JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

CHAIR OF HYDROLOGY AND HYDRAULIC ENGINEERING

MASTERS PROGRAM IN HYDRAULIC ENGINEERING

EVALUATION OF LAND USE LAND COVER CHANGE IMPACTS ON STREAM FLOW; IN CASE OF FETAM WATERSHED, ETHIOPIA

A Thesis submitted to the School of Graduate Studies of Jimma University, Jimma institute of Technology, Hydrology and Hydraulic Engineering Chair for Partial fulfillment of the requirements for the degree of Masters of Science in Hydraulic Engineering.

By: Eleni Negussie

March, 2020

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Advisor: Dr. Ing. TameneAdugna
Co-advisor: Mr.Bekan. Chelkeba (M.Sc.)

March, 2020
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APPROVAL SHEET

I, the undersigned, declare that this thesis entitled: "Evaluation of land use and land cover change impacts on stream flow: in Case of Fetam watershed, Ethiopia" is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used in this thesis have been duly acknowledged.

Candidate:

Eleni Negussie

Signature _____________

As Master's Research, we hereby certify that we have read and evaluated this MSc thesis prepared under our guidance by Eleni Negussie entitled: Evaluation of land use and land cover change impacts on stream flow: in Case of Fetam watershed, Ethiopia.

We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

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ABSTRACT

Land use land cover has been the major factors alters flow regime. The evaluation of the impacts of land use land cover change on flow regime, and understanding influence of it on river flow regimes was important for sustainable watershed management. This study is used to evaluate the land use change from 1993 to 2013, and the effect changes on the stream flow of Fetam watershed. Geographic Information system was integrated with the Soil and water assessment tool (SWAT) model to carry out the study. Arc GIS10.1 and ERDAS imagine2015 were used to process soil data set and prepare land use/cover map data (Landsat-7 ETM+ and Landsat-8 OLI_TIRS, for the year 1987and 2017 respectively) acquired from the website of USGS. The Land use classification was performed using a supervised classification system and accuracy assessment was done using a confusion matrix. Using the two land use/cover map SWAT model was set up and run and the default simulation was compared with the observed data. Then sensitivity analysis was made on a monthly basis using 20 input flow parameters, twelve flow parameters were used for model calibration. Runoff curve number (CN2),base flow alpha factor (ALPHA_BF)and ground water delay (GW_DELAY) are the most sensitive parameters ranking from one up to three, respectively. The model calibration was done from 1993 to 2005 years and the validation was carried out from 2005 to 2013 period. The model performance was checked using performance indicators, coefficients of determination (R^2), Nash-Sutcliff efficiency (NSE), and percent of bias (PBIAS). The performance indicators results in R^2 = 0.89, NSE = 0.87, and PBIAS = 12.7 for calibration, and R^2= 0.84, NSE=0.72, and PBIAS=-7.5 for validation. The results indicated a well performance of the model. The annual simulated stream flow through the study period is increased for wet season from 34.58m^3/s in 1993 to 40.37m^3/s in 2013), the short rain season increased from 0.0113m^3/sec in 1993 to 17.994m^3/se in 2013) and dry season decreased from 14.75m^3/s in 1993 to 7.405m^3/s in 2013). Generally, the study result indicated flow during wet season and short rain season increased whereas during dry season decreased though the watershed. Therefore, curving the changes of LULC towards increasing vegetation cover is very necessary in order to reduce surface runoff that contribute to wet season flow and increase infiltration that supply groundwater from which dry season/base flow is contribute.

KEYWORDS: LULC, Runoff, SWAT-CUP, SWAT Model

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ACRONYMS

DEM………Digital Elevation Model

ERDAS……Earth Resources Data Analysis System

ERRMAT …Error Matrix

ET …………Evapotranspiration

ETM+ ……..Enhanced Thematic Mapper plus

FAO ……….Food and Agricultural Organization of United Nations

GIS ………...Geographic Information System

GLUE………Generalized Likelihood Uncertainty Estimation

GPS…………Global Position System

HEC-HMS …Hydraulic Engineering Center Hydrologic Modeling System

HRU ………..Hydrological Response Unit

LULC……….Land Use Land Cover LU/LCC Land Use/Land Cover Change

MCMC………Markov Chain Monte Carlo

MOFED …….Ministry of Finance and Economic Development

MOWIE……..Ministry of Water, Irrigation and Energy

MRS ………...Mean Relative Sensitivity

NMAE ………National Meteorology Agency of Ethiopia

NSE …………Nash and Sutcliffe Efficiency

OLI_TIRS …..Operational Land Image &Thermal Infrared Sensor

PARASOL ….Parameter SOLUTION

PBIAS ………Percent Bias

PET ………….Potential Evapotranspiration

95 PPU ………95 Percent Prediction Uncertainty

R^2 ……………………Coefficient of Determination

RMSE………..Root Mean Square Error

SCS…………..Soil Conservation Service

SUFI-2 ………Sequential Uncertainty Fitting Ver_2

SWATCUP… Soil & Water Assessment Tool Calibration &Uncertainty Program

SWAT………..Soil and Water Assessment Tool

USGS…………United States Geological Survey

UTM…………Universal Transversal Mercator

WGEN………Weather Generator

1. INTRODUCTION

1.1 Background

Water is a precious substance and necessary for all living things. It is a finite resource and must be managed in sustainable way to meet human as well as environmental needs. Land use/ land cover change has an impact for alteration of watershed hydrology. The land use planning and management are highly related to the sustainability of water resources as changes of land use are linked with amount of water through relevant hydrological processes (Guo, 2008). Effective methods and mechanism should be used to maintain water sustainability. Nowadays, the hydrological models are good to represent the hydrological characteristics (Surur, 2010).

Hydrological modeling and water resource management are highly related to the processes of the hydrologic cycle. This cycle can be affected by land use and land cover change. Land use land cover is in a dynamic condition especially in developing countries like Ethiopia. The land use and land cover changes can be caused by human and natural factors (Meyer, W.B. and Turner, B. L., 1994). The understanding of the influence of land use land cover change on hydrology enables water resource planners to formulate policies to minimize the effects of future land cover changes on hydrology.

The sustainable use of water is becoming increasingly important in legislative agenda of Ethiopia. The overall goal of the Ethiopian Water Resource Policy is to enhance and promote all national efforts toward the efficient, equitable and optimum utilization of the available water resources of the country for significant socioeconomic development on sustainable basis.

Over the past years, increasing extents of land were converted into agricultural lands (Ambachew Getnet and Fungai Svondo, 2010) because of population growth and increase in foreign direct investment which change the use and distribution of water. The removal of surface water and ground water for irrigation changes the water’s natural distribution and impacts the sustainability of ecosystem that depends on it.

The increase in population number put pressure on water resource. The land use changes due to population increment that impact water resources are expansion of agricultural activities and urbanization. Tillage of the land and clearing of forests can change infiltration and runoff characteristics, which affect ground water recharge, water yield and Evapotranspiration.

Changes in land use have potential impacts on water resources, yet quantifying these impacts remain among the more challenging problems in hydrology.

Land and water resources degradation are the major problems in the Ethiopian Central Rift Valley Basin. The area is one of the most important from its water resources development point of view. The CRV basin lakes are undergoing degradation due to upstream land use land cover change impacts like agricultural expansion which affects streams feeding the lakes. The lakes surface water level have dropped across the Central Rift Valley because of water extraction for irrigation (Legesse, D. and Ayenew, T., 2006). Agricultural expansion (irrigation system), urbanization, poor land use practices and improper management systems have a significant impact on basin hydrology. Farm lands and settlements expanded which is mostly associated with the decrease in forest land (Kassa, 2007). The Katar River catchment, a sub catchment of CRV basin is experienced land use and land cover change which impacts basin hydrology. The Katar River which feed Lake Ziway showed flow variation over the past years due to catchment exposure to LU/LC change. The Katar Catchment flow variation has an impact on Lake Ziway. Therefore, to propose type of management it requires, the identification of the LU/LC change impact on the Katar basin hydrology is very important. The understanding of the impacts of LULC change on hydrologic processes and combining this understanding into the emerging focus on LULC change are major needs for future. So far, limited studies have been conducted to identify the impact of LU/LC on basin hydrology to combat the problems in Rift Valley Basin Katar Sub watershed. In this study a physically based watershed model, SWAT model was applied to the Central Rift Valley Ketar Sub watershed for assessing impact of land use change on basin hydrology and the findings of this study will also enable planners to formulate policies to minimize the undesirable effects of future land use/land cover changes in the catchment.

1.2 Statement of the problem

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. Land cover and use 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 (Mustard, 2004). 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 (Sahin, & Hall ,1996). Human activities have modified the environment over the years. Urbanization, agriculture lumbering, mining and other land uses have substantially altered the earth's surface. The Land use and the resultant change in land cover have significant effects on ecological, environmental and hydrologic systems and processes. An understanding of past and present land cover change, together with analysis of potential future change, is necessary for proper management. Ethiopian Higher Land of Sub basin is one of densely populated with an annual growth rate of 2.3 % (CSA, 2008). The fast-growing population and the density of livestock in the Sub-basin, lack of awareness of the watershed management strategies and agricultural practices on the land resources, resulting in forest clearing and overgrazing (Tesfaye *et al.*, 2014). The Fetam watershed is facing densely populated that causes effects on resource bases like deforestation, expansion of residential area, and agricultural land. The Deforestation is a day to day activity of the people living in the watershed. The watershed is also facing high erosion by the effects of intense rainfall of the watershed that aggravates the land cover change of the watershed. This continuous change in land cover has impacted the water balance of watershed by changing the magnitude and pattern of the components of stream flow which are surface runoff and groundwater flow, which results increasing the extent of water management problem. Such and other issues should be evaluated deeply to know how land uses affect different hydrological process. The land use land cover change has significantly impacts on natural resource, socio economic and environmental system. Therefore, strong need is identified for the hydrological response of watershed used for water resources management at a watershed.

1.3 Objective of the study

1.3.1 General objective

The General objective of this study is to Evaluate land use land cover change impacts on the stream flow of Fetam watershed by using Soil and Water Assessment Tool (SWAT) model.

1.3.2 Specific objective

1. To analysis of the changes in the land use/land cover of Fetam watershed for different specified periods
2. To check SWAT Models performance to characterize and model Fetam watershed in terms of LULCC
3. The impact of land use land cover on the stream flow.

1.4 Research questions

To address the above objectives, the following research questions are designed:-

1. What is the trend of land use/land cover in Fetam watershed for the specified periods?
2. Is the SWAT Model applicable in the Fetam Watershed to predict stream flow?
3. What are the impacts of land use land cover change on stream flow?

1.5 Overall Framework of the Study

The method to evaluate the impact of land use and land cover change, on hydrological regimes can be achieved through integrating GIS, remote sensing, and hydrological models. Satellite image have great contribution for preparation of land use land cover of the area. LU/LC information is of critical importance in hydrologic modeling, as it helps determine model variables that account for the volume, timing, and quality of runoff. A Physically based distributed hydrological Arc SWAT model that allows several different subunits or objects to be defined within a catchment is utilized. Details of the approach followed are given in (Figure1.1).

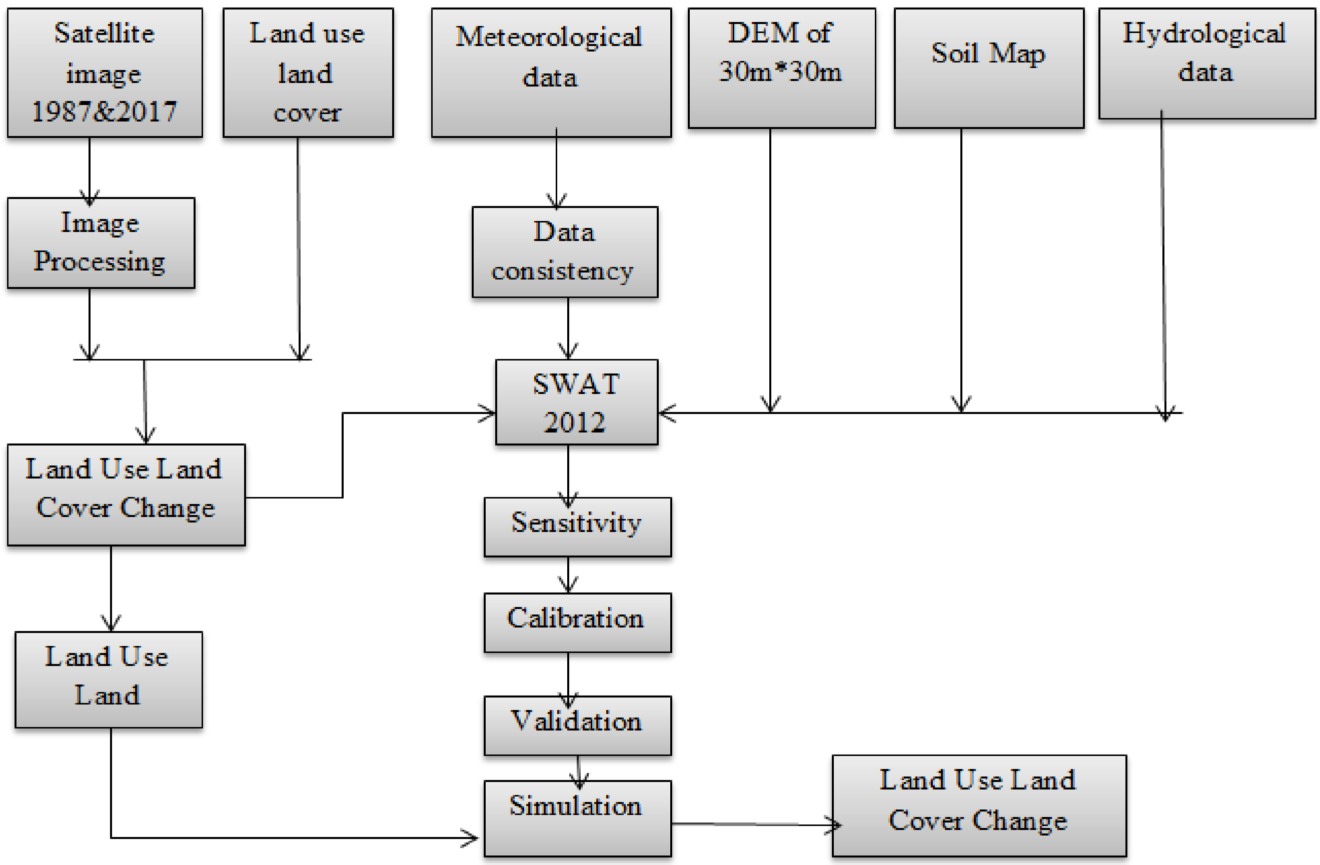

Figure 1.1 Overall Framework of the Study area

1.5 Significance of the study

The land use and land cover change has impacts on natural resources, socioeconomic and Environmental systems. However, to assess the effects of land use and land cover change on stream flow, it is important to have an understanding of the land use land cover Patterns and the hydrological processes of the watershed. Understanding the types and Impacts of land use and land cover change is essential indicator for resource base analysis and development of effective and appropriate response strategies for sustainable management of natural resources in the country in general and at the study area in Particular. This study will find measure of the knowledge how land use land cover dynamic influences in the stream flow of the watershed enable all concerned water users sectors in managing water resources in the study area.

The study analyzes land use and land cover change and their impact on stream flow this may achieve through a method that combines the hydrological model (SWAT) to Simulate the hydrological processes, to analysis the Land use and land cover change.

1.6 Scope of the study

This study is geographically limited to Fetam watershed. Within the time provided for this study, the objectives set addressed and the asked research questions answered. The land use and land cover change that expected to take place in the Fetam watershed was reached by integrating software and hydrologic models and the effect of these changes on the hydrological process of the watershed was discussed.

2. LITERATURE REVIEW

2.1 Land Use and Land Cover Change

Land use change is defined to be any biological, physical or chemical change attributable to management, which may contain conversion of grazing to cropping, change in fertilizer use, drainage improvements, installation and use of irrigation, plantations, building farm dams, pollution and land degradation, vegetation removal, changed fire regime, spread of weeds and exotic species, and conversion to non-agricultural uses (Quentin et al, 2006). According to the International Geosphere Biosphere Program and The International Human Dimension Program (IGBP_IHDP, 1999) land cover refers to the physical and biophysical cover over the surface of earth, including circulation of vegetation, water, bare soil and artificial structures. Land use refers to the proposed use or management of the land cover type by human beings such as agriculture, forestry and building construction. Land use land cover change (LUCC) is commonly divided in to two broad categories: modification and conversion of land use land cover (Meyer & Turner, 1995). Modification refers to represents a change within one land use or land cover category due to changes in its physical or functional attributes, Conversion on the other hand a change from one cover or use category to another These changes in land use and land cover systems have important environmental consequences through their impacts on soil and water, biodiversity, and microclimate (Lambin et al., 2003). Land cover changes have been influenced by both the increase and decrease of a given population (Lambin et al., 2003). In most developing countries like Ethiopia population growth has been a dominant cause of land use and land cover change than other forces (Sage, 1994). There is a significant statistical correlation between population growth and land cover conversion in most of African, Asian, and Latin American countries (Meyer & Turner, 1995). Due to the increasing demands of food production, agricultural lands are expanding at the expense of natural vegetation and grasslands (Lambin et al., 2003).

2.2 Trends of Land-Use and Land Cover Change

Land-use changes are compound processes that arise from modifications in land-cover to land conversion process (Noe, 2003). There are also the potential influences on physical and social dimensions. According to (Bronstert, Niehoff, &Bürger, 2002) throughout the whole history of mankind, intense human utilization of land resources has resulted in significant changes on the land-use land-cover. According to (Lambin *et al*., 2003) land-use change is determined by the collaboration in space and time between biophysical and human dimensions. Since the era of industrialization and rapid population growth, land-use change phenomena have strongly accelerated in many regions. Land-use changes are frequently indicated to be one of the main human-induced factors influencing the hydrological system (Dams *et al*., 2008). It was estimated that undisturbed areas represent 46% of the earth's land surface (Mittermeier et al., 2003). It is reported that 8000 years ago forests covered about 50% of the earth's land area, as opposed to 30% today (Lambin et al., 2003). Agriculture has expanded into forests, savannas, and steppes in all parts of the world to meet the demand for food. Agricultural expansion has shifted between regions over time; this followed the general development of civilizations, economies, and increasing populations (UN-FAO, 2001). Regardless of the global spatial distribution of land-use/cover changes these studies did not attempt to give the contribution on the land-use trends and processes on the small sub-catchment, which affected its management in the near future.

2.3 Land Use and Land Cover Change Studies in Ethiopia

In Ethiopia, land is a public property and has been administered by the government since 1975. Before 1975 was the imperial era in which land was controlled by the King and the ruling elites (Ambaye, 2012). The land is used to grow crops, trees, animals for food, as building sites for houses and roads, or for recreational purposes. Most of the land in the country is being used by smallholders who farm for subsistence. With the rapid population growth and in the absence of agricultural intensification, smallholders require more land to grow crops and earn a living; it results in deforestation and land use conversions from other types of land cover to cropland. The researches that have been conducted in different parts of Ethiopia have shown that there were considerable land use land cover changes in the country. Most of these studies indicated that croplands have extended at the expanse of natural vegetation including forests and shrub lands; for example ((Tegene, 2002); (Bewket, 2003); (Kidanu, 2004); (Abebe, 2005)) in northern part of Ethiopia, (Zeleke&Hurni, 2001) in north western part of Ethiopia, (Kassa, 2003) in north eastern part of Ethiopia; and (Denboba, 2005) in south eastern part of Ethiopia. (Kassa, 2003) in his study, in southern Wello, reported the decline of natural forests and grazing lands due to conversions to croplands. (Bewket, 2003) have reported an increase in wood lots (eucalyptus tree plantations) and cultivated land at the expense of grazing land in both Chemoga watershed in north-western Ethiopia, and Sebat-bet Gurage land in south-central Ethiopian. The changes of land use land cover that occurred from 1971/72 to 2000 in Yerer Mountain and its surrounding results an expansion of cultivated land at the expense of the grasslands (Gebrehiwet, 2004). (Hadgu, 2008) identified that decrease of natural vegetation and expansion of agricultural land over a period of 41 years in Tigray, northern part of Ethiopia. He concluded that population pressure was an important deriver for expansion and intensification of agricultural land in recent periods. (Garedew, 2010) in the semiarid areas of the central Rift Valley of Ethiopia, during the period 1973-2000 cropland coverage has increased and wood land cover lost.

But, most of the empirical evidences indicated that land use land cover changes and socioeconomic dynamics have a strong relationship; as population increases the need for cultivated land, grazing land, fuel wood; settlement areas also increases to meet the growing demand for food and energy, and livestock population. Thus, population pressure, lack of awareness and weak of management are considered as the major causes for the deforestation and degradation of natural resources in Ethiopia.

2.4 Land Use and Land Cover Change Impacts on Hydrology

Water on earth exists in a space called the hydrosphere and lithosphere, circulates and forming hydrologic cycle. The cycle has no beginning and no ending and can be 6 affected by different factors. Among those factors, manmade activities, land use and land cover change can affect hydrological processes such as infiltration, runoff and groundwater recharge. Different studies indicate that land use and land cover change have an impact on hydrologic components. For instance, (Adamu, 2013) concluded that land use and land cover changes have major impacts on hydrological processes, such as runoff and ground water flow, (Melesse, 2012) concluded that the decrease of forest land and grass land was accompanied by the increase in agricultural and built up areas and this change in land use and land cover increased surface run off during wet seasons and reduced base flow during the dry seasons. (Gebrie, 2016) Concluded that the land use and land cover change have a great influence on stream flow especially during wet season than dry season. Cultivation of land exerts a major influence on the relationship between surface and subsurface flow. According to data from long term observations done in paired catchments, in the forest zone of Central Russia (Golosov, V. and Panin A., 2006). Surface runoff is extremely limited under grass or forest vegetation compared with agricultural land.

2.5 Effects of LULC change on Hydrology

The relationship between land use and hydrology is of greater interest worldwide as it can provide advice for management actions in order to avoid or minimize the negative effects of specific land use activities on the hydrology of a certain region. However, there are still uncertainties on the impact of specific land use practices to different processes of the hydrological cycle due to the complexity and specificity of characteristics of each catchment. Much of the present understanding of land use effects on hydrology is derived from controlled experiments and manipulations of the land surface coupled with observations of hydrological processes, commonly precipitation inputs and stream discharge outputs (De Friesand Eshleman, 2004). According to (Calder ,1999) the largest changes in terms of land area, and arguably in terms of hydrological impacts, of ten arise from afforestation and deforestation activities. One of the direct effects of land use changes on hydrology and hence on water resources is through its link with the evapotranspiration regime. Any change inland use and vegetation cover can have impacts on potential and actual evapotranspiration as well as on the discharge regime, which reflects the integrated behavior of all the hydrological processes acting in the catchment. The higher evapotranspiration loss from afforest than from any other land surface is the main reason for this situation (Lorupand Hansen, 2002).

2.6 Effects of Afforestation and Deforestation on Hydrology

The magnitude of changes on the stream flow due to land use changes varies with catchments and other factors such as climate and human activities. Regarding the impact of deforestation and afforestation on the dry season flow in the tropics, there are conflicting statements and findings. (Edwards ,1999) in an experiment conducted in Meyer observed that the dry season flow was higher from a catchment with traditional small holder cultivation than with forest cover, even on steep slopes. Similar results were observed after deforestation of Brachy stegia woodland in Zambia (Mumeka, 1986) and Montane hard wood forest in Taiwan (Hsia and Koh, 1983).

In South Africa, afforestation of dry grassland and fynboscrub land resulted in a highly significant decrease in low flows(Smith and Scott,1992).Bosch and Hewlett(1982) suggested that forest cutting and removal activities usually cause increases in flood peaks for several years following disturbance, but some authors including Reinhart et al.(1963),Jones and Grant (1996),White head and Robinson(1993) have suggested that these effects can be at least partially attributed to soil compaction during road and skid trail construction. In the case of the in comati basin, few detailed studies have been conducted to assess the impact of land use changes on river flow regime. (Nkomo, 2003) modeled the water resources in the basin using the WAFLEX model and observed that commercial afforestation, which is one of the major economic activities in the basin, created significant reduction of the natural runoff. The relationship between land use and hydrology is of greater interest worldwide as it can provide advice for management actions in order to avoid or minimize the negative effects of specific land use activities on the hydrology of a certain region. However, there are still uncertainties on the impact of specific land use practices to different processes of the hydrological cycle due to the complexity and specificity of characteristics of each catchment. Much of the present understanding of land use effects on hydrology is derived from controlled experiments and manipulations of the land surface coupled with observations of hydrological processes, commonly precipitation inputs and stream discharge outputs (De Friesand Eshleman, 2004).

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2.7 Hydrologic Models

Hydrologic modeling has proved to be very important tool that can be applied to understand and explain the effects of LU/LC change on hydrologic response of a catchment (Baldyga, J. T., 2005). Hydrological models are mathematical descriptions of components of the hydrologic cycle. They have been developed for many different reasons and therefore have many different forms. However, hydrological models are in general designed to get a better understanding of the hydrologic processes in a watershed and of how changes in the watershed may these phenomena and for hydrologic prediction (Kassa Tedele, 2007). They are also providing valuable information for studying potential impacts of changes in land use and land cover or climate change. There are many classification of hydrologic models, deterministic versus stochastic, lumped versus distributed and etc. On the basis of process description, the hydrological models can be classified in to three main categories (Cunderlik, 2003).

1. Lumped models; Parameters of lumped hydrologic models do not vary spatially within he basin and thus, basin response is evaluated only at the outlet, without explicitly accounting for

the response of individual sub basins. The parameters often do not represent physical features of hydrologic processes and usually involve certain degree of empiricism. These models are not usually applicable to event scale processes. If the interest is primary in the discharge prediction only, then these models can provide just as good simulations as complex physically based models (Beven, K.J.;, 2000).

2. Distributed models; Parameters of distributed models are fully allowed to vary in space at resolution chosen by the user. Distributed modeling approach attempts to incorporate data concerning the spatial distribution of parameters together with computational algorithms to evaluate the influence of this distribution on simulated precipitation runoff behavior. Distributed models generally require large amount of data.

3. Semi distributed models; Parameters of semi-distributed (simplified distributed) models are partially allowed to vary in space by dividing the basin in to a number of smaller sub-basins. The main advantage of these models is that their structure is more physically-based than the structure of lumped models, and they are less demanding on input data than fully distributed models. SWAT (Arnold, et al., 1993), HEC-HMS (US-ACE, 2001), HBV (Bergström, 1995), are considered as semi-distributed models. Hydrologic models can be further divided into event-driven models, continuous-process models, or models capable of simulating both short-term and continuous events. Event-driven models are designed to simulate individual precipitation-runoff events. Their emphasis is placed on infiltration and surface runoff. Typically, event models have no provision for moisture recovery between storm events and, therefore, are not suited for the simulation of dry-weather flows. On the other hand, continuous-process models simulate instead a longer period, predicting watershed response both during and between precipitation events. They are suited for simulation of daily, monthly or seasonal stream flow, usually for long-term runoff-volume forecasting and for estimates of water yield (Cunderlik, 2007).

2.7.1 Hydrological Model Selection Criteria

There are many criteria which can be uses for choosing the right hydrologic model. These criteria always project dependent, since every project has its own specific requirements and needs. Further, some criteria are user dependent, such as the personal preference for graphical user interface (GUI), computer operating system, input out management system and structure. SWAT model is a semi distributed; time continuous watershed simulator operating on daily time step. It is developed for evaluating the impact of management and climate on water supplies, sediment and agricultural chemical yields in watersheds and larger river basins. The model is physically based and allows simulation of a high level of spatial detail by dividing the watershed into a large number of sub watersheds. The major components of SWAT include hydrology, weather, erosion, plant growth, nutrients, pesticides, land management and stream routing. The program is provided with an interface in Arc GIS for the definition of watershed hydrologic features and storage as well as the organization and manipulation of the related spatial and tabular data. (Moriasi et al, 2007). SWAT model has been applied in agricultural watersheds and have been successfully calibrated and validated in many areas of the world. The studies indicated that the SWAT model is capable of simulating hydrologic process from complex and data poor watershed with reasonable model performance statistical values. According to (Aduah et al, 2017) was used SWAT models to predict water balance and water yield of a catchment. It was suggested that, SWAT model could be a promising tool to predict water balance and water yield in sustainable management of water resource.(Getahun and HAJ, 2015) Was applied SWAT model on reported that, the overall model performance was satisfactory. Similarly, (Roth et al., 2018) also applied SWAT model to evaluate surface runoff generation and soil erosion rates for a small watershed in Ethiopia, and recommended that, the SWAT model provides a useful tool for soil erosion assessment from watersheds and facilitates planning for a sustainable land management. The above literature review indicated that the SWAT model is capable of simulating hydrological process with reasonable accuracy and can be applied to large and complex watersheds.

2.7.2 Introduction to SWAT Model

The SWAT watershed model is one of the most recent models developed at the USDA-ARS (Arnold, Srinivasan, Muttiah, & Williams, 1998) 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 (Neitsch, Arnold, Kiniry, & Williams, 2011). 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 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 (Neitsch et al., 2011). Major hydrologic processes that can be simulated by the this model include evapotranspiration, surface runoff, infiltration, percolation, shallow aquifer and deep aquifer flow, and channel routing (Arnold et al., 1998).

2.7.3 SWAT Model Application Worldwide

SWAT model has good reputation for best use in agricultural watersheds and its uses have been successfully calibrated and validated in many areas of the USA and other continents (Ndomba, 2002) & (Tripathi et al., 2003). The studies indicated that the SWAT Model is capable in simulating hydrological process and erosion/sediment yield from complex and data poor watersheds with reasonable model performance statistical values. (Ndomba, 2002) was applied the SWAT model in modeling of Pangari River (Tanzania) to evaluate the applicability of the model in complex and data poor watersheds. (Tripathi et al., 2003) applied the SWAT model for Nagwan watershed in India with the objective of identifying and prioritizing of critical sub-watersheds to develop an effective management plan and the model was verified for both surface runoff and sediment yield.

2.7.4 SWAT Model Application in Ethiopia

The SWAT model application was calibrated and validated in some parts of Ethiopia, frequently in Blue Nile basin. Through modeling of Gumara watershed (in Lake Tana basin), (Awulachew et al., 2008) indicated that stream flow and sediment yield simulated with SWAT were reasonable accurate. The same study reported that similar long term data can be generated from ungauged watersheds using the SWAT model. A study conducted on modeling of the Lake Tana basin with SWAT model also showed that the SWAT model was successfully calibrated and validated (Setegn, Srinivasan, Dargahi, & Melesse, 2009).This study reported that the model can produce reliable estimates of stream flow and sediment yield from complex watersheds. (Gessese & Yonas, 2008) used the SWAT model performed to predict the Legedadi reservoir sedimentation. According to this study, the SWAT model performed well in predicting sediment yield to the Legedadi reservoir. The study further put that the model proved to be worthwhile in capturing the process of stream flow and sediment transport of the watersheds of the Legedadi reservoir. The SWAT model showed a good match between measured and simulated flow and sediment yield in Gumara watershed both in calibration and validation periods (Asres & Awulachew, 2010). (A. Tekle, 2015) through modeling of Bilate watershed also indicated that SWAT Model was able to simulate stream flow at reasonable accuracy.

2.7.5 SWAT Calibration and Uncertainty Procedures

Distributed watershed models are increasingly being used to support decision making in land use change. These models should pass through a careful calibration and uncertainty analysis. Large scale distributed models are difficult to calibrate and to interpreter the calibration because of large model uncertainty, input uncertainty and parameter non uniqueness. To perform parameter calibration and uncertainty analysis different programs are introduced. SWAT-CUP is one of the program which is currently used by different researchers. SWATCUP is a public domain and any calibration, uncertainty or sensitivity can be linked to SWAT. The program links Generalized Likelihood Uncertainty Estimation (GLUE), Parameter Solution (ParaSol), Sequential Uncertainty Fitting (SUFI2) and Markov Chain Monte Carlo (MCMC) procedures to SWAT process in which iteration and unknown parameter estimates are achieved before the final estimates (Abbas et al, 2015). It enables sensitivity analysis, calibration, validation and uncertainty analysis of SWAT models. SUFI method determines uncertainty through the sequential and fitting.

2.8 SWAT Calibration and Uncertainty Procedures (SWAT-CUP)

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2.9 ERDAS Imagine Model

It is a remote sensing application with raster graphics editor capabilities designed by ERDAS, Inc. for geospatial applications. Prior to the ERDAS IMAGINE Suite, Earth Resources Data Analysis System (ERDAS), Inc. developed various different products to process satellite imagery from Advanced Very High Resolution Radiometer (AVHRR), Land sat, Multiple Spectral Scanner (MSS) and Land sat TM and SPOT imagery into land cover / land use maps, map deforestation. The latest version ERDAS IMAGINE is aimed primarily at geospatial raster data processing and allows the user to prepare, display and enhance digital images for mapping use in Geographic Information Systems (GIS)) software. It is a toolbox allowing the user to perform numerous operations on an image and generate an answer to specific geographical questions. By manipulating imagery data values and positions, it is possible to see features that would not normally be visible and to locate geo-positions of features that would otherwise be graphical. The level of brightness or reflectance of light from the surfaces in the image can be helpful with vegetation analysis, prospecting for minerals etc. Other usage examples include linear feature extraction, generation of processing work flows ("spatial models" in ERDAS IMAGINE), import/export of data for a wide variety of formats, orthorectification , mosaicking of imagery, stereo and automatic feature extraction of map data from imagery.

2.10 Model Performance Evaluation

For evaluation of model performance (Taye et al, 2019) describes model evaluation guidelines for quantification of accuracy in watershed modeling. The evaluation was performed by visual and statistical comparison of the measured and simulated data. The graphical method provided an initial overview. The statistical criteria used to evaluate the performance of the model. The Nash and Sutcliffe simulation efficiency (NSE) describes the deviation from the unit of the ratio of the square of the difference between the observed and simulated values and the variance of the observations. The value of the coefficients varies from minus infinity to one with the latter value indicating perfect agreement between the simulated and observed data. A smaller NSE value indicates poorer fit between the simulated and observed data. It is possible to obtain negative value of the NSE indicating that the average of the observational data provides a better fit to the data compared to the simulated data. The percent bias (PBIAS) describes the tendency of the simulated data to be greater or smaller than the observed data, expressed as percentage. The optimum PBIAS value is zero and low values indicate that the model simulation is satisfactory. Positive values indicate a tendency of the model to underestimate while negative values are indicative of overestimation. This test is recommended due to its ability to reveal any poor performance of the model. There are no existing standards describing the range of the values of the statistical parameters that would indicate acceptable performance of the model (Pohlert et al, 2007).

Table 2.1 1The table reported performance rating for R2, NSE and PBIAS for SWAT model

Modeling Phase	R^2	NSE	PBIAS	Performances Rating
1. Calibration and Validation	$0.75<R^2\leq1.00$	$0.75<R^2\leq1.00$	PBIAS≤±10	Very good
2. Calibration and Validation	$0.65<R^2\leq0.75$	$0.65<R^2\leq0.75$	±10≤PBIAS±15	Good
3. Calibration and Validation	$0.5<R^2\leq0.65$	$0.5<R^2\leq0.65$	±15≤PBIAS±25	Satisfactory

Source; (Griensven *et al*, 2012)

In General, Model simulation can be judged as satisfactory if $R^2>0.50$, NSE>0.50 and if PBIAS±25 for stream flow.

3. MATERIALS AND METHODS

3.1 Description of Study Area

3.1.1 Location

The study area of Fetam watershed is found in West Gojjam administrative zone of Amhara region and drain to Abbay river basin. In terms of geographic coordinate system, the watershed lies between 10°25'0''-10°55'0''North latitudes and 36°55'0''-37°15'0'' East longitudes. (Figure 3.1). The total area of the watershed, upstream the gauging station is estimated to be 45912.7 km^2. The topography or elevation of the watershed ranges from 1188 to 2765m above mean sea level.

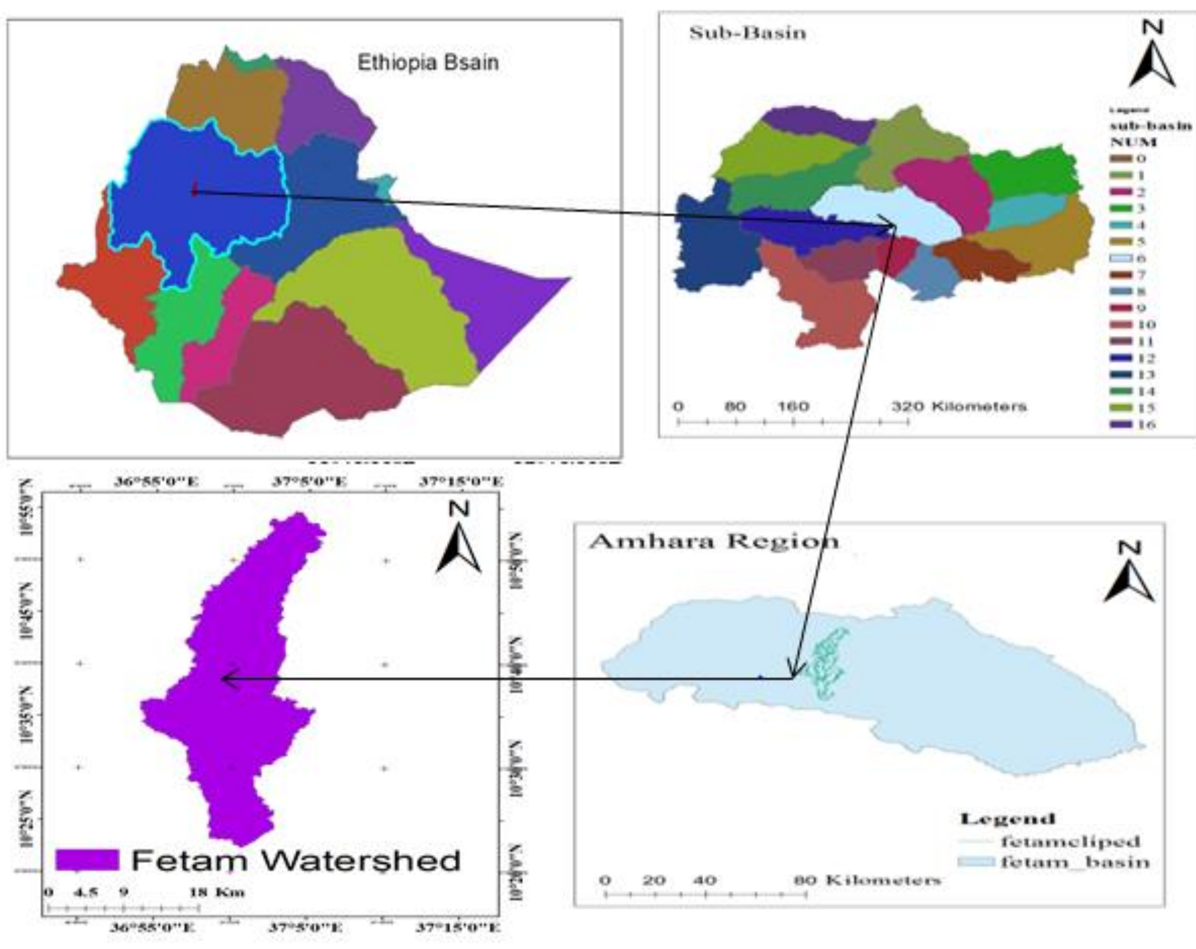

Figure 3.1 Location of the study are

3.1.2 Topography

The topographic parameters during watershed delineation process such as elevation of watershed and its sub watershed were generated from the digital elevation model data. The maximum and minimum value of DEM is 1188 and 2765m respectively used for this paper is collected from MOWIE having 30m spatial resolution.

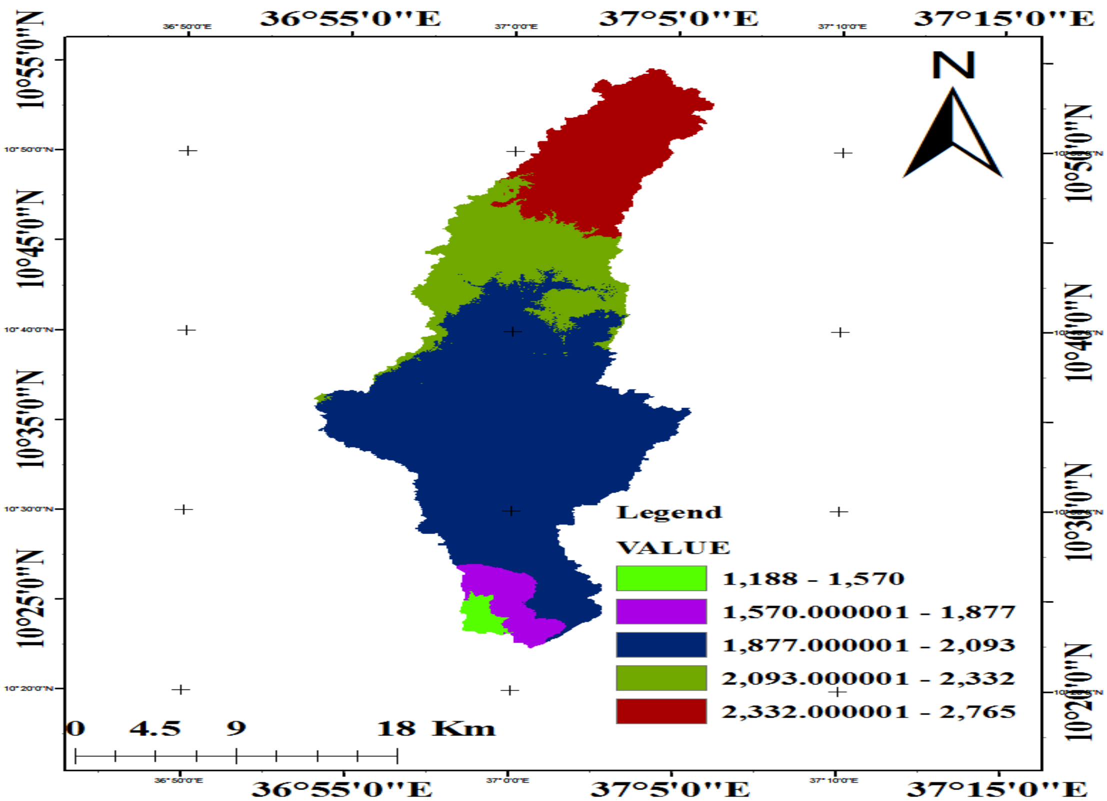

Figure 3.2 Digital elevation model of fetam watershed

3.1.3 Climate condition

Based on the seasonal migration of the Inter-Tropical Convergence Zone (ITCZ) and the seasonal distribution of atmospheric pressure system seasons was classified to three in Ethiopia including Blue Nile basin (NAM, 2015). The basin has three distinctive seasons: wet season (Jun-September) which is mainly characterized by heavy rainy seasons, Spring season (February-May) characterized by small rainy, especially at the end of the last two Months (April and May) and Winter season (October-January) this season mainly called the dry season. This rainfall distribution system was categorized under monomodal rainfall system.

The climate of Ethiopia can be classified in different ways including the Traditional, Koppen's, Throthwaite's, Rainfall regimes, and Agro-climatic zone classification systems. The most common used classification systems are the traditional and the agro ecological zones. According to the traditional classification system, this mainly relies on altitude and temperature; there are five climatic zones namely: Wurch (cold climate at more than 3000 altitude), Dega (temperate like climate-highlands with 2500-3000 Mts. altitude), Woina Dega (warm at 1500-2500 altitude), Kola (hot and arid type, less than 1500m in altitude), and Berha (hot and hyper-arid type) climate (NMSA, 2001).

The rainfall distribution in the Fetam watershed varies from higher altitudes in the mountainous regions to the low land areas. The monthly rainfall distributions of the study area indicate that June, July, August and September are the wettest season of the months and March, April, and May are the short rain season months and January, February, October, November, and December are dry season month of the year in all the selected stations. The mean monthly rainfall of the Bure, Shindi, and Enjebara stations (1993-2013) are in (Figure 3.3). The mean annual rainfall (1993-2013) of the study area as shown varies from around 6.062549mm Bure up to 985.827mm for Enjebara.

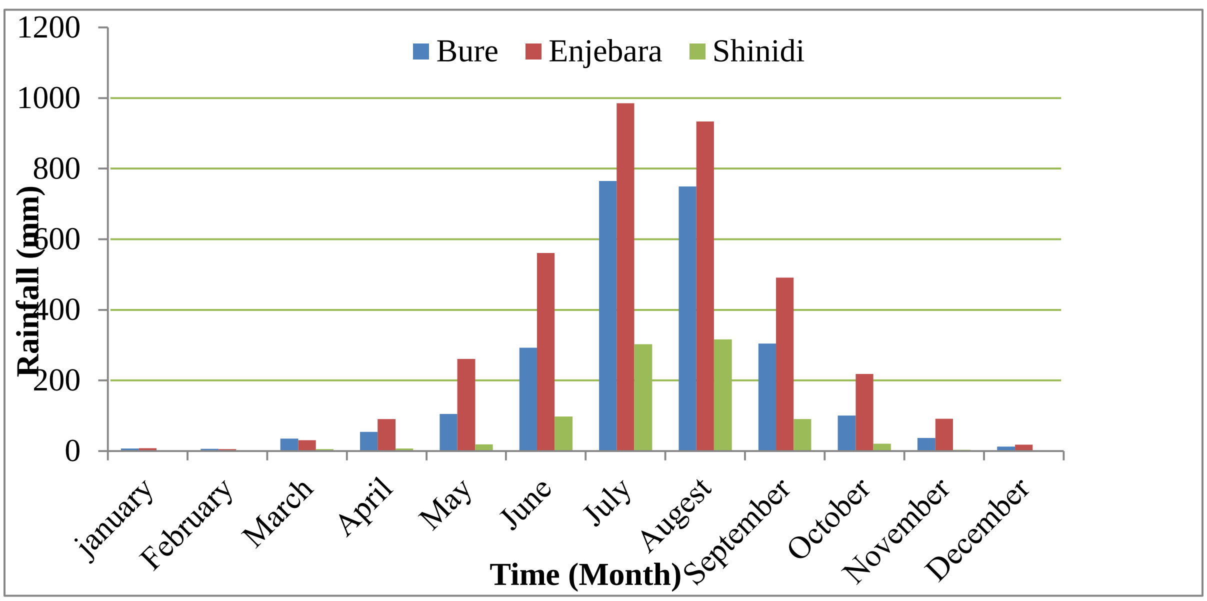

Figure 3.3 Mean monthly rainfall of different station (1993-2013)

The (average) daily maximum and minimum air temperatures in degrees Celsius (°C) are required. The mean Temperature varies between 14.7001 and 25.8576 (Figure 3.6), respectively. The climate data is among the most prerequisite parameter of SWAT model. This data were collected from Ethiopian National Meteorological Agency.

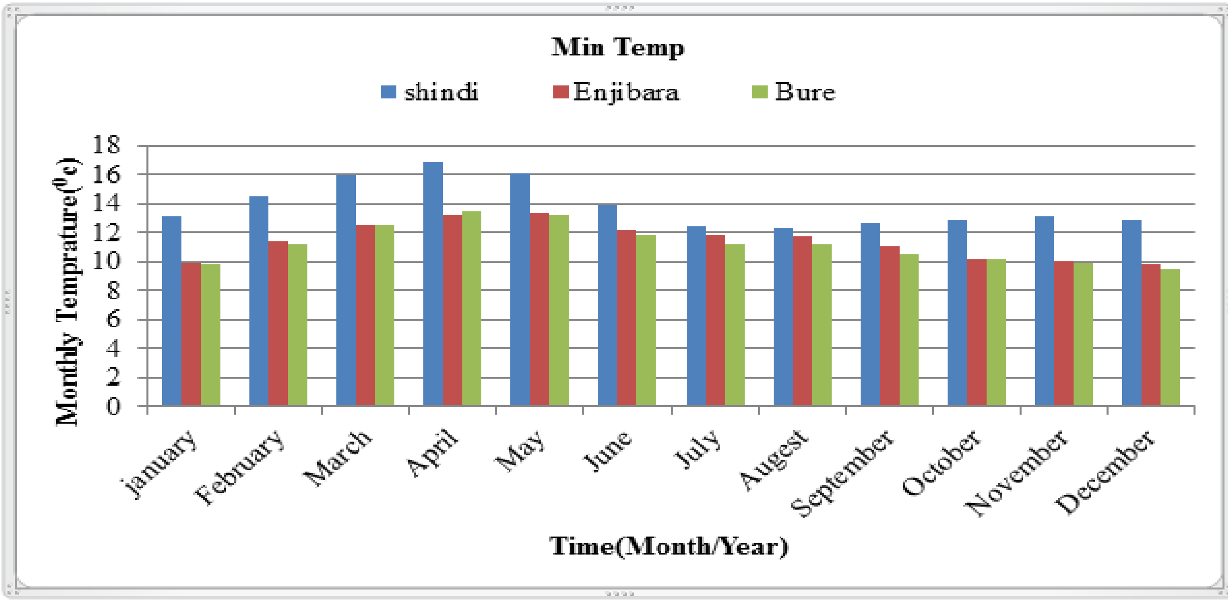

Figure 3.4 Minimum Monthly temperature from (1993-2013)

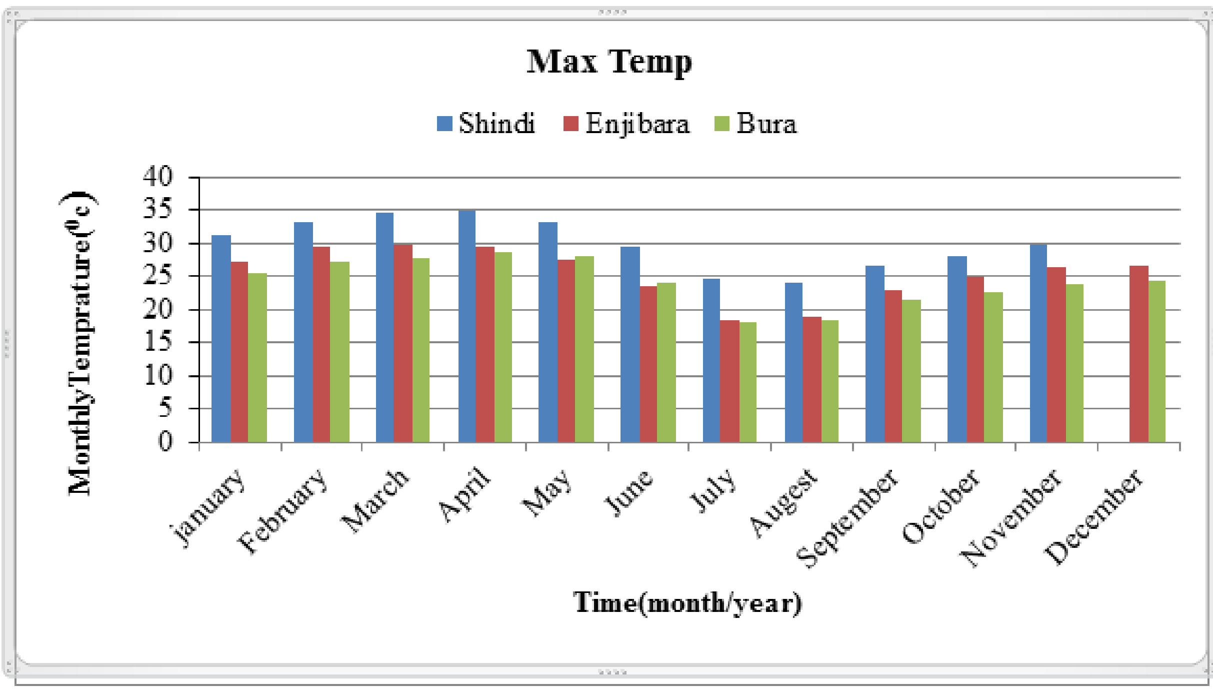

Figure 3.5 Maximum Monthly temperature from (1993-2013)

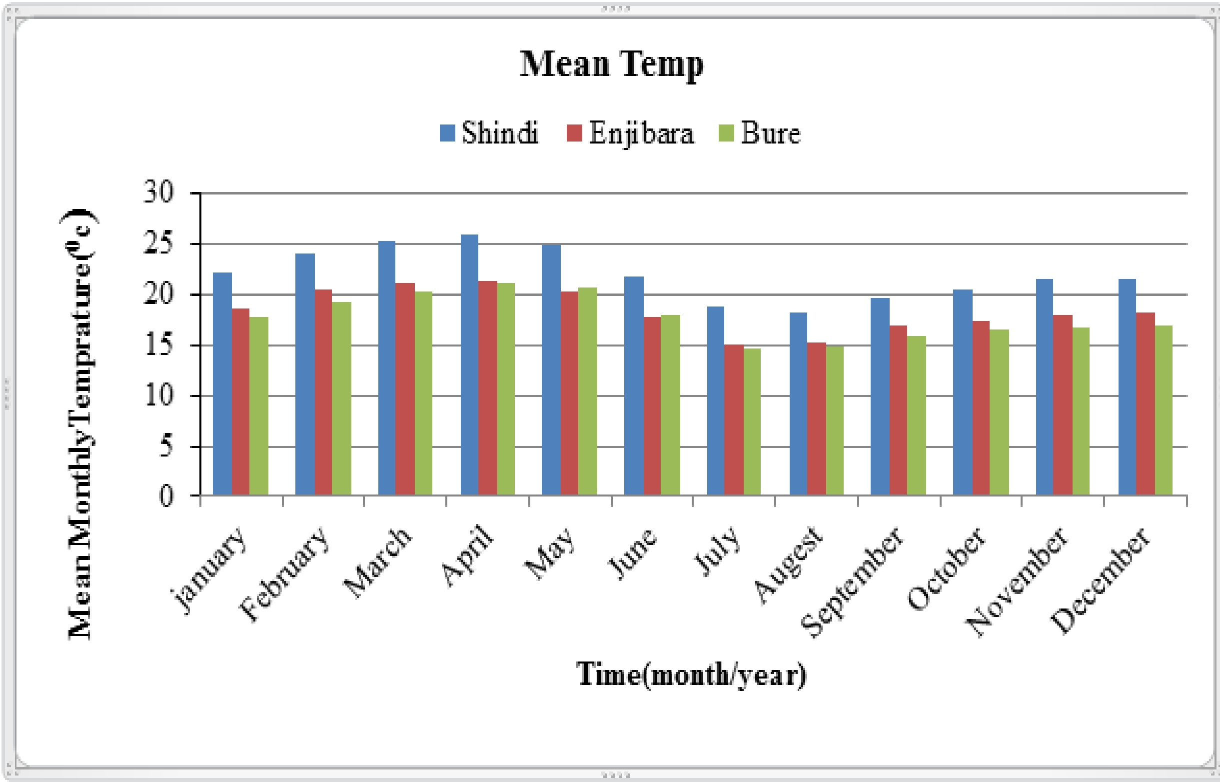

Figure 3.6 1Mean Monthly temperature from (1993-2013)

3.1.4 Geology

The Geological Study data is collected from Ministry of Water, Irrigation and Electricity of Ethiopia. The Fetam watershed which is dominated by a huge volcano system named as Basalts Volcanic shield volcano. Basalt is a hard, black volcanic rock, it corresponds to the eruptive events that occurred during the early Miocene to Pliocene period and classified in the shield group basalt. Shield volcanoes are almost exclusively basalt, a type of lava that is a very fluid when erupted. And also Adigrate sandstone, Alluvium, and Lateriteon Adigrate Sandston are also common.

3.2 Materials used

To process it and come up with the required outputs, different software were implemented. Some of the software and data used in this study are: XL STAT, statistical software that was used to stack hydro meteorological, Arc-GIS for spatial data analysis and in conjunction with Arc-SWAT model were used to generate flow in to the required points of interest and ERDAS 2015 was used Land use land cover classification. Since the assessment was based on analytical basis, Excel spreadsheet was also used to observe and rearrange the output from the model. For proper implementation of the study, some equipment, materials and software are required for data collection, processing and evaluation. Some of the software and data required for this study include in (Table 3.1).

Table 3.1 Software and data used for work

Software and data	Its uses
ArcGIS 10.1	To arrange Spatial data and prepare their Map
Arc SWAT	To delineate watershed and simulate hydrological parameters of watershed
ERDAS Image E 2015	For Landsat Image process, image classification and accuracy assessment
PCPSTAT	To calculate statistical parameters of daily precipitation data used in WGN
Dew02	To calculate average daily dew point temperature per month
XLSAT 2018	For filling of missed data
SWAT CUP	To calibrate and validate SWAT output
Google Earth	To provide recent information on watershed LULC
DEM Resolution data 30m	Used input data for Arc-GIS software for catchment delineation and estimation of catchment characteristic
Hydrological data	Stream flow
Meteorological data	Precipitation, Temperature(Minimum & Maximum), Wind Speed, Relative humidity, and Sunshine
Soil data	To integrate the soil map with SWAT model and in user soil database
Excel spread sheet	for pre and post processing

3.3 Methods

The procedures followed to accomplish the study are discussed under the following sub-topics starting from data collection to analysis of the impact of Land use and land cover change on hydrological process.

3.3.1 Data collection and sources

3.3.1.1 Meteorological Data

The SWAT model needs long years of climate data for the simulation of hydrological processes. For this specific study, the necessary climate data were collected from the National Meteorological Services Agency (NMSA). The three meteorological stations such as Shindi, Enjibara, and Bure stations have relatively selected with long period of record the meteorological variables collected are like Temperatures (maximum and minimum), rainfall, wind speed sunshine hours and relative humidity.

3.3.1.2 Spatial Data

Engineering studies of water resources development and management depends heavily on hydro-meteorological data. SWAT models is data driven and it requires several types of data like topography, land use, soil, hydro-meteorological, and, etc. These data were secondary and collected from various sources and different processes have been carried out to utilize them. These data are, land use and land cover data acquired from www.usgs Earth Explorer, Soil data and Topography collected from GIS department of ministry of water, irrigation and electricity (MOWIE), Stream flow data that collected from the hydrology department of ministry of water, Irrigation and Electricity (MOWIE). The analysis of collected data carried out before using it. The data collected is analyzed by ArcGIS software.

3.3.1.3 Soil Data

Soil data is one of the major input for SWAT model. The soil data of the study area was collected from Ministry of Water, Irrigation and Electricity of Ethiopia. SWAT model requires soil 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. Using the FAO/UNESCO soil classification system, the study area comprises of six major soil types and with Ethio_Soil classification such as Dystric Leptosois, Eutric Cambisois, Eutric Regosois, Eutric Vertisois, Haplic Alisois, and Haplic Nitisois. To integrate the soil data with SWAT model, a user soil data base was prepared and added to the SWAT user soil data bases. The soil in Fetam watershed is in (Figure 3.7).

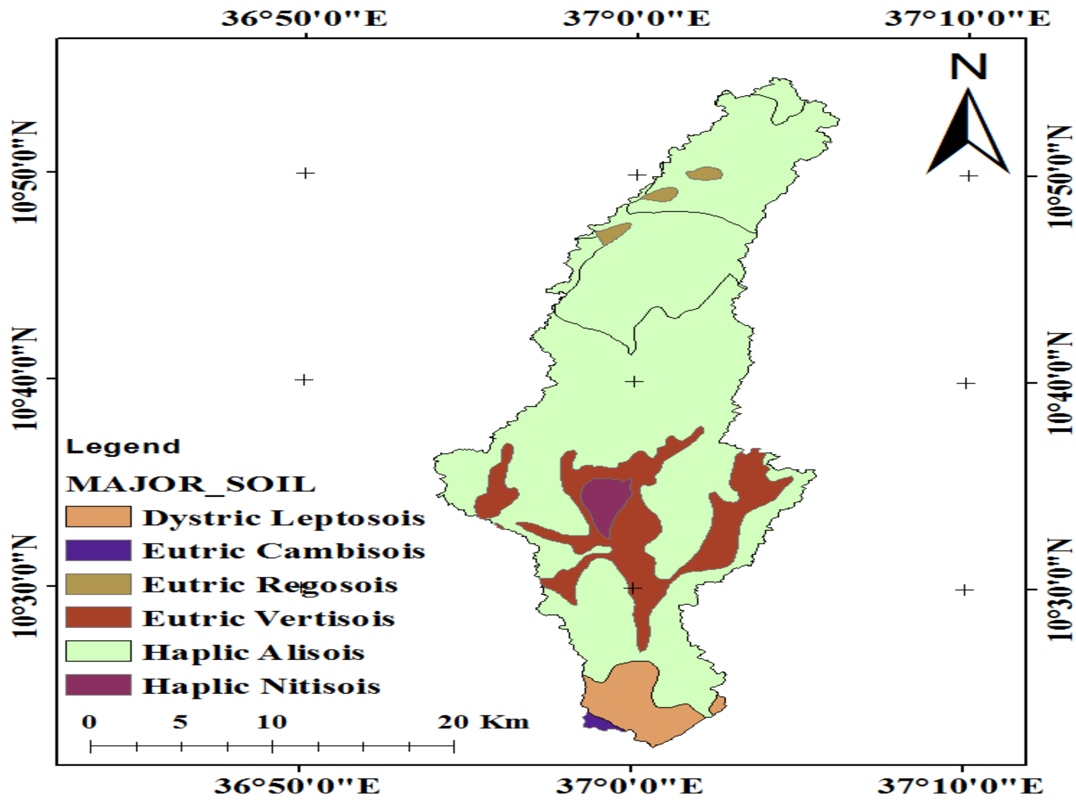

Figure 3.7 Fetam watershed soil types

3.3.1.4 Digital Elevation Model (DEM)

Spatial input data a Digital Elevation Model (DEM) gives the elevation, slope and defines the location of the streams network in a basin. Digital Elevation Model is one of the essential inputs required by SWAT to delineate the watershed in to number of sub watershed or sub basins. The DEM is used to analyze the drainage pattern of the watershed, stream lengths, and widths of channel within the watershed. The raw DEM was processed and projected using Arc GIS. A DEM with a spatial resolution of 30 m by 30 m was used in this study obtained from Ministry of water Resources MOWIE (figure3.2)

3.3.1.5 Land use Land cover data

It is also used for comparison of impacts on stream flow of the watershed with in time. The LULC map and all datasets for the years 1987 and 2017 were collected from USGS Earth Explore down loaded in GEOTIFF file format and analyzed by ERDAS imagine 2015 software. Land use land cover is one of the main input data of the SWAT model to describe the

Hydrological Response Units (HRUs) of the watersheds which affect runoff, evapotranspiration and surface erosion in a watershed in.

3.3.1.6 Stream flow

The measured stream flow data were required for calibrating and validating the model. Stream flow data was available for one Station. The stations had data ranging in time from 1993 to 2013. Stream flow data obtained from Ministry of Water Resource (MoWR).

Justification: - stream flow data only from 1993 up to 2013 because data is not available in the MOWIE, so i use the data itself.

3.3.2 Data Analysis and Preparation

The collected and acquired were analyzed and prepared before any use through the approaches. Among these software and data required for the work, filling missed data, checking consistency and analysis of the included.

3.3.2.1 Filling Missing Weather Data

The SWAT model needs full daily weather data to analysis and generate the result. The collected from National Meteorological Service Agency (NMSA) have much missed data. The missed daily rain fall and temperature data filled by XL STAT 2018 program, where multiple linear regression used to fill missed daily rain fall data from neighboring station and missed maximum and minimum daily temperature data were filled by average multiple imputation methods. Since the SWAT model requires solar radiation in day, the sunshine hour data of Bure station collected from NMAE was converted to solar radiation by using empirical equation developed by Angstrom (Equation 3.1). The Angstrom-Prescott equation (Prescott, 1940) related extraterrestrial radiation to solar radiation in given location and average fraction of possible sunshine hours (Muzathik *et al*, 2011).

$$Rs = [a + b\,(n/N)] * Ra \qquad \text{………………………………} \qquad (3.1)$$

Where;

- ✓ Rs is the solar radiation or short wave radiation
- ✓ Ra is extraterrestrial radiation
- ✓ n is the actual of sunshine (hour)
- ✓ N is the maximum possible duration of sunshine or daylight hours (hour)
- ✓ n/N is relative sunshine duration
- ✓ a and b are empirical coefficients

Expressing the fraction of extraterrestrial radiation reaching the earth on overcast days (n=0) and a+b fraction of extraterrestrial radiation reaching the earth on clear day (n=N). N and Ra are computed by (equation 3.3)

$N=24*\grave{\omega}s/\pi$ …………………………………………………………………………… (3.2)

$Ra = 24(60)/\pi * Gsc * dr * [\grave{\omega}s \sin\varphi \sin\delta + \cos\varphi \cos\delta \sin\grave{\omega}s]$ ………………………………… (3.3)

Where;

- ✓ Ra is extraterrestrial radiation ($MJM^{-2}day^{-1}$)
- ✓ Gsc is solar constant =0.0820MJM^{-2} Min^{-1}
- ✓ dr is inverse relative distance Earth –sun
- ✓ φ is latitude of the site (rad)
- ✓ δ solar declination (rad) and
- ✓ ὼs sunset hour angle (rad)

(Allen *et al*, 1998) suggested the value of a=0.25 and b=0.5 and as the inverse relative distance Earth-sun, dr, latitude of the site, φ and solar declination are calculated by the equation (3.4).

$dr=[1+0.033\cos(2\pi J/365)]$ ……………………………………………………………...(3.4)

$\varphi = Lat * 180/\pi$ ……………………………………………………………………….. (3.5)

Where; Lat-latitude in degree

$\delta = 0.409\sin[2\pi J/365 - 1.39]$ ……………………………………………………………. (3.6)

Where;

J is the number of the day in the year between 1(January) and 365 or 366 (31 December).

The sunset hour angle, ὼs could be computed from the equation (3.7).

$\grave{\omega}s = \cos^{-1}[-\tan(\varphi)\tan(\delta)]$ ………………………………………………………………… (3.7)

3.3.2.2 Checking Consistency of Weather Data

Inconsistency of climatic data could be happen during record because of the changes in conditions during record, changes in instrumentation, changes in gauge location, changes in observation practices etc. Before using any weather data, it is necessary to analysis and check whether it is consistent or not. For this particular study, the consistency of recorded data for three stations checked by double mass curve and no need of corrections because they are correlated (Figure 3.8). The Bure station used as weather generator station. The data of precipitation, maximum and minimum temperatures, sunshine hours, relative humidity, and wind speed were collected from meteorological stations such as Bure, Enjibara, and Shindi. The data collected from the meteorological stations have a missing value. To analysis this data the first procedure is since the collected data from NMAE is not suitable for the software the transposing the horizontal recorded to vertical data must be prepared by using excel sheet to fill the missed data since the collected data have missing. Therefore, using different methods, infilling for missed data and extension of short records encountered in the actual data processing activity should be done. Some techniques of filling missing data are simple linear interpolation, arithmetic mean method, XL stat and PCPSTAT, inverse distance and normal ratio method (Firat *et al.*, 2010). For this study XL STAT was used to fill the missing data of rainfall, temperature minimum and maximum, solar radiation and wind speed data stations since missing data are small. Numerous factors could affect the consistency of rainfall record at a given station. A time series observational data is relatively consistent and homogeneous if the periodic data are proportional to an appropriate simultaneous period. This proportionality can be tested by double mass analysis in which accumulated rainfall/hydrological data is plotted against the mean value of all neighborhood stations. The double mass curve technique was used to check whether the collected rainfall data from Ethiopian meteorological station were consistent through the selected period of study and reveals if correction was needed. The recording rain gauge station may have undergone change during the period of record as a result of shifting of rain gauge to new location, change due to change in ecosystem such as forest and occurrence of observational error from a certain date. This technique is based on the principle that when each recorded data comes from the same parent population, they are consistent. A group numbers of neighboring stations was chosen as base stations from the vicinity of a doubtful, all stations said as doubt stations unless they are checked (‘vedio Lec 9 Double Mass Curve). The data of the annual rainfall of the doubtful station and the average rainfall of the group of base stations covering a long period was arranged in the reverse chronological order (i.e. the latest record as first entry and the old record as the last entry in the list.

The precipitation of station x (doubtful station) can be corrected using the following formula

$$Pcx = PxMc/Ma \quad (3.8)$$

Where;

- ✓ Pcx =Corrected precipitation at any time period t at station X

- ✓ Px =original recorded precipitation at time period t at station X
- ✓ Mc =Corrected slope of double mass curve

Ma =original slope double mass curve

To investigate whether there was inconsistency for gauging stations in the watershed a group of three stations were chosen. Cumulative annual rainfall data of those stations within the Fetam watershed were used in this study in developing double mass curve. The cumulative values of the doubtful stations were plotted against the cumulative average group using Microsoft Excel spread sheet.

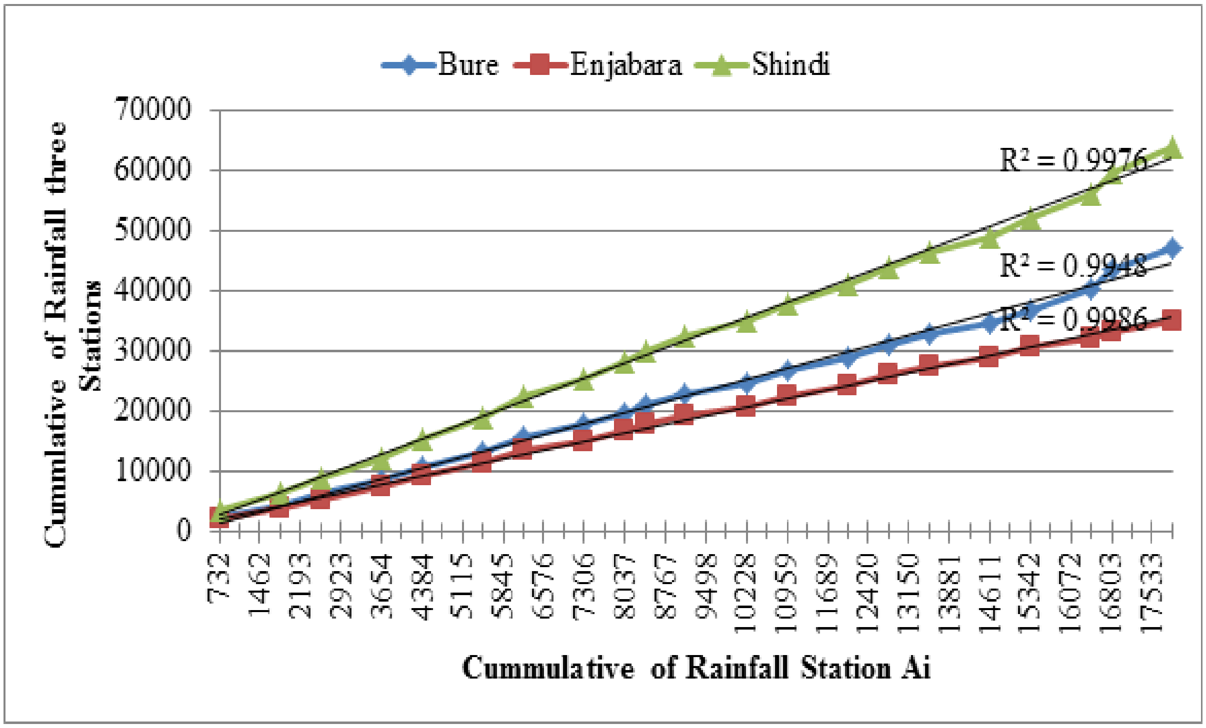

Figure 3.8 Double mass curve graph for different station data by using (1993-2013) data

The records of these stations did not show inconsistency since the graph was found to follow nearly straight line and therefore, these stations had no recording problems or subjected to any external factors during the study period.

3.3.3 Soil and Land use Land cover Data preparation

3.3.3.1 Soil Data

The soil data base was prepared and added to the SWAT user soil data base using SWAT Map window from MWSWAT extension by preparing look up table by using ArcGIS soil data and the soil type specified from FAO soil data are clay, sandy loam and loam in the watershed. To integrate the soil map with SWAT model, a user soil data base which contains textural and chemical properties of soils was prepared for each soil layers and added to the SWAT user soil data bases and the soil map prepared with look up table is loaded from disk with fixing value from soil grid loading soil map have been done from look up table SWAT soil classification table was filled and reclassification checked during the work. .

3.3.3.2 Land use Land Cover Data

Land use/land covers have a major impact on runoff generation of the watershed. Therefore, land use /land cover classification is a mandatory to evaluate the impact of land use/ land cover change on stream flow. The method to evaluate the land use land cover change impact on stream flow can be achieved through integrating GIS, remote sensing, and hydrological models (Figure 4.1 and 4.2). Satellite image have great contribution for preparation of land use land cover of the area. LU/LC information is critical importance in stream flow as it helps determine model variables that account for the volume, timing, and quality of runoff. A Physically-based distributed hydrological (Arc SWAT) model that allows several different subunits or objects to be defined within a watershed is utilized. A lookup table that identifies the SWAT land use code for the different categories of LULC was also prepared so as to relate the grid values to SWAT LULC class. The SWAT model has predefined four letter codes for each land use category (Table 3.2). These codes were used to link or associate the land use map of the study area to SWAT land use databases. Hence, while preparing the lookup-table, the land use types were made compatible with the input needs of the model.

Table 3.2 Land use and cover classification of Fetam watershed as per SWAT code

N_o	Land Use cover	Land Use according to SWAT data base	SWAT Code
1	Cultivated Land	Agricultural Close to grown	AGRC
2	Forest Land	Forest mixed	FRST
3	Shrub Land	Range Brush	RNGE
4	Grass Land	Range Grass	RNGB
5	Water Body	Water	WATR

6	Urban	Urban residential	URBN

1. Land Sat Images

In the study of the impacts of land use and land cover change on hydrological responses of catchment, remote sensing images are required and can be processed by computers to produce land use/cover map. In water resource engineering, the mapping of land use/cover map in a wide area catchment, remotely sensed data plays a paramount role. Therefore, in this study Land Sat images were used for mapping LU/LC map of the Fetam catchment. The characteristics of the images used in this research were presented in the following (Table 3.3) for this study Land sat images of 1987 and 2017 were downloaded from United States Geological Survey (https:earthexplorer.usgs.gov/) website in GEOTIFF file format. The Selection of the Land sat satellite images date was influenced by the quality of the image especially for those with limited or low cloud cover and also to prevent seasonal variation of vegetation coverage. Therefore, the images were almost cloud free and almost in the same annual season.

Table 3.3 Characteristics of Used Satellite Images

Spacecraft _ID	Path/row	Pixel Size(X&Y)	Sensor_ ID	Date	Procedure
LANDSAT_7	170/53	30m by 15m	ETM+	1987-02-12	USGS
LANDSAT_8	170/52	30m by 15m	OLI&TIFF	2017-04-14	USGS

Each land sat was geo referenced to WGS_84 datum and Universal Traverse Mercator (UTM) Zone 37N. Preprocessing such as layer stacking, mosaic king and band color combination were carried out in order to Ortho-rectify the images. The images were processed using ERDAS IMAGINE 2015 software. The satellite image of each band stacking and mosaic king was done in ERDAS IMAGINE2015. Then the study area was subset (clipped) from the mosaicked images using ERDAS IMAGINE2015. To better view the surface features clearly and the satellite images were performed color composition.

2. Image Classification

Image classification is the process of sorting pixels into a finite number of individual classes or categories of data based on their data file values. In remote sensing there are various image classification methods, supervised, unsupervised and hybrid. Unsupervised classification is computer controlled and the limitation is, we can't control computer's selection of pixels into clusters. In supervised image classification system, the user relies on her/his own prior knowledge and skills and can select a group of pixels belongs to a particular land use/land cover. In this system the user should have a good knowledge about the land cover to be studied. Supervised classification is the most common type of land use classification system and depends on prior information about the land use and land cover.

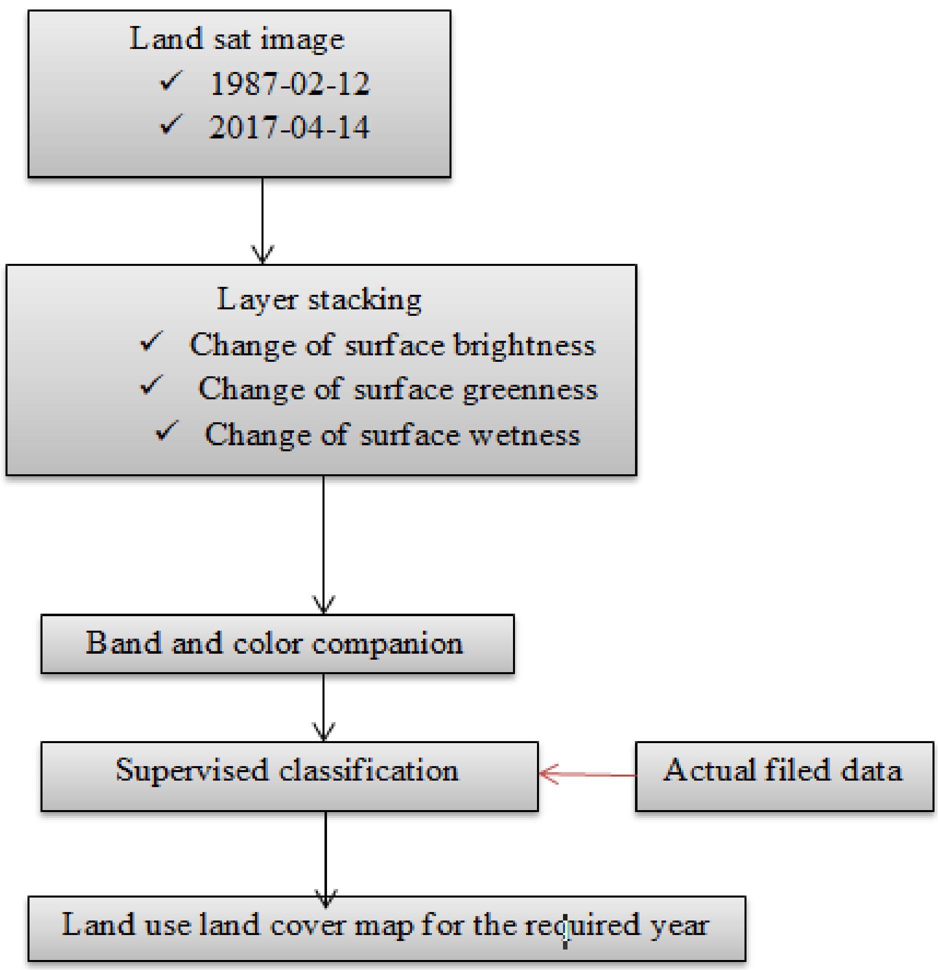

Figure 3.9 Flow chart for land cover mapping

3. Supervised Classification

In this study, analyses of the different LULC classes were performed using supervised classification method. This was done using the two Land sat satellite images, the Landsat_7 and Land sat_8 with 1987 and 2017 period. The supervised classification was applied after defined the area of interest (AOI) which is called training classes. The training sites were selected in agreement with the Land sat Image and Google Earth. In supervised land use classification, defining of training sites, extraction of signature editor and classification of image was performed using Maximum Likelihood classifier.

4. Accuracy Assessment

A vital step in the classification process, whether supervised or unsupervised is the accuracy assessment of the final classification produced (Acharya *et al.*, 2016). This involves identifying a set of sample locations that are visited in the field or using previous studies. The land use land cover found in the field is then compared to that which was mapped in the image for the same location. Then, statistical assessment (using ERRMAT) of accuracy may then be derived for the entire study area.

5. Site Observation

The site observation was done by two methods: moving through selected villages and looking for the present land use and land cover and interviewing people living a long time in the area about the land feature of the past. During Site observation and field works by GPS was conducted on selected kebeles near to the watershed to get a physical characteristics and land use features of watershed and for ground truth verification of the mapped features and accuracy assessment. Information on these areas was obtained through discussion with key informants and data that exist in wereda. Elders who are longtime residents of the areas and guards of forests were selected for the study discussion. During the discussion and interviews, the main focuses were to obtain the past and present trends of land use land cover information and the factors contributing to the changes. Both conducted data of the present and acquired information of the past was used for land sat image classification and accuracy assessment.

3.3.4 Weather Data Generator

Weather data are one of the major input data for SWAT simulation. They are daily data of precipitation, maximum and minimum temperature, relative humidity, wind speed and solar radiation. The weather data were collected from NMAE and only Three of them were used for this research due to all weather data are not full of recorded in all weather data required for the required work with SWAT model such as station of Kessa,Gundil, Laybirr,Sebadir,Sekela,Tillili, and Wogedad stations. The used stations were Bure, Enjibara, and Shindi stations. The climatic data used for this study covers from 1993-2013. All Weather data were vertically prepared on excel and finally saved as notepad format with lookup table (batch) as required by the SWAT model. Once water is introduced to the system as precipitation, the available energy, specifically solar radiation, exerts a major control on the movement of water in the land phase of the hydrologic cycle. Since evaporation is the primary water removal mechanism in the watershed, the energy inputs become very important in reproducing or simulating an accurate water balance. Arc SWAT need daily solar radiation but the data acquired from National Meteorological Service Agency is sunshine hour but changed into solar radiation by (Equation 3.1). By using SWAT 2012 data base preparation of weather generator for the study area with its latitude and longitude by naming Rbatch, with each station name of file was prepared for the ARCGIS software to simulate the discharge required. The weather data definition is divided into six tabs: weather generator data, rainfall data, temperature data, solar radiation data, wind speed data and relative humidity data. Weather data of all stations was used as an input to determine the value of the weather generator parameters. Therefore, for weather generator data definition, the weather generator data file WGEN_user, rainfall data, temperature data, relative humidity data; solar radiation data and wind speed data were selected and added to the model respectively. The weather generator parameters were developed by using excel (pivot table), dew point temperature calculator software, DEW02 the program are designed to calculate the average daily dew point temperature per month using daily temperature and humidity data and PCP STAT to calculate average monthly precipitation, standard deviation, skew coefficient, probability of a wet day following a dry day and average number of days of precipitation in a month.

3.4 SWAT Model Description

Arc SWAT version 2012 was downloaded from SWAT website and its toolbar was added to Arc GIS for modeling process. The modeling procedure includes SWAT project setup, Watershed delineation, and HRU Analysis, Write Input Tables, Edit SWAT Input and SWAT simulation. Simulation of hydrology of a watershed will in two separate components. One is the land phase of the hydrologic cycle that controls the water movement in the land and determines the water, sediment, nutrient and pesticide amount that will be load in to the main stream. Hydrological components that will simulate in land phase of the Hydrological cycle are storage; infiltration, redistribution, and Evapotranspiration, lateral subsurface flow, surface runoff, ponds and tributary channels return flow. The second component is routing phase of the hydrological cycle in which the water can route in the channels network of the watershed, carrying the sediment, nutrients and pesticides to the outlet (Haile, 2012).

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

$SWT = SWO + \sum_{i=1}^{t} (Rday - Qsurf - Ea - Wdeep - Qgw)$ ……………………………….(3.9)

Where;

- ✓ SWt is the final soil water content (mm)
- ✓ SWO is the initial soil water content for day i (mm)
- ✓ t is the days
- ✓ Rday is the amount of precipitation on day i(mm)
- ✓ Qsurf is the amount of surface runoff on day i(mm)
- ✓ Ea is the amount of Evapotranspiration on day i(mm)
- ✓ Wdeep is the seepage from the bottom soil layer (mm) and
- ✓ Qgw is the amount of groundwater flow on day i (mm).

Surface runoff occurs whenever the rate of precipitation exceeds the rate of infiltration. SWAT offers two methods for estimating surface runoff: the SCS curve number procedure and the Green & Ampt infiltration method Using daily or sub daily rainfall, SWAT simulates surface runoff volumes and peak runoff rates for each HRU.

The SCS curve number equation;

$Qsurf = (Rday - 0.2S)^2 / Rday + 0.8S$…………………………………………………… (3.10)

Where;

- ✓ Q_{surf} is the accumulate runoff or rainfall excess (mm)
- ✓ R_{day} is the rainfall depth for the day (mm), and
- ✓ S is the retention parameter (mm).

The retention parameter may be defined by equation;

$S = 25.4\ (100/CN - 10)$………………………………………………………………… (3.11)

SWAT includes two methods for calculating the retention parameter; the first one is retention parameter varies with soil profile water content and the second method is the retention parameter varies with accumulate plant Evapotranspiration. The soil moisture calculation method over estimate runoff in shallow soil. However, calculating daily CN as a function of plant

Evapotranspiration, the value is less dependent on soil storage and more dependent on antecedent climate.

$S = Smax * 1 - SW / SW + exp(W1 - W2 * SW)$ …………………………………………(3.12)

Where;

- ✓ S is the retention parameter for a given day (mm),
- ✓ S_{max} is the maximum value the retention parameter can achieve on any given day (mm),
- ✓ SW is the soil water content of the entire profile excluding the amount of water held in the profile at wilting point (mm), and
- ✓ W1 and W2 are shape coefficients.

The maximum retention parameter value, S_{max} is calculated by solving equation 3.14 using CN_1. When the retention parameter varies with plant Evapotranspiration, the following equation is used to update the retention parameter at the end of every day.

$S = Sprev - Eo * exp(CNcoif - Sprev) / Smax - Rday - Qsurf$ …………………………(3.13)

Where;

- ✓ S is the retention parameter for a given day (mm)
- ✓ S_{prev} is the retention parameter for the previous day (mm)
- ✓ E_o is potential Evapotranspiration for the day (mm per day)
- ✓ CN_{coif} is the weighting coefficient used to calculate the retention coefficient for daily curve number calculations dependent on plant Evapotranspiration
- ✓ Smax is the maximum value the retention parameter can achieve on any given day (mm)
- ✓ Rday is the rainfall depth for the day (mm) and
- ✓ Qsurf is the surface runoff (mm).

The initial value of the retention parameter is defined.

$S = 0.9 * Smax$…………………………………………………………………………... (3.14)

The SCS curve number is a function of the soil permeability, land use and antecedent soil water condition. SCS defines three antecedent moisture conditions: I dry (wilting point), II average moisture and III wet (field Capacity). The moisture condition I curve number is the lowest value the daily curve number can assume in dry conditions. The curve number for moisture conditions III and I are calculated with equations 3.15 and 3.16 respectively.

$CN1 = CN2 - 20 * (100 - CN2)/(100 - CN2 + exp * (2.533 - 0.0636 * (100 - CN2))$ ……………………………………………………………………………………………..(3.15)

$$CN3 = CN2 * \exp(0.00673 * (100 - CN2)) \quad \ldots\ldots(3.16)$$

Where;

- ✓ CN1 is the moisture condition I curve number
- ✓ CN2 is the moisture condition II curve number, and
- ✓ CN3 is the moisture condition III curve number

3.5 SWAT Model Setup

Arc SWAT version 2012 was downloaded from SWAT website and its toolbar was added to Arc GIS10.1for modeling process. The modeling procedure includes SWAT project setup, Watershed delineation, and HRU Analysis, Write Input Tables, Edit SWAT Input and SWAT simulation.

3.5.1 Watershed Delineation

The watershed and sub watershed delineation was performed using 30 m resolution DEM data using Arc SWAT model watershed delineation function. First, the SWAT project set up was created. The watershed delineation process consists of five major steps, DEM setup, stream definition, outlet and inlet definition, watershed outlets selection and definition and calculation of sub basin parameters. Once, the DEM setup was completed and the location of outlet was specified on the DEM, the model automatically calculates the flow direction and flow accumulation. Subsequently, stream networks, sub watersheds and topographic parameters were calculated using the respective tools. The stream definition and the size of sub basins were carefully determined by selecting threshold area or minimum drainage area required to form the origin of the streams. The Fetam watershed was delineated in to 33 sub watersheds. (Figure 3.9).

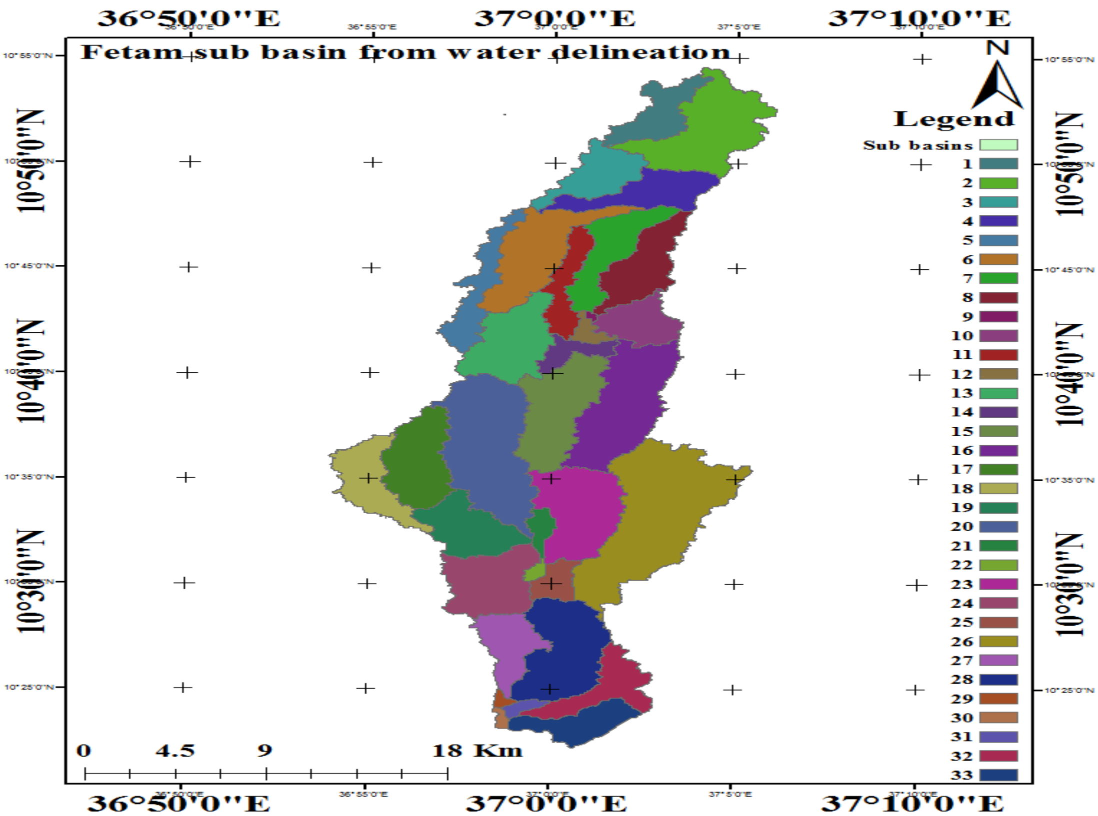

Figure 3.10 Watershed delineation of study by HRU analysis

After HRU analysis the weather data to be used in a watershed simulation was imported using the first command in the Write Input Tables menu item on the Arc SWAT toolbar. This tool helps to load weather station locations into the current project and assign weather data to the sub watersheds.

3.5.2 Hydrological Response Units (HRUs)

After watershed delineation, land use, soil and slope characterization for watershed was performed using commands from the HRU analysis menu on the Arc SWAT Toolbar. These tools were used in loading land use and soil layers of Fetam Watershed into the current project, evaluate slope characteristics and determine the land use/soil/slope class combinations and distributions for the delineated Fetam watershed and each respective sub watershed. The watershed was divided into hydrologic response units (HRU) which have a unique soil and land use combination. The multiple scenario that create account for 10% land use, 20% soil and 10% slope threshold combinations gives a better estimation of runoff (Neitsch *et al.*, 2002). The SWAT2012 model provides options for defining HRU distribution. HRU definition with multiple options that accounts for 10% land use, 20% soil and 10% slope threshold combination was used to eliminate minor land use and land covers in sub basin, minor soil within a land use and land cover area and minor slope classes within a soil on specific land use and land cover area. The input information for each sub-basin is grouped into categories of weather; unique areas of land cover, soil, and management within the sub-basin; ponds; groundwater; and the main channel or reach, draining the sub-basin. HRU analysis in SWAT includes divisions of HRUs by slope classes in addition to land use and soils. The LULC, soil and slope map was reclassified in order to correspond with the parameters in the SWAT database. After reclassifying the land use, soil and slope in SWAT database, all these physical properties made to be overlaid for HRU definition. Based on this the Fetam Watershed have 33 sub basin each has a unique land use and soil combinations. In this study, two slope classes with slope range of 0-15% and greater than15% was selected

3.5.3 Write input tables

The input data needed include the Digital Elevation Model (DEM), soil data, land use and weather data and river discharge for prediction of stream flow and calibration purposes. Soil Data; SWAT model requires different soil textural and physic-chemical properties such as soil texture, available water content, hydraulic conductivity, bulk density and organic carbon content for different layers of each soil type. Land Use; Land use is one of the most important factors that affect runoff, evapotranspiration and surface erosion in a watershed. Weather Data: SWAT requires daily meteorological data that could either be read from a measured data set or be generated by a weather generator model. In this research, the weather variables used for driving the simulated stream flow are daily precipitation, minimum and maximum temperature, solar radiation, wind speed and relative humidity prepared suit for the software on WGN-user for the period 1993-2013.

3.5.4 SWAT simulation

Running the model, read SWAT output and set default simulation are included with sensitivity analysis, calibration and validation was carried out.

3.5.5 Sensitivity analysis, calibration and validation in the SWAT-CUP

Soil and Water Assessment Tool - Calibration and Uncertainty Programs (SWAT-CUP) is an automated calibration model which provides link between the input/output of a calibration program and the model. It is a generic interface that was developed for calibrating the SWAT model.

3.5.5.1 Sensitivity Analysis

Measured daily and Monthly River flow at Fetam from 1993 to 2013 was used for calibration and validation of the SWAT model applied to the Fetam watershed. As semi distributed model, SWAT has several parameters and almost impossible to calibrate all of them. A sensitivity analysis is therefore needed to determine the most sensitive parameter in the basin for the calibration process. Sensitivity analysis also helps to understand the model's behavior and the predominant processes (Arnold et al., 2012). The parameters under consideration for the analysis were chosen based on literature review ((Neitsch et al., 2011), (Setegn et al., 2008), (Easton et al., 2010), (Betrie, Mohamed, van Griensven, & Srinivasan, 2011), (Arnold et al., 2012)).The sensitivity analysis was performed in two ways: first by varying one parameter at a time while keeping the others constant, second by varying all the parameters simultaneously. For this analysis 20 parameters were selected based on previous literatures and only 12 parameters were identified to have significant influence in controlling the stream flow in the watershed. Flow parameters that tested for their sensitivity values for monthly and daily time steps are presented as below (Table 4.7).

3.5.5.2 Conceptual Basis of the SUFI-2 Uncertainty Analysis Routine

In SUFI-2, uncertainty of input parameters are depicted as uniform distributions, while model output uncertainty is quantified by the 95% prediction uncertainty (95PPU) calculated at the 2.5% and 97.5% levels of the cumulative distribution of output variables obtained through Latin hypercube sampling. SUFI-2 starts by assuming a large parameter uncertainty, so that the measured data initially falls within the 95PPU, then decrease this uncertainty in steps until two rules are satisfied: (1) The 95PPU band brackets ‘‘most of the observations’’ and (2) The average distance between the upper (at 97.5% level) and the lower (at 2.5% level) parts of the 95PPU is ‘‘small’’. Quantification of the two rules is somewhat problem dependent. If measurements are of high quality, then 80–100% of the measured data should be bracketed by the 95PPU, while a low quality data may contain many outliers and it may be sufficient to account only for 50% of the data in the 95PPU. For the second rule we require that the average distance between the upper and the lower 95PPU be smaller than the standard deviation of the measured data. This is a practical measure based on our experience. A balance between the two rules ensures bracketing most of the data within the 95PPU, while seeking the smallest possible uncertainty band. We use the above two measures to quantify the strength of calibration and accounting of the combined parameter, model, and input uncertainties (Abbaspour, 2007).

3.5.5.3 Calibration and validation

The calibration was performed based on the twelve parameters. The Sequential Uncertainty Fitting (SUFI- 2) model by (K. Abbaspour, Johnson, & Van Genuchten, 2004) for optimization and uncertainties analysis was used in the SWAT-CUP for calibration and validation. The Nash-Sutcliff_ (SN) efficiency (Nash & Sutcliffe, 1970) was assigned as the objective function. In SUFI-2, a parameter uncertainty is propagated (as uniform distribution) through a Latin Hypercube (statistical method for generating a sample of plausible collections of parameter values from a multidimensional distribution) sampling (Schuol & Abbaspour, 2006). It is referred to as the 95% depicting prediction uncertainty or 95PPU (known as P-factor) calculated at 2.5% and 97.5% levels for each parameter. The 95PPU is the degree to which all uncertainties are accounted for (Abbaspour, 2013). The average thickness of the 95PPU band divided by the standard deviation of the measured data quantifies the strength of the calibration and uncertainty analysis is known as R-factor. The perfect situation would be 100% of the observed data bracketed in the 95PPU while at the same time R-factor is close to zero (Abbaspour, 2013). SUFI-2 accounts for all uncertainties including uncertainties in driving variable like rainfall, conceptual model, parameters and measured data. For this project, the calibration covered the period 1995-2005 and the validation for the period 2008-2013 with two warming up years (i.e. 1993 and 1994). A model validation is comparing the model output to an independent set of data without making any further adjustment in the parameters.

3.5.5.4 Model Performance Evaluation

To evaluate the model simulation outputs in relative to the observed data, model performance evaluation is necessary. There are various methods to evaluate the model performance during the calibration and validation periods. For this study, two methods were used: coefficient of determination (R^2) and Nash Sutcliffe efficiency (NSE). The determination coefficient (R^2) describes the proportion the variance in measured data by the model. It is the magnitude linear relationship between the observed and the simulated values. R^2 ranges from 0 (which indicates the model is poor) to 1 (which indicates the model is good), with higher values indicating less error variance, and typical values greater than 0.6 are considered acceptable (Santhi et al., 2001).

$R^2 = \sum^{n}_{K=0}(Oi - Oimean)(Si - Simean)^2 / \sum^{n}_{k=0}[(Oi - Oi\ mean)(Si - Si\ mean) * \sum^{n}_{k}=0(Si - Si\ mean)]^2$

…………………………………………………………………………………………………..(3.17)

Where;

- ✓ R^2 is coefficient of determination
- ✓ O_i measured value
- ✓ S_i is simulated values
- ✓ Oimean average measured values
- ✓ Simean average simulated values

The Nash and Sutcliffe simulation efficiency (NSE) describes the deviation from the unit of the ratio of the square of the difference between the observed and simulated values and the variance of the observations. The value of the coefficients varies from minus infinity to one with the latter value indicating perfect agreement between the simulated and observed data. A smaller NSE value indicates poorer fit between the simulated and observed data. It is possible to obtain negative value of the NSE indicating that the average of the observational data provides a better fit to the data compared to the simulated data. NSE is recommended and widely used in literature therefore there is a lot of reported values for use as evaluation guidelines. NSE, in a simplified explanation by (Moriasi et al 2002) is an indication of how well the plot of observed versus simulated data fits the 1:1 line. NSE is computed using in the equation

$NSE = 1 - \sum^{n}_{k=0}(Osim - Si)^2 / \sum nk=0(Oi - Si,av)^2$ …………………………………………….(3.18)

Where;

- ✓ NSE is Nash Sutcliff efficiency
- ✓ Oi measured value
- ✓ Si is simulated values
- ✓ Omean average measured values and
- ✓ *Si*mean average simulated values

The percent bias (PBIS) describes the tendency of the simulated data to be greater or smaller than the observed data, expressed as percentage. The optimum PBIAS value is zero and low values indicate that the model simulation is satisfactory. Positive values indicate a tendency of the model to underestimate while negative values are indicative of overestimation. This test is recommended due to its ability to reveal any poor performance of the model. $PBIAS=\sum_{k=0}^{n}(Oi-Osi,av)*100/\sum_{k=0}^{n}Oi$ …………………………………………………..(3.19)

Where;

- PBIAS is percent of bias,
- Oi is measured value and
- Osi is simulated value

The evaluation was performed by visual and statistical comparison of the measured and simulated data. The graphical method provided an initial overview. The statistical criteria used to evaluate the performance of the model.

4. RESULTS AND DISCUSSION

4.1 Land use/land cover change assessment

4.1.1 Land use/land cover Classification accuracy assessment

The columns of the matrix indicate the number of pixels per class for the reference data and the rows indicate the number of pixels per class for the classified images. From this statistical accuracy assessment such as, overall accuracy, user's accuracy and producer's accuracy were derived to test the classification. User's accuracy is the probability of classified pixels representation of reference data, whereas, producer's accuracy is the probability of reference data to be correctly classified. In this study, classification accuracy assessment was carried out using Google Earth imageries and Existing land cover maps (Guzha *et al.*, 2018). A total of 200 and 168 testing sample points were randomly collected for the year 1987 and 2017 respectively and the result presented in the result and discussion section. The user's and producer's accuracy indicate accuracy of individual classes. The overall classification accuracy which is the ratio of the total number of correctly classified pixels (diagonal) to total number of reference pixels was to be 95.5% and 96.43% for the maps 1987 and 2017 (Table 4.5 & Table 4.6) respectively. According to (Anderson, 1976) the minimum accuracy value for reliable land cover classification is 85%. In this study the result indicated that the classification accuracy assessment according to Anderson and the result satisfies the minimum accuracy assessment criteria.

Table 4.1 Confusion matrix for the classification of 1987

Classified Classes								Producer's Accuracy (%)	Kappa coefficient (Ka)
	RNGB	AGRC	FRST	RNGE	URBN	WATR	Total		
RNGB	22	0	0	1	0	1	24	91.66 %	0.9357
AGRC	1	84	0	1	0	0	86	97.67%	0.977
FRST	1	1	30	0	0	0	32	93.75%	0.9454
RNGE	1	0	1	28	0	0	30	93.33%	0.9434
URBN	0	0	0	0	10	0	10	100%	1
WATR	0	0	0	0	1	17	18	94.44%	0.9486
Total	25	85	31	30	11	18	200		

Use's Accuracy (%)	88%	98.82 %	96.77%	93.33%	90.09 %	94.44 %		95.5% Overall Efficacy	**0.9448**

Table 4.2 Confusion matrix for the classification of 2017

Classified Classes								Producer's Accuracy (%)	Kappa coefficient (Ka)
	RNGB	AGRC	FRST	RNGE	URBN	WATR	Total		
RNGB	15	0	0	1	0	0	16	93.75 %	0.922
AGRC	0	83	0	0	0	1	84	98.88%	0.986
FRST	0	1	15	0	0	0	16	93.75%	0.922
RNGE	0	0	1	16	0	0	17	94.12%	0.923
URBN	0	0	0	0	17	0	17	100%	1
WATR	0	0	0	2	0	16	18	88.88%	0.906
Total	15	84	16	18	17	17	168		
Use's Accuracy (%)	100 %	98.8 %	93.7 %	88.8 %	100%	94.1 %		96.43% Overall Efficacy	**0.967**

4.2 Land Use Land Cover Map

Mapping and classifying land use land cover is very important in hydrological study. This is done after image classification of the two land use land cover maps (1987and 2017) using the method maximum likelihood classification of land sat satellite image. The study area of the dominant land use land cover are summarized to six major class namely agricultural land, Forest (deciduous and ever green),Grass Land, Shrub land, Urban and water body.

Table 4.3 Land cover categories of Fetam watershed

N_o	Parameters	Definition of parameters
1	Agricultural Land	Areas in the image that have agricultural crop present
2	Range Grass Land	Areas covered with grass used for grazing and bare lands that have little grass or no grass cover

3	Forest Land	Area covered with dense trees which includes mixed forest and plantation forest
4	Range shrub land	Areas covered with mixed trees on high land areas and every year green
5	Built up Area Settlement areas of residential building	Settlement areas of residential building
6	water Areas covered with water	Areas covered with water

In water resource engineering, the mapping of land use/Land cover map in a wide area catchment, remotely sensed data plays a paramount role. Therefore, in this study Land Sat images were used for mapping LU/LC map of the Fetam watershed. For this study, Land sat images of 1987 and 2017 were downloaded from United States Geological Survey (https:earthexplorer.usgs.gov/) website in GEOTIFF file format. The Selection of the Land satellite images date was influenced by the quality of the image especially for those with limited or low cloud cover and also to prevent seasonal variation of vegetation coverage. Therefore, the images were almost cloud free and almost in the same annual season. Each land sat was geo_ referenced to WGS_84 datum and Universal Traverse Mercator (UTM) Zone 37N. Preprocessing such as layer stacking and band color combination were carried out in order to Ortho-rectify the images.

4.2.1 Land use land Cover Map of 1987

The land cover map of 1987 in (figure 4.1) and the histogram of the land class coverage shows that about 56.79% of the Fetam watershed was covered by agricultural land, 34.15% by Grass Land, 4.52% by forest land, 0.95% by water body, 2.13% by shrub land and 1.46% by Urban area. The distribution of land cover class as it is shown in the (Table 4.4).

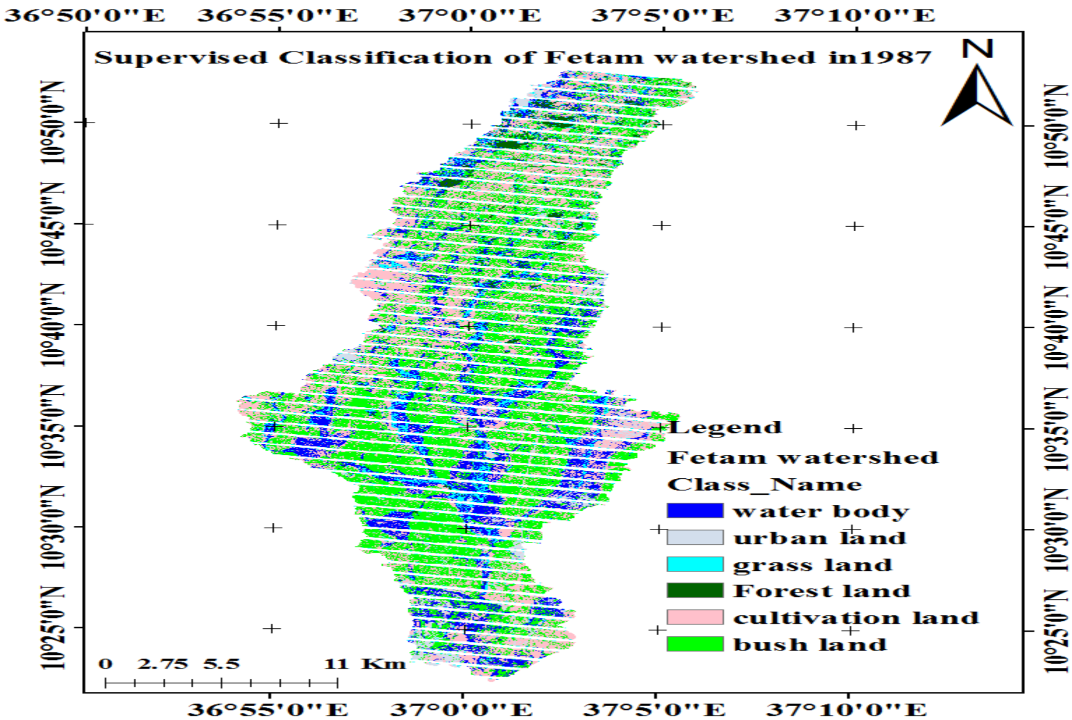

Figure 4.1 Land use land cover map of Fetam catchment in the year 1987

Table 4.4 Area of LU/LC of Fetam Watershed for the Study Period 1987

LULC classify categories 1987			
LULC classes)	Area(Ha)	Percentage Area %	LULC Classes
RNGB	977.94	2.13%	RGNB=Range Brush Land
AGRC	26073.83	56.79%	AGRC=Agricultural Land
FRST	2075.25	4.52%	FRST= Forest Land
RNGE	15679.19	34.15%	RGNE=Range grass land
URBN	670.32	1.46%	URBN=Urban
WATR	436.171	0.95%	WATR=Water body
Total	45912.7125	100%	

4.2.2 Land use land Cover Map of 2017

The land cover map of 2017 in (figure 4.2) and the histogram of the land class coverage shows that about 66.44% of the Fetam watershed was covered by agricultural land, 28.45% by grass land, 2.18% by forest land, 0.52% by shrub land, 2.329% by settlement (urban) area, and 0.081% by water body. The distribution of land cover class as it is shown in the (Table 4.5).

Table 4.5 Area of LU/LC of Fetam Watershed for the Study Period 2017

LULC classify categories 2017			
LULC classes)	Area(Ha)	Percentage Area %	LULC Classes
RNGB	238.75	0.52%	RGNB=Range Brush Land
AGRC	30504.41	66.44%	AGRC=Agricultural Land
FRST	1000.89	2.18%	FRST= Forest Land
RNGE	13062.17	28.45%	RGNE=Range grass land
URBN	1069.31	2.329%	URBN=Urban
WATR	37.19	0.081%	WATR=Water body
Total	45912.7125	100%	

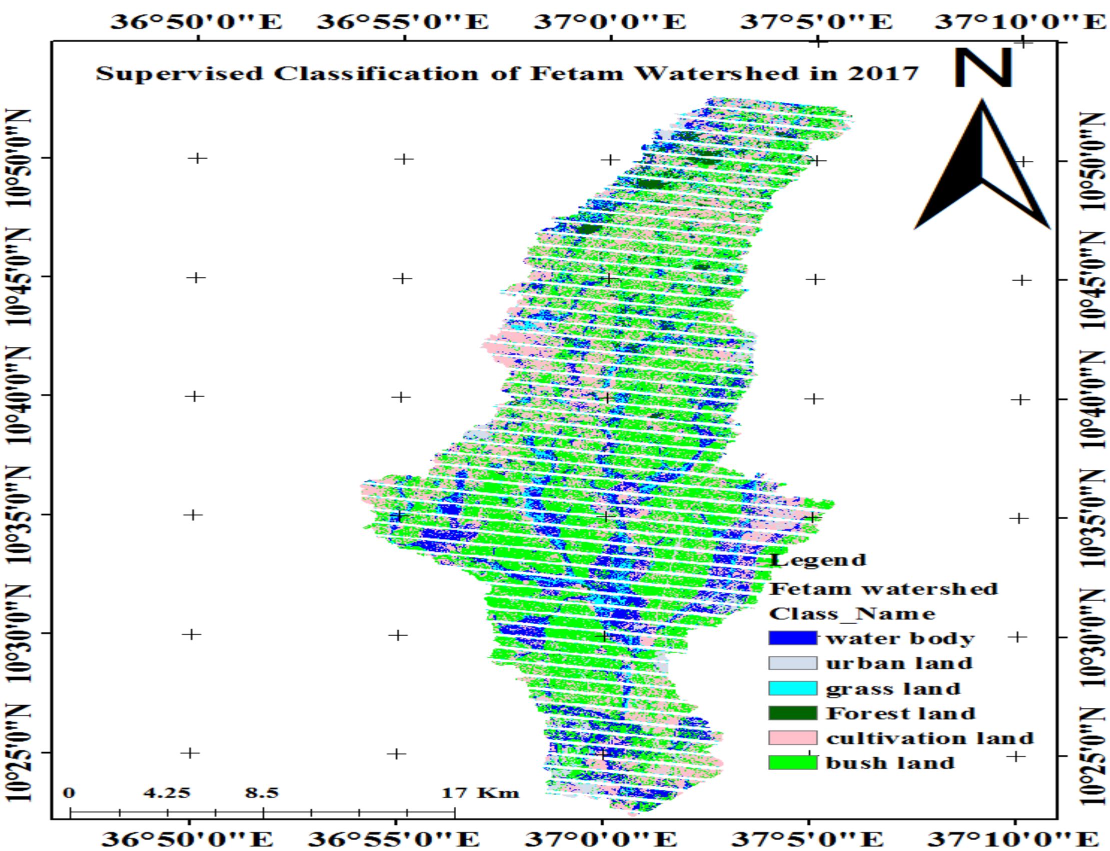

Figure 4.2 1Land use land cover map of Fetam watershed in the year 2017

Table 4.6 Summary of area of LU/LC of Fetam watershed for the study period

LULC classify categories 1987			LULC classify categories 2017		2017-1987 change rate of LULC	
LULC classes)	Area(Ha)	Percentage Area %	Area(Ha)	Percentage Area %	Area(Ha)	Percentage Area %
RNGB	977.94	2.13%	238.75	0.52%	-739.19	-1.61%
AGRC	26073.83	56.79%	30504.41	66.44%	4430.58	9.65%
FRST	2075.25	4.52%	1000.89	2.18%	-1074.36	-2.34%
RNGE	15679.19	34.15%	13062.17	28.45%	-2617.01	-5.7%
URBN	670.32	1.46%	1069.31	2.329%	398.99	0.869%
WATR	436.171	0.95%	37.19	0.081%	-398.981	-0.869%
Total	45912.7125	100%	45912.7125	100%		

4.2.3 Land Use Land Cover Analysis

The two-land use cover maps of 1987and 2017 years generated from the land sat ETM+ and OLI-TIRS imaginary Classification (Figure 4.1 and 4.2) respectively. This is done after image classification of the two land use land cover maps 1987 and 2017 whose results for each analysis can be expressed. From the result the increase of cultivated land, Urban and decrease of forested areas, shrub land, and grass land and water bodies over 30 years in the watershed. The forest cover decreased markedly between 1987 and 2017 by 2.34%, in the Watershed. The decrease could be attributed to the cutting of trees in the forests for various uses such as firewood and clearing for cultivation and agricultural purposes. The agricultural land increase between 1987 and 2017 by 9.65% at the most part of the watershed. This increase could be linked with high increase population growth. The built up area also changed significantly between 1987 and 2017 by 0.869% due to rapid development of urban centers the expansion of the town. The growth of urban centers can be attributed to high rate of rural urban migration. The Grass land cover was found in the most parts of the watershed. Grass land, Shrub land, and water of the watershed decrease between 1987 and 2017 by 5.7%, 1.61% and 0.869% respectively.

4.3 Sensitivity, Calibration & Validation of stream flow

4.3.1 Sensitivity Analysis

Let us recall that the SWAT has several parameters and it is quasi impossible to calibrate all of them. The sensitivity analysis was therefore needed to determine the most sensitive parameters in the Fetam watershed for the calibration process. The sensitivity analysis was performed in two ways: first by varying one parameter at a time while keeping the others constant, second by varying all the parameters simultaneously. Table 4.7 Final Parameter range and their sensitivity rank.

Table 4.7 Final Parameter range and their sensitivity rank

No	Parameter Name	t-Stat	P-Value	Fitted Value	Min Value	Max Value	Sensitivity Rank
1	R__CN2.mgt	-7.448	0	-0.0983	-0.25	0.25	1
2	V__ALPHA_BF.gw	2.81023	0.005177	0.4522	0	1	8
3	V__GW_DELAY.gw	-38.72	0	47.266	30	450	2
4	V__GWQMN.gw	-20.7570	0	305.55	0	5000	3
5	R__EPCO.bsn	-1.1848	0.2367	0.3433	0	1	10
6	R__SOL_Z (..).sol	4.4988	0.0000088	-0.1805	-0.25	0.25	5
7	R__SOL_K (..).sol	3.8400	0.000141539	0.21166	-0.25	0.25	7
8	R__SOL_AWC(..).sol	4.27269	0.000023809	0.36777	0	1	6
9	R__BIOMIX.mgt	0.840612	0.401033	0.94111	0	1	12
10	R__RCHRG_DP.gw	-1.10355	0.27040	0.09666	0	1	11
11	R__HRU_SLP.hru	-2.20930	0.02768	0.88333	0	1	9
12	R__OV_N.hru	7.323311	0	14.5666	0.01	30	4

Note; "R_"; relative change to the existing parameter value i.e. the existing value is multiplied by 1+ a given value. And "V_"; the existing parameter value is to be replaced by the given value.

T_ stat provides a measure of sensitivity (larger in absolute values are more sensitive); P_ values determined the significance of the sensitivity. A value close to zero has more significance. Sensitivity analysis of simulated stream flow for the watershed was performed using the daily observed flow for identifying the most sensitive parameter and for further calibration of the simulated stream flow. 20 flow parameters were checked for sensitivity and 12 sensitive parameters were identified to have significant influence in controlling the stream flow in the watershed. The sensitive parameters identified were presented in the table above.

4.3.2 Calibration and Validation

The simulation of the model with default value of parameters showed relatively weak matching between simulated and observed stream flow. So the calibration and validation process was carried out automatically by the help of SWAT CUP model using sensitive parameters by Sequential Uncertainty Fitting program (SUFI2). Calibration was performed for 10 years from 1995 to 2005. The result of calibration for daily flow showed that there is a good agreement between the measured and simulated daily flows with Nash-Sutcliffe simulation efficiency (NSE) of 0.87 and coefficient of determination (R^2) of 0.89 and PBIAS of 12.7 as shown in Table 4.8. The model validation was also performed for 5 years from 2008 to 2013.The validation simulation also showed good agreement between the simulated and measured daily flow with the PBIAS value of -7.5, R^2 of 0.84 and NSE of 0.72as shown in Table 4.8.

Table 4.8 Calibration & Validation results for stream flow

Performance Criteria	Model efficiency		
	R^2	NSE	PBIAS
Calibration	0.89	0.87	12.7
Validation	0.84	0.72	-7.5

Different studies that were conducted in the upper Blue Nile basin also showed similar result. For example, (Awulachew *et al.*, 2010), (Lemann *et al.*, 2018) report that SWAT model showed a good match between measured and simulated flow of Gumara watershed and Lake Tana both in calibration and validation periods. With (NSE = 0.76 and R^2= 0.87) and (NES=0.68 and R^2= 0.83), through modeling of the Lake Tana basin, (Dile *et al.*, 2019) respectively.

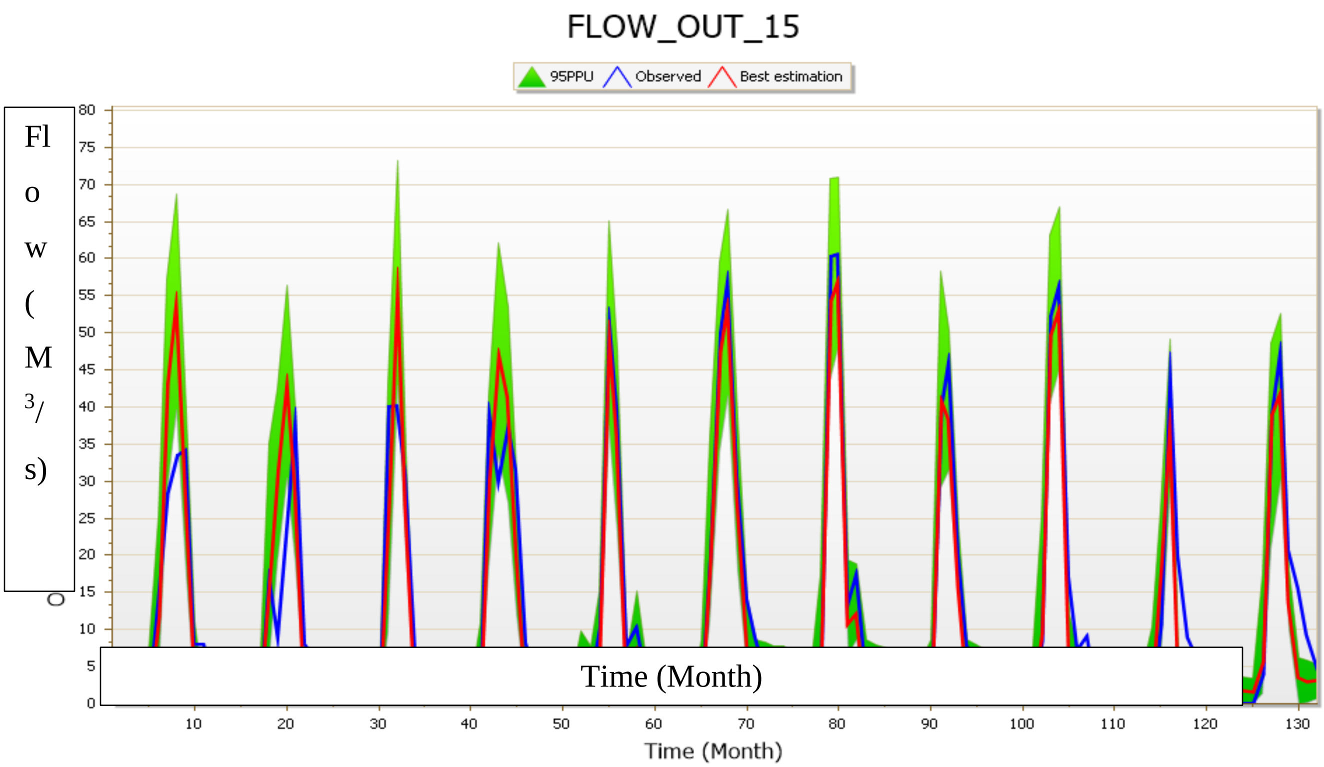

Figure 4.3 Calibration result for the study area

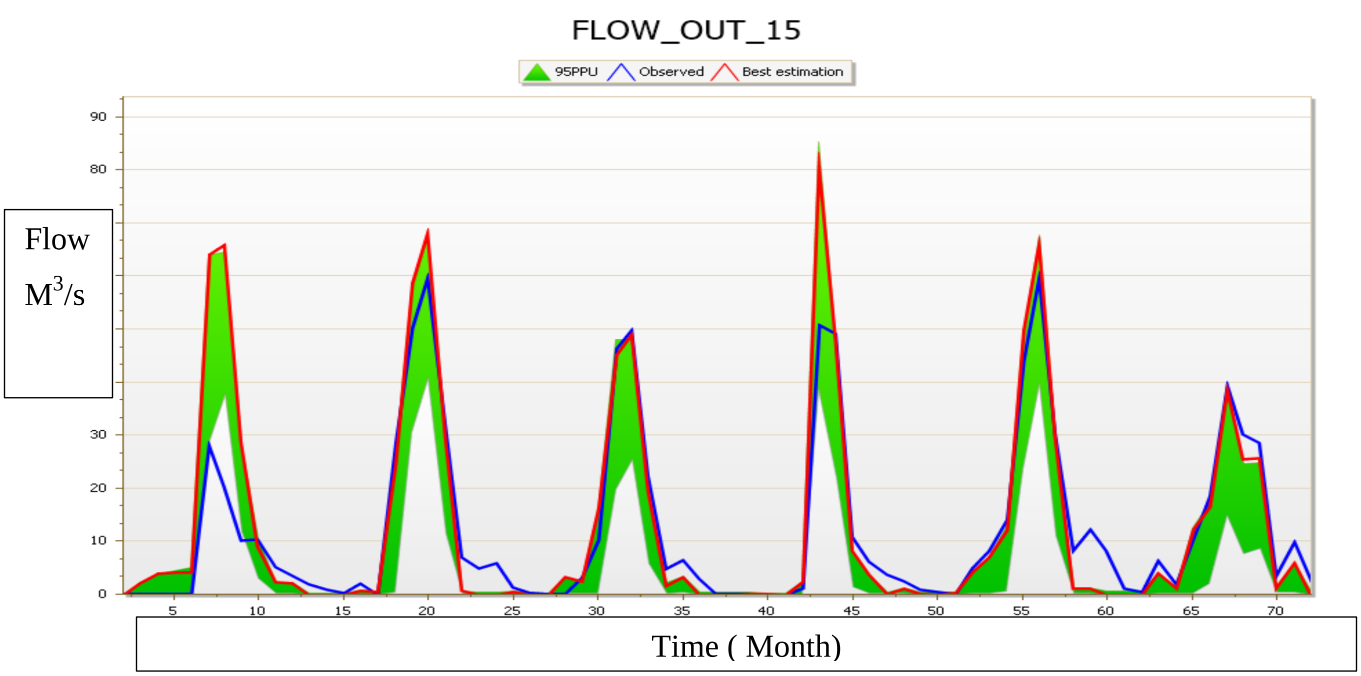

Figure 4.4 Validation results for the study Area

4.4 Impact of LULC on the stream flow of Fetam watershed

One of the most important parts of the study was to evaluate the Stream flow responses of Fetam Watershed to LU/LC change. Therefore, surface runoff, lateral flow and ground water flow were the most important catchment processes and the evaluation was done depending on these processes at the watershed outlet. These processes can be affected with changing of LU/LC change. It was done to see the stream flow change as a result of LU/LC change during the years of 1987 to 2017. After calibrating and validating the model using the two land use and land cover maps for their respective periods (1987 and 2017), SWAT2012 was executed land use land cover maps for the periods and 1987 and 2017 while setting all the other set of input variables similar i.e. soil, climate change, etc. for both simulations in order to evaluate the variability of stream flow due to the land use land cover changes. This gave river discharge outputs that correspond to both land use land cover patterns. These outputs were then compared and percentages of discharge change during the wet, short rain and dry seasons were assessed at watershed and sub watershed levels and used as indicators to estimate the hydrological effects due to land use and land cover change

Table 4.9 Seasonal variation of stream flow 1987 and 2017

Season	1987	2017	Change
Wet Season (June-September)	34.58 m^3/s	40.37 m^3/s	5.79 m^3/s
Short rain Season (March –May)	0.0113 m^3/s	17.994 m^3/s	17.98 m^3/s
Dry Season(October -February)	14.7556 m^3/s	7.405 m^3/s	-7.3506 m^3/s

The model was calibrated and validated using different land use data i.e. land use data for the periods of 1987 and 2017. Similarly the SWAT was run differently using land cover maps (1987 and 2017 maps) while other remaining variables were kept constant i.e. (change in climate and soil management activities and other land use variables like sediment load) during simulations in order to evaluate the variability of stream flow due to the changes in land use and land cover. This technique presented the flows for both land use and land cover forms.

Then, the results were compared and the discharge change during the season cycles, during the wettest months of stream flow were taken as June, July, August the shortest Rainy months of the stream flow were taken as March –May and the driest stream flow were in the months of January, February, March. These were taken as means of estimating the effect of land use land cover change on the stream flow. To evaluate the effects of LULC change on stream flow, SWAT model was calibrated and validated for stream flow. After calibration and validation of SWAT model, the model was run using the two land use maps (1987 and 2017) while maintaining the other parameters the same i.e. (climate change and soil management activities) to estimate the change of stream flow due to LULC changes. The annual stream flow through study period is increased for wet season (June to September), and short rainy season (March to May) whereas, decreased for dry season (October to February). The mean monthly stream flow for wet months had increased from 34.58 m^3/s to 40.37 m^3/s, the mean monthly stream flow for short Rainy months had increased from 0.0113 m^3/s to 17.994 m^3/s, and dry season decreased 14.7556 m^3/s to 7.405 m^3/s between the 1987 and 2017 periods due to the land use land cover changes (Table 4.9). Considering wet season of the stream flow by taking June to September, Short Rainy Season of the stream flow by taking (March to May) and dry season stream flow taken as October to February for detecting the change of stream flow the comparison of simulated stream flow for the LULC of the two Periods are summarized as below;

For Example; the finding of the study is consistent with other study. The mean monthly discharge for wet months, discharge for short Rainy Season and in the dry season during the 1987 and 2017 periods due to the LULC changes by graph;-

Justification: - short rain season (March & May) rainfall and stream flow did not show any land use land cover change, low flows, and degradation of the watershed.

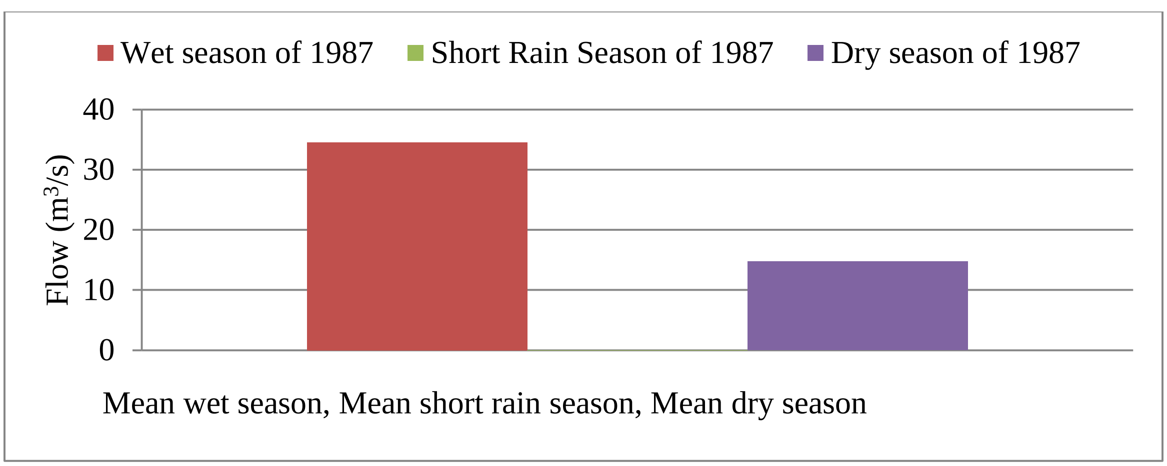

Figure 4.5 Simulated mean seasonally monthly flow of 1987

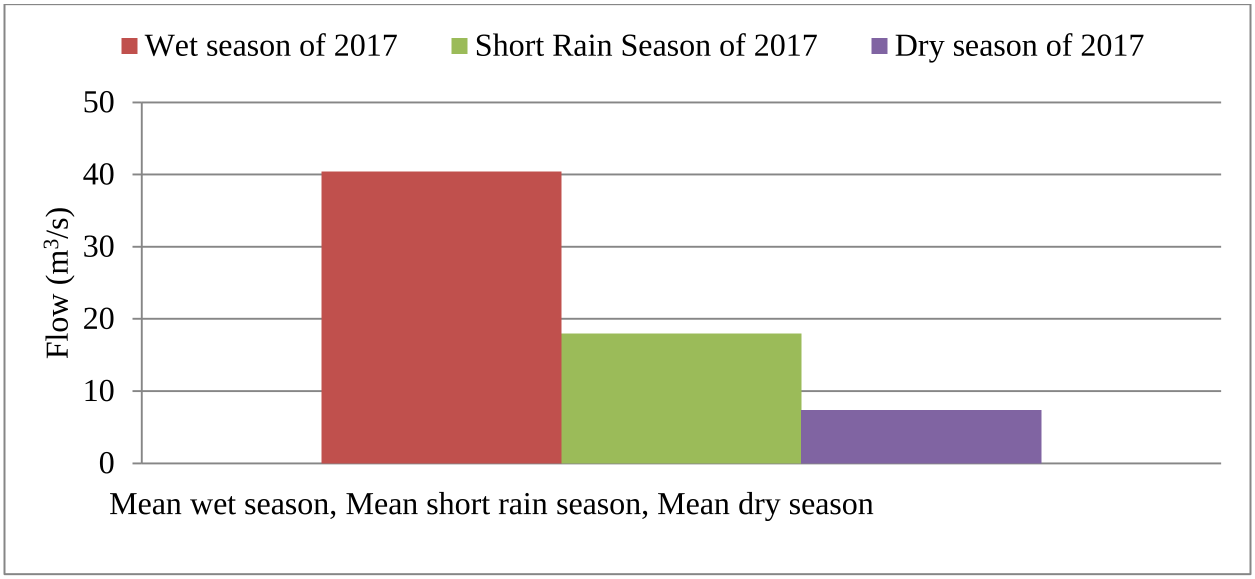

Figure 4.6 Simulated mean seasonally monthly flow of 2017

To assess the change in the contribution of the components of the stream flow due to the land use and land cover change, analysis were made on the surface runoff (SURQ) and ground water flow (GWQ). Table 4.10 presents the SURQ and GWQ of the stream simulated using 1987 and 2017 land use and land cover map for the same period.

Table 4.10 Surface runoff and Ground water flow of the stream simulated using 1987 & 2017

No	Years of Land use	SURQ (mm)	GWQ (mm)
1	Land use/cover map of 1987	518.69	377.47
2	Land use/cover map of 2017	723.30	262.42

As shown in the table 4.10 the contribution of surface runoff has increased from 518.69 mm in to 723.30 whereas the ground water flow has decreased from 377.47mm in to 262.42mm due to the land use and land cover change occurred between the periods of 1987and 2017. This is because of the expansion of cultivated land over bush and forest that results in the increase of surface runoff following rainfall events. We can explain this in terms of the crop soil moisture demands.

Crops need less soil moisture than bush and forests; therefore the rainfall satisfies the soil moisture deficit in cultivated lands more quickly than in bush and forests there by generating more surface runoff where the area under cultivated land is extensive. This is caused variation in soil moisture and groundwater storage. This expansion also results in the reduction of water infiltrating in to the ground. Therefore, discharge during dry months (which mostly comes from base flow) decreases, whereas the discharge during the wet months increases. These results demonstrate that the land use and land cover change have a significant effects on infiltration rates, on the runoff production, and on the water retention capacity of the soil. Different studies have been conducted in different parts of the country to evaluate the effects of land use and land cover changes on stream flow. Study on a Hare watershed, in Southern Ethiopia, (Tadele, 2007) reported that due to the replacement of natural forest in to farmland and settlements, the mean monthly discharge for wet months had increased while in the dry season decreased. A modeling study of Anger watershed, in Ethiopia, (Brook, Argaw, Sulaiman, & Abiye, 2011) introduced that the surface runoff increased and the base flow decreased due to the expansion of agricultural land and declined of forest land. Generally, the hydrological investigation with respect to the land use and land cover change within Fetam watershed showed that the flow characteristics have changed, with increase in surface flow and reduction of base flows through the selected period of study.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study has addressed the impact of land use cover changes on Fetam watershed for over 30 years period using Landsat satellite images from USGS earth explorer. The classification of land use and land covers were performed on ERDAS IMAGE 2015, which were integrated with other GIS data and the stream flow was done using SWAT model. This was done to map the land use/cover classes and evaluate classification accuracy. Then, the effects of land cover dynamics on the Stream flow of the watershed were evaluated. The SWAT model was calibrated and validated in the Fetam watershed and Statistical performance of the model was seen. Then, the evaluation of the impacts of land use/cover change on stream flow was done. One of the main aims of this study is to evaluate LU/LCC and its impacts on the watershed. On the other hand, data preparation, sensitivity analysis, calibration, validation and evaluation of model performance were performed on the selected, SWAT and SWAT_CUP, model. 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 1987 to 2017 showed slightly changed. Cultivated land was drastically changed from 56.79 % in 1987 to 66.44 % in 2017 in the expenses of the other classes. Urban area also increased from 1.46 % in 1987to 2.329 % in 2017. The expansion of agricultural land and urban area has an impact for the decrease of bush and forest land. Thus, the bush land which constituted 2.13% in 1987 decreased to 0.52 % in 2017. Forest and grass land also decreased from 4.52% and 34.15% in 1987 to 2.18% and 28.45% in 2017 respectively and also water body decreased from 0.95% in 1987 to 0.081% in 2017. The sensitivity analysis using SWAT_CUP has identified twelve most important parameters that control the stream flow of the studied watershed. Monthly model Performance for both the calibration and validation watershed were very good with (NSE) values of 0.87 and 0.89 and (R^2) values of 0.84 and 0.72 for the calibration and validation respectively. LULUC recognized to have major impacts on hydrological processes, such as runoff and groundwater flow. The result of model for all land use and land covers (1987 and 2017) indicated that the mean monthly flow for all land covers were increased during the wet season while the mean monthly flow decreased by during the dry season. The surface runoff increased from 518.69 mm to 723.3mm while the ground water decreased from 377.47 mm to 262.42 mm for the year 1987and 2017 land cover maps.

5.2 Recommendation

- ✓ In this study I have attempted to show only the effect of land use and land cover change on stream flow into the Fetam watershed by using the calibrated and having good performance model SWAT. However, I would like to suggest for other future researchers, planners and policy makers of water resource projects in this watershed to consider the effect of climate change as well as other different management practices on stream flows, sediment yield and soil erosions that appropriate alleviation measures can be made.
- ✓ The continuation of the land use/land cover change is becoming a serious threat to Fetam watershed. The land use/land cover change should be controlled in the watershed and soil and water conservation measures should be taken for the stabilization of the land cover change by natural resources managers and planners.
- ✓ The other thing which is highly recommended is that the weather stations should be in or near by Fetam watershed which have full data sources in order to get a good result and to improve the performance of the model.

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APPENDIX

Appendix - A Parameter used in sensitivity analysis name

No	Parameter	Name
1	CN2	SCS runoff curve number
2	ALPHA_BF	Base flow alpha factor (days)
3	GW_DELAY	Ground water delay (days)
4	GWQMN	Treshold depth of water in the shallow aquifer required for return flow to occur (mm)
5	EPCO	Plant uptake compensation factor
6	SOL_Z	Depth from soil surface to bottom of layer
7	SOL_K	Saturated hydraulic conductivity (mm/h)
8	SOL_AWC	Available water capacity of the soil layer (mmH_2O/mm Soil)
9	BIOMIX	Biological mixing efficie
10	RCHRG_DP	Deep aquifer percolation fraction
11	HRU_SLP	Average slope steepness
12	OV_N	Manning's "n" value for overland flow

Appendix - B Annual Rainfall Stations used in developing double mass curve

Year	Bure RF	Enjabara RF	Shinidi RF
1993	3114.05	3794.195	1068.675
1994	2595.95	3056.17	874.879
1995	2397.61	2818.684	862.079
1996	3088.71	3490.152	1113.917
1997	2800.03	3765.582	770.854
1998	3252.72	3728.362	1047.238
1999	2962.17	3798.564	833.567
2000	2471.75	3495.697	796.759
2001	2548.64	3163.019	918.16
2002	1538.98	2270.786	459.557
2003	2113.2	2604.346	698.429

2004	2057.15	2871.687	821.615
2005	2529.3	3191.733	911.218
2006	2729.93	3527.445	919.972
2007	2647.43	3380.148	982.347
2008	2146.45	2999.781	770.623
2009	2176.01	2795.996	838.326
2010	2603.86	3209.264	884.34
2011	2030.68	6234.416	870.636
2012	1649.63	5439.368	709.605
2013	2379.21	6455.114	929.073

Appendix - C Mean, Maximum and Minimum Temperature of Three Stations

	Bure			Enjabara			Shinidi		
Year	Mean temp	Min temp	Max temp	Mean temp	Min temp	Max temp	Mean temp	Min temp	Max temp
1993	16.6124	10.59517	22.62966	17.49	11.00936	23.97066	20.6699	13.31337	28.02578
1994	16.9041	10.54985	23.25843	17.7953	10.85696	24.73368	20.7215	13.25206	28.19166
1995	17.438	11.19068	23.68536	18.1992	11.33005	25.06836	21.7474	13.95605	29.53955
1996	16.7209	11.11337	22.32853	17.6164	11.35308	23.87971	20.951	13.79163	28.11007
1997	17.0805	11.09485	23.06614	17.9189	11.47231	24.36549	21.4047	13.92802	28.88235
1998	17.1598	11.24861	23.07098	18.0899	11.54203	24.63776	21.2947	14.0809	28.50983
1999	17.079	10.63672	23.5212	18.0963	11.16344	25.02914	20.9688	13.40678	28.53139
2000	17.3348	10.89095	23.77869	18.3947	11.36854	25.42087	21.54	13.69646	29.38325
2001	17.983	11.43857	24.52735	18.5716	11.5362	25.60696	22.3691	14.1868	30.55267
2002	18.7204	11.5024	25.93837	19.387	11.65651	27.11744	23.1024	14.20472	32.00114
2003	18.7316	11.68488	25.77834	19.6334	11.91271	27.35419	22.833	14.32443	31.34176
2004	18.7311	11.49282	25.96937	19.1721	11.57584	26.76843	22.9485	14.28179	31.61522
2005	18.455	11.57738	25.33257	19.1284	11.82611	26.4307	22.593	14.49599	30.69001
200	18.258	11.6506	24.8663	18.932	11.8277	26.0377	22.57	14.4734	30.6664

6	5	8		7	2	5		7	8
2007	18.0305	11.4595	24.60153	18.7643	11.68596	25.84265	22.3934	14.30805	30.48015
2008	18.182	11.35134	25.01264	18.957	11.57398	26.34009	22.4668	14.1296	30.80291
2009	18.4049	11.63255	25.17728	19.2338	11.87931	26.58829	23.0114	14.5972	31.42605
2010	17.7232	11.59219	23.85415	18.3884	11.66788	26.58829	21.9494	14.37663	29.52091
2011	17.0249	11.00528	23.04446	16.7757	11.06903	25.10901	21.7637	13.31256	30.21529
2012	17.6213	11.0889	24.15371	17.1069	11.11661	23.09715	21.9914	12.97941	31.00329
2013	17.2363	11.14941	23.32326	16.8739	11.12797	22.61976	21.6987	13.27207	30.12543