity analysis indicated for flow calibration, about 11 parameters were reported as sensitive in different degree of sensitivity. Among these 11 parameters, only 8 and 9 of them have an effect on the simulated result when changed on Katar river and Meki rivers respectively. So, on category specified by sensitivity classes, the parameters changed for flow calibration were highly sensitivity parameters as shown in Tables 1 and 2 based on lower p-value and higher t-stat value on both river basins.

During calibration period to identify the most important SWAT parameters, global sensitivity analysis [24] which allowed changing each parameter at a time [25] was employed in SWAT-CUP 2012. Indices such as t-Stat and p-value were used to provide a measure and significance of sensitivity, respectively [24]. Hence, higher t-test in absolute values measures high sensitivity while a p-value of 0 is more significant [24].

By performing the global sensitivity analysis and viewing the results at a different stage, the P-factor and p-value t-statistic can be used to eliminate non-sensitive parameters from the calibration process as shown in Tables 1 and 2.

Parameter Name	t-Stat	P-Value	Rank
V__ESCO.hru	-0.05113	0.959292	11
R__HRU_SLP.hru	0.160406	0.872796	10
V__ALPHA_BNK.rte	-0.22129	0.825195	9
R__SOL_AWC(..).sol	-0.35158	0.725689	8
V__GWQMN.gw	0.51544	0.60707	7
V__GW_DELAY.gw	0.768935	0.443246	6
R__OV_N.hru	-0.88215	0.379228	5
R__CN2.mgt	-0.9374	0.350188	4
V__SFTMP.bsn	-1.01977	0.309624	3
V__ALPHA_BF.gw	-1.23054	0.22059	2
R__SOL_K(..).sol	12.96871	0	1

Table 1: Sensitive flow parameters and their rank for Katar River Basin. Note: V implies replace the parameter with the fitted value; R indicates multiply the parameter with a fitted value.

A similar attempt was made for Meki River basin, the most sensitive parameters were identified by SWAT CUP sensitive analysis techniques and eight important parameters were identified by the model to be used for calibration. The most sensitive parameters that govern simulated stream flow on Meki River basin are described in Table 2.

Parameter Name	t-Stat	P-Value	Rank
R__BIOMIX.mgt	-0.18	0.86	9
R__SOL_AWC(..).sol	-0.36	0.72	8
R__REVAPMN.gw	-0.55	0.59	7
V__GWQMN.gw	-0.63	0.54	6
R__GW_REVAP.gw	0.68	0.5	5
V__ALPHA_BF.gw	-0.83	0.42	4
R__ESCO.bsn	-1.98	0.06	3
R__CN2.mgt	-24.36	0	2
R__SOL_Z(..).sol	92.37	0	1

Table 2: Sensitive flow parameters and their rank for Meki river Basin. Note: V implies replace the parameter with the fitted value; R indicates multiply the parameter with a fitted value.

Model Calibration and Validation

Model calibration

On the SWAT model calibration is done by adjusting model parameters to match the observed and simulated flow data as much as possible, with a limited range of deviation accepted. After each calibration, checking R^2 and NSE values and calibrate at least until the minimum recommended values were embraced by the model that is R^2>0.6, NSE>0.5 and PBIAS< ± 25% [26].

The model calibration was done from (January 1993-December 2001) for Katar as well as for Meki independently. The first one years of the simulation period was used as the warm-up period. The analysis of simulated result and observed flow data comparison was considered monthly. Until the model performance evaluation is satisfied, the sensitive parameters were changed again and again in the allowable range recommended by sensitivity analysis of the SWAT model. Calibration resulted after simulation from (January 1994-December 2001) in a coefficient of determination (R^2) of 0.71 and 0.73 and Nash-Sutcliffe efficiency (NSE) of 0.64 and 0.7, for Katar and Meki respectively (Tables 3 and 4). The result also indicated that model was calibrated satisfactorily to simulate monthly stream flows adequately. Seasonal variability trend and monthly average discharge were generally well captured (Figure 6).

Model validation

The purpose of model validation is to check whether the model can predict flow for another range of time period or conditions than those for which the model was calibrated. Model validation involves re-running the model using input data independent of data (meteorological data) used in calibration (by the differing time period of simulation) but keeping the calibrated parameters unchanged. In this study, the validation period is from (January 2002-December 2007) as shown on the hydrograph (Figure 7). Like Model calibration, the model performance evaluation parameters were calculated and checked whether the model performed very well or not and with this information the monthly streamflow resulted at R^2=0.79 and NSE=0.65 for Katar river and R^2=0.8 and NSE=0.74 for Meki River basins.

The simulation results are usually expressed by the 95PPU, they cannot be compared with the observation signals using the traditional R^2 and NSE statistics. For this reason, Nash, et al. and Neitsch, et al. [27,28] suggested using two measures, referred to as the P-factor and the R-factor. The P-factor is the percentage of the measured data bracketed by the 95PPU. This index provides a measure of the model's ability to capture uncertainties. Ideally, the P-factor should have a value of 1, indicating 100% bracketing of the measured data, hence capturing or accounting for all the correct processes. But the R-factor measures the quality of the calibration and indicates the thickness of the 95PPU. Its value should ideally be near zero, hence coinciding with the measured data. The combination of P-factor and R-factor together indicate the strength of the model calibration and uncertainty assessment, as these are intimately linked as shown in Tables 3 and 4.

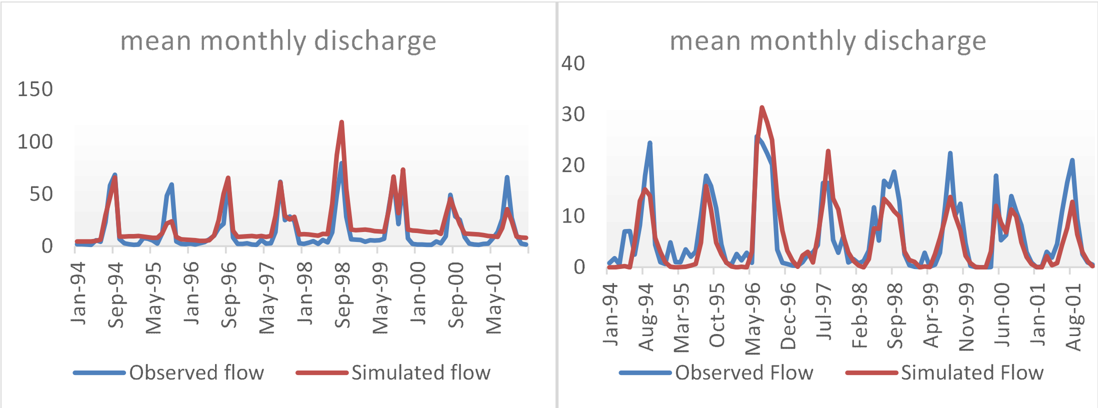

Figure 6: Monthly simulated and measured streamflow (cumecs) during the calibration period (1994-2001) for Katar (left) and Meki (right) river basins.

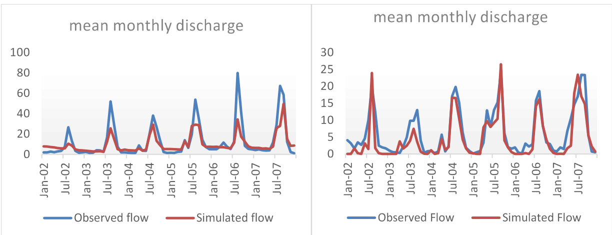

Figure 7: Simulated and measured monthly streamflow on during the validation period (2002-2007) for Katar (left) Meki (right) River basins.

Variable	p-factor	r-factor	R^2	NS	PBIAS
FLOW_OUT_2 (Cal)	0.62	0.44	0.71	0.64	-32.1
FLOW_OUT_2 (Val)	0.62	0.28	0.79	0.65	32.5

Table 3: The Calibration (1994-2001) and Validation (2002-2007) statistics for Katar River flow.

Variable	p-factor	r-factor	R^2	NS	PBIAS
FLOW_OUT_5 (Cal)	0.68	0.23	0.73	0.70	12.4
FLOW_OUT_5 (Val)	0.65	0.43	0.8	0.74	26.4

Table 4: The Calibration (1994-2001) and Validation (2002-2007) statistics for Meki River flow.

Analysis of land use land cover change

The LULC analysis revealed a significant change from the period 1996 to 2014. The analysis was made using dominant LULC on Katar and Meki river basins. LULC map of the year 1996 and 2014 was selected for analyzing the effect of the change on the simulated hydrological water balance of the selected river basins (Meki and Katar) depending on the spatial coverage in between the selected years. According to the work of Mayer and Turner [2], land cover changes are caused by a number of natural and human driving forces. Whereas natural effects such as climate change are felt only over a long period of time, but the effects of human activities are immediate and often radical.

LULC change analysis on Katar river basin

The land cover map of 1996 (Figure 8) showed that about 64.4% of the Katar river basin was covered by Intensively cultivated land, 11.6% by Moderately Cultivated Land, followed by 10.8% by sparse forest.

Intensively Cultivated Land areas mostly dominate southern, central and northern parts of the river basin during 1996.

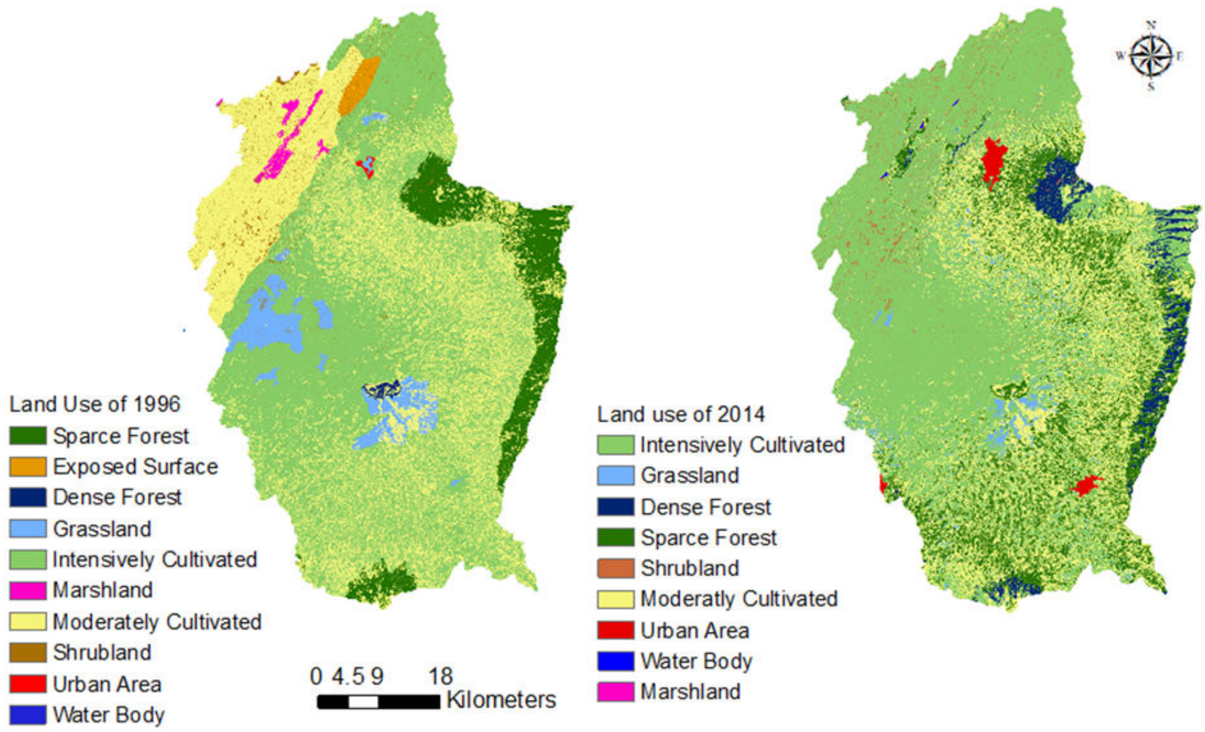

Figure 8: Katar river basin land use Land cover map of 1996 and 2014.

During the study periods, LULC change periods Moderately Cultivated land has shown increment from 11.9% to 24%, however Intensively Cultivated decreased drastically from 64.4% to 51.6% on these change periods (Figure 9). These values show that agricultural areas are increased with respect to increasing the demands for agricultural activities and urbanizations which can be resulted from the high population density in the study area. On the other hand reduction on Intensively Cultivated Land has attributed by freshwater resource reduction in the region which made state and private farms difficult in the regions [4,29].

Grassland having total coverage (5%) in 1996 was changed into agricultural land. The Shrubland had an area coverage approximately (0.056%) in 1996 and it increased to (3.13%) in 2014. On the contrary, from 1996 to 2014, the proportional extent of urban areas increased from 0.089% to 0.705%. Water bodies and the exposed surface had a relatively negligible percent of the area coverage from the study area as compared to 1996 land use classes possibly due to the high density of plantation and extreme climatic variability in the river basin.

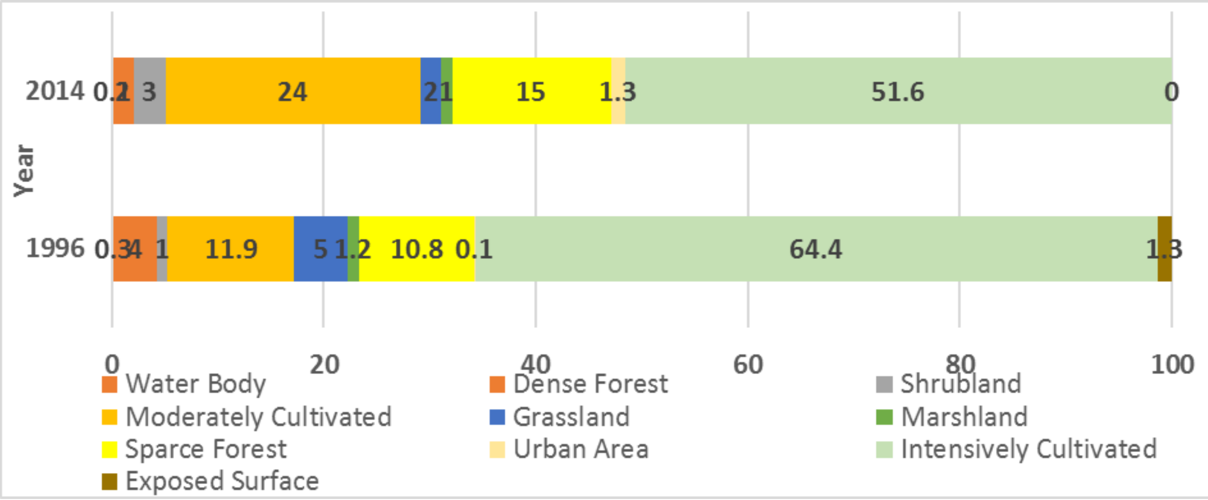

Figure 9: LULC change patterns of Katar River basin in 1996 and 2014.

From the observation in Figure 9, the parts of lands mostly changed throughout the two references years are located close to the residential areas. The previous study in the area suggested that cropland has declined [29]. The ever-growing demand for wood for different purposes has highly influenced the change in land use land cover condition of the Katar river basin.

LULC change analysis on Meki river basin

Most parts of Meki river basin was covered by agricultural and settlements land for both reference years. These referenced LULC patterns (Figure 10) are also revealed that the increase in Intensively cultivated lands mostly at the expense of Shrubland and Forest over the basin.

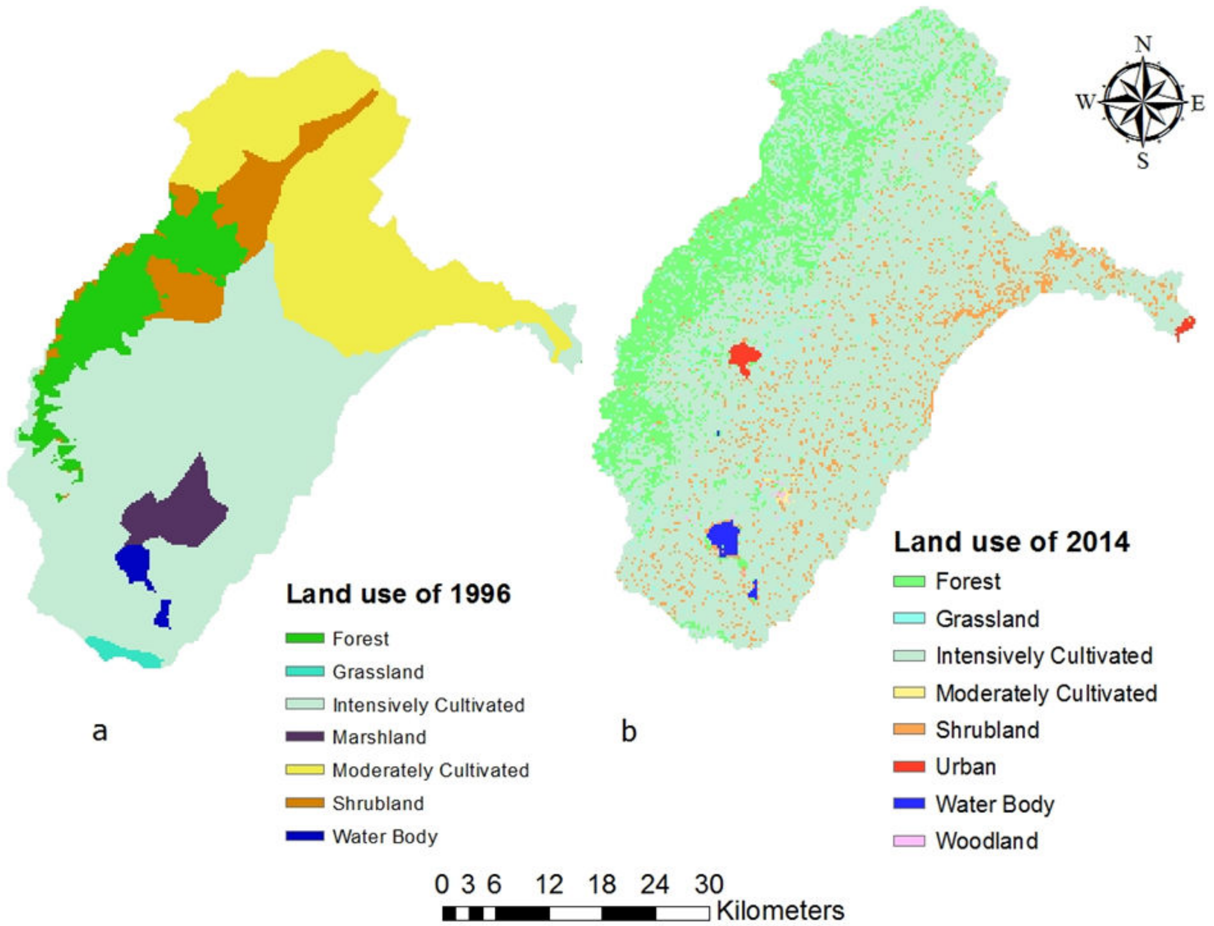

Figure 10: Meki river basin Land Use Land Cover map of 1996 and 2014.

As indicated in Figure 11 during the periods of 1996 and 2014 Moderately Cultivated land coverage showed a reduction from 22.6 to 17.9% whereas Intensively cultivated land showed increment from 46.3-58.1% during these periods. These values show that agricultural practices were increased with respect to increasing the demands for agricultural activities which can be resulted from the high population density in the study area [4]. Forest areas having 12.2% coverage of in 1996 reduced to 8.2% which is expected to be changed to Intensively cultivated land. A Shrubland area coverage of 15.3% in 1996 reduced to 8.3% during 2014.

The above land use changes were mainly driven due to the living community of Meki river basin is dependent on agricultural activities and the livelihood of peoples mainly relied on agricultural production. This situation triggered a decrease in Forest and Marshland, especially in the parts of lands which is close to the residential areas.

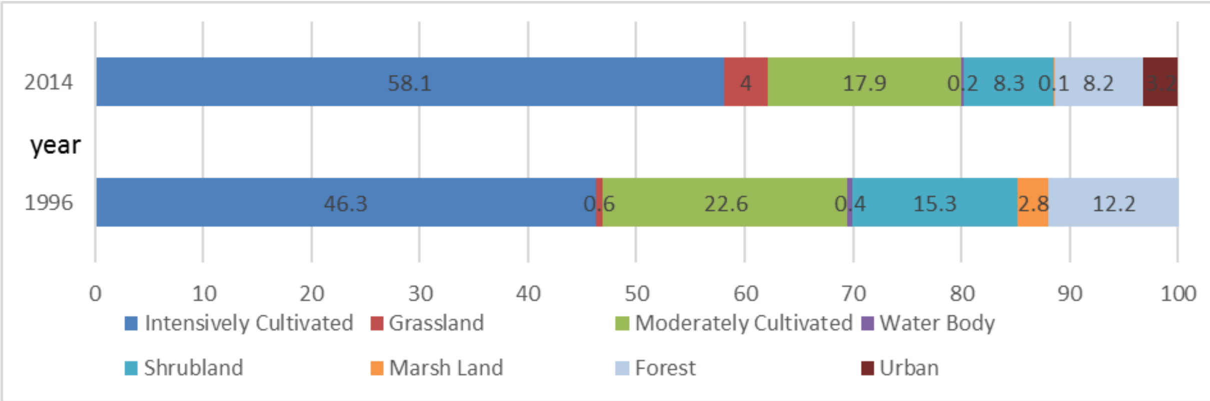

Figure 11: LULC patterns of Meki River basin in 1996 and 2014.

Impacts of LULC change on water balance at lake Ziway watershed

The studies of the land use land cover change impact on streamflow have received a considerable amount of interest in hydrology. LULC is an important characteristic in the runoff process that affects infiltration, erosion, and evapotranspiration. Understanding the effects of historic land use changes has importance for river flow to understand the future effects of LULC change on hydrological regimes at a watershed level. Along with these changes, considerable consequences are expected in the hydrological cycles and subsequent effects on water resources [17]. The SWAT model simulated for the two-time periods corresponding to the land use cover of 1996 and 2014 for the two river basins as shown below.

Impacts of LULC change on the water balance of Katar river basin

Simulation runs were conducted on monthly basis to compare the modeling outputs using the 1996 and 2014 land covers. The result indicated that the mean annual surface flow was increased by 91.20%, the mean Total AQ Recharge also increased by 16.94% and the mean annual total water yield of the basin increased by 78.56% respectively.

The previous study on the area showed, irrespective of annual rainfall pattern the discharge in Katar river showed a slight increment over the years. This result has indicated the importance of variables other than LULC change could also affect the flow in other watersheds [30]. This requires further study including investigating the relationship between the flow rate and the existing management of the watershed. However, the LULC change analysis agrees with the assertion by previous studies [30,31] that, an increase in urban set-up increases impervious surfaces and declining Forest lands, which accelerates surface runoff formation. Similarly, Ngo et al. [32] reported that an increase in annual surface runoff increased when Forestlands were converted to urban areas and decreased when Forestland gained a significant expansion.

The rise of mean annual basin-scale surface runoff mostly attributed to the increase of agricultural land and the decline in a woody shrub (Shrublands) as well as it may result from the expansion of agriculture and settlements areas owing to the reduction soil infiltration in the basin. More generally, increased in surface runoff from the Ethiopian basins because of intensified land use and land degradation brought by population increase [33].

A summary of the simulated average annual watershed runoff and water balance components values of Katar River basin for each reference's year (1996 and 2014) are given in Table 5.

Simulated (mm)	LULC map of 1996	LULC map of 2014
Surface runoff	67.54	129.14
Lateral Soil Q	14.09	48.99
Evapotranspiration	713.3	614.9
Total AQ Recharge	87.86	102.75
Total Water Yield	154.07	275.11

Table 5: Average annual simulated water balance components for 1996 and 2014 land covers on Katar River basin.

Impacts of LULC change on the water balance of Meki river basin

As it is discussed in the LULC changes analysis parts from 1996 to 2014 in the Meki watershed scale, the results revealed that most substantial changes occurred in LULC classes of Meki watershed are specifically agricultural, Marshland, Forest, and Shrubland. Expansion of agriculture and Grasslands have an influence on the water movements and water balance. The simulated average annual watershed runoff and water balance components values of Meki river basin for each reference's year (1996 and 2014) are given in Table 6. As indicated in Table 6 the simulated surfaces runoff and the corresponding water balances of Meki Watershed in 1996 is relatively lower in comparison to other references years of 2014.

The simulated surfaces runoff using LULC maps of 1996 is lower than the 2014 value. The primary reason could be the cultivated areas in the periods 2014 was relatively higher than the time periods of 1996. A relative increase in Grassland covers was noticed during the study periods which would have an expected impact for the reducing surface runoff in the study area. The rises of surface runoff and streamflow might come up along with the loss of Shrublands and an increment of urban areas which agrees with the study by Tang et al. [31]. Similarly, the total water yield, loss of water due evaporation of the watershed show a significant increment from 1996 to 2014.

Hence, the simulated average annual surfaces runoff showed increment by 46.55% from 1996 to 2014. The increase in surface runoff is possible as the result of higher surface runoff contribution from cultivated areas. The total groundwater recharge in the shallow aquifer has also increased by 34.11% from the 1996 LULC. With this regard, Han et al. [34] reported the amount of groundwater recharge can be affected by subcategories of different land use within agricultural and urban areas. However, the groundwater recharge rates and mechanisms can be significantly affected by the conversion of land towards irrigated or rain-fed agriculture [35,36]. The simulated average annual evapotranspiration showed an increment by 25.05% from 1996 to 2014. The increase in evapotranspiration maybe again associated with the decline of Waterbody in the river basin.

Simulated (mm)	LULC map of 1996	LULC map of 2014
Surface runoff	40.64	59.56
Lateral soil Q	30.21	34.58
Evapotranspiration	360.4	450.7
Total AQ Recharge	47.15	63.8
Total Water Yield	85.63	109.41

Table 6: Average annual simulated water balance components for 1996 and 2014 land cover on Meki River basin.

The rise of mean annual basin-scale surface runoff mostly attributed to the increase of agricultural land and the decline in a woody shrub (Shrublands) as well as it may result from the expansion of agriculture and settlements areas owing to the reduction soil infiltration in the basin.

Variability of surface runoff contributing area under LULC change

Figure 12 shows the interpolation of average annual streamflow variability for the 1996 and 2014 LULC over Katar River basin. The total average surface runoff to the outlet was 67.54 mm during the 1996 land cover and 129.14 mm by the 2014 land cover. Maximum surface runoff occurs over Grassland dominated area followed by Exposed Surface while the smallest amount of surface runoff contribution has come from Dense Forest, Sparce Forest, and from Intensively Cultivated Land during 1996 land cover. In 2014 the extent of Grassland and the Moderately Cultivated land was completely converted towards Intensively Cultivated Land and therefore, the 1996 maximum surface runoff amount of 248-297 mm range was increased to a range of 284-339 mm during 2014 on the Intensively Cultivated land. During the time period also minimum surface runoff contributing areas were increased from the range of 4-53 mm to 10-65 mm mainly on the area of degraded forest.

In 2014 the extent of Grassland and the Moderately Cultivated land from Meki river basin has changed towards Intensively Cultivated Land (Figure 10). With this regard, the 1996 maximum surface runoff amount of 163-198 mm range was increased to a range of 211-249 mm during 2014. On Meki river basin minimum surface runoff contributing areas were increased from the range of 2-34 mm to 23-60 mm mainly from the area of degraded Forest.

On the Katar and Meki River Basin expansion of agricultural land was exhibited which might have contributed to the increment of the surface runoff (Figure 12). Han et al. [34] mentioned subcategories of different land use within agricultural and urban LULC do have different responses for the hydrology of a region. Evidence from blue Nile region has also revealed a decline in woodland/ Forested regions increases surface run-off and increases groundwater components [37].

Previous authors [35,36] have reported the mechanism of hydrologic balance together with surface runoff to be driven by the conversion of land towards either of irrigated or rain-fed agriculture. Moreover, the conversion of Forest towards Intensively cultivated land, which usually has shallower root systems than the replaced Forest, has resulted in the changes of groundwater recharge quantity on Katar and Meki River Basin agrees with the studies in different places of the globe [38,39]. Furthermore, their high percentage increases in the surface runoff will greatly be influenced by an increment in built-up areas on both river basins, which indicated that areas that experienced more urban growth had a larger potential for increased average annual surface runoff. Various studies across the world also suggested that rapid urban expansion increased annual runoff, and flood volume [18,40,41].

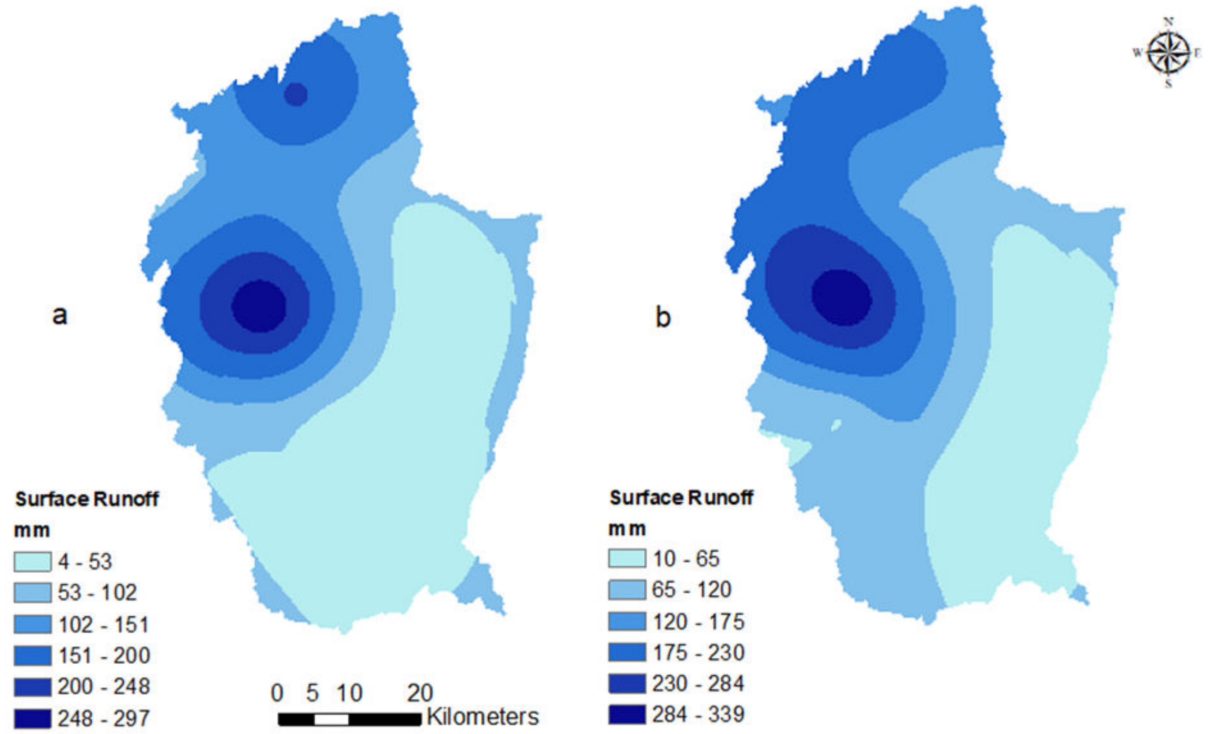

Figure 12: Kriging interpolation of surface runoff during the 1996 LULC (a) and 2014 LULC (b) on Katar river basin.

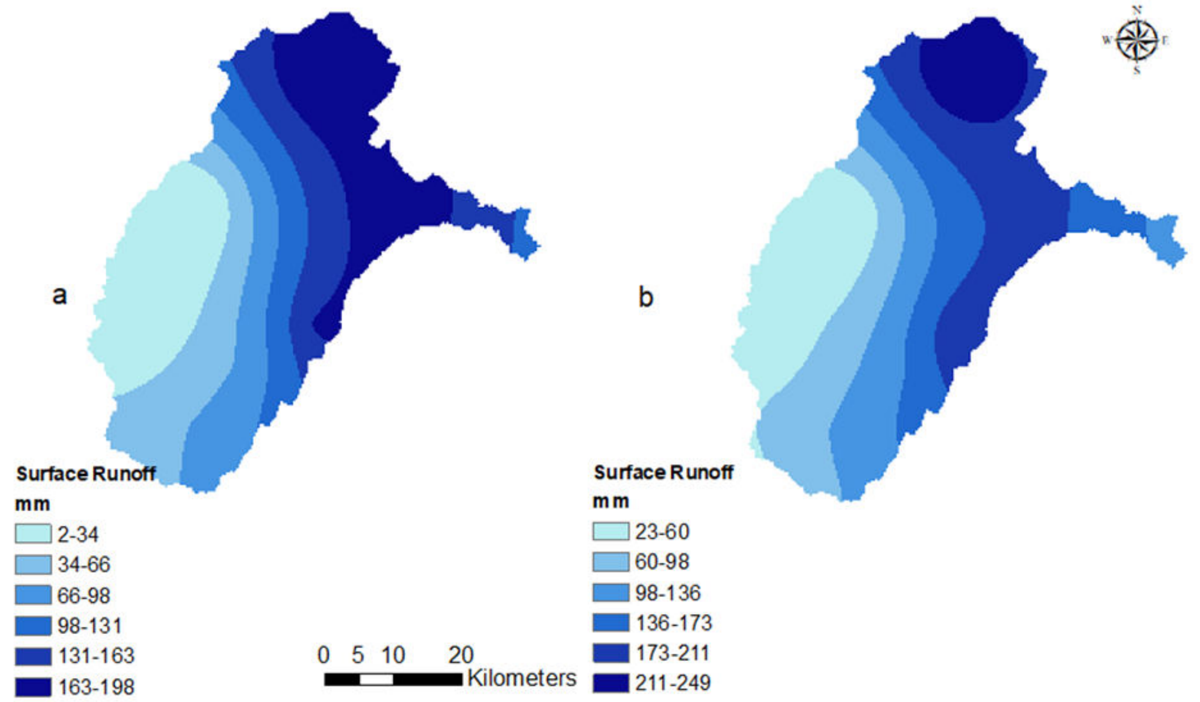

Figure 13: Kriging interpolation of surface runoff during the 1996 LULC (a) and 2014 LULC (b) on Meki river basin.

It is obvious that trees enhance infiltration of water into the soil, thereby reducing surface runoff that may occur during storm events. The study by Chandler et al. [42] showed that dense Forests are not only able to reduce surface runoff but also to 'soak up' runoff generated further up the hillslope. Therefore, Forests particularly planted downslope of areas where soil compaction or poaching is likely occurring is very important to mitigate surface flooding [43]. However, this mitigation action may not be efficient to provide this flood management strategy as it may be masked by land use effects on the soil hydraulic properties itself.

Therefore, it is important to give attention to both vegetation and land use types to take a management decision on protecting water quality and flooding. The increment of surface runoff due to a reduction in Forest and urbanization from this study can be used to make an informed decision and creates awareness of potential long-term impacts of land use change. It also implies that future land use management should consider mitigation approaches, such as low impact development mainly from intensive cultivation and urbanization.

Conclusion

In this study impacts of LULC between 1996 and 2014 were analyzed to assess spatial variation of areas contributing surface runoff towards Lake Ziway by two River basins namely Katar and Meki. SWAT was applied to the Katar and Meki river basins located in the Rift valley of Ethiopia in monthly time intervals using the sequential uncertainty fitting intervals. The model performance result showed that the SWAT model performed at R^2 of 0.71 and 0.73 and NSE of 0.64 and 0.7 for Katar and Meki river basins during the calibration period and R^2 of 0.79 and 0.8 and NSE of 0.65 and 0.74 during validation period respectively by showing a good agreement between measured and simulated flow.

For Katar and Meki river basins expansion of Intensively Cultivated Land and reduction of Forest land was maximum than other land use types. With this regard, there was also a remarkable loss of Grassland between the year 1996 to 2014. For the land use change periods, the increment of annual surface runoff from 67.54 mm to 129.14 mm has resulted from Katar river basin and 40.64 mm to 59.56 mm has resulted from Meki river basins. This situation has revealed that the above land use changes are the main contributors to the increment of surface runoff on both river basins. With this regard, major changes on the Forested region on both river basins have resulted in a change in the range of 4-53 mm to 10-65 mm runoff depth on Katar river basin. The same Forest land reduction has resulted in increment on runoff from a range of 2-34 mm to 23-60 mm from Meki river basin. The results obtained from this study identifies the major LULC changes that have affected the surface runoff changes. Furthermore, the outcome of this study serves for policymakers as a valuable information for the planning of best land management strategies and policies for the region.

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