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Evaluating the Effects of Watershed Characteristics on River Flow for the Case of Fetam River, Ethiopia

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Abstract: Evaluating the effects of watershed characteristics have impacted on the stream flow of the watershed by changing the magnitude of surface runoff and ground water flow. This study is mainly focusing the effects of watershed characteristics on the stream flow by changing SURQ and GWQ for the wet months (June, July, August) and dry months (January, February, March) through satellite Remote Sensing (RS) and Geographic Information System (GIS) integrated with the SWAT model, climate characteristics on stream flow, slope and rainfall effects on stream flow. ArcGIS used to generate land use and cover maps from Landsat TM and ETM+ acquired, respectively, in 1995, 2005 and 2015. The result of this analysis showed that the cultivated land has expanded during the study period of 1975-2002. Using the three generated land cover maps, three SWAT models set up were run to evaluate the effects of watershed characteristics on the stream flow of the study area. The performance of the SWAT model was evaluated through sensitivity analysis, calibration, and validation. Ten flow parameters were identified to be sensitive for the stream flow of the study area and used for model calibration. The model calibration was carried out using observed stream flow data from 1975 to 1993 and a validation period from 1993 to 2002. Both the calibration and validation results showed good match between measured and simulated stream flow data with the coefficient of determination (R2) of 0.89 and Nash-Sutcliffe efficiency (ENS) of 0.78 for the calibration, and R^2 of 0.91 and ENS of 0.88 of the validation period. The result of this analysis indicated that the mean monthly stream flow increased by 21.92m^3/s for the wet months while for the dry months decreased by 13.1 m^3/s. Generally, the analysis indicated that flow during the wet months has increased, while the flow during the dry months decreased. The SURQ increased, while GWQ decreased from 1975 to 2002 due to the increment of cultivated lands. The model results showed that the stream flow characteristics changed due to the land cover changes during the study period.

Keywords: Geographic Information System (GIS), Fetam Watershed, Land Use and Cover Change, Remote Sensing, Soil and Water Assessment Tool (SWAT), Surface Runoff

1. Introduction

Land and water resources degradation are the major problems on Ethiopian highlands. Poor land use practices and improper management systems have significant role in causing high soil erosion rates, sediment transport, loss of agricultural nutrients and most importantly the loss of water resources both in quantity and quality [1]. Erosion disturbs the channel substrate and as a result downstream areas may receive excessive sediment loads, leading to poor water quality [2].

In globally LULC influence on the hydrologic condition of the watershed needed for planners to formulate policies, to minimize the undesirable effects of future land cover changes for sustainable management of resources. Among thus, quantifying LULC changes within a catchment is an important component of monitoring watershed quality [3]. Therefore, estimating and understanding the impact of LULCC on stream flow is important to accurately assess the type and direction of changes occurring within the catchment.

The main to quantify and identify the scale and effect of watershed characteristics on stream flow for the case of Fetam River, Upper Blue Nile. It is important to understand the hydrology of the watershed particularly the physical processes occurring and the controlling factors within the watershed and hydrological processes reacting to the effect of watershed characteristics of Fetam catchment [4]. Since SWAT uses a two level disaggregation scheme; preliminary sub-basin identification is carried out based on topographic criteria, followed by further discretization using land use and soil type considerations. And also it is continuous time model that operates on a daily time step at basin scale [5].

Hydrologic modeling and water resources management studies are closely related to the spatial processes of the hydrologic cycle. Hydrological cycle is the continuous movement of water on, above and below the surface of the Earth [6]. This cycle is affected by several factors like climate and land use and land cover change, slope characteristics and river morphology [7]. Therefore, the interaction between land use and land cover and hydrological cycle should be well understood. Land use and land cover are highly changes especially in the developing countries which have agriculture based economics and rapidly increasing populations [8]. The land use and land cover changes are caused by a number of natural and human driving forces [9]. Natural effects are such as climate changes are only over 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 [10]. As it is common in developing countries. Therefore, the result of these activities is the land use and land cover changes due to daily human intervention [11].

This study is to examine the influence of catchment characteristics on stream flow, in the case of Fetam River, upper Blue Nile basin, Ethiopia is to evaluate the effect of watershed characteristics change on stream flow and predict its response for futures changes, to identify the most sensitive watershed characters that governs the runoff generation, to identify the features of the surrounding landscape on Fetam river watershed characteristics.

2. Materials and Methods

2.1. Description of the Study Area

Fetam watershed is found in Upper Blue Nile Basin, Ethiopia. This watershed is located in West Gojjam and Awi Administrative Zones of the Amhara National Regional State (ANRS) of Ethiopia. It is located at a distance of 420km north of Addis Ababa (130km from Bahir Dar town, capital city of the Amhara Region) and has a total drainage area of about 722.37km^2. Fetam watershed which is located in the Northern highlands of Ethiopia, within 10°6'30''North to 11°43'30''North and 36°49'00''East to 37°16'30''East and Elevation 2570m is located as shown figure 1.

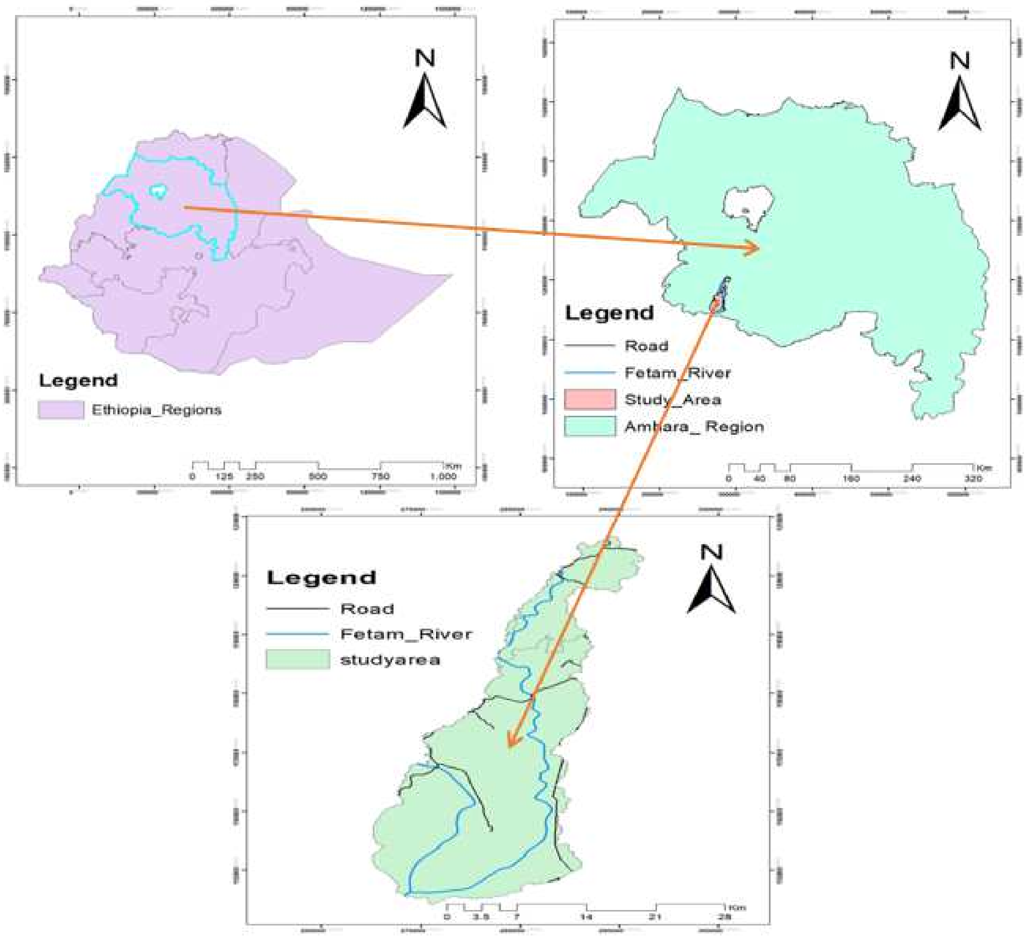


Figure 1. *Description of the study area.*

2.2. Soil Types and Geology

The regional geology of the Fetam watershed is dominated by the Tertiary volcanic rock and Quaternary Basalts. Based on FAO classification, in this watershed Six main soil types are found which include, are Vertisols, Cambisols, Lithosols, Nitosols, Acrisols and Rock Surfaces (figure 2). Generally, the soils types of this watershed area are characterized with shallow, moderate to deep and very deep in depth and sandy clay to clay texture types. The erodibility of these soils also varies from medium to very erodible characteristics.

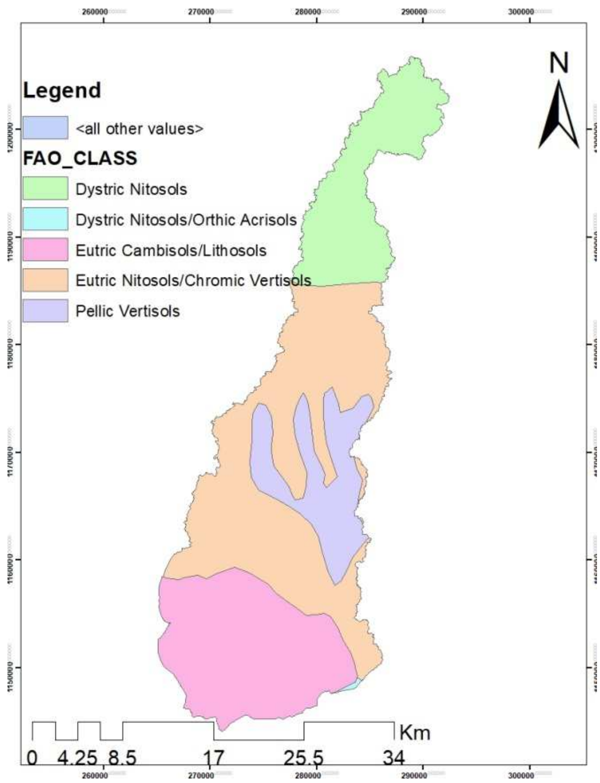


Figure 2. *Map of the soil types of Fetam watershed.*

2.3. Land Use and Land Cover

The land use land cover data combined with the soil cover data generates the hydrologic characteristics of the basin or the study area, which in turn determines the excess precipitation, recharge to the groundwater system and the storage in the soil layers. The land use/ cover map is shown in figure 3 based on FAO classification. In the watershed, there are Eight land use/land cover types such as cultivated land, shrub and bush land, grass land, forest land, marsh land, wood land, water body and built up area. Among these types, cultivated land is the dominant one in the watershed that covers most of the land area.

The SWAT model has predefined four letter codes for each land use category. These codes were used to link or associate the land use map of the study area to SWAT land use databases. While, preparing the lookup-table, the land use types were made compatible with the input needs of the model.

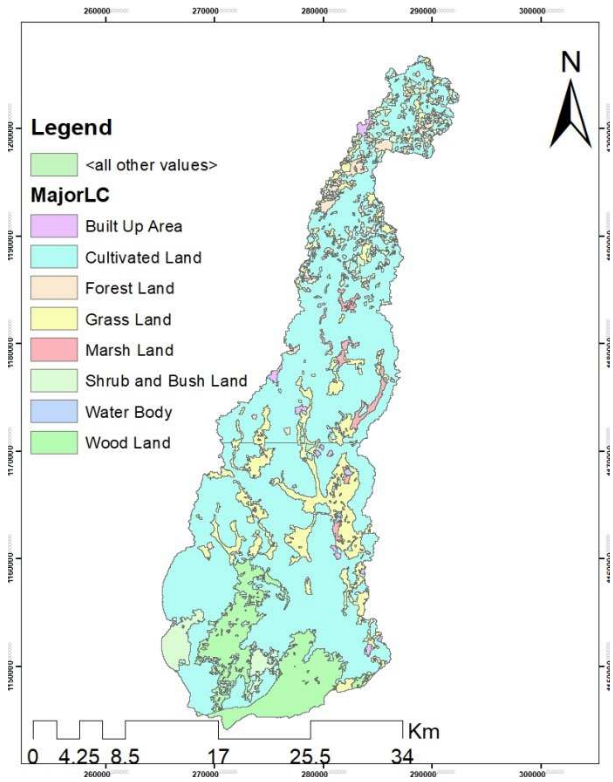


Figure 3. *Land Use/Land Cover Map of Fetam watershed.*

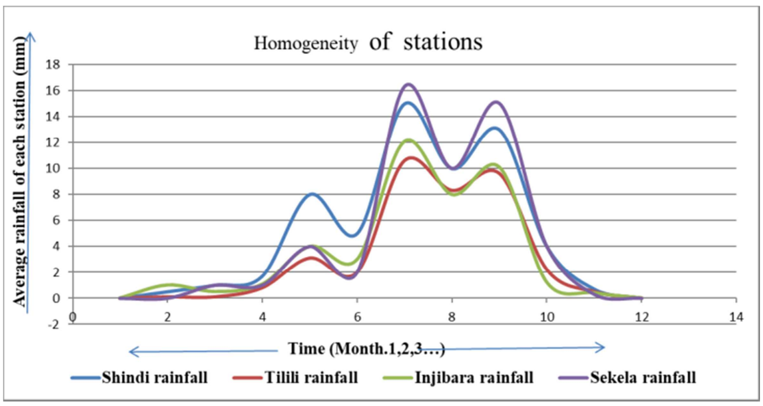


Figure 4. *Homogeneity test for selected station in Fetam catchment.*

2.4. Data Collection and Analysis

The meteorological data, such as rainfall and maximum and minimum temperature of different record length that is used for this study were collected from the National Meteorological Agency (NMA). Before using the data for further analysis, it is important to make sure that data are homogenous, correct, sufficient, and filling of the missing values. Observational errors may result missing and inconsistent data records [12]. Vandalism of recording gages and instrument failure are also other problems that results in incomplete data records, because of mechanical or electrical malfunctioning [13]. The hydrological data was required for performing sensitivity analysis for calibration and validation of the model. The daily Fetam watershed stream flow data (1975-2002) is quite sufficient and were collected from Ministry of Water and Energy Bureau.

2.5. Estimation of Aerial Rainfall

In this study, Thiessen polygon method was used to estimate mean areal rainfall because of its sound theoretical basis and availability of computational tools [14].

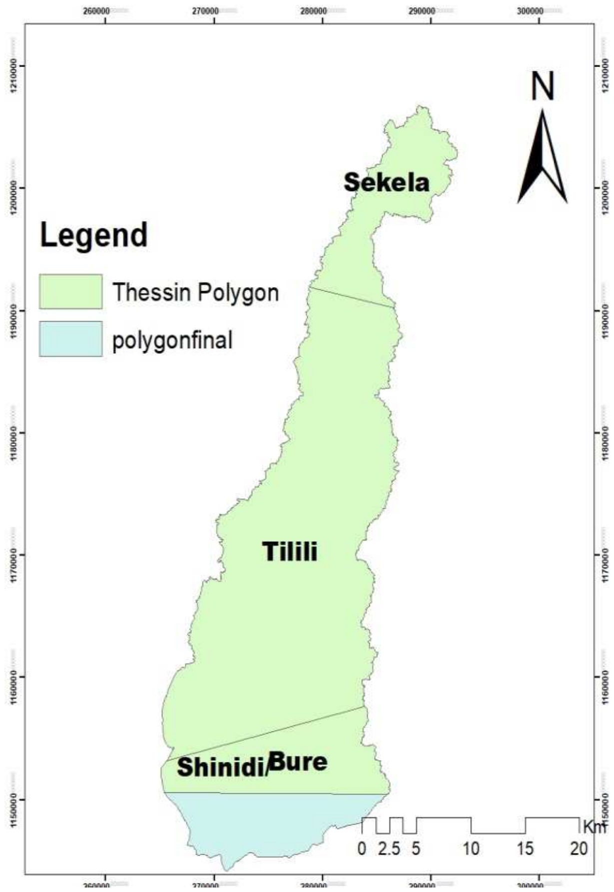


Figure 5. *Mean areal rainfall of Fetam watershed (Thiessen polygon method).*

2.6. Methodology

The study required different materials and methods to arrive at the stated objectives. Meteorological, hydrological, digital elevation model, land use and land cover and soil data were required. Those data were selected based on the objective of this research which answered the problem to the study area. The SWAT model interface with Arc GIS and SWAT Cup is used to evaluate watershed characteristics on stream flow. Arc GIS 10.4 and its extension Arc SWAT 2012 were used for hydrological model. The stream flow simulation by the SWAT model was calibrated and validated by comparing simulated stream flow with observed values. The basic data set that are required to develop an input database for the model are: topography, soil, land use and climatic data. In general the following conceptual frame work indicates that the overall methods and analysis to be followed throughout the study of this research is shown in figure 6.

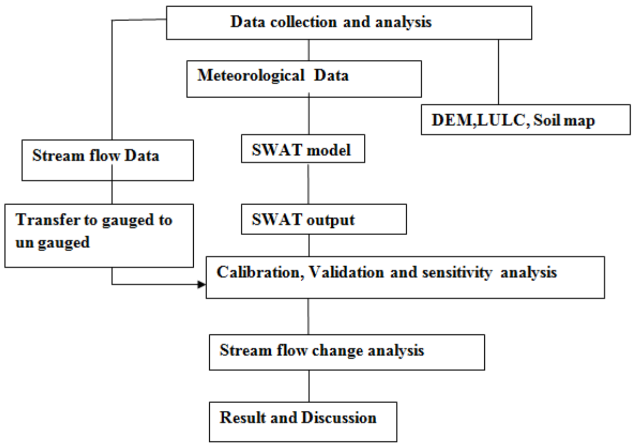


Figure 6. *Conceptual framework of SWAT Model.*

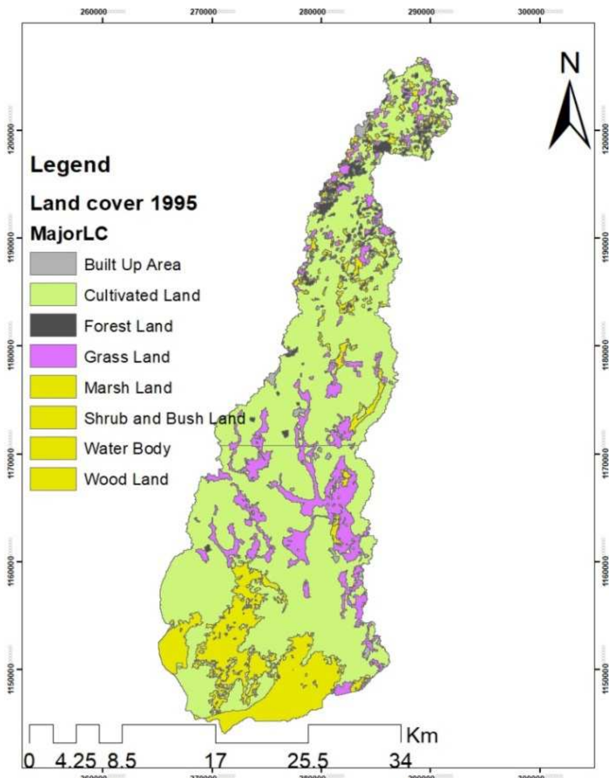


Figure 7. *LULC classification of 1995 Map.*

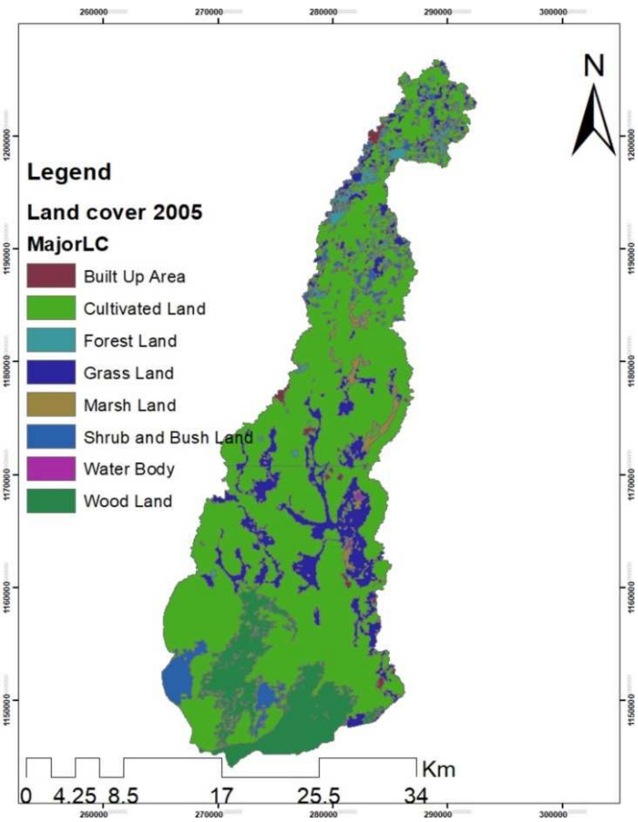


Figure 8. *LULC classification of 2005 map.*

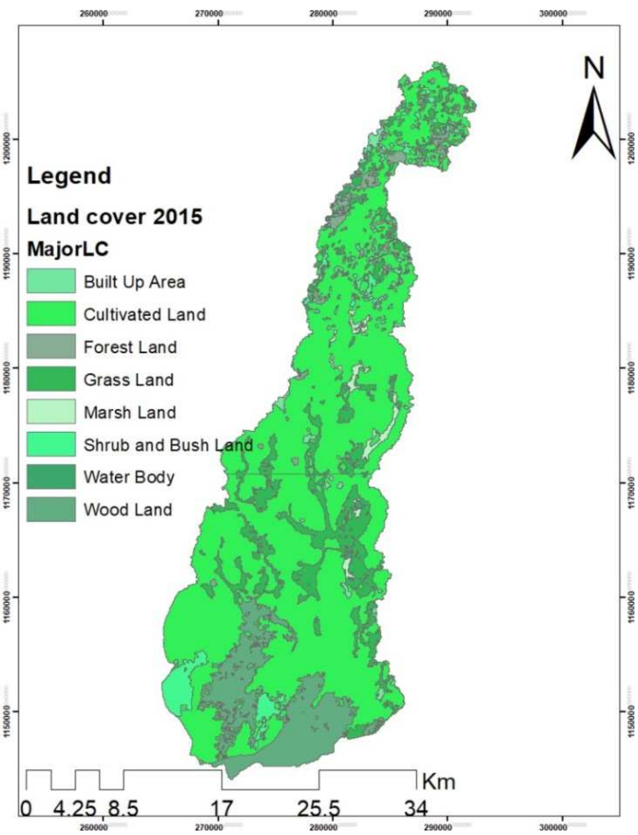


Figure 9. *LULC classification at 2015 map.*

A land use and land cover classification system which can effectively employ orbital and high-altitude remote sensor data should meet the following criteria [15]. Some of these criteria should apply to land use and land cover classification in general, but some of the criteria apply primarily to land use and land cover data interpreted from remote sensor data [16]. It is hoped that, at the more generalized first and second levels, an accuracy in interpretation can be attained that will make the land use and land cover data comparable in quality to those obtained in other ways [17]. For land use and land cover data needed for planning and management purposes, the accuracy of interpretation at the generalized first and second levels is satisfactory when the interpreter makes the correct interpretation 85 to 90 percent of the time [18].

3. Results and Discussion

3.1. Land Use and Land Cover Maps

The land use and land cover map of 1995 in that the total cultivated land coverage class was about 21% of the total area of the watershed. It increased rapidly and became 55% of the watershed in 2005 and 72% of the watershed in 2015. This is mainly because of the population growth that caused the increase in demand for new cultivation land and settlement which in turn resulted shrinking on other types of land use and land cover of the area [19]. On the land use and land cover map of the year 1995 in the total forest coverage was about 6% of the total area of the watershed. But in the year 2005 it reduced to almost 5% of the total area. These deforestation activities that have mostly takes place for the purpose of agriculture [20]. In general, during the 20 years period the cultivated land increased almost 45% whereas the forest land decreased 4%. The individual class areas and change statistics for the two periods are summarized in table 1.

3.2. Stream Flow Modeling

Sensitivity Analysis

Sensitivity analysis was performed on flow parameters of SWAT on monthly time steps with observed data of the Fetam River gauge station. For this analysis, 26 parameters were considered and only 10 parameters were identified to have significant influence in controlling the stream flow in the watershed or to identify the most sensitive watershed characters that governs the runoff generation

The result of the sensitivity analysis indicated that these 10 flow parameters are sensitive to the SWAT model i.e. the hydrological process of the study watershed mainly depends on the action of these parameters. Curve number (CN2), ground water delay (GW_DELAY), soil available water capacity (SOL_AWC), soil evapotranspiration factor (ESCO), and Effective hydraulic conductivity of the main channel (CH_K2) are identified to be highly sensitive parameters and retained rank 1 to 5, respectively. The other parameters such as, total soil depth (SOL_Z), Manning's roughness coefficient (CH_N2) Alpha factor (ALPHA_BF), threshold depth of water in the shallow aquifer required for return flow (GWQMN) and surface lag (SURLAG) are identified as slightly important parameters that were retained rank 6 to 10, respectively. The remaining parameters (16 parameters) were not considered during calibration process as the model simulation result was not sensitive to these parameters in the watershed.

Table 1. *Area of land covers types and change statistics of Fetam watershed for the period of 1995 - 2015.*

Land cover types	1995		2005		2015		2015-1995	
	Ha	%	Ha	%	Ha	%	Ha	%
Cultivated land	15227.362	21.23	39571.0577	55.17	51651.9000	72.01	36422.3003	50.78
Forest land	4375.2665	6.1	3514.5583	4.9	2840.2200	3.96	-1534.9296	-2.14
Shrub and Bush land	10170.701	12.18	6053.6474	8.44	560.7900	0.78	-9611.2411	-11.4
Grass land	44391.023	51.52	19946.9116	27.69	16905.449	22.3	-15485.574	-29.22
Marsh land	6168.408	8.6	2632.33246	3.67	68.8500	0.73	-6096.683	-7.87
Water body	57.3805	0.08	25.5177	0.03	7.17257	0.01	-24.8628	-0.07
Wood land	208.004	0.29	71.7257	0.1	7.17257	0.21	-134.2783	-0.08

Table 2. *Parameter sensitivity analysis.*

Parameters		Lower and Upper Bound	t-stat	p-values	Rank
Name	Description				
CN2	SCS runoff curve number (%)	-0.2 to 0.4	11.56	0.000	1
GW_DELAY	Ground water delay (days)	46.4 to 458.12	5.15	0.000	2
SOL_AWC	Soil available water capacity (water/mm soil)	-0.35 to 0.48	2.26	0.009	3
ESCO	Soil evaporation compensation factor	0.03 to 1.83	2.09	0.037	4
CH_K2	Effective hydraulic conductivity of the main Channel (mm/hr.)	-11.35 to 113.2	2.04	0.042	5
SOL_Z	Total soil depth (mm)	-0.2 to 0.2	1.97	0.049	6
CH_N2	Manning's roughness coefficient	-0.12 to 0.14	1.83	0.069	7
ALPHA_BF	Base flow alpha factor (days)	0.44 to 1.52	1.68	0.093	8
GWQMN	Threshold depth of water in the shallow aquifer required for return flow (mm)	0.08 to 2.56	1.63	0.103	9
SURLAG	Surface lag	0.04 to 1.06	1.59	0.111	10

These parameters are related to ground water, runoff and soil process and thus influence the stream flow in the watershed. The result of the analysis was found that Curve number (CN2) is the most important factor influencing stream flow in the Fetam watershed. The Curve number (CN2) is a direct index of surface runoff response to changes in stream flow. The Fetam watershed is characterized with tertiary basalt and volcanic regional geology that have good potential for ground water recharge. The other most influencing stream flow parameter in this analysis is the ground water delay (GW_DELAY).

Calibration was done for sensitive flow parameters of SWAT with observed average monthly stream flow data. The stream flow data of fetam river is 1975-2002 was recording out of this 1975-1993 for calibration and 1993- 2002 for validation. In this procedure, the values of the parameters were varied iteratively within the allowable ranges until the simulated flow as close as possible to observed stream flow. Then, auto calibration was run using sensitive parameters that were identified during sensitivity analysis. Table 3 presents the result of calibrated flow parameters.

Table 3. *Flow sensitive parameters and their fitted value in SUFI_2.*

Parameters		Lower and upper bound	Fitted value
Name	Description		
CN2	SCS runoff curve number (%)	-0.2 to 0.4	0.09
GW_DELAY	Ground water delay (days)	46.4 to 458.12	447.41
SOL_AWC	Soil available water capacity (water/mm soil)	-0.35 to 0.48	0.05
ESCO	Soil evaporation compensation factor	0.03 to1.83	1.73
CH_K2	Effective hydraulic conductivity of the main Channel (mm/hr.)	-11.35 to 113.25	52.2
SOL_Z	Total soil depth (mm)	-0.2 to 0.2	- 0.18
CH_N2	Manning's roughness coefficient	-0.12 to 0.14	-0.1
ALPHA_BF	Base flow alpha factor (days)	0.44 to 1.52	0.61
GWQMN	Threshold depth of water in the shallow aquifer required for return flow (mm)	0.08 to 2.56	1.97
SURLAG	Surface lag	0.04 to 1.06	0.96

3.3. Calibration and Validation of Stream Flow Simulation

During this step, the model was run for period of 27 years from 1975-2002. Calibration was performed for 18 years from 1975 to 1993. The calibration result for monthly flow is shown in the figure 10. The result of calibration for monthly flow showed that there is a good agreement between the measured and simulated average monthly flows with Nash-Sutcliffe simulation efficiency (ENS) of 0.78 and coefficient of determination (R^2) of 0.89 as shown in Table 4.

The model validation was also performed for 9 years from 1993 to 2002 without further adjustment of the calibrated parameters. The validation result for monthly flow is shown in the figure 11. The validation simulation also showed a good agreement between the simulated and measured monthly flow with the ENS value of 0.88 and R^2 of 0.91 as shown in Table 4.

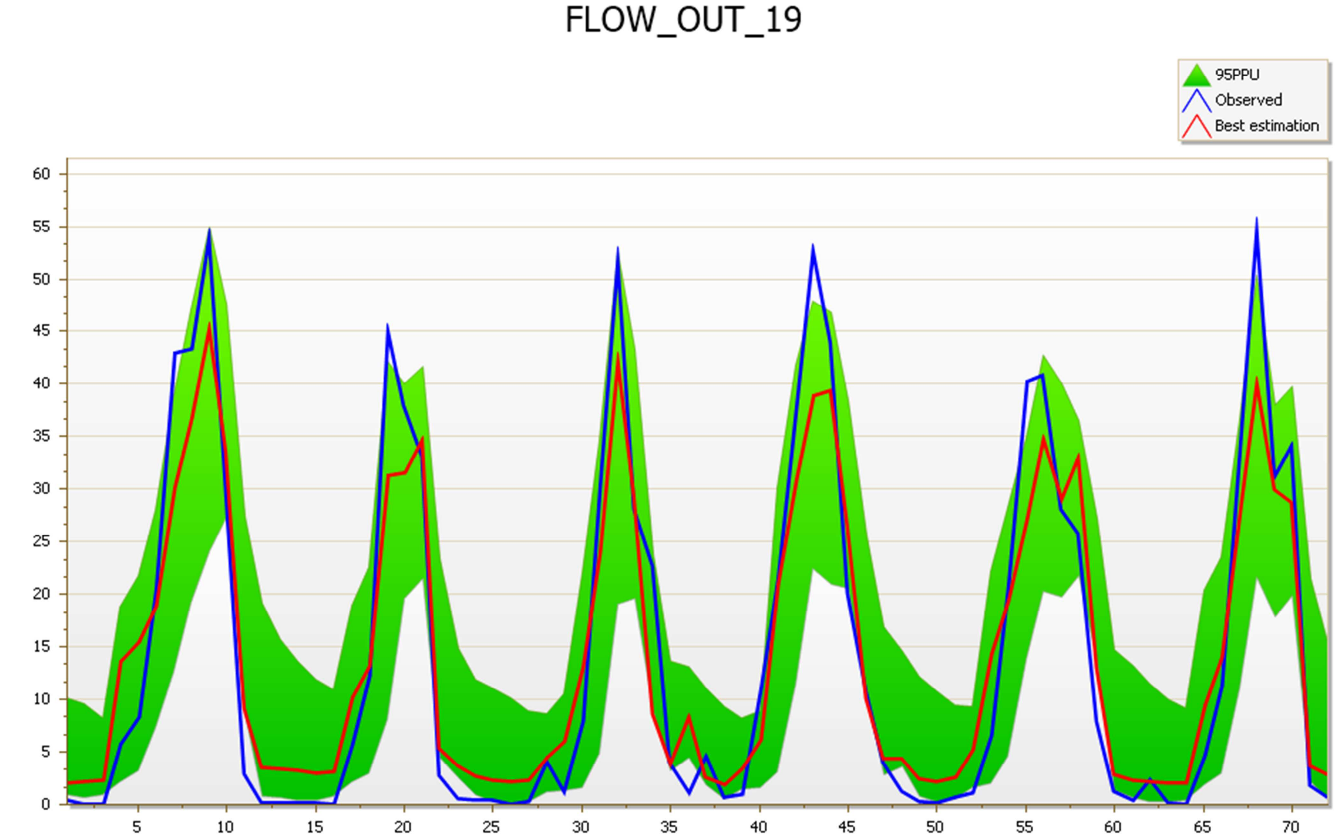


Figure 10. *Comparison of observed and simulated stream flow (1975 to 1993) for model calibration.*

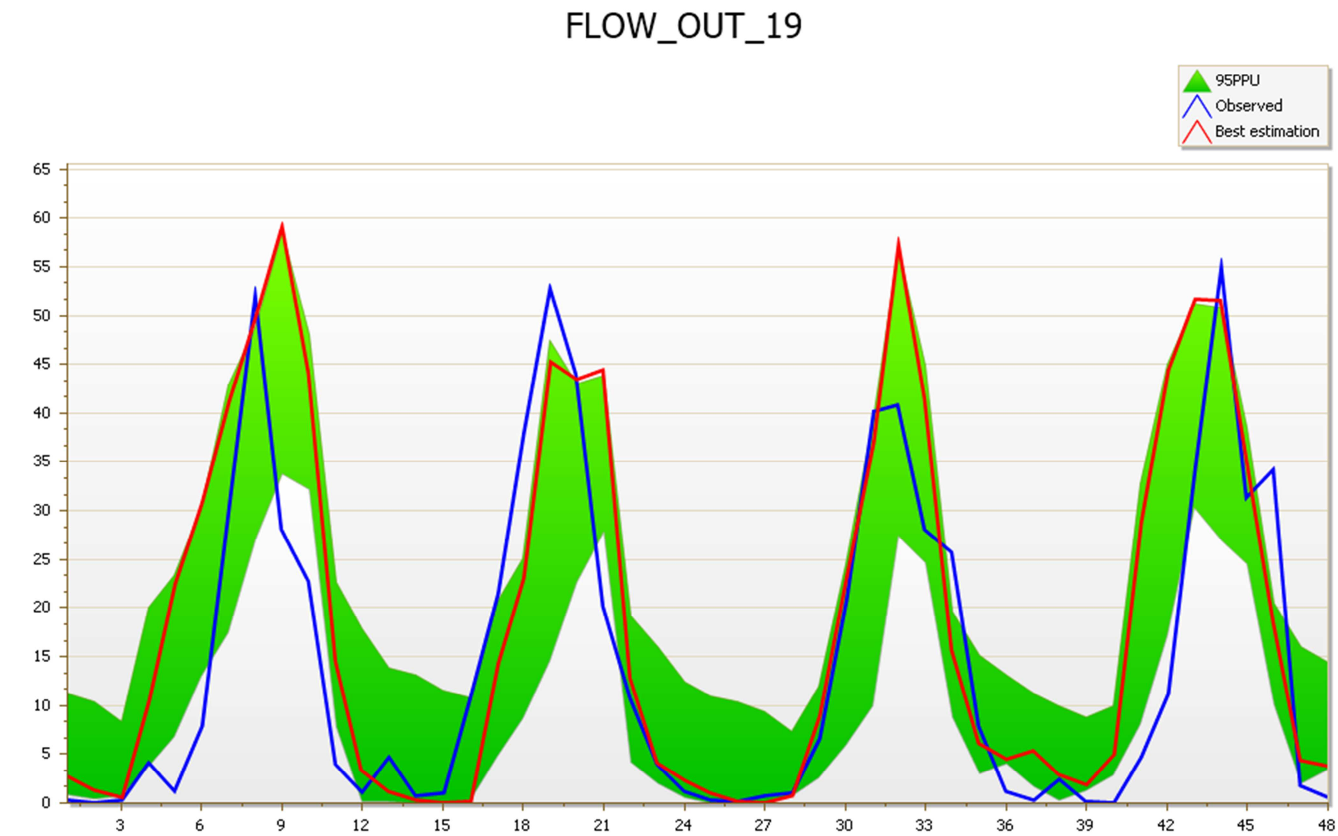


Figure 11. *Comparison of observed and simulated stream flow (1993-2002) for model validation.*

The measured and simulated average monthly flow for Fetam was obtained, during the calibration period; they were 26.467 and 24.940m^3/s, respectively. The measured and simulated average monthly flow for the validation period was 24.614 and 25.910m^3/s, respectively. These indicate that there is a reasonable agreement between the measured and the simulated values in both calibration and validation periods (Table 4).

Table 4. *Comparison of Measured and simulated monthly flow for calibration and validation.*

Period	Average monthly flow (m^3/s)		ENS	R^2
	Measured	Simulated		
Calibration (1975-1993)	26.467	24.940	0.78	0.89
Validation (1993 - 2002)	24.614	25.910	0.88	0.91

As indicated in the Table 4, the model performance values for calibration and validation of the flow simulations are adequately satisfactory. This indicates that the physically processes involved in the generation of stream flows in the watershed were adequately captured by the model. Hence, the model simulations can be used for various water resource management and development aspects.

3.4. Change in the Seasonal Stream Flows

After calibrating and validating of the model using the two land use and land cover maps for their respective periods of 1975 to 1993 and 1993 to 2002 respectively, SWAT was run using the two land cover maps for the period of 1995 to 2005. This process gave the discharge outputs for both land use and land cover patterns [21]. Then, these outputs were compared and the discharge change during the wettest months of stream flow taken as June, July and August and driest stream flow are considered in the months of January, February and March were calculated and used as indicators to estimate the effect of land use and land cover change on the stream flow [22]. Table 5 presents the mean monthly wet and dry month's stream flow for 1995 and 2005 land use and land cover maps and its variability (1975 -2002).

Table 5. *Mean monthly wet and dry month's stream flow and their variability (1975-2002).*

Mean monthly flow (m^3/s)				Mean monthly flow change	
Land use/cover map of 1995		Land use/cover map of 2005			
Wet months (Jun, Jul, Aug)	Dry months (Jan, Feb, Mar)	Wet months (Jun, Jul, Aug)	Dry months (Jan, Feb, Mar)	Wet	Dry
145.75	67.97	167.67	54.87	+21.92	-13.1

As indicated in the table 5, the mean monthly stream flow for wet months had increased by 21.92 m^3/s while the dry season decreased by 13.1 m^3/s during the 1975-2002 periods due to the land use and land cover change.

Table 6 presents the SURQ and GWQ of the stream simulated using 1995 and 2005 land use and land cover map for the same period.

Table 6. *Surface runoff and Ground water flow of the stream simulated using 1995 and 2005 land use/cover map.*

Land use/cover map of 1995		Land use/cover map of 2005		Change of SURQ & GWQ	
SURQ (mm)	GWQ (mm)	SURQ (mm)	GWQ (mm)	SURQ (mm)	GWQ (mm)
39.75	49.50	45.39	43.70	+5.64	-5.80

3.5. Climate Characteristics on Stream Flow

Climate characteristics include precipitation, temperature, wind, relative humidity and other Metrological elements for a given region over a long period of time [23]. In and around the study area there are four metrological stations, all station data's required as an input parameters for estimation of reference evapotranspiration by Penman-Monteith, the weights of those stations is estimated by thiessen polygon method. The climate index was important parameter to analysis the effect of climate index on stream flow by compared the climate index value because the larger climate index shows that the watershed is generated more stream flow discharge and the smallest climate index shows that the watershed generated small discharge [24].

using the station in and around the watershed from 1975-1990 and based on the Thiessen polygon area and the weights of the station contribute to the watershed, the long-term annual rainfall for was 1105.4 mm/year and from the SWAT model Evapo-transpiration of the watershed was 1187.9 mm/year, so the climate index was calculated by average annual rainfall divided by annual Evapo-transpiration. The result would be 1105.4 mm/year per 1187.9 mm/year =0.93 and the simulated annual stream flow from the SWAT model was recorded 108.5 mm/year.

3.6. Rain Fall Effects on Stream Flow

Rain fall data was affect the stream flow in different ways, rainfall intensity, rainfall duration and annual rainfall amount affect the stream flow [25]. But for this study considered only average annual rainfall amount with 15 and 12 year interval and using the 1975-1990 and 1990-2002 rainfall, for the first run, SWAT model were run by using all the climate data from 1975-1990 and 1995 LULC, for the next run, the SWAT model were run by changing only the rainfall data of 1990-2002 keeping the other model input constant. Change of stream flow by changing of rainfall as shown in Table 7 and Figure 12.

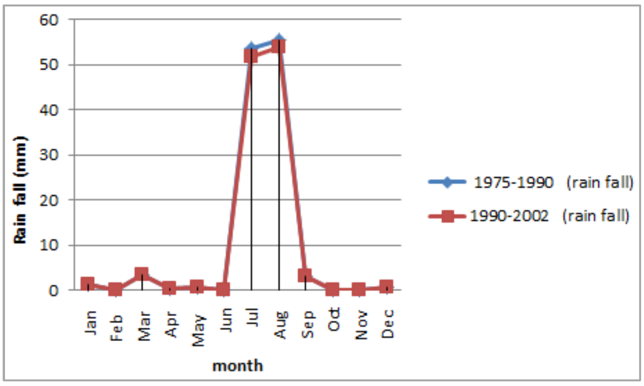


Figure 12. *Monthly and annual surface runoff from rain fall change.*

Table 7. *Change in rainfall amount effects on stream flow.*

Month	1975-1990 (rain fall)	1990-2002 (rain fall)
Jan	1.19	1.15192
Feb	0.01	0.00968
Mar	3.43	3.32024
Apr	0.43	0.41624
May	0.66	0.63888
Jun	0.12	0.11616
Jul	53.5	51.788
Aug	55.61	53.83048
Sep	3.17	3.06856
Oct	0.05	0.0484
Nov	0.18	0.17424
Dec	0.59	0.57112
AV annual flow (mm)	128.78	134.14578

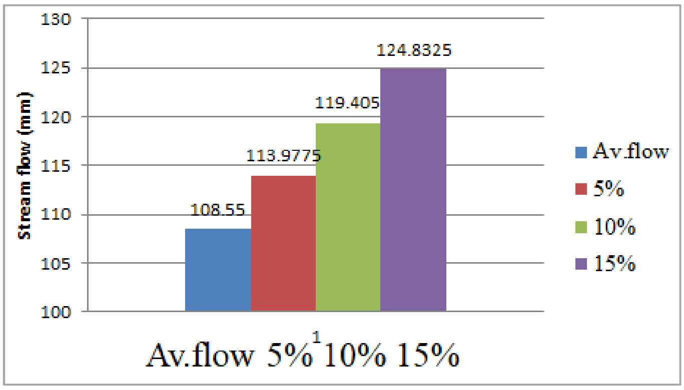
From the above table and figure, the model output result showed that the first 15 year (1975-1990), the annual average rainfall was 1105.4 mm/year and the next 12 year (1990-2002) average rainfall was 1062.7 mm/year. The first SWAT model run the annual stream flow from watershed obtained 128.78 mm/ year and from the 2nd model run the annual stream flow was 134.15 mm/ year. This result shows that the 2nd 12 year average annual rainfall was decreased by 8.7% compared from the first 15 years average annual rainfall and the annual stream flow from the watershed was decreased by 5.9%. According to Singh [26] rain fall amount was significant effect on stream flow that generate from the watershed, so we conclude that from this study rain fall amount affect the stream flow in fetam watershed.

3.7. Slope Effect on Stream Flow

Slope is one of the factors which influence the stream flow velocity. Where higher slope result in higher velocity of flow, therefore the water will travel quickly to reach the river outlet [27]. For this study five slope class based on FAO major slope classes were classified [28]. The average slope of tributary channel in each sub basin is used to evaluate the change of slope to change stream flow [29]. The scenario of the study was developed based on increased the slope by 5% above the average tributary channel slope [30]. Each sub basin tributary channel slope increase 5%, 10%, 15% from average slope and using SWAT executive run [31]. The text out from SWAT model and the swat executive were run by increase the slope. The result of the model was presented in Table 8 and Figure 13.

Table 8. *Monthly stream flow change for slope increased by each percent.*

month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Av. flow	0.57	0.04	1.89	0.32	0.58	0.56	47.24	52.8	3.59	0.37	0.3	0.29
5%	0.5985	0.042	1.9845	0.336	0.609	0.588	49.6	55.44	3.77	0.389	0.315	0.3045
10%	0.627	0.044	2.079	0.352	0.638	0.616	51.96	58.08	3.949	0.407	0.33	0.319
15%	0.6555	0.046	2.1735	0.368	0.667	0.644	54.33	60.72	4.129	0.426	0.345	0.3335



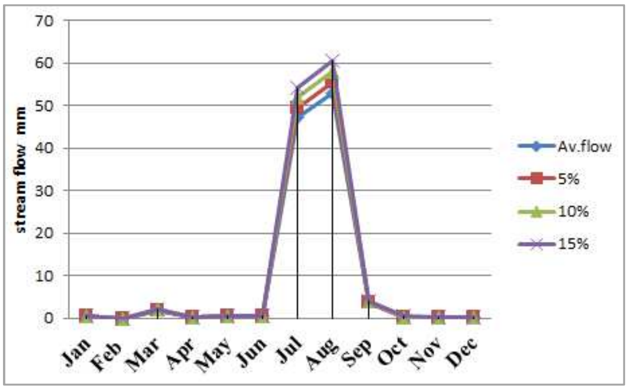


Figure 13. *Stream flow change for slope increased each percent change.*

This means that the water is exposed for a longer duration to infiltration and evaporation before it reaches the measuring point [32]. The above model result showed that slope was significant effect on stream flow change, the slope increase with 5%, 10% and 15% the stream flow were increase with 2.1%, 3.3%, and 3.7% respectively.

Therefore the physical watershed characteristics are includes climate, slope, area of the watershed, shape of the watershed, soil and land use land cover was the major characteristics.

4. Conclusions

In this study, SWAT and GIS were integrated with a hydrological model to evaluate the effects of watershed characteristics on the stream flow of the Fetam watershed of Blue Nile basin. An integrated approach of GIS and remote sensing are excellent tools to map different land cover classes and to detect and analyses spatial temporal land cover dynamics. To do this analysis, first land use and land cover change during the past 27 years (1975– 2002) was analyzed; then SWAT model were tested for its performance at the Fetam watershed in order to examining the hydrological response of the watershed to changes in land use and land cover.

From the land use and land cover change analysis, it can be concluded that the land use and land cover of the Fetam watershed for the period of 1995, 2005 to 2015 showed significantly changed. Cultivated land was drastically changed from 21.33% in 1995 to 55.17% in 2005 in the expenses of the other classes. The expansion of agricultural land and rural settlement has an impact on the decrement of forest land. Thus, the forest land which constituted 6.1% in 1995 diminished to 4.9% in 2005.

Performance of the model for both the calibration and validation of watershed were found to be reasonably good with Nash-Sutcliffe coefficients (ENS) values of 0.78 and 0.89 and coefficient of determination (R^2) values of 0.88 and 0.91 for the calibration and validation respectively.

Following calibration and validation of the model, impacts of the land use and land cover change on stream flow was carried out. Land use and land cover changes recognized to have major impacts on hydrological processes, such as surface runoff and groundwater flow. The result of model for both periods of land use and land cover 1995and 2005 indicated that during the wet season, the mean monthly flow for 2005 land cover was increased by 21.92 m^3/s relative to that of 1995 land cover period while the mean monthly flow decreased by 13.1 m^3/s during the dry season. The surface runoff increased from 39.75 mm to 45.39 mm, while the ground water decreased from 49.5 mm to 43.7 mm for the 1995 and 2005 land cover maps respectively.

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