ADDIS ABABA UNIVERSITY

INSTITUTE OF TECHNOLOGY

School of Civil and Environmental Engineering

Evaluate the Effects of Watershed Characteristics on Stream Flow, the Case of Blue Nile River Basin, Beshilo Watershed, Ethiopia.

A thesis submitted to Addis Ababa Institute of Technology, School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirement for the Degree of Masters of Science in Civil and Environmental Engineering

Major in Hydraulic Engineering.

By

Asalf Shumete

Advisor: Dr. Yenesew Mengiste

Addis Ababa, Ethiopia.

October 2018

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Approval by Board of Examiners

Dr. Yenesew Mengiste	--------------------	-------------------
(Advisor)	Signature	Date
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(Internal Examiner)	Signature	Date
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(External Examiner)	Signature	Date
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Chairman (Department of graduate committee)	Signature	Date

DECLARATION

I, the undersigned, declare that this thesis is my, own work with the exception of such quotation or reference which has been attributed to their authors or sources, and this thesis has not been previously submitted to this or any other university for a degree award.

Name Asalf Shumete

Signature -------------------------- date ----------------

Addis Ababa Institute of Technology

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ABSTRACT

Land degradation is a series problem in Ethiopia highlands, particularly in Blue Nile River Basin reflected in the form of soil erosion and soil fertility decline from time to time. Beshilo watershed is one of the major Blue Nile River Basin tributary, which covers 5,700 km^2. The effect of watershed characteristics on Stream flow of Beshilo watershed were evaluated by distributed physically based hydrological model known as soil and water assessment tool (SWAT) model. The model was used for detail evaluation of the watershed characteristics on stream flow and the effects of physical watershed characteristics were analyzed and character which have higher effect on stream flow were identified and also identify model remedial measure for most stream flow generation in the watershed. The model was calibrated and validated by transferred flow data from gauged upper reaches of Gummara watershed to ungauged Beshilo watershed. The model was calibrated for the period from 1999-2008 and validated for the period from 2009-2014. The performance of the model was evaluated on the basis of performance rating criteria, coefficient of determination, and Nash & Sutcliff efficiency on monthly based value, the coefficient of determination (R^2) and Nash- Sutcliffe coefficient was 0.77 and 0.80 for calibration period, 0.83 and 0.84 for validation period. The overall performance of the models gives good result and the effect of watershed characteristics on stream flow were evaluated and tested by created different scenarios. The land use land cover change scenario, the climate characteristics and the slope change scenario are developed, from the land use land cover change analysis, it was found that has been a substantial decline of forest land, shrub land, grass land and expansion of agricultural land. The mean annual stream flow at 2004 LULC were increase by 7.4 % compared from 1996 LULC and increased by 6.8 % compare from 2013 LULC. Whereas compared the two recent LULC 2004 and LULC2013, at 2013 LULC the stream flow decrease by 2.3 %, this result show that LULUC change was affect the stream flow in the watershed. And the other scenario were developed by increasing the average tributary slope by 5% rate and decrease by 5% rate, the annual stream flow averagely increased by 2.1% and decreased by 1.8 % respectively. Whereas the climate effect was observed by changing the climate data with 10 year interval, the model output clearly demonstrate physical watershed characteristics affect the stream flow, the land use land cover change was highly affects the stream flow in Beshilo watershed. So, to reduce the stream flow in the study area land use land cover management is important.

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LIST OF ABBREVIATIONS

a.m.s.l	above mean sea level
BNRB	Blue Nile River Basin
PCC	Physical catchment characteristics
Arc GIS	Aeronautical Reconnaissance Coverage Geographic Information Systems
DEM	Digital Elevation Model
SWAT	Soil and Water Assessment Tool
EMA	Ethiopian Mapping Agency
FAO	Food and Agricultural Organization
HRU	Hydrologic Response Unit
LULC	Land Use and Land Cover
MWIE	Ministry of Water, Irrigation and Electricity
NMA	National Metrology Agency
SCS	Soil Conservation Service
SWAT-CUP	Soil and Water Assessment Tool- Calibration and Uncertainty Programs
SUFI-2	Sequential Uncertainty Fitting Procedure Version 2
WXGEN	Weather Generator
95PPU	95% Prediction Uncertainty
WWDS	Water Works Design and Supervision Enterprise
DEW02	Dew Point Temperature Calculator
ET	Evapotranspiration
MCM	Million Cubic Meter
NSE	Nash Sutcliff Efficiency
SCS	Soil Conservation System
R^2	Coefficient of Determination

1. INTRODUCTION

1.1 General

Land and water resources degradation are the major problems on Ethiopian highlands. Poor land use practices and improper management systems have significant role in causing high soil erosion rates, sediment transport and most importantly the Loss of water resources both in quantity and quality (Shimelis, 2008). Erosion disturbs the channel stability and as a result downstream areas may receive excessive sediment loads, leading to poor water quality (Robert, 2002).

Stream flow and water quality is dependent on the land-use practices within their entire watershed. Therefore, watershed management is an essential part of maintaining healthy productive rivers. Particularly a better understanding of the hydrological characteristics of different watersheds in the head of the Blue Nile River Basin is one of considerable importance for government special interest towards developing water resources. For instance, the Beshilo watershed is considered as one of tributary of Blue Nile River Basin. To enhance national economic development the great Ethiopian renaissance dam is one the major project development attempts on the Blue Nile River Basin. Beshilo watershed is one of most affected Sub Basin in the region as soil erosion, sediment transport and land degradation are great concerns. The land and water resources of the Sub Basin and its ecosystem are in danger due to the nature of watershed and rapid growth of population, deforestation and overgrazing, soil erosion or sediment transportation is serious problem for Beshilo watershed Yared mengstu (2011). So in this study the effect of watershed characteristics of Beshilo watershed on stream flow was evaluated and study the effect of watershed characteristics on stream flow generation by using soil and water assessment tool (SWAT) model and GIS are adopted. Previously effects of Watershed characteristics of Ribb and Gummara watershed on its River flow to lake Tana where studied, but both the two watershed are gauged and flows to Lake Tana and located at the middle of the floodplains, especially the Ribb watershed is affected by a flood passes outside the station and accumulation of sand in the stream. Therefore it is better to locate the station away from the flood plain in the downstream or else revising and updating the conveyance profile of the existing station every time (Ephrem Alemu, 2001). Whereas Beshilo the watershed was not gauged, so stream flow data for calibration and validation were transferred from the nearest gauged Gummara watershed through flow data transfer techniques.

1.2 Problem of Statement

Land degradation is a series problem in Ethiopia highlands, particular in Blue Nile River Basin reflected in the form of soil erosion and soil fertility decline from time to time (Abeyou 2008). Beshilo watershed is one of the major tributary for this Basin, which covers 5,700 km^2. This shows that the problem of Beshilo watershed is significant in Blue Nile River Basin development. According (Abeyou 2008) the effects of land degradation and soil erosion are a major cause for deposition of sediment in major reservoirs like Grand Renaissance dam. This problem happened due to untreated watershed available in this Basin and still there is no a detail studied in Beshilo watershed. Therefore, it is vital to examine the influence of watershed characteristics on stream flow in Beshilo watershed in order to protect land degradation and soil erosion. The land degradation and soil erosion are strong relation with watershed characteristics especially the stream flow is affected by this characteristics (Ephrem Alemu 2011). However, such association was not observed in Beshilo watershed, so research on this area specially related to watershed characteristics is important.

1.3 Objectives

1.3.1 General Objective

The main objective of this study is to examine the influence of watershed characteristics on Beshilo watershed using SWAT model in the upper Blue Nile basin.

1.3.1 Specific Objectives

1. To identify the most watershed character for stream flow on Beshilo watershed.
2. To understand the concept of how stream flow data transferred from gauged to ungauged watershed.
3. To identify the possible remedial measure for the sensitive watershed character that highly affect the stream flow in the watershed.

1.5 Significance of the study

Watershed characteristics has significant impact on natural resources, socioeconomic and environmental systems. This study has identified the most watershed character changes and showed how can affect the stream flow in the watershed. Therefore, it will improve the sustainable management of natural resources in the country in general and at the study area in particular by providing useful information that will assist the decision making. In addition, methods and procedures used in this study can be used for related work and the final result of this research can be used as a guide in planning the water resources for the future purposes in watershed under study.

1.6 Scope of the study

This study was investigated the effect of watershed characteristics on stream flow in the watershed and hydrologic modeling were done using SWAT model incorporated with GIS. Moreover, this model is calibrated, validated by using transferred flow from gauged station and the parameter values were used for further estimation of discharge in to the river. Also the land use/cover change were identified using ten year interval, based on the climate condition of the watershed the initial year was as reference year and 1996, 2004 and 2013 land use land cover maps were used for the SWAT model. Furthermore, using these maps the river discharge was estimated and its impact on the watershed were assessed. Although, water resources are affected by many factors, for this study the climate characteristics, slope or hillside effects were evaluated how effect the stream flow, which watershed character significantly affect the stream flow, finial identify the remedial measure for most affected watershed character that affect stream flow in the watershed.

1.7 Thesis outline

1: Introduction:

Under this part included problem of statement, objectives of the study, significant and scope of the study.

2: Literature review.

About the subject matter is presented and it gives a scientific review this study is mainly based on. The reviewed literatures are relevant to hydrological model, studies on upper Blue Nile River basin, about watershed characteristics and land cover classification, change detection, impact on stream flow.

3: Material and Methods:

This includes; Description of the study area, which includes location, topography; climate, hydrology, and land cover of the study area are also described in this chapter, Data source, collection and analysis. Methodology of the study followed for determination of impacts. Describes the procedure how to address the objective using Hydrological model and also and use Land cover classification using SWAT for the year of 1996, 2004 and 2013, sensitivity analysis also include in this chapter

4 Result and Discussion:

This part includes presents the outcome of model application to assess the impact watershed characteristics effect stream flow in Beshilo watershed. It gives a detailed account of the model set up, sensitivity of model parameters, calibration, validation and model prediction uncertainty, remedial measure for the most character for governing stream flow.

5 Conclusion and Recommendation:

this summarizes the contribution of this research for wares resource management and suggests related future research issues.

2. LITERATURE REVIEW

2.1 Hydrological model

Hydrological model is a mathematical model used to simulate stream flow and evaluate water quality condition. These models generally came in to use in the 1960s and 1970s when demand for numerical forecasting of water quality was driven by environmental legislations in the United States and United Kingdom. At about this time computers became more widely accessible and powerful enough to significantly assist in modeling processes.

There are numerous hydrological models and they can be grouped by pollutant addressed, complexity of pollutant sources, whether the model is steady state or dynamic, and the time period modeled. Also important in determining the selection of model is whether it is distributed (i.e. capable of predicting multiple points within a river) or lumped. Simple models may only address a single pollutant, whereas a complex model could have multiple runoff and point sources for pollution for more than one chemical, as well as sediment data. It could further divide the channel flow in to strata in which various biotas are modeled in relation to chemical and sediment transport. Models often address individual steps modularly in the simulation process. Typically subroutines for surface runoff include components for a land use type, topography, soil type, vegetation cover, precipitation and land management practice (regular agricultural activities e.g. pesticide or fertilizer application).

The predictions of the model are directly compared with measurements for two purposes. First, most water Resource models include "free parameters," i.e. variables used in the mathematical formulation for which direct measurements do not exist. These can be estimated by adjusting their values until the resulting model prediction agrees with measurements, a process referred to as model "calibration." Second, the model is operated under the same external conditions as encountered during collection of a set of field data, and the model predictions compared to the field measurements, without any adjustment or "fitting" of the model, to evaluate the performance of the model, a process referred to as model "verification. (Ward, 1999).

2.2 Classification of hydrological models

Many different types of hydrological models have been developed. Many of these models share structural similarities because of underlying assumptions, while some of the models are distinctly different. Therefore, these models are classified according to different criteria. Hypothesis traditionally proposed two kind of modeling approaches with their strong points and limitations: physically based and Conceptual lumped models. Physically based models consist of formulation in terms of physical laws expressed in the form deterministic conservation equation for mass, momentum and energy. The equations are solved numerically by dispraising the hydrological system in to smaller entities on a square or polygonal mesh. However, accurately modeling of all processes of the hydrologic cycle becomes very complex, demands an eminent insight in hydrological behavior and is very demanding for input data. Due to these properties it is a time consuming and expensive. An example of such model is SHE (Abbott, 1986).

As an alternative to physically based distributed models, conceptual lumped models are often used as robust tools at catchment scale. The model structures of these models are relatively simple and often are based on a series of interconnected reservoirs. Further these models are invaluable instruments for operational water management (eg. Reservoir operation and flood forecasting). The description of the reservoirs behavior is kept simple in most structures and their response are controlled by parameterization that are rarely described in terms of physical principles such as gravity, pizieometric heads or hydraulic conductivity and cannot be measured in the field. They must be estimated using a calibration procedure whereby the model parameters are fined tuned manually or automatically, by means of optimization algorisms, until the natural system output and the model output show an acceptable level of agreement. However, once environmental forcing condition (eg. Land cover pattern) change, the parameters usually need to recalibrated (Refsgaard, 1996). Because of the fact that the required input and output data are usually easily available, consequently these models are mostly used in rainfall-runoff modeling. The SWAT rainfall runoff model is an example of a conceptual model (Bergsrtom, BergsrtThe HBV model. In: V.P. Singh (Ed.) Computer models of watershed hydrology. Water Resources publications, Highlands Ranch, CO. , 2005).

2.3 Swat model

Among the many hydrologic models developed in the past decade, the Soil and Water Assessment Tool (SWAT), developed by (Arnold, 1993), has been used extensively by researchers. This is because SWAT uses readily available inputs for weather, soil, land, and topography, it allows considerable spatial detail for basin scale modeling, and it is capable of simulating change in catchment characteristics using different scenarios.

SWAT is recognized by the U.S. Environmental Protection Agency (EPA) and has been incorporated into the EPA's BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) (Di Luzio, 2002) . [BASINS is a multipurpose environmental analysis software system developed by the EPA for performing watershed and water quality studies on various regional and local scales.]. In order to optimally calibrate the model parameters, especially for large-scale modeling, an auto-calibration routine has been added to SWAT. SWAT is a river basin scale, continuous time, a spatially distributed model developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long period of time (Neitsch S. L., 2005) SWAT model, has proven to be an effective tool for assessing water resource and nonpoint source pollution problems for a wide range of scales and environmental conditions across the globe.

SWAT is a physically based watershed-scale continuous time-scale model, which operates on a daily time step. The SWAT model can simulate runoff, sediment, nutrients, pesticide, and bacteria transport from agricultural watersheds (Arnold et al., 1998). The SWAT model delineates a watershed, and sub-divides that watershed in to sub-basins. In each sub-basin, the model creates several hydrologic response units (HRUs) based on specific land cover, soil, and topographic conditions. Model simulations that are performed at the HRU levels are summarized for the sub-basins. Water is routed from HRUs to associated reaches in the SWAT model. SWAT first deposits estimated pollutants within the stream channel system then transport them to the outlet of the watershed. The HRUs provide opportunity to include processes for possible spatial and temporal variations in model input parameters. The hydrologic module of the model quantifies a soil water balance at each time step during the simulation period based on daily precipitation inputs. The SWAT model distinguishes the effects of weather, surface runoff, evapotranspiration, crop growth, nutrient loading, water routing, and the long-term effects of varying agricultural management practices (Neitsch et al., 2005). In the hydrologic module of the model, the surface runoff is estimated separately for each sub-basin and routed to quantify the total surface runoff for the watershed. Surface runoff volume is commonly estimated from daily rainfall using modified SCS-

CN method. The model needs several data inputs to represent watershed conditions which include: digital elevation model (DEM), land use and land cover, soils and climate data. SWAT can analyze both small and large watersheds by subdividing the area in to homogeneous parts. Hence, SWAT will be used in this study to simulate evaluation of effects of watershed characteristics on river flow.

2.4 Hydrological component of swat

Simulation of hydrology of a watershed is done 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 loaded into the main stream. Hydrological components simulated in land phase of the Hydrological cycle are canopy 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 is routed in the channels network of the watershed, carrying the sediment, nutrients and pesticides to the outlet. In the land phase of the hydrologic cycle, SWAT simulates the hydrological cycle based on the water balance equation (Neitsch et al., 2005).

$$SWt = SWo + \sum_{i=1}^{t}\left(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

Where,

SWt is the final soil water content (mm)

SWo is the initial water content (mm)

t is the time (days)

R_{day} Is the amount of precipitation on day i (mm)

Q_{surf} Is the amount of surface runoff on day i (mm)

E_a Is the amount of evapotranspiration on day i (mm)

W_{seep} Is the amount of water entering the vadose zone from the soil profile on day i (mm), and Q_{gw} Is the amount of return flow on day i (mm).

Potential evapo transpiration: Evapotranspiration is the combination of two terms which are transpiration from the plant and evaporation from the water bodies and soil. SWAT provides three options for PET calculation: Penman-Monteith (Monteith, 1956), Priestley-Taylor (Priestley, 1972), and (Hargreaves, 1985). These have different data requirement of climate variables. Penman-Monteith method requires solar radiation, air temperature, relative humidity and wind speed; Priestley-Taylor method requires solar radiation, air temperature and relative humidity; whereas Hargreaves method requires air temperature only. Penman- Monteith method is used in this study.

Surface Runoff: Surface runoff occurs whenever the rate of precipitation exceeds the rate of infiltration. SWAT offers two methods for estimating the surface runoff: the Soil Conservation Service (SCS) curve number method (USDA, 1972) or the Green & Ampt infiltration methods (Green, 1911). The Green and Ampt method requires sub-daily time step rainfall which was difficult to be used for this study due to unavailability of sub-daily rainfall data. As a result, the SCS curve number method was adopted for this study which is computed by using equation 2:

$$Q_{surf} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)} \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots 2$$

Where,

Q Is the accumulated runoff or rainfall excess (mm)

R_{day} is the rainfall depth for the day (mm water),

I_a Is initial abstraction which includes surface storage, interception and infiltration prior to runoff (mm water),

S is retention parameter (mm water).

The retention parameter computed by equation 2:

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

Where, *CN* is the curve number for the day and its value is the function of land use practice, soil permeability and soil hydrologic group.

The initial abstraction, I_a is commonly approximated as 0.2*S* and equation 2-2 rewritten as follows:

$$Q_{surf} = \frac{(R_{day} - 0.2S)^2}{(R_{day} + 0.8S)} \dots\dots\dots\dots 4$$

Ground Water Flow To simulate the ground water flow, SWAT separates groundwater into two aquifer systems: a shallow, unconfined aquifer which contributes return flow to streams within the watershed and a deep, confined aquifer which contributes return flow to streams outside the watershed (Arnold J. G., 1993). In SWAT the water balance for a shallow aquifer is computed by using equation 5

$$aq_{sh,i} = aq_{sh,i-1} + W_{rchrg} - Q_{gw} - W_{revap} - W_{deep} - W_{pump,sh} \dots\dots 5$$

Where,
$aq_{sh,}$ is the amount of water stored in the shallow aquifer on day i (mm),

aq, is the amount of water stored in the shallow aquifer on day i-1 (mm),

W_{rcharg} is the amount of recharge entering the aquifer on day i (mm),

Q_{gw} is the ground water flow, or base flow, or return flow, into the main channel on day i (mm),

W_{revap} is the amount of water moving in to the soil zone in response to water deficiencies on day i (mm),

W_{deep} is the amount of water percolating from the shallow aquifer in to the deep aquifer on day i (mm), and

$W_{pump,sh}$, is the amount of water removed from the shallow aquifer by pumping on day i (mm).

Flow Routing Phase

The second phase of the SWAT hydrologic simulation, the routing phase, consists of the movement of water, sediment and other constituents (e.g. nutrients, pesticides) in the stream network. The change in channel dimensions with time due to down cutting and widening is also included. Similar to the case for the overland flow, the rate and velocity of flow is calculated by using the manning's equation. The main channels or reaches are assumed to have a trapezoidal shape by the model. Two options are available to route the flow in the channel networks: the variable storage and Muskingum methods. Both are variations of the kinematic wave model. The variable storage method uses a simple continuity equation in routing the storage volume, whereas the Muskingum routing method models the storage volume in a channel length as a combination of wedge and prism storages.

While calculating the water balance in the channel flow, the transmission and evaporation are also well considered by the model. For this study, the variable storage method was adopted. The method was developed by (Williams, 1995) and recommended (Arnold J. J., 1995).

The Storage routing is based on the continuity equation ------------:6

$$\Delta V_{stored} = V_{in} - V_{out} \qquad \text{----------------------------6}$$

Where,
ΔV is the change in volume of storage during the time step (m3)

V_{in} is the volume of inflow during the time step (m3), and

V_{out} is the volume of outflow during the time step (m3)

2.5 Swat-cup

The SWAT-CUP program is linked to four algorithms to run calibration and validation in SWAT Models. These includes

i. Generalized Likelihood Uncertainty Estimation GLUE (Beven, 1992)

ii. The Sequential Uncertainty Fitting (SUFI-2) (Abbaspour, 2007) method

iii. The Parameter Solution (Van Griensven, 2006) and

iv. The Bayesian inference which is based on the Markov Chain Monte Carlo (MCMC) method. SUFI-2 algorithm, in particular, is suitable for calibration and validation of SWAT model because it represents uncertainties of all sources. It can perform parameter sensitivity analysis to identify those parameters that contributed the most to the output variance due to input comprehensive description on the SUFI-2 algorithm can be found in (Abbaspour et al., 1997).From this alternative used the Sequential Uncertainty Fitting (SUFI-2)

2.6 Previous study in Blue Nile River Basin.

The study conducted by the United States department of the interior, bureau of reclamation in 1964 is named as study of land and water resource of the Blue Nile and at this time there was no enough available data recorded. This study was conducted at reconnaissance level mainly done to identify considerable potentials for irrigation and hydropower in both Tana and Beles basins. The USBR studies have also propose a regulation dam for Lake Tanawith the objective to the upper Beles hydropower plant. According to Abeyou (2008) water balance of Lake Tana and in his study a conceptual hydrological model known as HBV has been applied to estimate the water balance components of the Lake. He used regionalization techniques to transfer parameters from gauged catchments to UN gauged watershed. Evaporation from the Lake surface was estimated using Penman combination equation. He found the mean annual flow of the Gummara watershed is 1229Mm^3 and Ribb 510m^3, He also tested the physical watershed characteristics while calculating flow in UN gauged catchments. Abeyou, (2008). Performance of SWAT in the northern highlands of Ethiopia for modeling of hydrology and sediment yield. The main objective of his study was to test and examine the influence of topography, land use, soil and climatic conditions on stream flows, sediment yield and soil erosion. He made modeling of four tributaries of Lake Tana and he found SWAT model gives good agreement with observed and simulated flows. (Shimeles, 2008).

Effects of Watershed characteristics on Ribb and Gummara watershed and on its River flow where studied, the gauging stations of the two watershed are flows to Lake Tana and located at the middle of the floodplains, especially the Ribb watershed is affected by a flood passes outside the station and accumulation of sand in the stream. Therefore it is better to locate the station away from the flood plain in the downstream or else revising and updating the conveyance profile of the existing station every time. By (Ephrem, 2011).

2.7 Previous works on Beshilo.

As far as previous works are concerned, the area has been a major interest for potential ground water exploration by different researchers in the past. Different issues related to geology, hydrogeology, engineering Geology, etc. are conducted in the area. Works related to groundwater potential assessments are: The detailed study of Gerado valley by Dessie Water Supply and Design project; recent works are done related to assessment and exploration of ground water for Dessie town by Water Works Design and Supervision Enterprise (WWDSE, 2007). Therefore, the present study comprises the detail works on assessments of surface and ground water on the basis of the hydrology and hydrogeology, aquifer characterization, and interaction of the various water bodies as well as the groundwater potential. It contributes a lot to the use and management of the water resource as well as input for further related studies (Yared, 2008).

2.8 Data transfer from gauged to ungauged watershed

Stream flow measurements are important for characterizing the hydrologic behavior of River basins within modeling frameworks, so that future assessments of hydrologic behavior in response to climate and/or land-use change can be obtained. Most of the Ethiopian's rivers do not have sufficient historical recorded data. In such situation, there must be a mechanism of transferring data from the gauged site to the UN - gauged site; to do prediction of stream flow for un gauged station are develop by different methods;

1. **Through model development at UN gauged watershed:** Studies focusing on the transfer of parameters of rainfall-runoff models have typically used either physical proximity measures (e.g.,

topography, soil type, land cover) or partial proximity measures (distance) as a surrogate for hydrologic similarity between the gauged and UN gauged watershed. (Seibert., 1999).

2. **Direct transfer of stream flow time** series from nearby gauged watershed. These methods are inherently restricted to using spatial proximity based similarity measures since stream flow transfer from far away watershed will cause large errors (due to climate heterogeneity).

3. Direct transfer of daily area-normalized stream flow values from neighboring gauged watershed using **inverse distance weighted (IDW) interpolation**. Its ability to transfer information from multiple donor gauged watershed to un gauged watershed and it required no of station from the region but the operation is difficult to develop daily historical data.

4. Regionalization approach is becoming more popular to alleviate the problem related to UN - gauged watershed. There are many definitions of regionalization available but a general definition as stated in (Subramanya, Subramanya, K. 2008. Engineering Hydrology. Tata McGraw-Hill Publishing Company, 2008) is used most often. “Regionalization is the process of transferring information from comparable catchments to the catchment of interest”. The four regionalization methods that are used to predict discharge from ungauged watershed are;

1. Similarity of spatial proximity: The transfer of watershed information was based on some sort of PCCs similarity between ungauged and gauged watershed. The PCCs were determined using Arc GIS integrated with Arc SWAT. Therefore, calibrated model parameter values from gauged watershed were transferred to the ungauged watershed based on PCCs similarities.

2. Sub-basin mean method: It represents the arithmetic mean, calibrated model parameters of gauged watershed to simulate the stream flow for ungauged watershed.

3. Regional model: watershed for which flow time series are to be estimated may not have comparable gauged watershed. Thus, prohibiting extrapolation using similarity of spatial proximity. Therefore, the methods of regionalization using similarity of watershed characteristics (regional model) were applied to estimate the flow of ungauged watershed.

4. Area ratio method: Parameter set of gauged watershed are transferred to un gauged watershed of comparable area based on the assumption that watershed area was the dominant Factor for controlling the volume of water that can be generated from the rainfall and gauged watershed that is located nearest to the un gauged watershed of interest is identified as stream flow values are transferred from gauged to un gauged watershed.

2.9 Physical watershed factors controlling stream flow

Numerous previous studies (e.g.,Williams, 1975; Walling, 1994) indicate that surface runoff and sediment yield are sensitive, basin characteristics like soil, topography, climate and land use. Summerfield and Hilton (1994) studied the variables controlling mechanical denudation rates in drainage basins exceeding 5 x 10^5 km^2 in area and concluded that physical factors (basin area, mean annual rainfall, land use ,temperature) have significant influence on physical denudation processes of surface runoff , although channel gradient and basin relief can be considered as dominant controlling variables. The main source of surface runoff and stream flow is rainfall (precipitation), some of which is lost through evaporation, ground water recharge, and other processes. Therefore, the intensity of rainfall plays a key role in detaching particles from the ground surface and thus controlling the amount of sediment particles removed. Other meteorological parameters such as temperature, rainfall intensity, wind, number of storms, and areal distribution of precipitation also influence runoff and sediment movement. (Langbein, 1958) analyzed the relationship between effective rainfall and annual surface yield from 100 gaging stations in the United States (Douglas, 1967) and (Dedkov, 1992).They concluded that effective precipitation influences annual surface runoff and sediment yields such that effective precipitation in the range of 200mm - 700mm is likely to have create the highest annual sediment yield. Basin area; smaller watersheds typically have larger sediment yields because smaller basins are likely to have steeper slopes and stream gradients compared to larger basins. Although basin area integrates several factors such as storage capacity and gradient, basin area alone is not the determining factor of sediment yield, but likely has great influence on surface runoff and sediment yields in a watershed. (Milliman, 1992) Studied the importance of topography and basin area as controlling factors on sediment yields for mountainous rivers in North and South America, Asia, and Oceania. They concluded that these two variables (topography and basin area) are the most dominant influences on sediment yield and surface runoff, with climate, land use, and geology being second-order influences. As drainage basin area increases, the catchment become more topographically complex and sediment yield often becomes transport limited, meaning that sediment cannot easily move out of the basin because of sediment deposition. In general, there is an inverse relationship between sediment yield and drainage area (Griffiths, 2006). Basin elevation and morphology have great influences on river sediment fluxes according to (Subramanya, Engineering Hydrology. Tata McGraw-Hill Publishing Company, 2008). They found that sediment fluxes are linearly correlated with mean basin elevation based on sediment yields in large world rivers. Relief is also a major controlling variable as indicating greater mechanical erosion ((Montgomery and Brandon, 2002). Even though many previous studies have tried to investigate the significance of relief, only a few mathematical relationships have been published. In the early 1960s, Schumm reported a linear relationship between erosion rate and drainage basin relief for basins in the United States (Schumm, 1963). Relief such as mean slope also influences micro-climate, lithology, and vegetation controlling erosion rates. Under natural conditions, sediment yields in mountainous areas are 28 times greater than in low relief areas, and mechanical erosion rate changes based on altitude and relief (Dedkov A. P., 1992).

Human effects: the morphology of alluvial river systems has been altered as a result of natural and human activities, which could be gradual or rapid over time. Any disturbances or modifications not only influence upstream but also downstream conditions (Simons, 1992). Many studies have pointed to the significant influence of anthropogenic activities including construction of dams, land-use practices, soil and water conservation practices, roads, and footpaths on river sediment fluxes. Morris and Fan (1997) reported the most significant land degradation factor to be human activities. Siakeu et al. (2004) also studied suspended sediment concentration in central Japan with a special reference to human impact. They concluded that anthropogenic activities, especially in industrial countries, create a large variation in the pattern of suspended sediment along relatively small sub-watersheds. The effects of human activities on suspended sediment load have been assessed in Turkey, as well. Reservoir construction and mining have a huge impact on riverine systems in Turkey. Isiket al. (2008). The results from this study indicate that sand mining for construction of roads and structures and over withdrawals of sediment may increase sediment inputs to river banks.

3. MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Location of the study area

The best known physiographic feature of Ethiopia is the Blue Nile River Basin, the area of interest in this thesis lies within the Blue Nile River Basin and its drainage area is around 5700 km^2 and surrounds one of the biggest tributary of Blue Nil River Basin named Beshilo watershed, it starts from the northeastern of the Blue Nile River Basin in South Wollo and flows towards the South through a picturesque canyon till it joins the Blue Nile River. its upper reach in the north east boundary and found at the junction between A wash Basin and Blue Nile River Basin (BNRB), it starts with the water divide between these basins with mountains and extends with plateau of wet land of the Gerado area and then with very rough mountainous regions till, all perennial and intermittent rivers within the study area flows to joins the main river of Beshilo. The geographic boundary of the study area is between 38.67– 39.70 degree longitude and 10.82 – 11.72 degree latitude and the watershed includes rural towns like Gerado, Tenta, WegelTena, Mekaneselam and Amba Mariam.

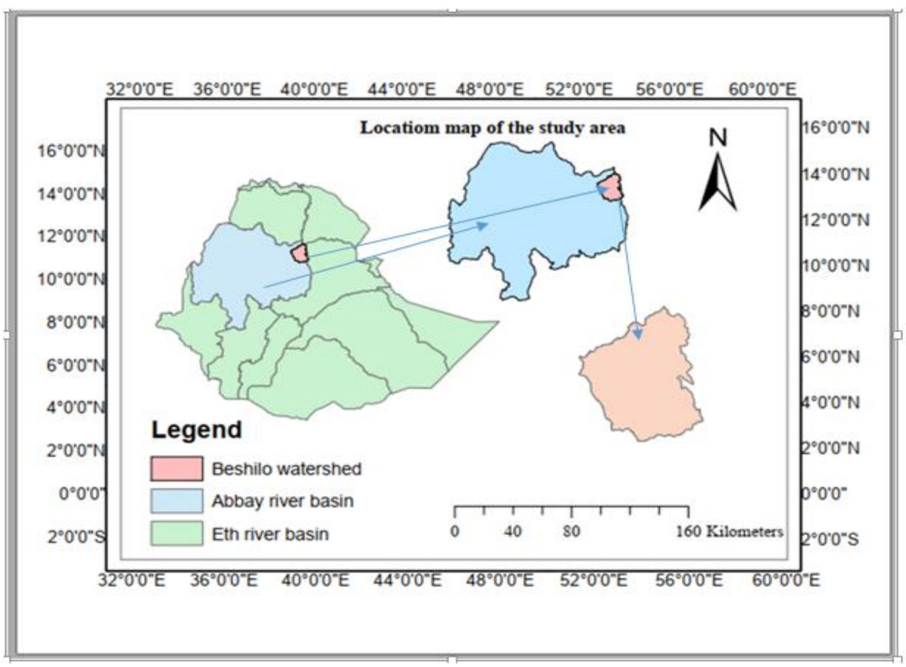

Figure 1 Location of the study area.

3.1.2 Topography of the study area

The Beshilo watershed is characterized by a complex topography with an elevation range over 4,250m in the headwater and about 1,100 m in downstream parts.

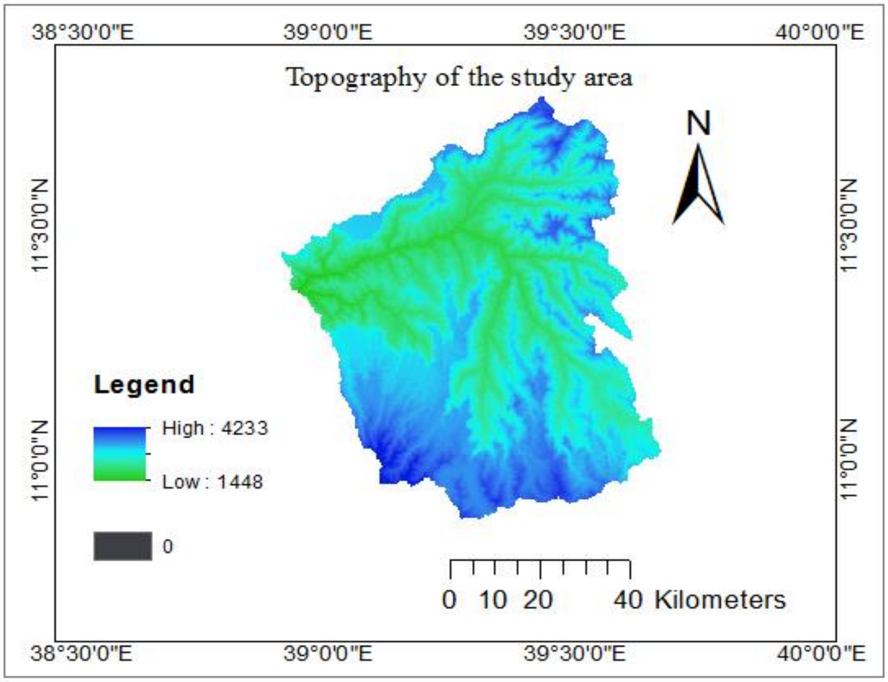

Figure 2 Elevation of the study area

3.1.3 Climate of the Study Area

1. Rainfall data

The annual rainfall may be divided in to two, rainy and dry season and a minor rainy season in April and May and a major rainy season from June through September. The dry season occurs between October and April, the long term annual rainfall using six station, by using theissen polygon method in the study area from (1997-2016) is estimated about 971.88mm. In Beshilo watershed, annual rainfall is maximum at Ambamariam with 1081 mm and a minimum at Tenta with 937 mm from 1997-2016 G.C.

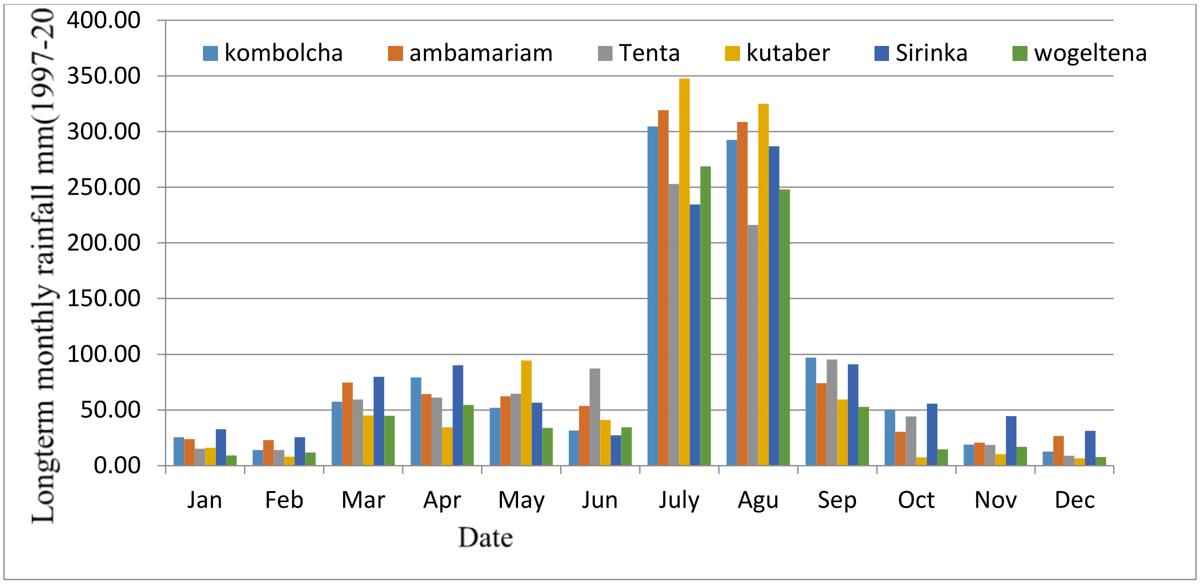

Figure 3 shows the long-term average monthly rainfall of the nearby stations.

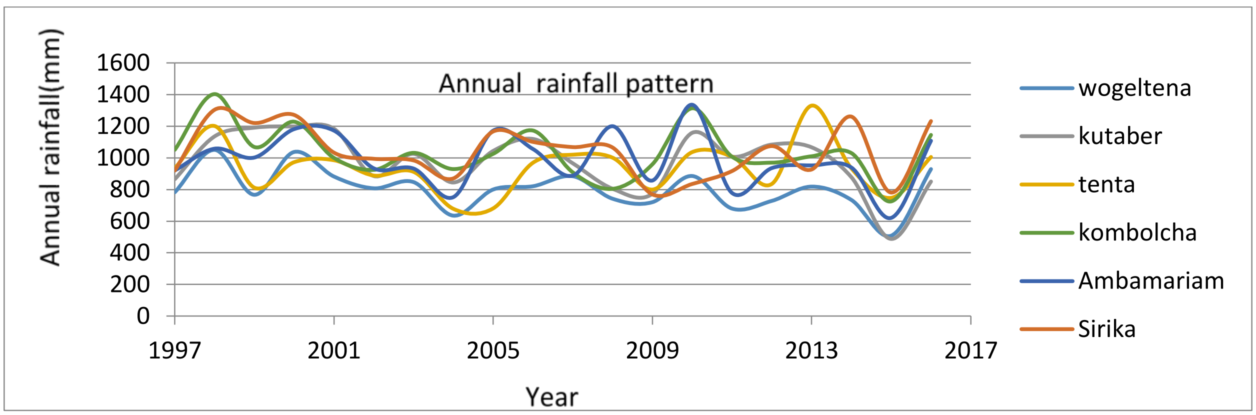

Figure 4 Annual rainfall pattern of station

1 Temperature

The long-term temperature of the study area is describe from six satiation, namely Srinka, Wogeltena, Kutaber, Tenta, Kombolcha and Ambamariam and the mean annual maximum and minimum temperature is between 10^0C and 32^0C, from 1997-2016 time serious data, the maximum temperature occurs in March to May and the mean monthly temperature exceeds 20^0C.

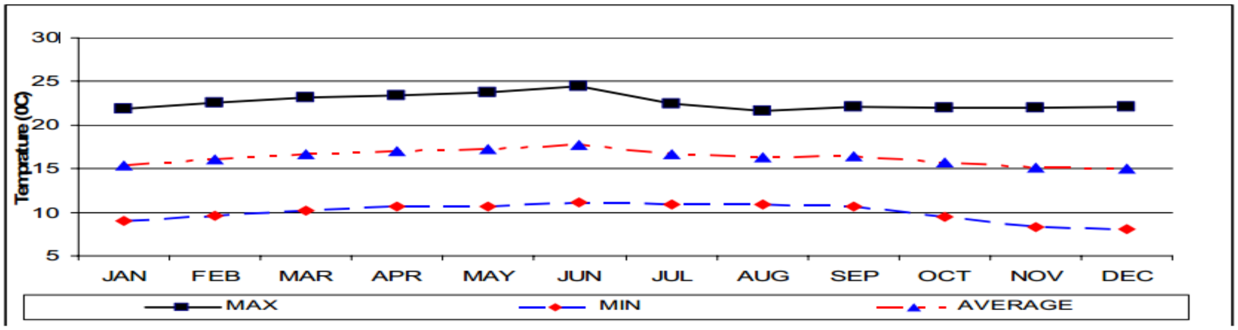

Figure 5 Maximum, Minimum, and Average monthly $T^{O}C$ from records (1997-2016)

3 Solar Radiation

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. Processes that are greatly affected by temperature and solar radiation include snow fall, snow melt and evaporation. Since evaporation is the primary water removal mechanism in the watershed, the energy inputs become very important in simulating an accurate water balance. Arc SWAT needs daily solar radiation, so the data obtained from National Meteorological Service Agency (NMSA) was sunshine hour from 1997 -2016 E.C and changed into solar radiation data.

4. Wind speed

Wind speed influences the aerodynamic situation, which a decrease the wind speed, decrease the rate of evaporation because the saturated vapor above the surface could not be removed instantaneously. Wind speed at the study area station is measured 2m above the ground surface and from 1997 to 2016 mean monthly data was analyzed. The mean monthly minimum and maximum wind speed is 1.45m/s in July and 2.0 m/s in March respectively, therefore the months, February, march, April, May and June are relatively windy, whereas the rest months are minimum and maximum wind speed created in the dry season whereas, the minimum wind speed is observed in the rainy season of the study area.

Table 1 mean monthly wind speed in (m/s)

Month	Jan	Feb	Mar	Apr	May	Jun	July	Agu	Sep	Oct	Nov	Dec
Mean	1.48	1.7	1.7	2	1.7	1.6	1.45	1.4	1.5	1.5	1.6	1.45

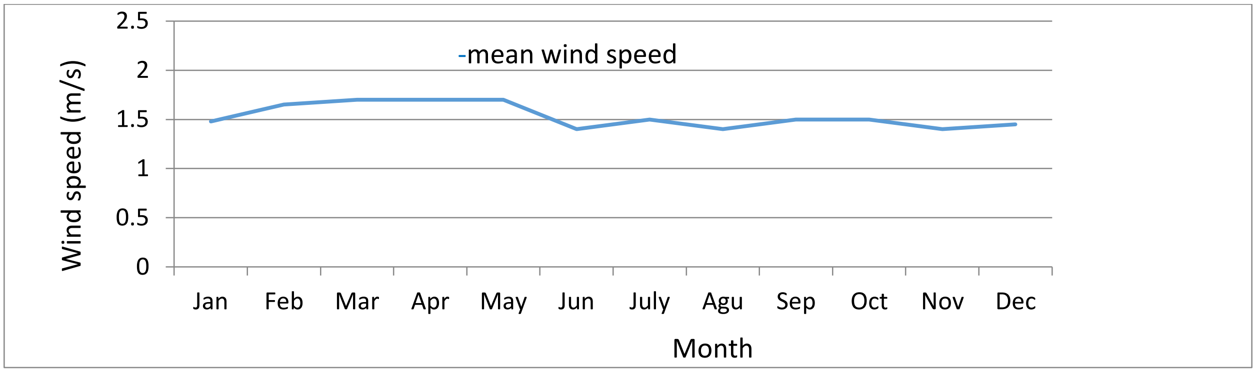

Figure 6 mean monthly wind speed (m/s)

5. Relative humidity

Relative humidity (RH) is the relative measure of the amount of moisture in the air to the amount needed to saturate the air at the same temperature or the degree of saturation of the air as a ratio of the actual (e^a) to the saturation (e^o) vapor pressure at the same temperature represents as a percentage. As air humidity increases, its ability to absorb water vapors decreases and evaporation rate slows down, for evaporation to take place there must be a difference in humidity (Tenalem, 1998) and (Fetter C.W, 1994)

Table 2 mean monthly RH in (%)

Month	Jan	Feb	Mar	Apr	May	Jun	July	Agu	Sep	Oct	Nov	Dec
Mean	57.9	52.8	55.4	58.9	53.7	49.6	60.9	65.8	63.2	59.1	54.8	52.65

3.1.4 Soil and Land use data

For this study a soil data of the major soil groups of Beshilo watershed as FAO soil group were collected from ministry of water resource (MWRE) GIS department. The major soil groups found in the study area were Cambisol, Leptosols, and Vertisols. And also land use data were collected as land cover map from Ethiopian Mapping Agency (EMA). According to Ethiopian Mapping Agency (EMA) land use land cover map of the Beshilo watershed is mostly dominated by agricultural land and pasture land.

3.1.5 Stream flow data

Beshilo watershed is one of the major watershed which contributes significant amount of flow to Abbay River. But the watershed is not gauge, for this reason the flow data is transferred from nearest gauged station that is Gummara watershed.

3.2 Data collection and analysis

For this study, daily river discharge data, metrological data, land use land cover data, and soil map are were collected from the concerned organization. The daily river discharge data, digital elevation (DEM) data for the study were collected from Ethiopian Ministry of Water Resources and Energy (MWRE) at records Gummera watershed. Daily metrological data such as rainfall, minimum and maximum temperature, relative humidity, wind speed and daily sunshine hours were collected from Metrological Agency of Ethiopia (NMA).

3.2.1 Meteorological Data

Ethiopian Meteorological Agency (EMA) classified meteorological stations into four, each identified by a code. Code one stations (primary stations) are stations at which observations such as rainfall, relative humidity, maximum and minimum temperature, wind speed and sunshine duration were taken every three hour. For stations categorized under code two (synoptic stations) are those in which observation such as measuring rainfall, relative humidity, maximum and minimum temperature, wind speed and sunshine duration were taken every 24 hours. Stations under code three (ordinary stations) are those only daily rainfall and daily maximum and minimum temperatures are observed, the rest which are categorized under station code four rerecording only daily rainfall amount. There are a total of six metrological stations in and around the study area named as Sirinka, Kombolcha, Ambamariam, Wogeltena, Tenta and Kutaber station which are owned by EMA.
From the first four stations the following daily metrological data are obtained such as precipitation, maximum and minimum temperature, relative humidity, wind speed and daily sunshine hours were collected but from the remaining two stations only daily precipitation, maximum and minimum temperature data were collected.

3.2.2 Rain fall data analysis

A) Estimating missing rainfall data

Failure of any rain gauge or absence of observer from a station causes short break in the record of rainfall at the station. The gaps should be estimated first before we use the rainfall data for any analysis. The surrounding stations located within the watershed help to fill the missing data on the assumption of meteorological similarity of the group of stations. In this study Arithmetic mean method and Normal ratio method were used.

Arithmetic mean method: used when the normal annual rainfall of the missing station is within 10% of the normal annual rainfall of the surrounding stations (Subramanya, 2008).

The general formula for computing missing precipitation by this method is:

$$Px = \frac{1}{n}\left[p_1 + p_2 + \cdots p_m\right] \ldots \ldots 7$$

Where P1, P2. . . ..Pm are the precipitations of index stations and P x is that of the missing station, n is the number of index stations.

Normal Ratio Method: is used when the normal annual precipitation of the index stations differs by more than 10% of the missing station. This is the case for the stations near the study area. The general formula for computing missing precipitation by this method is (Subramanya,2008):

$$Px = \frac{Nx}{n}\left[\frac{P1}{N1} + \frac{P2}{N2} + \cdots \frac{Pn}{Nn}\right] \cdots 8$$

Where P1, P2 . . . Pn are the rainfall data of index stations, N1, N2 . . . Nn the normal annual rainfall of index stations, Px and Nx the corresponding values for the missing station x in question and n is the number of stations surrounding the station x.

Table 3 Percent of missing precipitation and filling methods in the selected stations.

No	Stations	% of missing	Filling method
1	Tenata	9.3	Normal Ratio
2	Ambamariam	8.65	Arithmetic mean
3	Kutaber	11.12	Normal Ratio
4	Srinka	6.2	Normal Ratio
5	Wogeltena	5.4	Normal Ratio
6	Kombolcha	3.1	Normal Ratio

B) Annual effective aerial depth of rainfall

Precipitation measurement is a point observation and may not be used as a representative value for the area under consideration. Therefore it is necessary to obtain effective uniform depth of precipitation of the catchment to get a more reliable and representative results. Aerial depth of precipitation in the catchment was estimated by simple arithmetic mean, isohyet method and Theissen polygon method. Theissen polygon method is more reliable than arithmetic mean because the distribution of precipitation gauges in the catchment is non uniform.

Arithmetic mean method: is the simplest one for evaluation of mean uniform distribution of Precipitation of a basin. The Precipitation stations used in the calculation are those located in the watershed and nearby gauges considered representative of the area and relatively marked with no diversity in topography to get reliable measure of aerial Precipitation. The aerial depth of precipitation can be calculated using arithmetic mean as follows:

$p = (\sum P_i)/N$ Where, Pi = Mean annual precipitation measured at each station. N = number of gauging station

Table 4 Aerial precipitation using Arithmetic mean method for Precipitation data.

Month	kombolcha	ambamariam	Tenta	kutaber	Sirinka	Wogeltena	**Mean**
Jan	25.32	23.85	15.21	15.83	32.6	9.05	**20.30**
Feb	13.90	22.90	13.97	7.84	25.6	11.73	**15.98**
Mar	57.25	74.55	59.24	45.10	79.7	44.63	**60.08**
Apr	79.20	64.35	60.94	34.25	90.2	54.41	**63.88**
May	51.85	62.23	64.57	94.51	56.6	33.83	**60.59**
Jun	31.61	53.70	87.22	40.94	27.3	34.25	**45.83**
July	304.72	319.49	252.92	347.82	234.7	268.84	**288.09**
Agu	292.72	308.73	216.36	325.08	287.0	248.24	**279.69**
Sep	96.93	73.95	95.39	59.37	90.9	52.74	**78.20**
Oct	50.37	30.19	44.20	7.36	55.7	14.49	**33.72**
Nov	18.84	20.66	18.67	10.08	44.3	16.90	**21.57**
Dec	12.65	26.72	8.84	6.44	31.1	7.58	**15.55**
Annual	**1035.33**	**1081.29**	**937.50**	**994.64**	**1055.61**	**796.66**	**983.50**

Theissen polygon method

This method helps to calculate the weighted average precipitation of each station by the following formula:

$$P = \frac{\sum P_i A_i}{A_T} \text{ ---------------------- } 9$$

i = 1, for N number of station Where,

Pi = Precipitation measured at ith station (Table 5)

Ai =Area of the ith polygon bounded by ith station (Table 5)

A = Area of the whole catchment

Table 5 Mean Annual precipitation and area of the station bounded by the Theisson polygon

Station Name	Elivation(m)	Area coverage(Km)	Prciptation	Pp*Area	((Pp*area)/Total area)
Tenata	2605	878.6	937.5	823662.2	158.5
Ambamariam	2990	455.6	1081.3	492683.3	94.8
Kutaber	2672	343.6	994.6	341799.1	65.8
Srinka	1861	612.0	1055.6	646079.8	124.3
Wogeltena	2952	1135.3	796.7	904440.1	174.0
Kombolcha	1857	1771.3	1035.3	1833921.4	352.9
Total		5197			970.4

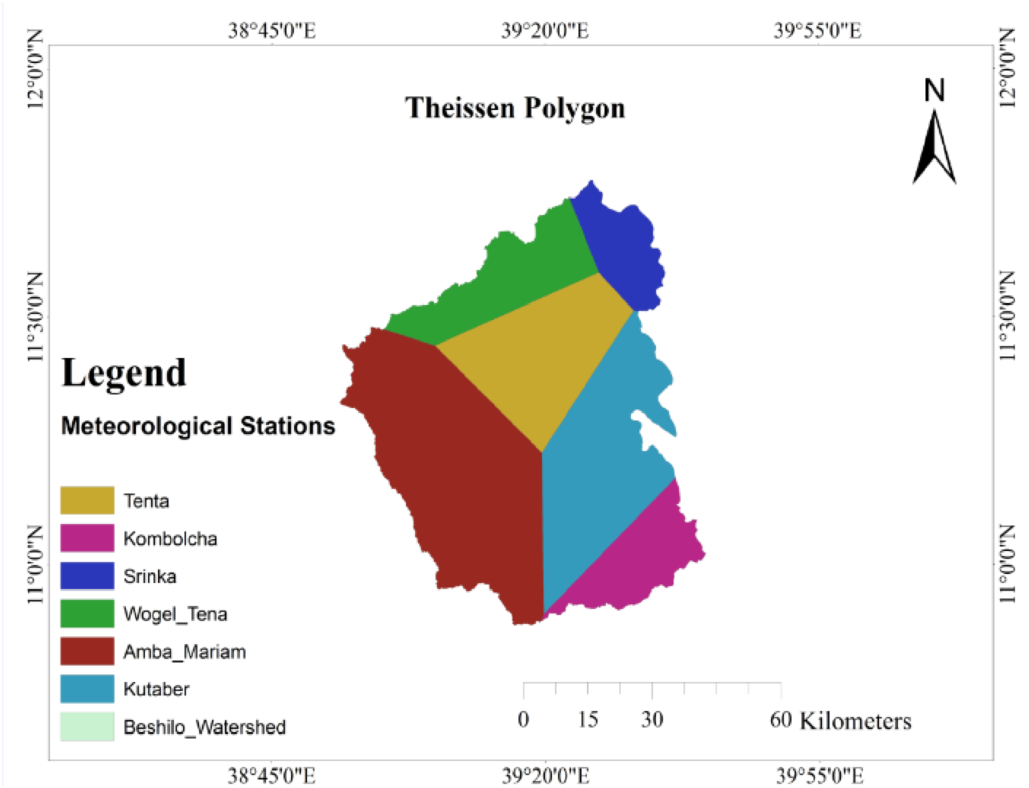

Figure 7 Theiysson Polygon of the study area.

C) Rainfall data consistency

If the conditions relevant to the recording of a rain gauge station have undergone a significant change during the period of record, inconsistency would arise in the rainfall data of that station. Some of the common causes for inconsistency of record are: Shifting of a rain gauge station to a new location**,** Change in exposure to the station due to deforestation, forest fires, landslides, and Change in observational procedure from a certain date. So Precipitation data must be adjusted to eliminate the effects of such changes before use in practical applications.

The checking of the inconsistency of a record is done by:

Double-mass curve. Double-mass curve analysis is a graphical method for identifying or adjusting inconsistencies in a station record by comparing its time trend with those of other stations. For this study accumulated annual values at the station are plotted against annual average cumulative group of station, but at this study area the data is consistency.

If significant change in the regime of the curve is observed, it should be corrected by using the following equation:

$$P_X' = PX * \frac{M'}{M} \text{----------------------10}$$

Where: Px'= corrected precipitation at station x Px =original recorded precipitation at station x M' =corrected slope of the double mass curve M= original slope of the double mass curve.

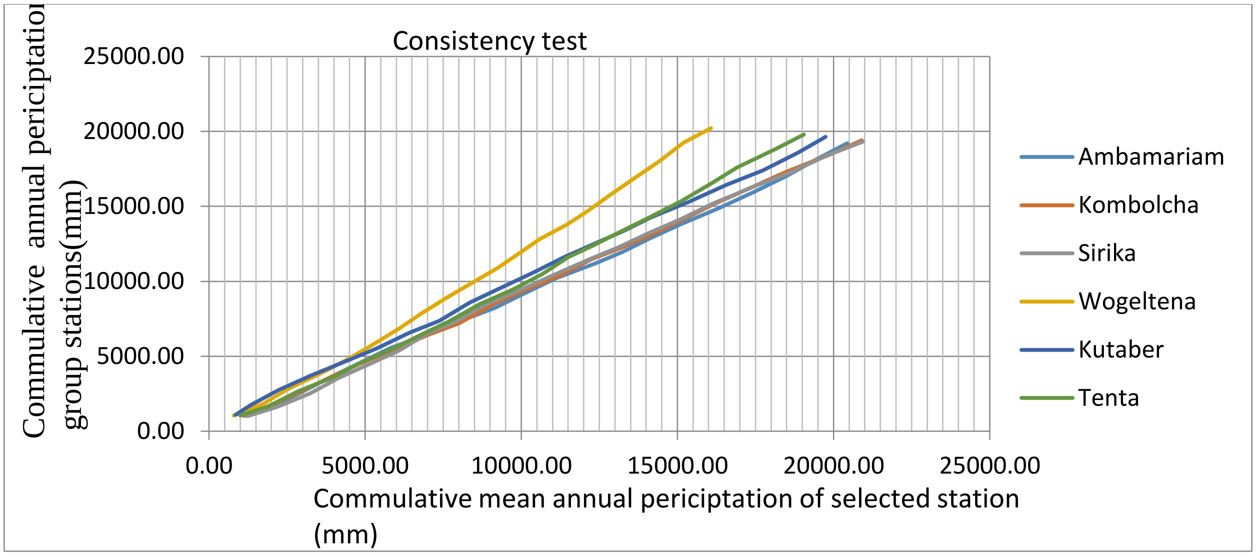

Figure 8 Double mass curve for selected stations

According to the double mass curves, and from the above figure 8 the station data's in the watershed were consistent.

Homogeneity test: Homogeneity analysis is used to identify a change in the statistical properties of the time series data. The cause's non homogeneity can be either natural or man-made, these include alterations to land use and relocation of the observation station. Therefore, to select the representative meteorological station for the analysis of areal rainfall estimation, checking homogeneity of group stations is essential, the homogeneity of the selected gauging stations

Monthly rainfall records were computed by: $\text{Pi} = \frac{\text{Pi,av}}{\text{pav}} * 100$------------11

Where, Pi=Non dimensional Value of precipitation for the month in station i

Pi,av =Over years averaged monthly precipitation for the station i

Pav= the over years averaged yearly precipitation of the station i

The data recorded in the selected stations of the study area are cheeked and plotted for comparison with each other.

As it is shown in the Figure 9 same-modes and pattern of the stations are observed and hence group stations selected are homogenous.

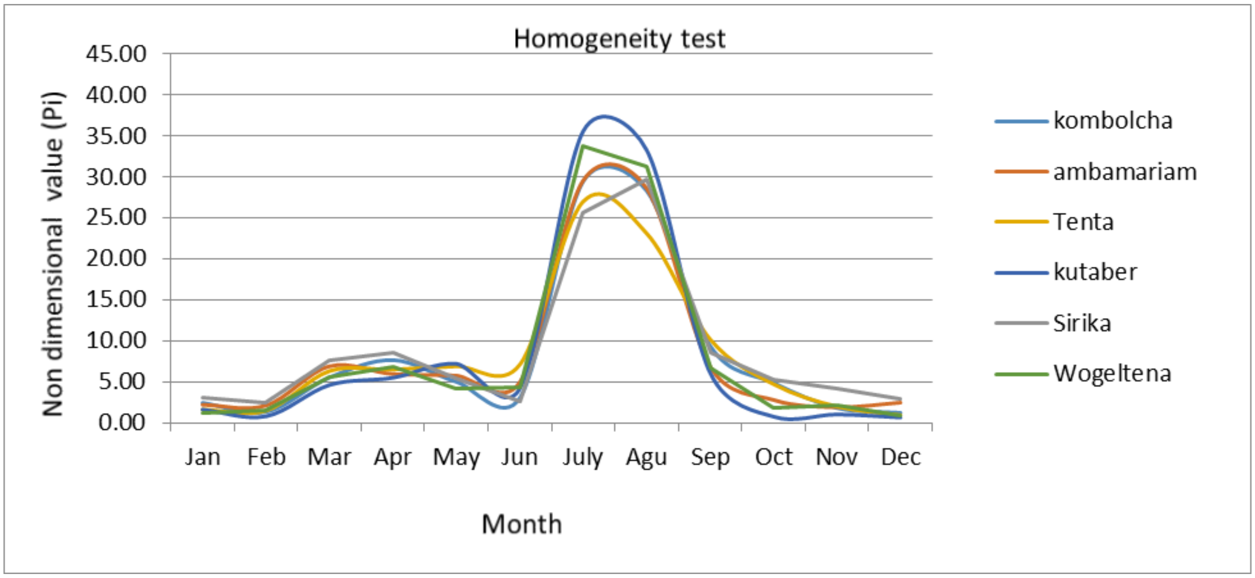

Figure 9 Homogeneity test for selected station in Beshilo catchment

Rainbow Homogeneity Test: in addition to non-dimensional method Rainbow software used to check the homogeneity of Rainfall data. Analysis of rainfall data requires the data be of long series; they should be homogeneous and independent. In Rainbow, the test for homogeneity based on the cumulative deviation from the mean (Raes, 2006). The figure 9 shows the homogeneity test of Kombolcha station. Probability of rejecting homogeneity test is accepted at all significance levels (90, 95, and 99 %) for both range of cumulative deviation and maximum of cumulative deviation. Appendix F: shows other stations homogeneity test of annual rainfall.

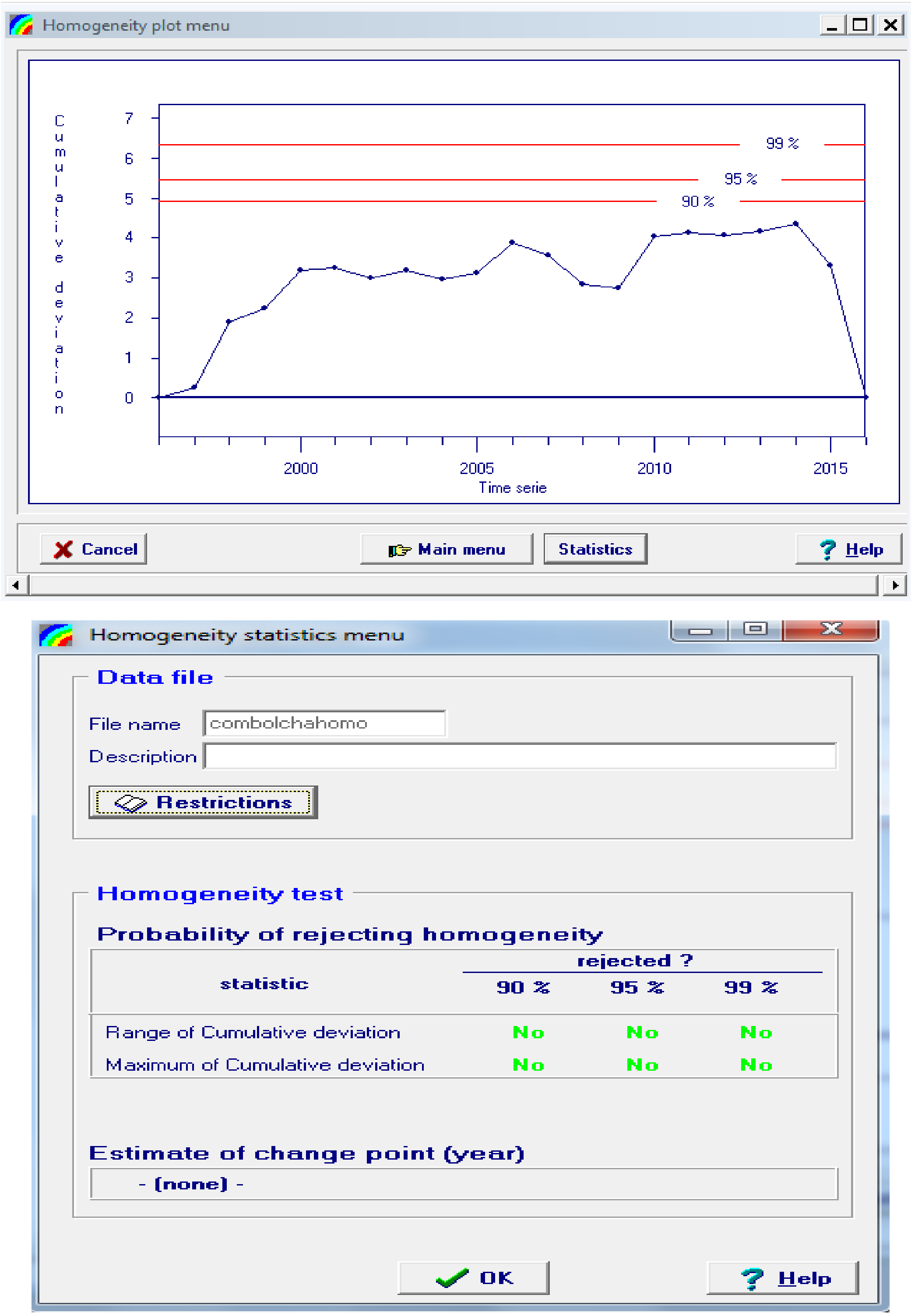

Figure 10 Cumulative deviation and probability of homogeneity test result of annual Rainfall at Kombolcha station

3.3 Methodology

3.3.1 Overall frame work of the study

The study required different materials and methods to arrive at the stated objectives. Meteorological, hydrological, digital elevation model, land use and land cover and soil data were required. Those data were selected based on my study objective which are fitted to the study area. The SWAT model inter face with Arc GIS and SWAT Cup is used to evaluate watershed characteristics on stream flow. Arc GIS 10.3 and its extension Arc SWAT 2012 were used for hydrological model. The stream flow simulation by the SWAT model was calibrated and validated by comparing simulated stream flow with observed values.

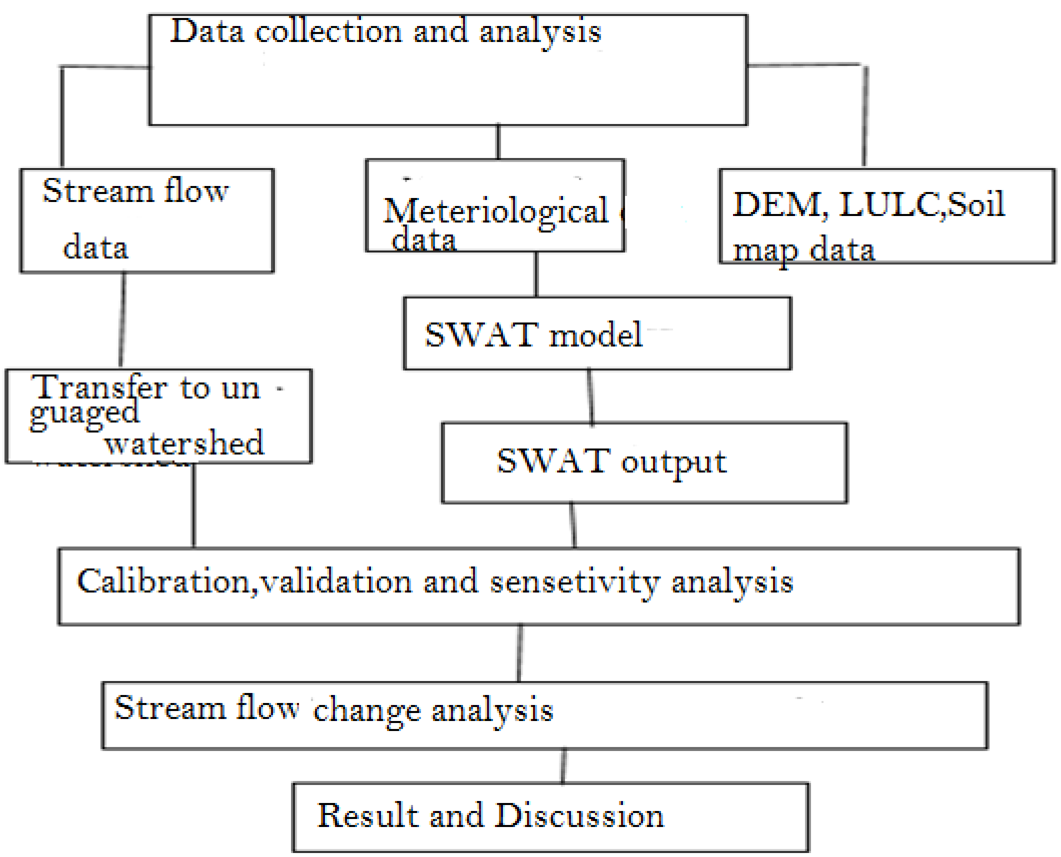

Figure 11 Overall flowchart used in the study

3.3.2 Transferring flow data from gauged to ungauged watershed

Stream flow measurements are important for characterizing the hydrologic behavior of River basins within modeling frameworks, so that future assessments of hydrologic behavior in response to climate and/or land-use change can be obtained. Most of the Ethiopian's rivers do not have sufficient historical recorded data (Ephrem Alemu, 2011). In such situation, there must be a mechanism of transferring data from the gauged site to the UN - gauged site; to do prediction of stream flow for un gauged station are develop by different methods. (Kim U. e., 2008). For this study using the combination:

Similarity of spatial proximity: The transfer of watershed information was based on some sort of PCCs similarity between ungauged and gauged watershed. The PCCs were determined using Arc GIS integrated with Arc SWAT. Therefore, calibrated model parameter values from gauged watershed were transferred to the ungauged watershed based on PCCs similarities.

Area ratio method: Parameter set of gauged watershed are transferred to un gauged watershed of comparable area based on the assumption that watershed area was the dominant Factor for controlling the volume of water that can be generated from the rainfall and gauged watershed that is located nearest to the un gauged watershed of interest is identified as stream flow values are transferred from gauged to un gauged watershed in upper Blue Nile is important (Ephrem Alemu, 2011). According to the Master Plan study, of Baro Akobo using integrating special proximity, area ration and annual rain fall ration is increase the reliability of data. Based on the idea mentioned, the nearest station for Beshilo was Gummara would be selected. Gummara watershed station is found 12.23 Latitude and 37.33 longitude to the north of the Beshilo River, and the stream flow data for Gummara were collected from the Ministry of Water, so adopt area and precipitation ratio to transfer the flow data to Beshilo watershed.

$$Qu = Wf * Qg \qquad \text{...12}$$

Where

Qu – the run off ungauged site (m^3/s)

Qg – the run off gauged site (m^3/s)

Wf – weighted factor

Wf = Au / Ag * Pu /Pg……………………………………………12.1

Au – area of ungauged site watershed

Ag – area of gauged watershed

Pu -precipitation at ungauged watershed

Pg--precipitation at gauged watershed

3.3.3 Similarity of gauged and ungauged watershed

1 Slope similarity of Beshilo and Gummara watershed

Gummara and Beshilo watershed have similar slope characteristic that range from

Slope: is one of the factors which influence surface runoff velocity. Where higher slope result in higher velocity of flow, therefore the water will travel quickly to reach the river outlet. For this study SRTM DEM of 30 m resolution is processed to estimate slope of the watershed pixel by pixel then the average slope and slope class based on FAO major slope classes are done.

2 Shape similarity of the two watershed

Geography and physiographic characteristics includes size and shape, elevation, slope and aspect characteristics.

Catchment Area: is an important watershed characteristics for hydrological modelling, the amount of water reaching the river from its catchment depends on the size of the area. Catchment area reflects the volume of water that can be generated from rainfall. In this study catchment area of the two catchments were calculated through DEM-Hydro process of using GPS coordinates of outlet location the watersheds.

Longest flow path length The length of longest flow path is usually used in computing the response time at the outlet of a watershed, which is a measure time of concentration which is defined as the length of time it takes for water to travel from hydro logically most remote point in the basin to the outlet, and time of concentration defined as the time required for all parts of a basin to contribute to the runoff at the outlet simultaneously. In this study through DEM-Hydro processing the length of longest flow path for the two catchments were calculated and the profile of longest flow path was constructed.

Basin Shape: Basin shape is not usually used directly in hydrologic modelling; however, parameters that reflect basin shape are used occasionally and have a conceptual basis. Watersheds have an infinite variety of shapes, and the shape supposedly reflects the way that runoff will accumulate at the outlet. A circular watershed would result in runoff from various parts of the watershed reaching the outlet at the same time. An elliptical watershed having the outlet at one end of the major axis and having the same area as the circular watershed would cause the runoff to be spread out over time, thus producing a smaller flood peak than that of the circular watershed (http://cnx.org/ content/m14421/latest/). A number of watershed parameters have been developed to reflect basin shape. For this study circular index were estimated for both Watersheds.

Circularity Ratio (CR): is the ratio of the area of a drainage basin to the area of a circle having the same perimeter as a drainage basin. To estimate this ratio, the area and perimeter of a drainage basin were measured. The ratio is equal to unity when the basin shape is perfect circle, decreases to 0.785 when the basin is square, and continues to decrease to the extent to which the basin becomes elongated

$$CR = \frac{A_b}{A_c} = \frac{4\pi A}{P^2}$$

Where Ab is area of basin, Ac area of circle whose circumference is equal to basin perimeter and P drainage basin parameter.

3 Soil similarity of both watershed

Soil data is required as input for hydrological modelling which influences runoff generation, generally runoff occurs when rainfall intensity exceeds the infiltration capacity of the soil which is a measure of the ability of the soil to absorb and transmit rain water. Runoff is limited on soils with a high infiltration capacity. For this study a soil map of the major soil groups of Gumara and Beshilo watershed as per FAO soil group is collected from MWRE GIS department. The detail soil properties of the study area were arranged for ready-made data for modelling.

4 LULC similarity of the two watershed

Land use and cover condition can affect the hydrological balance of the watershed by changing magnitude and pattern of runoff, peak flow and ground water levels. It is well known that deforestation causes changes in soil properties and infiltration rates, which ultimately affects the soil erosion processes and hydrological cycle of the catchment. In this study a land cover map was collected from MWRE GIS department.

3.3.4 Digital Elevation Model (DEM) Hydro-processing

The purpose DEM hydro-processing is to extract the watershed and to prepare a dataset for further processing. DEM is required as an input for the DEM hydro-processing. SWAT is a Basin scale, continuous time model that operates on a daily time step and is designed to predict the impact of watershed characteristics on stream flow in the watershed. The model is physically based, computationally efficient, and capable of continuous simulation over long time periods.

3.3.5 Watershed Characteristics Analysis on Stream flow.

A), Land use land cover: using three different period map of 1996, 2004, 2013 as input for the SWAT model the other SWAT input as constant for three model running.

B) Climate characteristics by using in two ways

1. Using six metrological station data as an input for the model and using ten year data which cover for the first model run 1997 up to 2006 and for the second model run from 2007 up to 2016.

2. Using the 20 year rainfall data in to two groups breaking by10 year the other climate data as constant and 1996 LULC. Climate characteristics include precipitation, temperature, wind, relative humidity and other metrological elements for a given region over a long period of time. For this study rain fall effect are considered using 10 year interval by taken the other parameter are constant (Abebe, 2006).

3. Slope: is one of the factors which influence surface runoff velocity. Where higher slope result in higher velocity of flow, therefore the water will travel quickly to reach the river outlet (Sharma et al. 1986). For this study using average tributary channel slope were increased by 5% change and decrease by 5% change.

3.4 SWAT Model setup

3.4.1 Watershed Delination

Watershed and sub watershed delineation was carried out using 30m by 30m Resolution DEM data and Arc SWAT is used to the setup of the project, so as to create necessary folders to store all the data, the watershed delineation process consists of five important steps, DEM setup, stream delineation, outlet and inlet definition, watershed outlet selection and definition and calculation of sub basin parameter. After 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, consequently stream networks, sub basin watersheds and topographic were calculated using the respective tool. The size of the sub basin in the watershed will affect the assumption of homogeneity, because definition of watershed, sub basin boundaries and stream is decided by selecting a threshold area or the minimum drainage area to define stream, configuration of a lot of sub -basin required a long time simulation period and even difficult to run. On the other hand too small number of sub basin watershed is affect the simulation result by ignoring spatial variability. In general the number of sub basins chosen to model depends on the size of the watershed, the spatial detail of available input data and the amount of detail required to meet the goals of the project. When subdividing the watershed, keep in mind that topographic attributes (slope, slope length, channel length, channel width) are calculated or summarized at the sub basin level. The sub basin delineation should be detailed enough to capture significant topographic variability within the watershed, for this study using 25000 ha threshold area in percentage and the watershed was divided in to eleven sub basin.

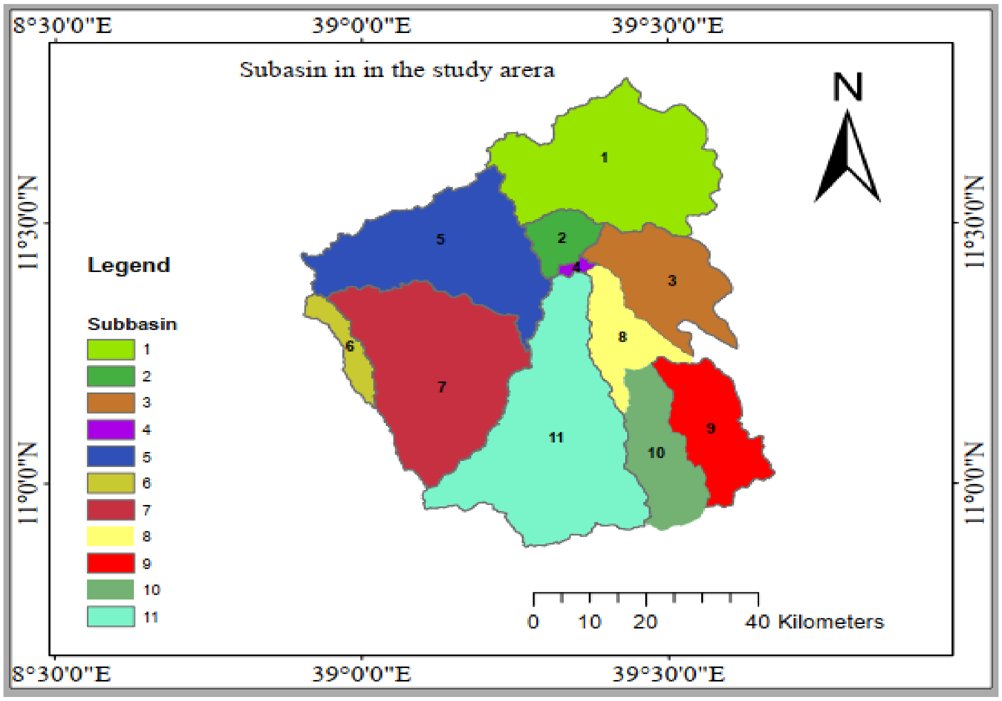

Figure 12 Sub basin in the catchment by SWAT

3.4. 2 HRU Definition

The Arc AWAT model required the creation of hydrologic Response units (HRUs), which are the unique combination of land use, soil and slope classes within each sub basin. In this study performed HRU analysis menu on the Arc SWAT tool bar, by loading land use and soil maps, evaluate slope characteristics and determine the land use/soil/slope class combination in the delineated sub watershed. In the model there are two options in defining HRU distribution assign a single HRU to each sub watershed or assign multiple HRUs to each sub watershed depends on a certain threshold value. The Arc SWAT 2012 user manual suggests that 20% land use threshold, 10% soil threshold and 20% slope threshold are adequate for most modeling application. So for this study using the above recommendation and the watershed divided in to 11 sub basin and 38 HRUs. In addition HRU analysis in Arc SWAT includes division of HRUs by slope class, multi slope was selected for this study slope classification carried out based on the elevation range of DEM, it reclassify in to 5 class

Table 6 the slope class used in the model

Class	Slope range (%)
Clss1	0-2
Class2	2-10
Class3	10-15
Class4	15-30
Class5	>30

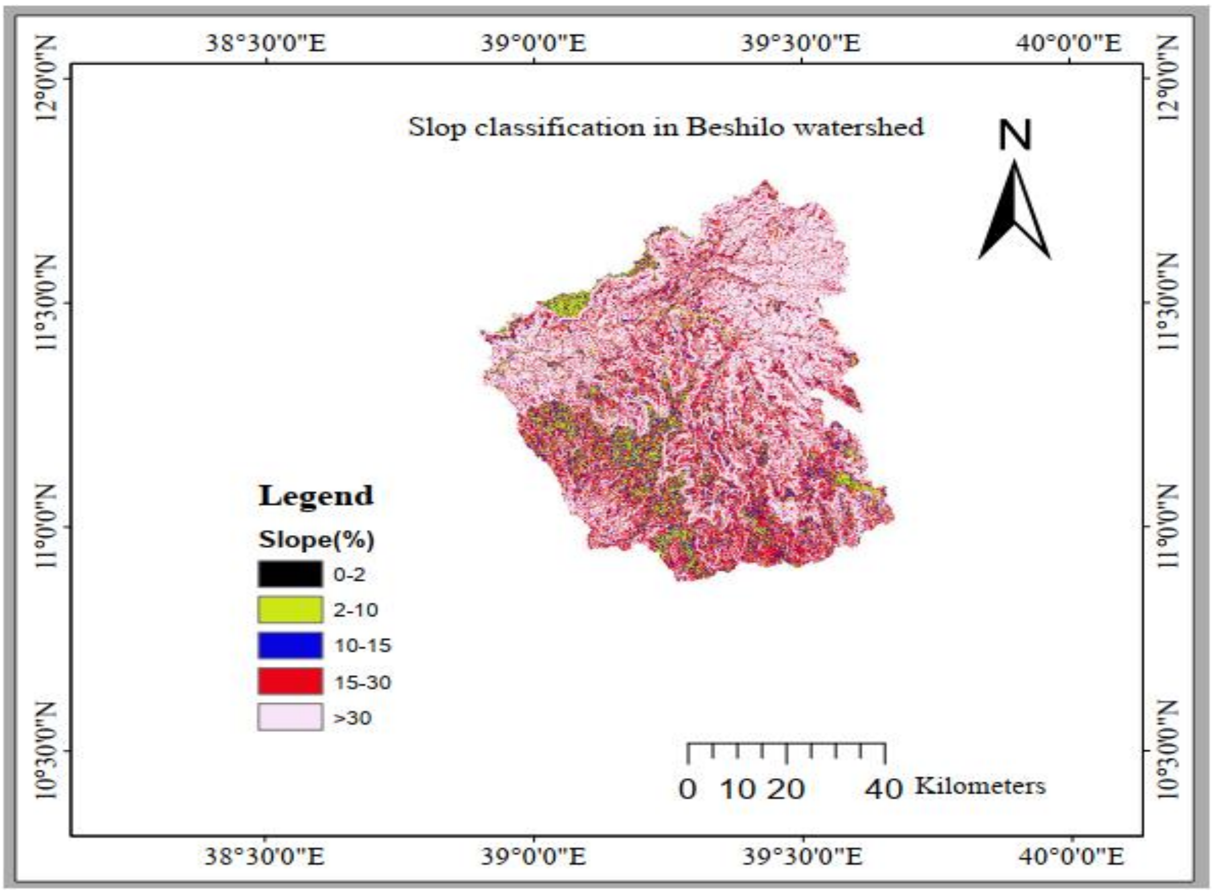

Figure 13 Slope classification at SWAT

3.4.3 Land use Classification

Agriculture land: These are the areas identified as dominantly cultivated on the land cover map. Although animals play an important role in these areas, they are considered as secondary to cultivation. The key economic activity in these areas is cultivation, especially for grains, and these area is sources of Crops production like Wheat and Teff.

Pastoral land: These are the grass land areas, Pastoral areas are particularly use for animal pastured Most cultivated land is pastured after harvest but not include in pasture land but include bush lands and shrub lands are all grazed.

Planted area-- it is difficult to define, but for this study land use including moderately forest, scarcely forest and land use by plantation area are grouped under this category.

Barr land: the land which are not used for human purpose

Wet land: areas which are lands but cover with water and used for wild life purpose

A. 1996 LULC

Table 7 LULC classification at 1996 map

Land use land cover at 1996			
Land use type	SWAT Code	Area (km^2)	Area (%)
Bare land	BARR	0.5174	0.01
Agriculture	AGRL	3707.17	71.65
Forest	FRSD	706.78	13.66
Pasture	PAST	626.57	12.11
Wet land	WATR	132.98	2.57

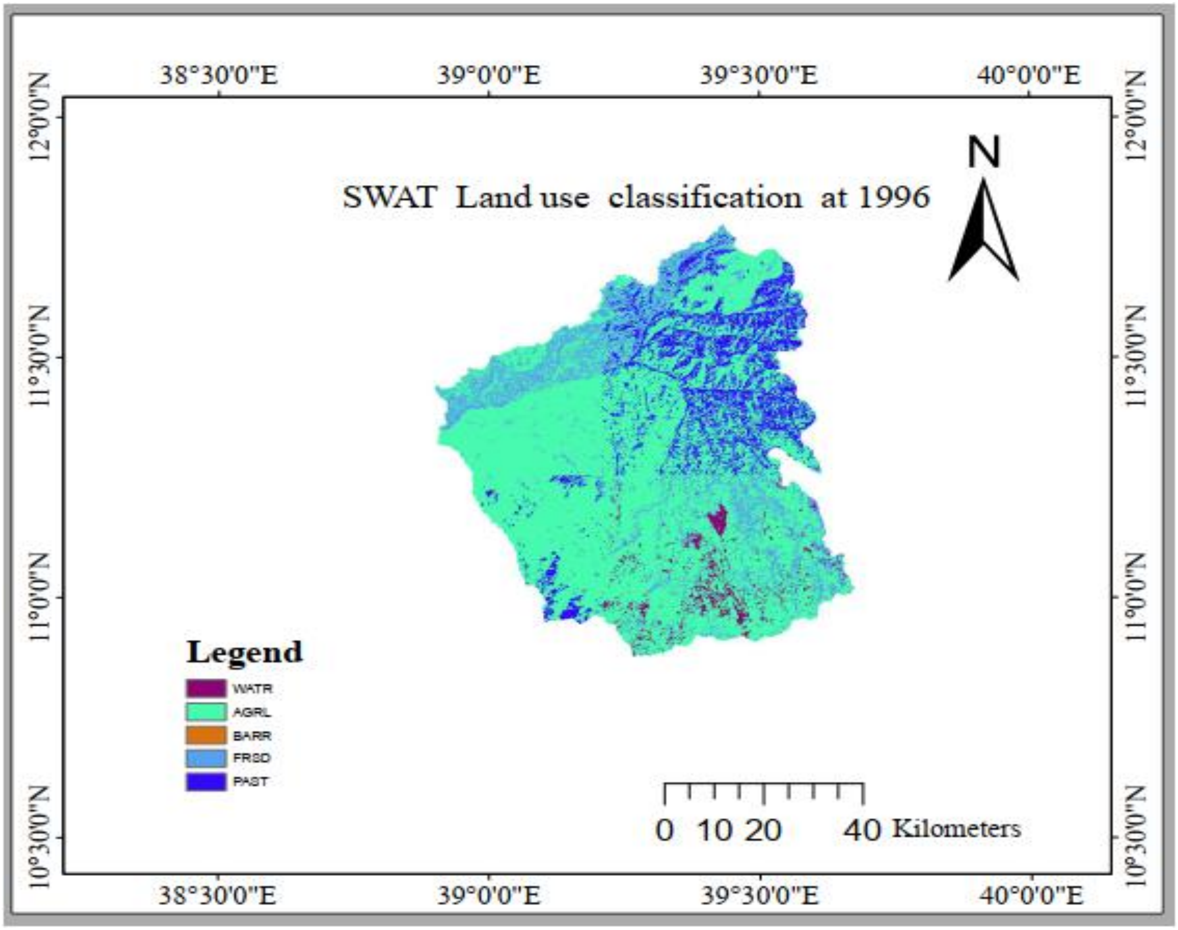

Figure 14 LULC classification at 1996 map

The above table7 and figure 17, shows that the LULC at 1996, Agricultural land is cover largest area which is 71.65% from the total watershed area, both densely forest and sparsely forest cover 13.66% and also grass land cover 12 %.

B. 2004 LULC

Table 8 LULC classification at 2004 map

Land use land cover at 2004			
Land use type	SWAT Code	Area (km2)	Area (%)
Bare land	BARR	5.69	0.11
Agriculture	AGRL	4477.6	86.54
Forest	FRSD	211.62	4.09
Pasture	PAST	472.9	9.14

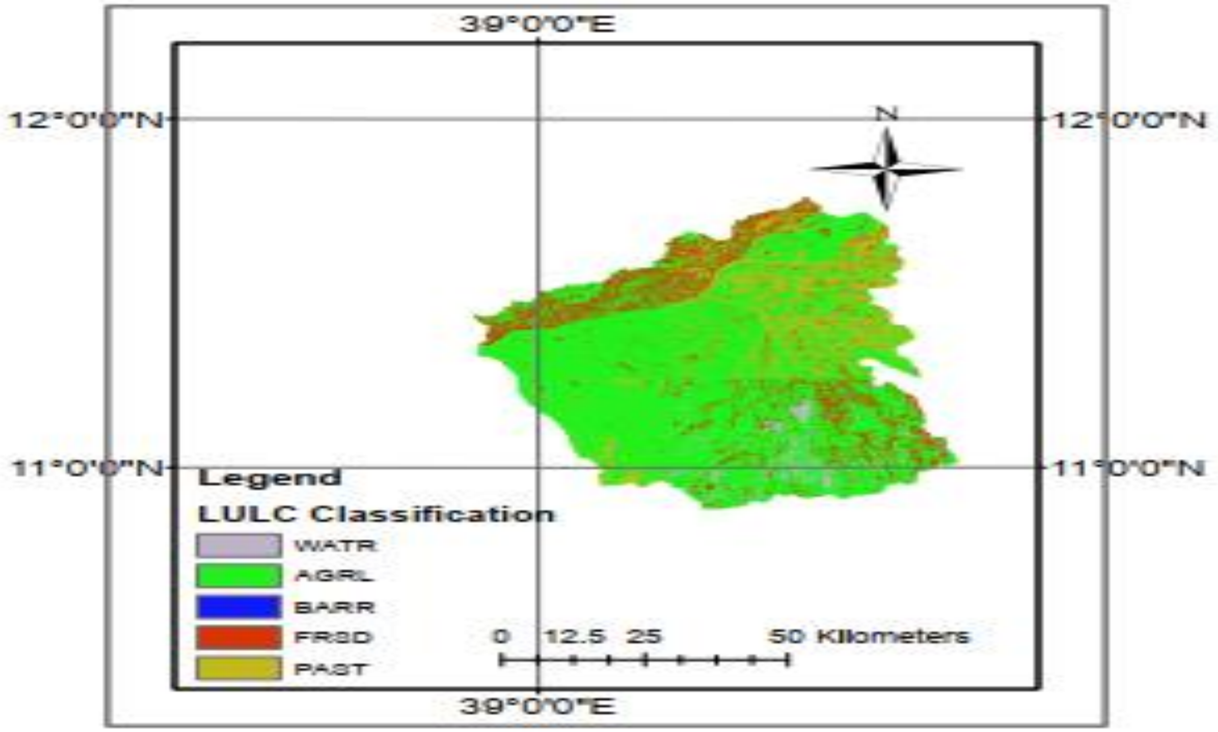

Figure 15 LULC classification at 2004

The above table8 and figure15 shows that the LULC at 2004, Agricultural land is cover largest area which is 86.54 % from the total watershed area, densely forest and sparsely forest cover 4.09 % and also grass land cover 9.14 % .

C.2013LULC

Table 9 LULC classification at 2004 map

Land use land cover at 2013			
Land use type	SWAT Code	Area (km^2)	Area (%)
Bare land	BARR	1.04	0.09
Agriculture	AGRL	4264	83.65
Forest	FRSD	662.3	12.06
Pasture	PAST	242.12	4.06
Wet land	WATR	4.66	0.14

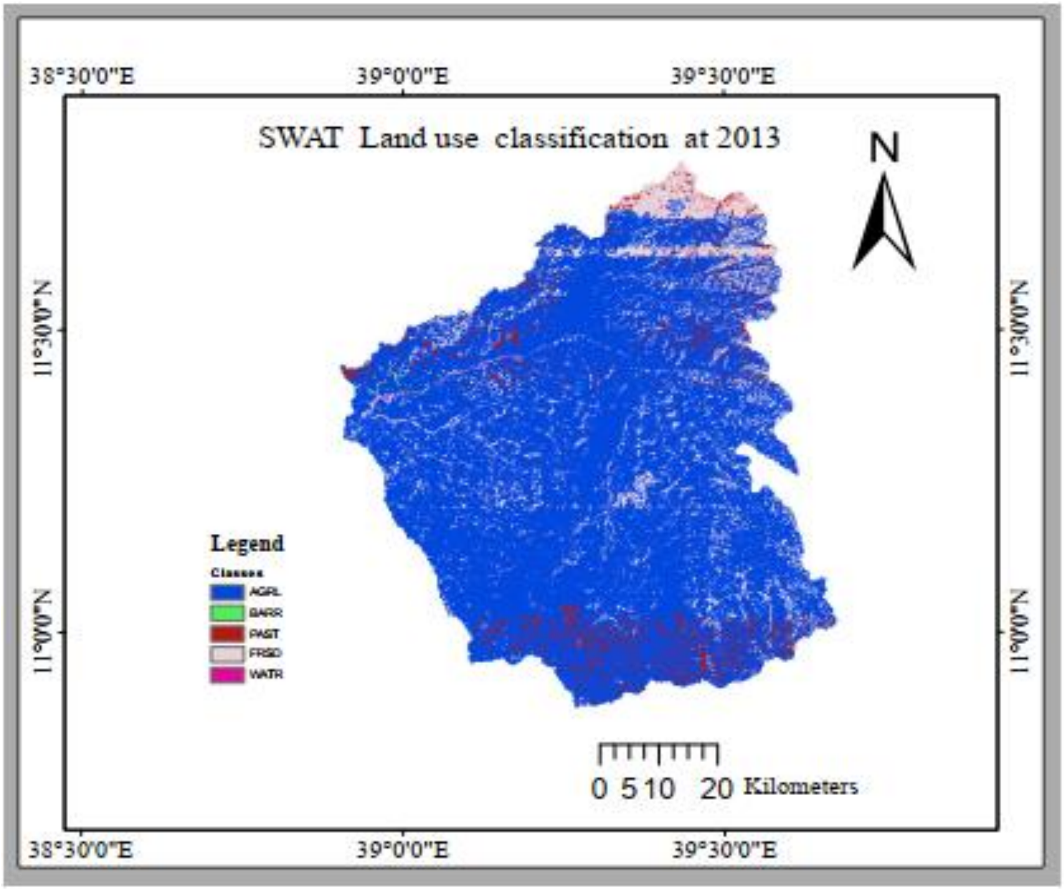

Figure 16 LULC classification at 2013

The above table 9 and figure16 shows that, the LULC at 2004, Agricultural land is cover largest area which is 83.68 % from the total watershed area, densely forest and sparsely forest cover 12.06 % and also grass land cover 4.06 %. From the above LULC classification at 1996, 2004 and 2013 shows that, agricultural land use were covered the largest area from the total watershed area. .

3.4.4 Soil Classification

Soil data are another spatial input required by Arc SWAT model the majour soil classification using soil map data. The classification shows below table 10 and figure 20 are shows the soil classification in the study area.

Table 10 Major type of (FAO-UNESCO Soil Classification Systems)

Soil Type	Symbol	Area (km^2)	% Watershed Area
Eutric Leptosol	PLe	4308.9	83.28
Calsic Vertisol	VRk	93.13	1.8
Eutric Cambisol	CMe	142.8	2.76
Rendzic Lepto	LPk	458.8	8.86
Verti Cambisol	CMv	15.5	0.3
Eutric Vertisol	VRe	569.65	11.01

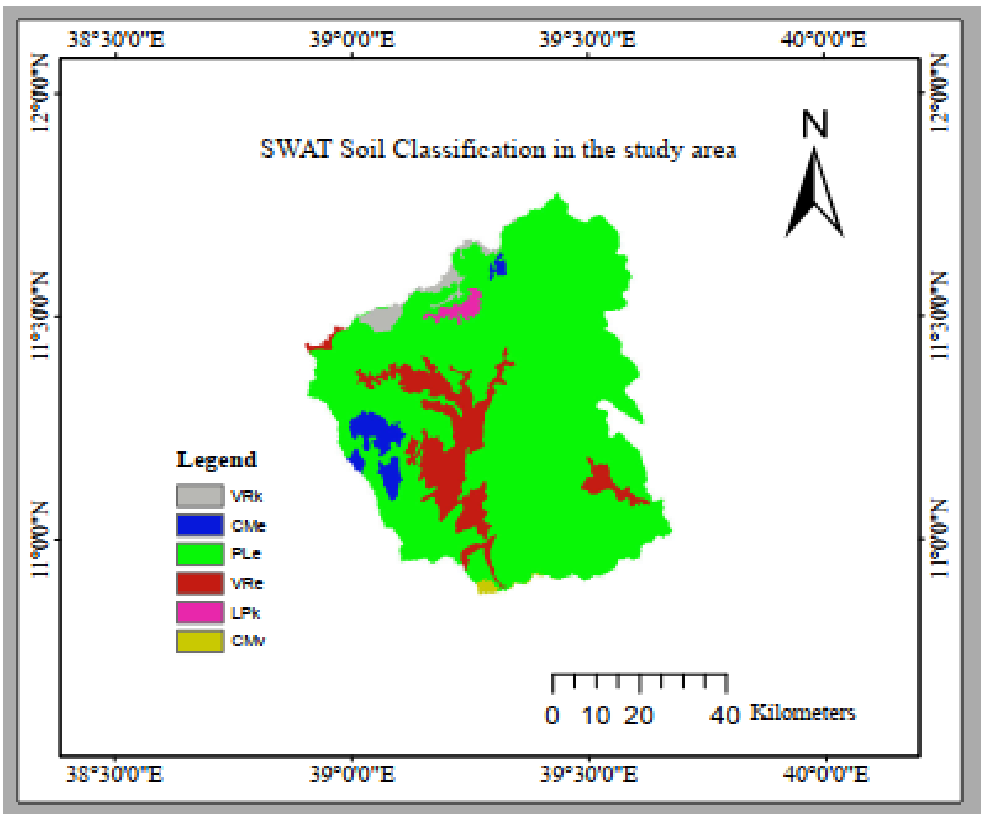

Figure 17 Soil classification by Arc SWAT

3.4.5 Watershed in put table

The weather data which are rain fall, temperature, relative humidity and wind seeped are prepare based on SWAT database format using text format and the table prepared using id, name, latitude, longitude, elevation, finally insert to the SWAT model. Weather Generator in SWAT includes the WXGEN weather generator model Sharpley and Williams, (1990) to generate climatic data gaps in measured records. The occurrence of rain on a given day has a major impact on relative humidity, temperature and solar radiation for the day. The weather generator first independently generates precipitation for the day, Once the total amount of rainfall for the day is generated, the distribution of rainfall within the day is computed if the Green & Ampt method is used for infiltration, maximum temperature, minimum temperature, solar radiation and relative humidity are then generated based on the presence or absence of rain for the day. Finally, wind speed is generated independently. To generate the data, weather parameters were developed by using the weather parameter calculator WXPARM (Williams, 1995) and dew point temperature calculator DEW02. For this study there are six station from those four station are synoptic station, the remaining two station have rain fall and temperature records from this used 1997-2016 G.C. Dew.exe model using average daily temperature and average daily relative humidity in percent whereas the dew02 model used daily minimum and maximum temperature, and relative humidity in %. For this study, preparation of weather generator was used by dew02 model calculator for temperature and using PCP STAT for prepared rainfall data. PCP STAT calculate 6 daily statistical parameter in 12 months of daily precipitation used by SWAT model. All data's are in the appendix F.

3.5 Model calibration and validation

3.5.1 Model Calibration

The time series of discharge at the outlet of the watershed was used as data for calibration and validation for SWAT model, the model was calibrated using the measured stream flow data from 1999 to 2008 with worm up period. The parameters were optimized first using the calibration tool, then calibration was done by adjusting parameters until the simulated and observed value showed good agreement. In this process, model parameters varied until recorded flow patterns are accurately simulated. Model calibration of SWAT run can be divided in to several steps. Among these Water balance and stream flow generation are the most important part is also (Refsgaard, 1996).

There are three types of calibration methods:

A: The manual trial-and-error method,

B: Automatic or numerical parameter optimization method; &

C: A combination of both the above methods

For this research work the measured stream flow data were calibrated using SWAT Cup model from SWAT model output using 10 years flow, automatic calibration period (from January 1st, 1999 to December 31st, 2008),and the warm up period (from January 1st, 1997 to December 31st, 1998). From three SWAT model using three year land use land cover map, 1196, 2004,, 2013, and also the calibration is operated as flows the scenario development based on the watershed characteristics used for evaluation for my study the calibration is done for the three land use land cover map, for evaluate climate characteristics, rain fall effect, and slope effect in the catchment area, finally table 11 shows the average calibration value.

3.5.2 Model Validation

In order to utilize the calibrated model for estimating the effectiveness of future potential, the model tested against an independent set of measured data. This testing of a model on an independent set of data set is commonly referred to as model validation. As the model predictive capability was demonstrated as being reasonable in both the calibration and validation phases, the model was used for future predictions under different management scenario. For this research work the measured stream flow data of Beshilo from 01 January 2009 to 31 December, 2014 were used. After calibrating and validation, simulated flow was executed and the hydrographs are well observed and the graph used for analysis. The agreement between the observed stream flow and simulated flow was generally very good, which are verified by NSE and R^2 and an acceptable result were obtained according to the model evaluation guideline (Moriasi et al., 2007). The calibration and validation period of the model was 16 years from 1999 to 2008G.C, for calibration and 2009-2014 for validation. The observed and simulated average monthly stream flow was computed. During calibration it was 121.79 m3/s and 105.45m3/s for observed and simulated respectively. On the other hand, the observed and simulated was 147.1m3/s and 112.33m3/s respectively during validation period. These indicates reasonable agreement between observed and simulated values in both calibration and validation periods

3.5.3 Sensitivity Analysis

After the SWAT model setup has been finished, the next step is to run the model and analyze the global sensitivity. Sensitivity analysis is used to estimate the rate of change of model outputs with respect to change of model inputs. It is also useful to recognize how the model depends on the information fed into it (Willems, 2000). Sensitivity analysis provides for better understanding of the behavior of the system being modeled, such as model parameters and applicability, thus it increases the confidence level of the model and its predictions. SWAT model have large number of parameters and a number of outputs, thus, an initial parameter selection makes the calibration process easier and reduces the uncertainties related to diverse parameters. In the sensitivity process, by using SWAT CAP is used for this study. SWAT-CUP is an interface that was developed for SWAT, Using this generic interface, any calibration/uncertainty or sensitivity is operated .program can easily be linked to SWAT. This is demonstrated by the program links SWAT Cup is having 4 algorism GLUE, Parasol, SUFI2, and MCMC procedures to SWAT. In this particular study it was preferred to use sequential uncertainty fittings (SUFI2). It is automated. It was shown that 27 parameters were sensitive with different degrees of sensitivity. Among these 18 parameters for the first iteration use, 12 parameter mostly related surface runoff in the study, So 12 water-related parameters (global parameters), with absolute minimum and maximum ranges in the SWAT model documents were selected to do sensitivity analysis. Then observe the sensitivity ranking, and edited the SWAT database with provides a measure of sensitivity (larger absolute values are more sensitive), and p values determine the significance of the sensitivity (a value close to zero has more significance) (SAWT Cup 2012 user manual).

Table 11 Sensitivity Rank

Flow parameter(SWAT)code	Description	**Lower bound**	**Upper bound**	**Fitted value**	Sensitivity rank
CN2	SCS curve number (%)	-25%	25%	23.9167	2
ALPHA_BF	Base flow alpha factor(days)	0	1	0.08927	1
GWQMN	Threshold depth of water in the shallow aquifer required for return flow(mm)	0	5000	412.6	6
REVAPMN	Threshold depth of water in the shallow aquifer for "revap" (mm)	0	500	312.500	5
SOL_AWC	Soil available water capacity (water/ mm soil)	-25%	25%	4.466	9
CANMX	Maximum canopy storage(mm)	0-10		0.2976	4
ESCO	Soil evaporation compensation factor	0-1		0.4918	12
SOL_K	Saturated Hydraulic conductivity [mm/hr.]	-25%	25%	-0.7107	8
GW_REVAP	Ground water "revap "coefficient	0.02-0.2		0.10209	7
SOL_Z	Total soil depth(mm)	-25%	25%	-17.75	11

CH_K2	Effective hydraulic conductivity of the main channel(mm/hr)	0-150		331.9	3
RCHRG_DP	Deep aquifer percolation fraction	0	1	0.708	10

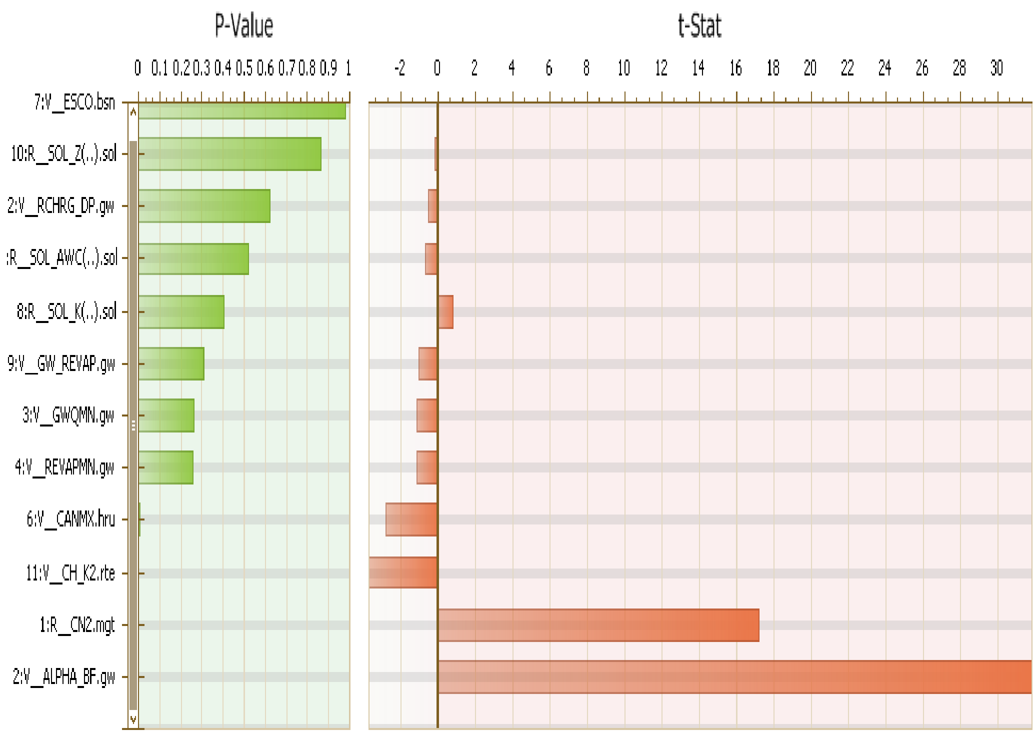

Figure 18 Sensitivity analysis of flow with graph view from SWAT cup

3.5.4 Uncertainties Analysis

Another issue with calibration of watershed models is that of uncertainty in the predictions. These can be divided into: conceptual model uncertainty, input uncertainty, and parameter uncertainty. The conceptual model uncertainty (or structural uncertainty) can be the following situations:

a) Model uncertainties due to simplifications in the conceptual model,

b) Model uncertainties due to processes occurring in the watershed but not included in the model,

c) Model uncertainties due to processes that are included in the model, but their occurrences in the watershed are unknown to the modeler, and

d) Model uncertainties due to processes unknown to the modeler and not included in the model

Input uncertainty is as a result of errors in input data such as rainfall, and more importantly, extension of point data to large areas in distributed models. Parameter uncertainty is usually caused as a result of inherent non-uniqueness of parameters in inverse modeling. Parameters represent processes.

The fact that processes can compensate for each other gives rise to many sets of parameters that produce the same output signal. A short explanation of uncertainty issues is offered below. Further errors could also exist in the very measurements we use to calibrate the model.

Another uncertainty worth mentioning is that of "modeler uncertainty"! It has been shown before that the experience of modelers could make a big difference in model calibration. We hope that packages like SWAT-CUP can help decrease modeler uncertainty by removing some probable sources of modeling and calibration errors. On a final note, it is highly desirable to separate quantitatively the effect of different uncertainties on model outputs, but this is very difficult to do. The combined effect, however, should always be quantified on model out puts.

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.

In SUFI2, we want that our model result (95PPU) envelops most of the observations. Observation, is what we have measured in the natural system. Observation is important because it is the culmination of all the processes taking place in the region of study. To quantify the fit between simulation result, expressed as 95PPU, and observation expressed as a single signal (with some error associated with it) we came up with two statistics: *P-factor* and *R-factor (*Abbas pour et al., 2004, 2007). *P-factor* is the percentage of observed data enveloped by our modeling result, the 95PPU. *R-factor* is the thickness of the 95PPU envelop. In SUFI2, we try to get reasonable values of these two factors. No hard numbers exist for what these two factors should be, similar to the fact that no hard numbers exist for R^2 or NS. The larger they are, the better they are. For *P-factor*, we suggested a value of >70% for discharge, while having *R-factor* of around 1. For sediment, a smaller *P-factor* and a larger *R-factor* could be acceptable. The goodness of fit and the degree to which the calibrated model accounts for the uncertainties are assessed by the above two measures. Theoretically, the value for *P-factor* ranges between 0 and 100%, while that of *R-factor* ranges between 0 and infinity. A *P-factor* of 1 and *R-factor* of zero is a simulation that exactly corresponds to measured data. The degree to which we are away from these numbers can be used to judge the strength of our calibration and validation. For this model the value of P-factor was 79% and R factor was 39%, it shows that the result is good.

3.5.4 Model Evaluation

The performance of SWAT was evaluated using statistical measures to determine the quality and reliability of predictions when compared to observed values. Coefficient of determination (R^2) and Nash-Sutcliffe simulation efficiency (ENS) were the goodness of fit measures used to evaluate model prediction. The R^2 value is an indicator of strength of relationship between the observed and simulated values. The Nash-Sutcliffe simulation efficiency (ENS) indicates how well the plot of observed versus simulated value fits the 1:1 line. If the measured value is the same as all predictions, ENS is 1. If the ENS is between 0 and 1, it indicates deviations between measured and predicted values. If ENS is negative, predictions are very poor, and the average value of output is a better estimate than the model prediction (Nash, Sutcliffe, 1970). The R^2 and ENS values are explained in the following equations below.

$$R^2 = \frac{\sum_{i=1}^{n} (q_{si}-q_s)(q_{oi}-q_o)^2}{\sum_{i=1}^{n} (q_{si}-q_s)^2(q_{oi}-q_o)^2}$$

Where:

q_{si} :- is the simulated value ,

q_{oi} :- is the measured values,

qs:- is the average simulated value and

q_o:- is the average measured value .

The ENS simulation efficiency for n time steps is calculated

$$\sum_{NS} = 1 - \frac{\sum_{i=1}^{n} (q_{oi}-q_{si})^2}{\sum_{i=1}^{n} (q_{oi}-q_o)^2}$$

Where: q_i: - is the average measured value

q_{si} is the simulated value and

q_{oi} is the measured value

Percent bias (PBIAS): measures the average tendency of the simulated data to be larger or smaller than the observations (Gupta, 1999).The optimum value is zero, where low magnitude values indicate better simulation and positive values indicate model underestimation and negative value indicates model over estimation (Guptal et al., 1999).

Table 12 General performance rating for recommended statistics for a monthly time (Moriasi, et al.2007)

Performance Rating	For Stream Flow		
	RSR	NSE	PBIAS (%)
Very good	0.0<=RSR<=0.5	0.75<NSE<=1	PBIAS<10
Good	0.5<=RSR<=0.6	0.65<NSE<=0.75	10<PBIAS<15
Satisfactory	0.6<=RSR<=0.7	0.5<NSE<=0.65	15<PBIAS<25
Unsatisfactory	RSR>=0.7	NSE<=0.5	PBIAS>25

Table 13 Model evaluation result

Performance criteria	1996 LULC		2004 LULC		2013 LULC	
	Calibration	Validation	Calibration	Validation	Calibration	Validation
R^2	0.77	0.83	0.79	0.8	0.74	0.79
NSE	0.77	0.80	0.73	0.78	0.72	0.73
RSR	0.48	0.45	0.52	0.47	0.53	0.52
Percent (PBIAS):	13.4	23.6	23.5	19.6	18.4	24.3
Evaluation period	1999-2008	2009-2016	1999-2008	2009-2016	1999-2008	2009-2016

After calibrating for flow simulation was executed and the hydrographs are well captured. The agreement between the measurement and simulation is generally very good, which are verified by NSE and R^2 and an acceptable result were obtained according to the model evaluation guideline (Moriasi et al., 2007). The results of these tests illustrated that the monthly coefficient of determination (R^2) and Nash- Sutcliffe coefficient was 0.77 and 0.77 for calibration period, 0.83 and 0.80 for validation period. The calibration and validation period of the model was 20 years from 1999 to 2016 G.C. The SWAT model is run after sensitivity analysis based on the fitting value from SWAT Cup output. The percent bias of the mode for this study is 18.4% for calibration and 19.2% for validation. The model performance were compared from near Beshilo which study by (Ephrem Alemu, 2011) on Gumeera watershed, the model was calibrated for the period from 1998-2004 and validated for the period from 2005-2007. The performance of the model was evaluated on the basis of performance rating criteria, coefficient of determination, Nash & Sutcliff efficiency. The overall performance of the two models gives satisfactory result. The physical catchment characteristics which have high differences R^2 =0.78 and NSE =0.67. So the model performance of this study is given good result.

4. RESULTS AND DISCUSSION

4.1 Land use land cover map

The model performed based on the climate data from 1997to 2016, the three land use land cover maps, 1986 soil map, through developed three model run by using LULC, slope change analysis and climate data change were used to assess the impact of watershed characteristics stream flow. To evaluate the variability stream flow by land use land cover change, three independent SWAT Runs were carried out on monthly time step using 1996, 2004, and 2013 land use land cover maps. The SWAT model parameter were observed from each run, based on the simulation output the stream flow variability caused by land use land cover change was assessed and comparison was made on stream flow change from the model output.

4.1.1 Land use land over map of 1996

The land cover map of 1996 was covered the following land class coverage, that about 71.65% by agricultural land, 13.66% by grass land or pasture land, 12.11% by forest land, 2.57% by wet land or water body and 0.01% covered by Bare land. The above percentage shows agricultural land cover large amount of area from the total area and the model calibration and validation of observed and simulated stream flow with 1996 LULC were showed figure 19.

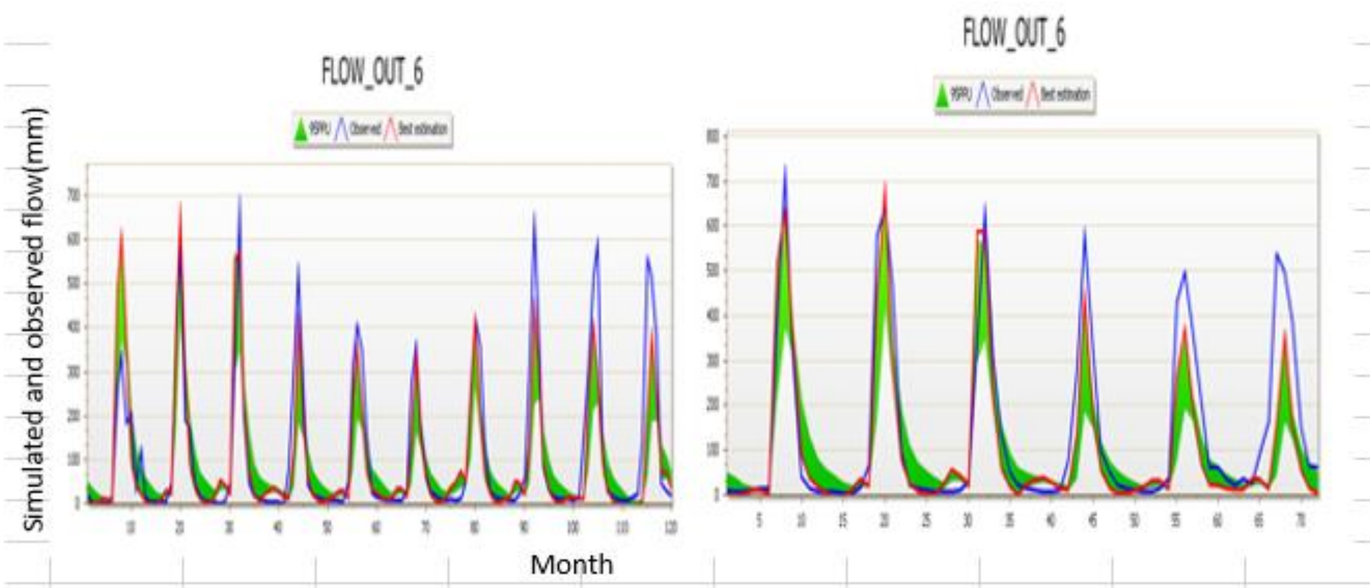

Figure 19 Hydrograph of the observed and simulated stream flow for the calibration and validation.

4.1.2 Land use land cover map of 2004

The land cover map of 2004 is covered the following land class coverage, that about 86.54% by agricultural land, 9.14% by grass land or pasture land, 4.09% by forest land or planted area, 0.11% by wet land or water body. The distribution of land cover class as indicates agricultural land cover large amount of percentage from the total area, and compare from land use/cover at 1996 agricultural land increased by 14.89%, forest land is reduced by 9.57% and grass land reduced by 2.97 %. The model calibration and validation of observed and simulated stream flow with 2004 LULC were showed figure 20.

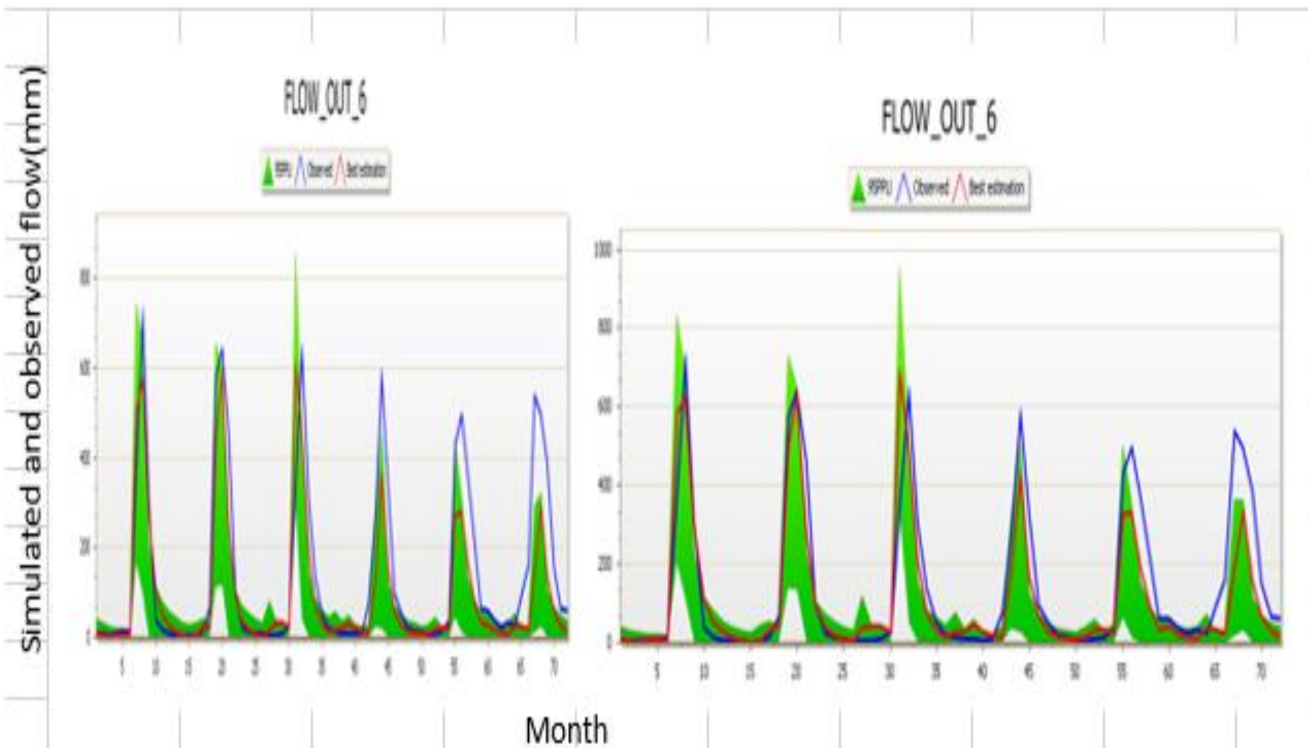

Figure 20 Hydrograph of the observed and simulated stream flow for the calibration and validation.

4.1.3 Land use land cover map of 2013

The land cover map of 2013 is covered the following land class coverage that, about 83.45% by agricultural land, 4.06 % by grass land or pasture land , 12.06 % by forest land or planted area , 0.14% by wet land or water body. The distribution of land cover class as indicates agricultural land cover more than 1996 LULC and less than 2004 LULC. Compare the coverage, agricultural increase by 11.8% from 1996 LULC and reduced by 3.09% from 2004 LULC, whereas the forest area increased by 7.8% from 2013 LULC, and reduced 1.6% from 2004 LULC. The grass land also reduced by 8.05% from 1996 and 5% from 2004 LULC. The model calibration and validation of observed and simulated stream flow with 2004 LULC are shows figure 21

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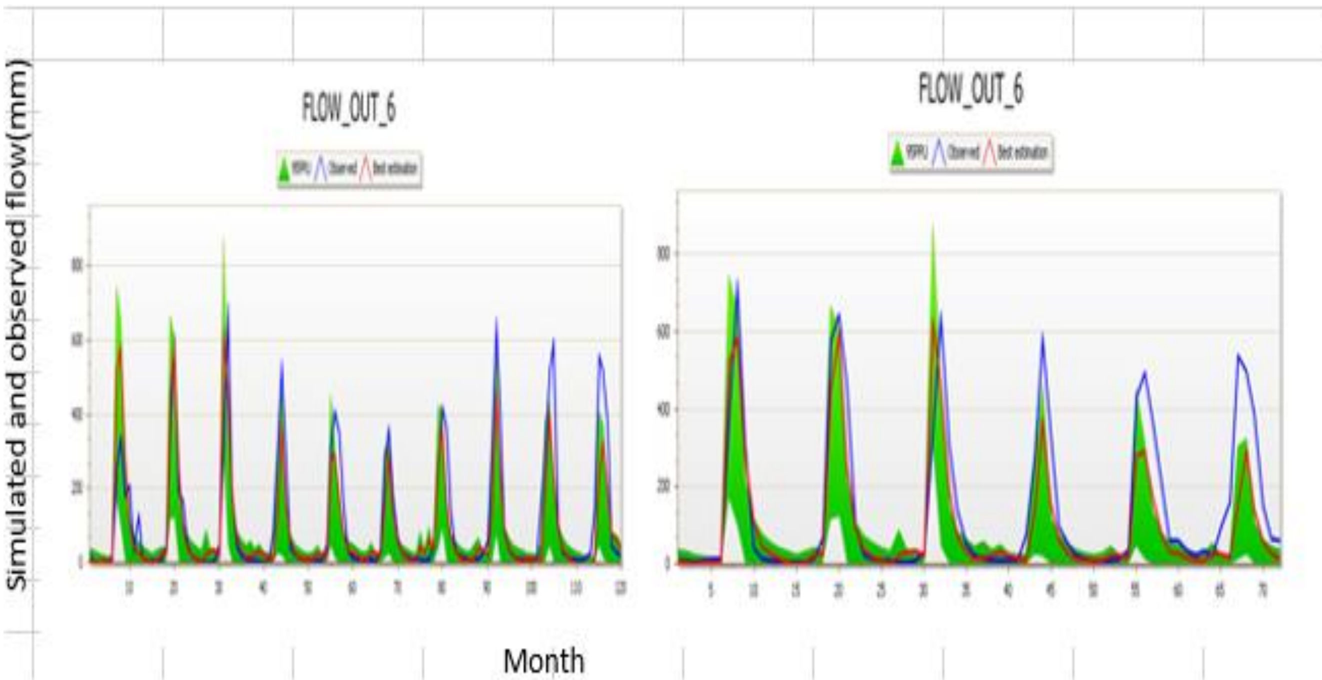


Figure 21 Hydrograph of the observed and simulated stream flow for the validation with 2013LULC.

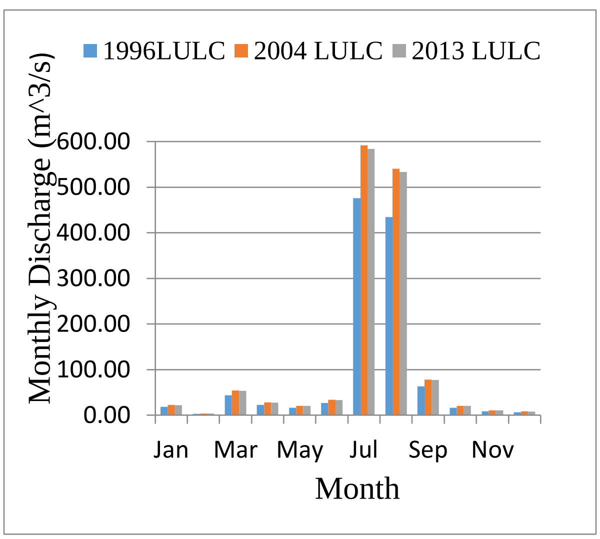
The model calibrations and validations were used by the observed stream flow from 1999-2008 and 2009 -2016 respectively. The model output from the above LULC were observed by using the SWAT model run with adjusted model parameter.

4.1.4 Model responses to land use land cover change

The hydrological impacts of land use have received a considerable amount of interest in hydrology. LULC is an important characteristic in the surface runoff process that affects infiltration, erosion, and evapotranspiration. Understanding the effects of historic land use changes have had on River flow is required to understand the future effects of land use and land cover on hydrological regimes at a watershed level. Along with these changes, considerable consequences are expected in the hydrological cycles and subsequent effects on water resources (Githu, 2007).

The SWAT model simulated for the three time periods corresponding to the land use map of 1996, 2004 and 2013, Simulation runs were conducted on monthly basis to compare the modeling outputs using the 1996, 2004 and 2013 land maps. A comparison of stream flow from the model output using 1996, 2004 and 2013 land use map and average annual stream flow from the watershed were presented, shows the significant change, and the result would be described in table14, figure22 and figure23.

The result indicated that the mean annual stream flow of 2004 LULC increase by 7.4 % compared from 1996 LULC and increase by 4.8% compared from 2013 LULC, whereas, compared the two recent LULC of 2004 and 2013, table 14 the annual stream flow was decreased by 2.3% for 2013 from 2004 LULC. Because of reduced agricultural land from 2004 up to 2013 and increased plantation in the watershed. According (Abeyou 2008), Hydrological balance of Lake Tana upper Blue Nile, Ethiopia, he conclude that expansion and reduction of agricultural land was strong relation for increasing and decreasing of stream flow from the watershed and decreased stream flow when increased afforestation.



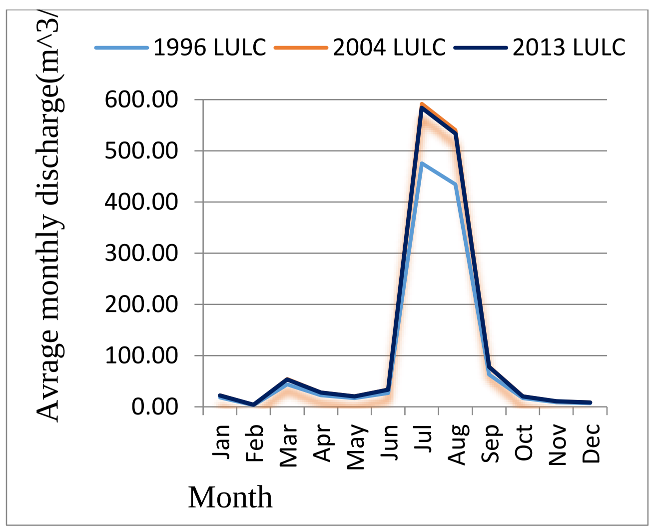


Figure 22 Monthly stream flow with three period LULC

Table 14 Mean annual simulated and observed stream flow

Runoff (mm)	LULC-1996	LULC-2004	LULC-2013
Observed annual stream flow	118.8	118.8	118.8
Simulated stream flow	98.28	105.52	103.0

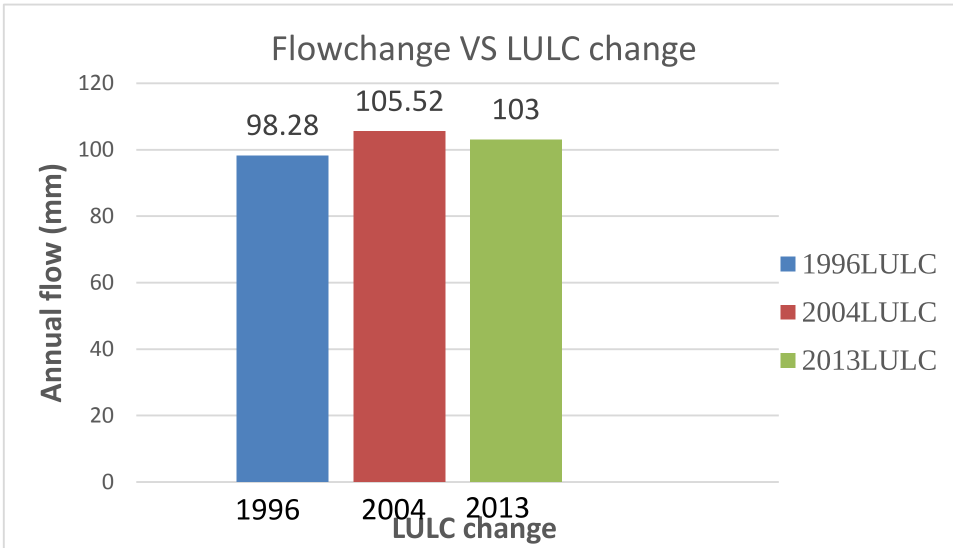


Figure 23 Annual simulated stream flow at different LULC

Average annual watershed stream flow was directly related to land cover type characteristics. In the study area, agricultural land/ cultivated land was increased between 1996 and 2004 and slightly decrease from 2004 up to 2013, whereas frost area was decreased from 1996 up to 2004 and increased from 2004 up to 2013. Agricultural land expansion were increased the stream flow by reduced the infiltration in the watershed, but Forest areas have the highest potential for decrease stream flow because the land was improve in a watershed and increase infiltrations (Abeyou, 2008).

According to Githu, (2007), Water resources, which are substantially affected by land use/land cover (LULC) and climate changes, are a key limiting factor for ecosystems in arid and semi-arid regions exhibiting high vulnerability. It is crucial to assess the impact of LULC and climate changes on water resources in different areas. However, conflicting results on the effect of the LULC and climate changes on stream flow have been reported for relatively large Basins but focused on quantifying both the combined and isolated impacts of LULC and climate changes on stream flow (Githu, 2007).

It is hypothesized that under climatic warming and drying conditions, LULC change, which is primarily caused by intensive human activities, such as the conversion of cropland to forest and grassland. The Soil and Water Assessment Tool (SWAT) was adopted to perform simulations. The simulated results indicated that although stream flow increased between the 1970s and the 2000s due to the combined effects of LULC and climate changes, however stream flow affected significantly due to LULC changes in each decade (Githu 2007).

4.2 Climate characteristics on stream flow

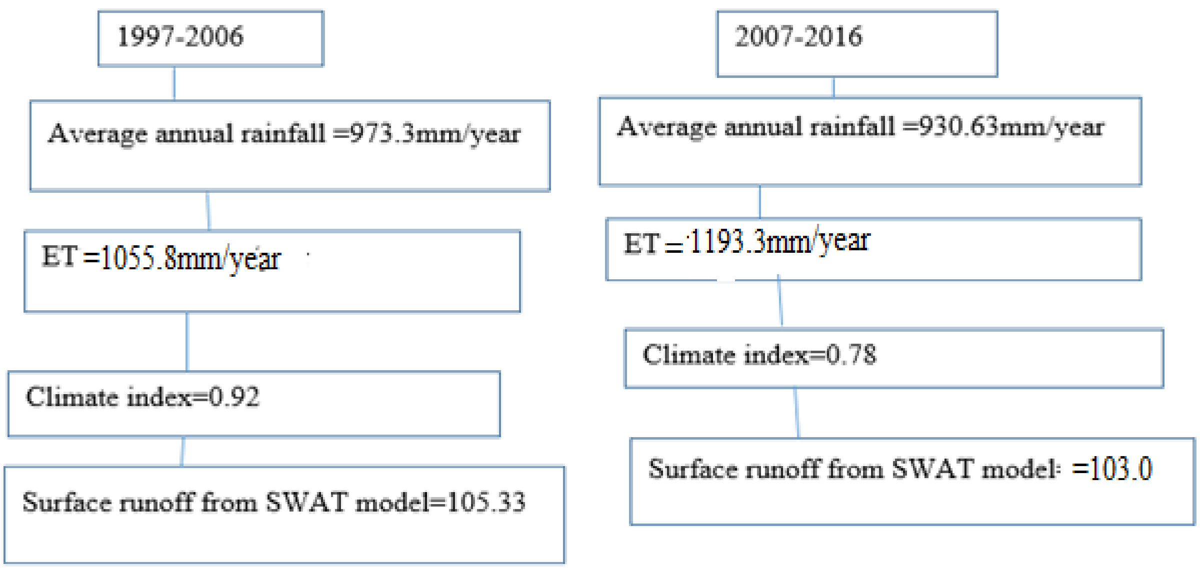
4.2.1 Effects of climate data on stream flow using climate index

Climate characteristics include precipitation, temperature, wind, relative humidity and other Metrological elements for a given region over a long period of time. For this study using climate index change and perception change on the change of stream flow.

Abebe and Foerch, (2006), often denoted as humidity/aridity index was used, it is the ratio of mean annual long-term precipitation to the mean annual long-term potential evapotranspiration. In and around the study area there are six metrological stations, all station data's required as an input parameters for estimation of reference evapotranspiration by Penman-Monteith, the weights of those stations is estimated by thiessen polygon method. The climate index was important parameter to analysis the effect of climate index on stream flow by compared the climate index value because the larger climate index shows that the watershed is generated more stream flow discharge and the smallest climate index shows that the watershed generated small discharge (Aphrem Alemu 2011). According to Yared Mengistu, (2002), he studies potential assessment of surface and ground water on Beshilo watershed and he conclude that climate index is one of the major factor that controlled the stream flow in the watershed. For this study evaluate how the climate index affect the stream flow in watershed by using 10 year climate data interval.

For case1: using the station in and around the watershed from 1997-2006 G.C and based on the Thiessen polygon area and the weights of the station contribute to the watershed, the long-term annual rainfall for was 973.3mm/year and from the SWAT model evapo-transpiration of the watershed was 1055.8mm/year, so the climate index was calculated by average annual rainfall divided by annual evapo-transpiration. The result would be 973.6 mm÷1055.8mm=0.92 and the simulated annual stream flow from the SWAT model was recorded 105.3mm/year.

For case2: using the climate data from 2007-2016 G.C and based on the Thiessen polygon area proportion and the weights of the station, the long term annual rainfall was 930.63 mm/year, the annual evapo transpiration from the SWAT model was 1190 mm/year, so the climate index was calculated annual average rainfall divided by average annual evapo-transpiration. The result would be 930.63mm÷1193.3mm=0.78 and the simulated annual stream flow from the SWAT model was recorded 103.0mm/year.



This shows that larger climate index provide the watershed more wet than smaller climate index (Aphrem Alemu 2011). From the model output for larger climate index the annual stream flow from the watershed was obtained 105.33mm, when climate index was smaller the stream flow from the watershed reduce to 103.0mm. The annual stream flow of the watershed decrease by 2.21% from the first 10 year climate data compared to the next 10 year climate data, from this result I conclude that the climate condition around and in the watershed can affect the stream flow.

4.2.2 Rain fall effects on stream flow

Rain fall data was affect the stream flow in different ways, rainfall intensity, rainfall duration and annual rainfall amount affect the stream flow. But for this study considered only average annual rainfall amount with 10 year interval and using the 1997-2006 G.C and 2007-2016 rainfall, for the first run, SWAT model were run by using all the climate data from 1997-2006 and 1996 LULC, for the next run, the SWAT model were run by changing only the rainfall data of 2007-2016 keeping the other model input constant. The change of stream flow by changing of rainfall as shown in table 15 and figure 24.

Table 15 change in rainfall amount effects on stream flow

Month	(Flow in m^3/s) from 1997-2006 G. C (rain fall)	(Flow in m^3/s) from 2007-2016 G.C (rain fall)
Jan	1.19	1.15192
Feb	0.01	0.00968
Mar	3.43	3.32024
Apr	0.43	0.41624
May	0.66	0.63888
Jun	0.12	0.11616
Jul	53.5	51.788
Aug	55.61	53.83048
Sep	3.17	3.06856
Oct	0.05	0.0484
Nov	0.18	0.17424
Dec	0.59	0.57112
AV annual flow (mm)	118.94	115.13392

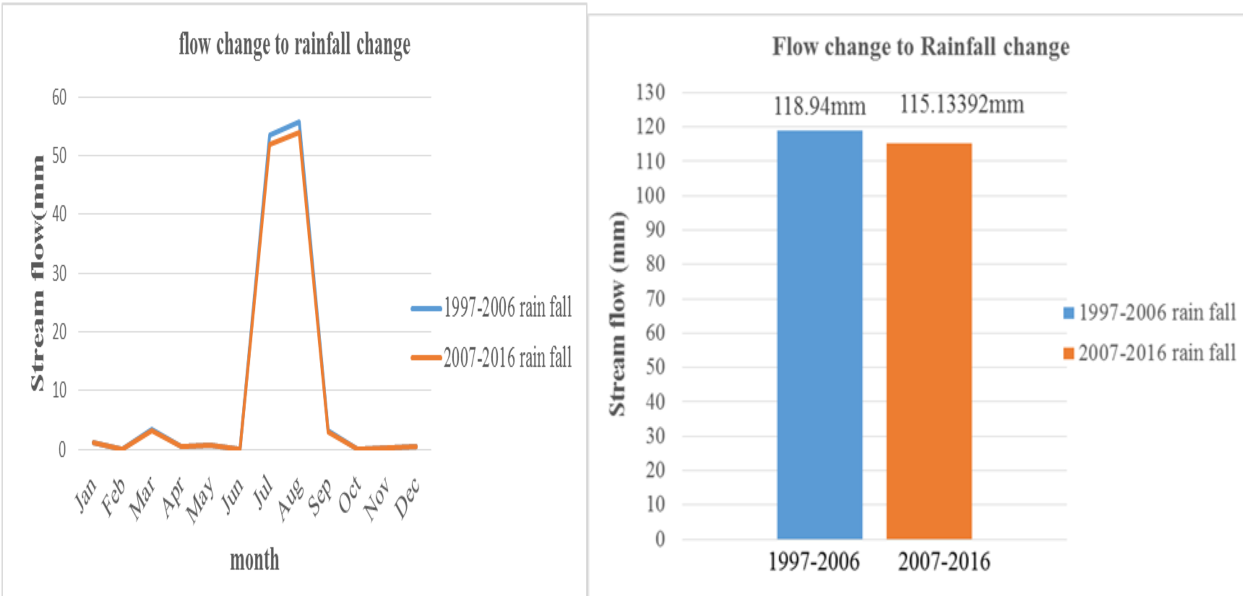


Figure 24 monthly and annual surface runoff from rain fall change

From the above table and figure, the model output result showed that the first 10 year (1997-2006), the annual average rainfall was 997.3 mm/year and the next 10 year (2007-2016) average rainfall was 930.63m/year. The first SWAT model run the annual stream flow from watershed obtained 118.94mm/ year and from the 2nd model run the annual stream flow was 115.3mm/ year. This result shows that the 2nd 10 year average annual rainfall were decreased by 6.2 % compared from the first 10 years average annual rainfall and the annual stream flow from the watershed were decreased by 3.2 %. According to (Abeyou, 2008), rain fall amount was significant effect on stream flow that generate from the watershed, so I conclude that from this study rain fall amount is affect the stream flow in Beshilo watershed.

4.3 Slope effect on stream flow

4.3.1 Slope increased above average tributary slope

Slope is one of the factors which influence the stream flow velocity. Where higher slope result in higher velocity of flow, therefore the water will travel quickly to reach the river outlet (Ephrem Alemu 2011). For this study five slope class based on FAO major slope classes were classified. The average slope of tributary channel in each sub basin is used to evaluate the change of slope to change stream flow. The scenario of the study was developed based on increased the slope by 5% above the average tributary channel slope. Each sub basin tributary channel slope increase 5%, 10%, 15%

from average slope and using SWAT executive run. The text out from SWAT mode and the swat executive were run by increase the slope. The result of the model were presented in table 16 and figure 25.

Table 16 monthly stream flow change for slope increased by 5%

month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Av.flow	0.57	0.04	1.89	0.32	0.58	0.56	47.24	52.80	3.59	0.37	0.30	0.29
5%	0.58	0.04	1.92	0.33	0.59	0.57	48.09	53.75	3.65	0.38	0.31	0.30
10%	0.59	0.04	1.94	0.33	0.60	0.58	48.56	54.28	3.69	0.38	0.31	0.30
15%	0.59	0.04	1.95	0.33	0.60	0.58	48.70	54.44	3.70	0.38	0.31	0.30

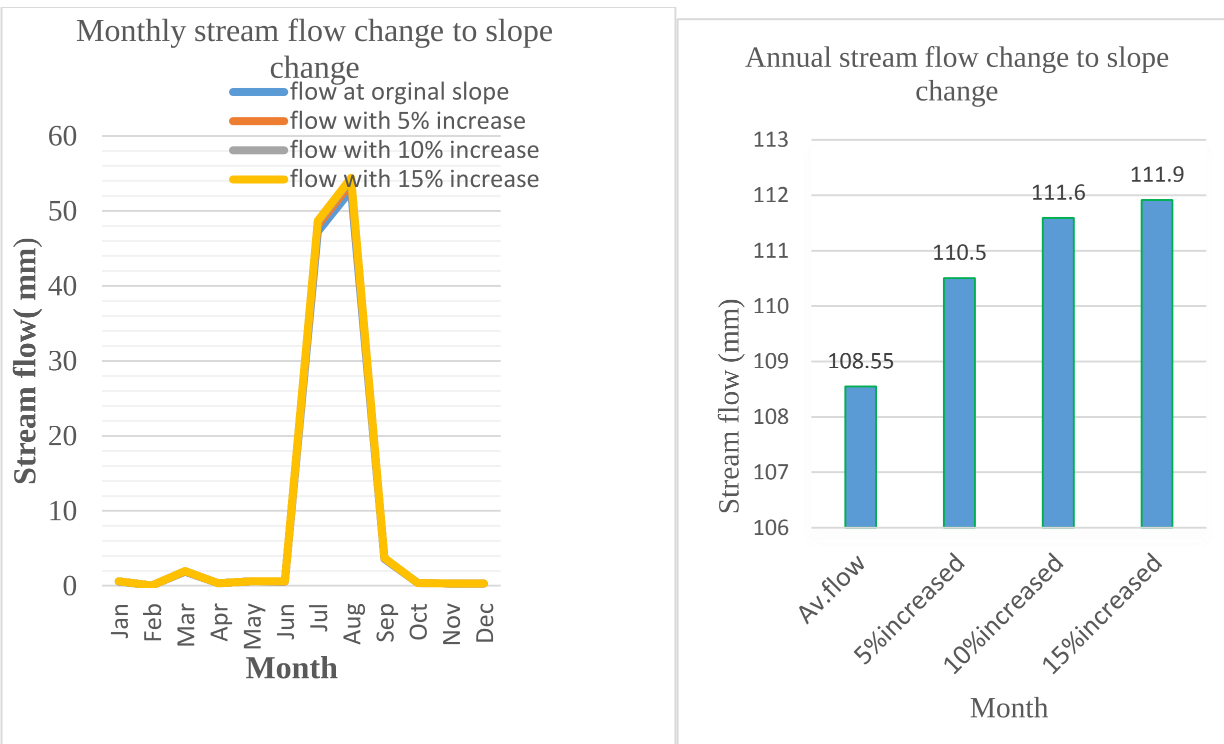


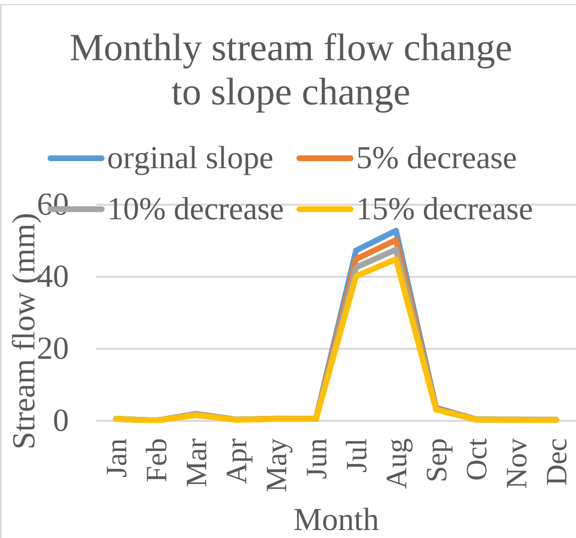
Figure 25 Stream flow change for slope increased by 5% change

4.3.2 Slope decreased above average tributary slope

In addition to increase slope of each sub basin tributary channel slope, this model is develop by decrease the slope with 5% rate and SWAT executive run for increasing with 5%, 10%, 15% slope change above average tributary channel. SWAT executive model output were presented in table 17 and figure 26.

Table 17 Monthly stream flow change for slope decreased by 5% change

month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Av.flow	0.57	0.04	1.89	0.32	0.58	0.56	47.24	52.8	3.59	0.37	0.3	0.29
5% decrease	0.5415	0.038	1.7955	0.304	0.551	0.532	44.878	50.16	3.4105	0.351	0.285	0.2755
10%decrease	0.513	0.036	1.701	0.288	0.522	0.504	42.516	47.52	3.231	0.333	0.27	0.261
15% decrease	0.4845	0.034	1.6065	0.272	0.493	0.476	40.154	44.88	3.0515	0.3145	0.255	0.2465



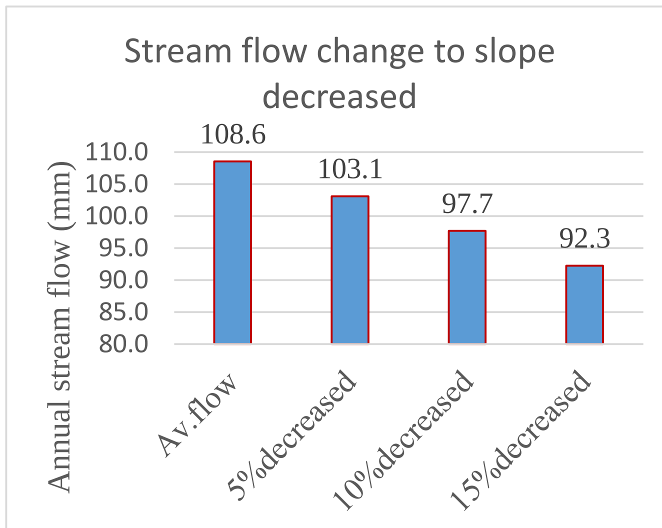


Figure 26 Stream flow change for slope decreased by 5% change

According to (Sharma et al, 1986), investigations on experimental plots have shown that steep slope plots yield more stream flow than those with gentle slopes plots. This is mainly due to gentle slopes were caused lower flow velocities and subsequently a longer time of concentration (defined as the time needed for a drop of water to reach the outlet of a watershed from the most remote location in the watershed). This means that the water is exposed for a longer duration to infiltration and evaporation before it reaches the measuring point. The above model result showed that slope was significant effect on stream flow change, the slope increase with 5%, 10% and 15% the stream flow were increase with 1.8%, 2.8%, and 3.1% respectively and the slope decrease by the same slope change the stream flow were reduced by 1.2%, 1.8%, 2.8% respectively. Generally, from this result conclude that the average tributary slope was increase by 5%, the annual stream flow increased by 2.6%, whereas the average tributary slope was decrease by 5%, the annual stream flow is decreased by 1.9%. According to (Ephrem Alemu 2011) the physical watershed characteristics are includes climate, slope, area of the watershed, shape of the watershed, soil and land use land cover were the major characteristics. The watershed characteristics that considered in a single watershed; climate characteristics, land use land cover and slope (hill side effect) were observe red the effects on stream flow change. From this study, land use land cover change, the slope change of the tributary channel, and climate characteristics and the rainfall magnitude were analyzed the effects on stream flow, so I conclude that, land use land cover change was the dominant factor to affect the stream flow in Beshilo watershed.

4.4 Stream flow data

4.4.1 Stream flow data for gauged watershed

The study was aimed to developing a simple methodology for flow prediction in ungauged watershed using existing data resources from gauged watershed. For this purpose, the stream flow were obtained from ministry of water resource. The longer daily time series stream flow data from 1999 to 2014 were used as a model input for calibration and validation. The long-term average monthly discharge of Gummera Rivers was maximum at August and minimum around March and April and it showed figure 27.

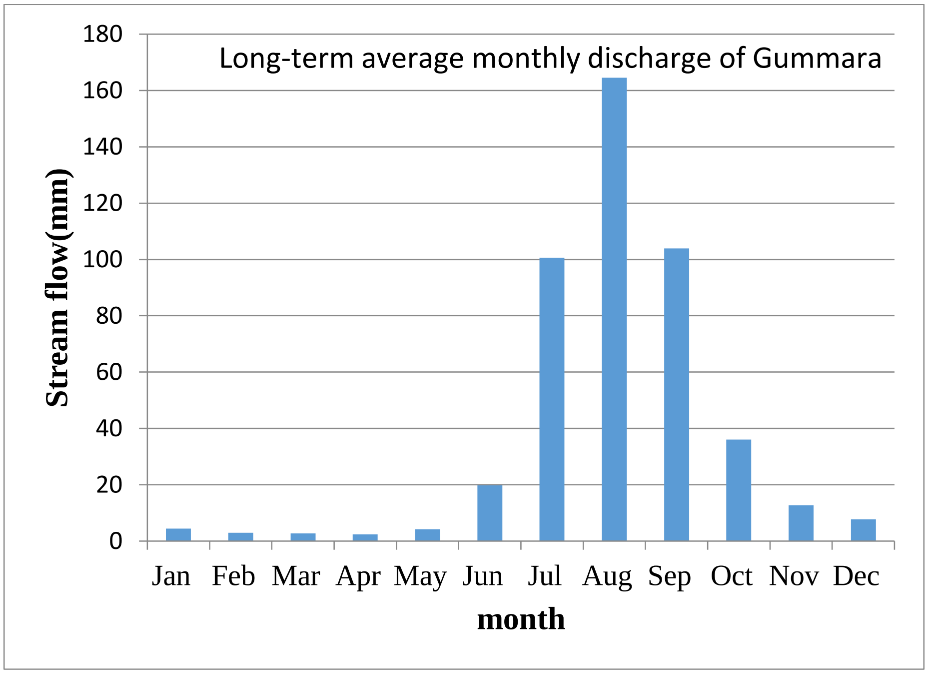


Figure 27 Long term average monthly discharge of Gummara

4.4.2 Stream flow for ungauged watershed

The stream flow data transferred from gauged station by using special proximity with combination of area and rainfall ratio. Gummara watershed stream flow data was transferred to Beshilo watershed, and the long-term average monthly discharge of Beshilo watershed was similar trained as Gummara that maximum at August and minimum around March and April and showed that in figure 28.

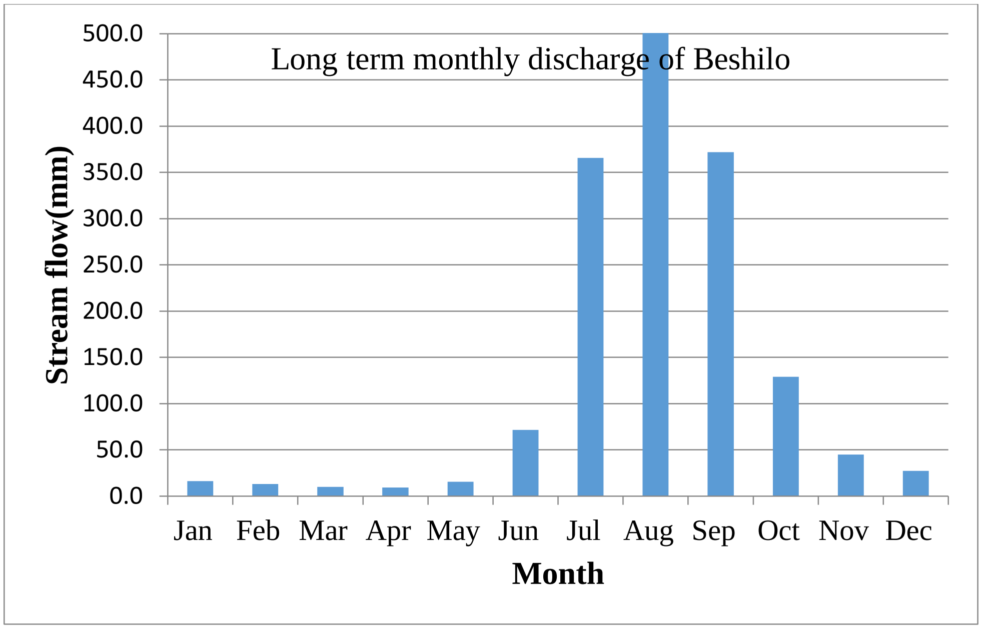


Figure 28 Long term average monthly discharge of Beshilo

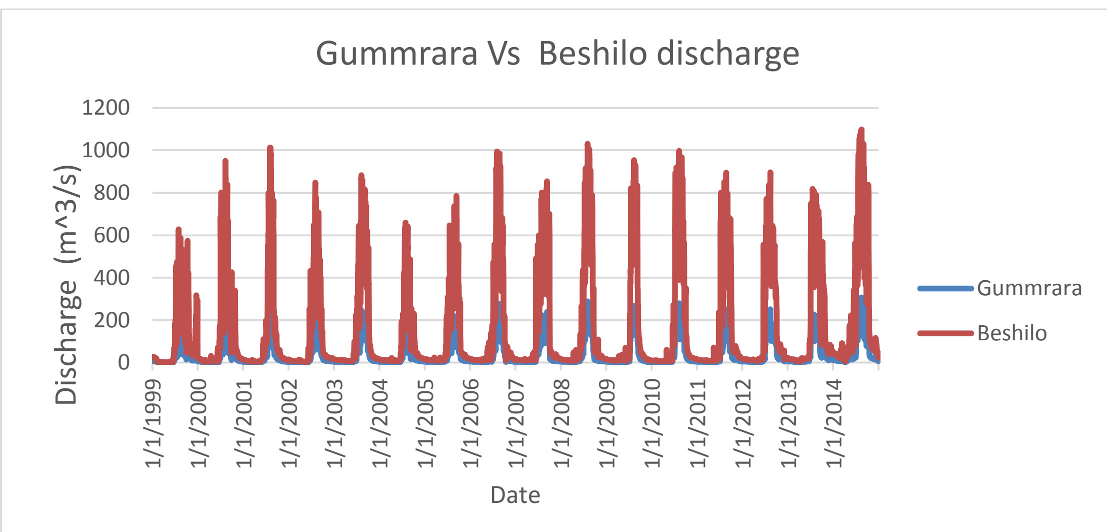


Figure 29 Discharge relation between Gummara and Beshilo watershed

Before the data were used for calibration and validation it have been checked the transferred flow data of gauged to ungauged watershed which have the same trends. Gummara and Beshilo watershed have a similar stream flow trends with a high correlation on a long-term monthly basis around 0.92 of R^2 for the study period and the result showed figure 29.

4.5 Remedial measure for most stream flow control factor

4.5.1 Stream flow control method

Mechanical Practices control erosion and stream flow in watershed, this mechanical control methods include Bunding, terracing, gully contraction, and construction of check dam are mechanical measures and requiring engineering techniques and structures to apply as a control measure. They reduce stream flow and impound water storage for longer time to help water infiltrate into the soil. Their construction and design will depend upon rainfall, soil slope and such other factors. Biological stream flow control measure were develop through changing the land cover condition of the watershed. Land use land cove change especially reduction of agricultural land and increasing afforestation were improved the soil infiltration and reduce the stream flow in the watershed (Abeyou, 2008).

4.5.2 Model verification remedial measure

From the above result the LULC change was significant effect on stream flow in Beshilo watershed, the land use land cover changes from one type of use to other type of use can affect the stream flow. Using 2013 LULC map, change agricultural and grass land in to forest land by GIS interface with SWAT, the original land cover map of 2013 was covered 83.45% of agricultural land, 4.06% of grass, 12.06% of forest area, so the reduction of agricultural land, bare and grass land were important to reduce the stream flow. By reduced agricultural land with 10%, reduce grass land with 5% and increase the forest with 15%. The SWAT model were run by the new land use land cover classification, the mode provided the new output different from the previous 2013 LULC map out put, the new land use land cover result showed below table 18 and figure 30.

Table 18 Land use land cover percentage at 2013 and modified

land use	2013LULC (%)	After modified LULC (%)
Bare land	0.02	0
Agriculture land	82.41	74.2
Planted area	12.8	28.82
Pasture	4.68	4.4
Wet land	0.09	0.09

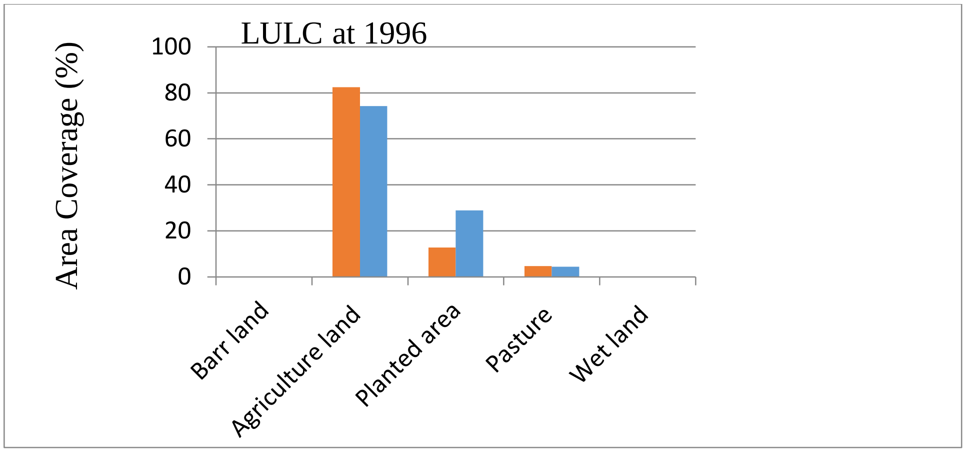


Figure 30 shows the new modified LULC classification

The SWAT mode run using the new modified LULC with the other model input were keeping as constant, the stream flow was changed, the new LULC were agricultural land reduced by % grass land reduced by 5% and the forest area increased by 15% ,the stream flow in the watershed reduce by 7.0%, the result showed table 19 and figure 31.

Table 19 Monthly stream flow change to land use change

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013LULC	35.57	8.38	77.85	42.14	29.76	46.66	563.87	507.02	113.30	29.23	14.93	13.71
New LULC	33.08	7.79	72.40	39.19	27.67	43.39	524.40	471.53	105.37	27.18	13.89	12.75

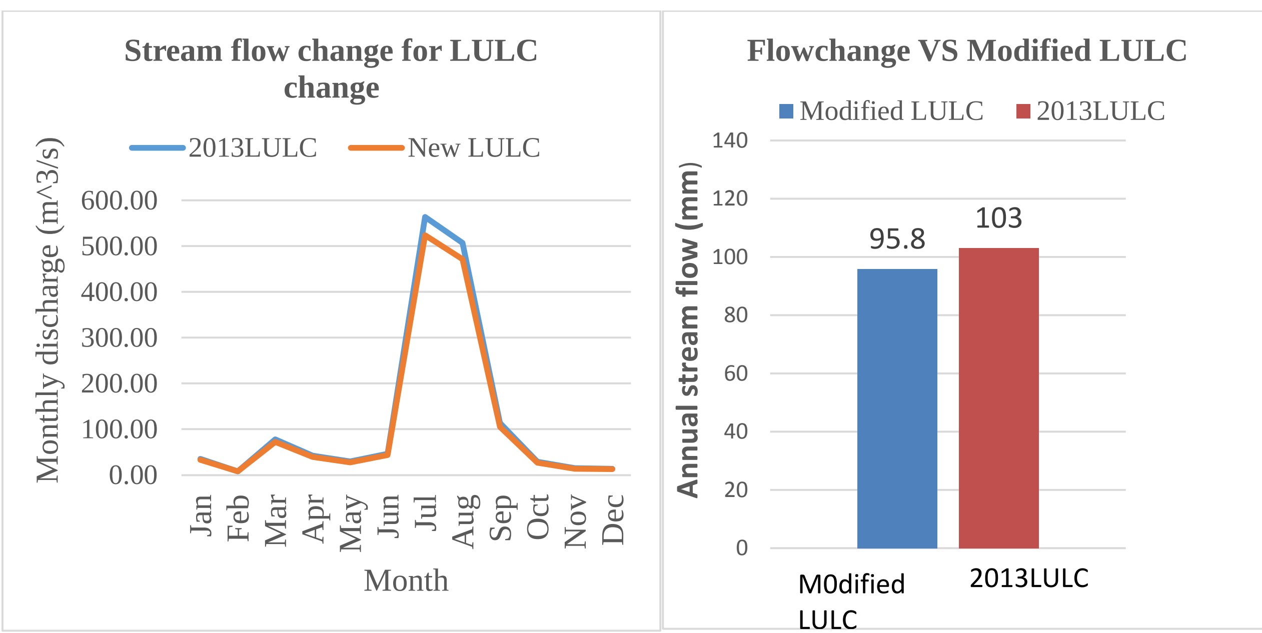


Figure 31 Stream flow change to LULC change

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In general, stream flow was affected by different physical watershed characteristics in the watershed, in this study the effects of watershed characteristics on stream flow were studied by identifying watershed characteristics for analyzed in a single watershed and the effects were observed through hydrological modelling that was SWAT model. The result of the model was analyzed after model calibration and model validation, from land use land cover change analysis, climate characteristics analysis and slope change analysis were concluded that land use and land cover change was significant effects stream flow in the watershed compared from climate and slope effects.

The performance evaluation of the model result were analyzed on monthly base coefficient of determination (R^2) and Nash- Sutcliffe coefficient was 0.77 and 0.83 for calibration period, 0.80 and 0.77 for validation period. The percent bias of the mode for this study is 18.4% for calibration 19.2 % for validation. The SWAT modeling result indicated that agricultural land increased by 14.89% and forest land reduced by 9.57% from 1996 up to 2004, from 2004up to 2013 agricultural land were reduced by 3.09% whereas the forest area increased by 7.8%. The mean annual stream flow were increased by 7.4 % and 6.8 % for 2004 LULC and 2013 LULC compared from 1996 LULC respectively but from 2004 up to 2013 the annual stream flow decreased by 2.3%. So the result showed that the land use land cover change was a great effect annual stream flow in the watershed, specially expansion of agricultural land and deforestation were significantly affect the stream flow than other watershed characteristic. While the best land use management that was reduction of agricultural land and increasing of afforestation were reduced the stream flow.

5.2 Recommendations

Generally from this specific study the following recommendations will be recommended:

- This study considered the effect of watershed characteristics on stream flow were analyzed in single watershed and the watershed character used for scenario development are climate characteristics, slope, rainfall, land use land cover change. Land use and land cover change has significant effect on stream flow in watershed, so the concerned organization gives attention to land use land cover change in Beshilo watershed.
- SWAT model were calibrated and validated by using observed flow data transfer from Gummera gauged watershed station, but Beshilo watershed is cover larger area in Blue Nile River Basin and the effect of this watershed in Basin development is significant, the River in the watershed will be needs gauging, so Ministry of water resource provide gauging for better data quality.
- As only River discharges were calibrated and validated, the result is analyzed only the stream flow, so it has to be emphasized that other model out puts, such as sediment yield is response to watershed characteristic in the watershed, future studies should be considered including sediment yield analyzed when data on sediment data is available.

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APPENDIX

Appendix A--: Annual River flow for gauged and ungauged station

Annual flow for Gumahara River (m3/s)

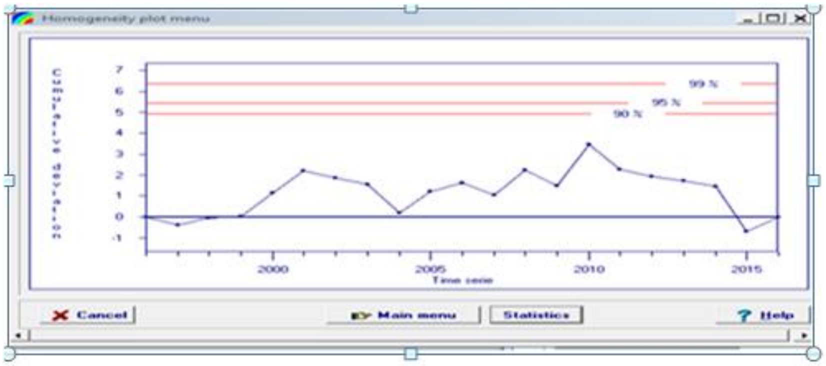
year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	2.4	0.9	0.6	0.4	0.5	1.3	52.8	180.4	109.3	19.8	4.1	1.9
1991	1.0	0.5	0.4	0.4	0.8	14.2	83.2	168.1	76.8	23.4	4.8	4.8
1992	3.0	2.1	2.7	0.8	1.9	2.0	42.1	158.5	71.1	50.3	14.9	6.3
1993	2.7	1.3	0.7	0.9	2.1	10.4	85.9	140.2	100.4	37.7	11.7	4.7
1994	2.4	1.3	0.6	0.3	1.0	19.4	84.9	194.4	122.5	20.0	7.0	4.1
1995	2.2	1.7	1.5	1.4	1.6	5.0	61.6	148.6	98.6	24.9	17.0	12.7
1996	7.5	3.6	3.4	3.4	8.0	56.4	179.1	200.5	101.5	36.9	22.1	15.2
1997	10.8	8.0	6.6	5.0	7.4	48.0	142.0	150.5	79.6	58.9	54.6	16.7
1998	8.8	4.9	3.7	2.8	1.9	10.8	67.4	138.1	92.6	28.1	8.8	8.7
1999	6.8	1.7	0.7	0.6	0.7	5.0	71.5	97.5	52.8	59.8	13.0	8.9
2000	5.0	1.8	1.3	2.7	1.9	13.4	107.5	172.2	53.7	48.1	13.2	5.4
2001	3.2	2.0	1.8	1.3	1.8	14.3	91.0	196.2	56.7	13.8	6.0	3.7
2002	2.8	2.1	2.0	1.7	1.2	23.3	89.9	153.0	78.7	12.4	6.9	5.2
2003	3.9	3.2	3.2	2.4	2.3	14.1	88.2	171.7	153.6	45.9	8.1	5.2
2004	3.8	3.2	2.7	3.1	2.5	9.5	77.1	104.7	52.7	20.5	8.2	5.5
2005	4.0	3.3	3.6	2.6	3.5	13.9	75.3	119.5	129.8	40.0	9.0	5.9
2006	4.3	3.5	3.3	3.3	6.6	17.3	89.0	213.6	142.4	24.4	9.5	5.8
2007	4.3	3.5	3.3	3.3	6.6	44.2	114.5	145.9	169.9	29.9	9.3	5.8
2008	4.1	3.3	3.3	4.7	6.6	39.1	158.1	229.5	106.9	13.8	8.7	5.5
2009	3.9	3.3	3.0	3.9	4.6	24.3	108.3	167.1	87.4	12.0	5.3	3.1
2010	2.7	2.7	1.8	2.0	5.2	19.1	161.9	181.5	130.8	28.1	7.3	5.2
2011	3.8	3.0	2.7	2.5	3.9	9.0	99.5	182.7	142.4	39.3	15.4	6.7
2012	4.7	4.0	3.3	3.0	3.7	28.0	134.7	167.2	120.9	27.8	15.1	7.0
2013	4.9	10.0	2.6	3.3	4.7	11.0	148.6	168.5	103.6	87.3	15.3	18.0
2014	11.2	17.8	10.7	7.7	27.1	46.1	141.6	167.8	164.6	99.4	19.4	18.1

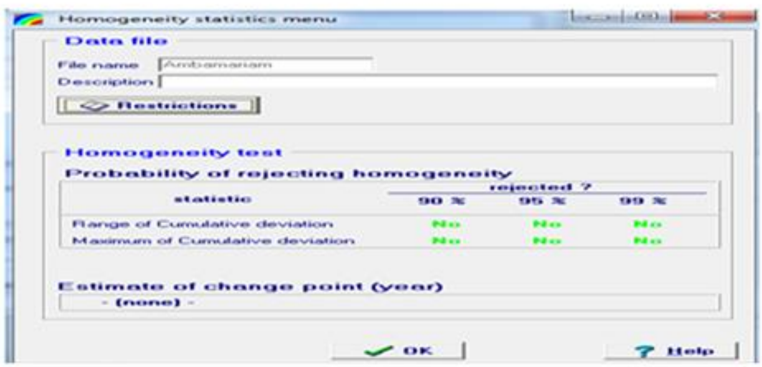
Annual flow for Beshilo River (m3/s)

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1995	7.74	5.98	5.30	4.99	5.56	17.84	220.35	531.37	352.48	89.22	60.86	45.56
1996	26.66	12.84	12.06	12.17	28.58	201.82	640.48	716.98	363.06	132.10	79.07	54.53
1997	38.54	28.59	23.72	17.77	26.29	171.77	507.78	538.39	284.77	210.67	195.20	59.70
1998	31.41	17.37	13.19	9.88	6.82	38.62	241.00	493.86	331.22	100.63	31.53	31.11
1999	24.27	6.15	2.67	2.00	2.65	17.88	255.66	348.85	188.81	213.70	46.51	31.89
2000	17.81	6.60	4.48	9.50	6.70	47.79	384.51	615.89	191.91	171.97	47.20	19.42
2001	11.36	7.05	6.29	4.81	6.54	51.11	325.35	701.66	202.85	49.20	21.39	13.34
2002	10.17	7.34	7.21	6.23	4.32	83.25	321.62	547.20	281.52	44.38	24.61	18.68
2003	13.87	11.30	11.45	8.65	8.19	50.55	315.57	614.24	549.53	164.14	28.87	18.45
2004	13.63	11.58	9.52	11.04	8.90	33.83	275.87	374.54	188.38	73.43	29.29	19.50
2005	14.38	11.80	12.99	9.40	12.35	49.83	269.33	427.37	464.11	143.09	32.32	21.02
2006	15.29	12.49	11.86	11.73	23.57	62.03	318.27	764.05	509.28	87.11	34.03	20.69
2007	15.29	12.49	11.86	11.73	23.57	158.07	409.47	521.96	607.53	106.78	33.18	20.86
2008	14.58	11.89	11.66	16.95	23.68	139.83	565.50	820.65	382.40	49.19	31.02	19.65
2009	14.11	11.74	10.59	14.00	16.29	86.83	387.41	597.60	312.73	42.89	19.12	11.22
2010	9.74	9.61	6.54	7.01	18.70	68.27	579.01	649.29	467.66	100.43	25.97	18.44
2011	13.67	10.80	9.75	9.01	14.08	32.33	355.91	653.27	509.32	140.52	55.21	24.00
2012	16.83	14.14	11.85	10.84	13.24	100.15	481.60	598.05	432.33	99.53	54.14	24.97
2013	17.63	35.63	9.24	11.91	16.98	39.27	531.40	602.48	370.65	312.29	54.67	64.35
2014	40.05	63.70	38.34	27.61	97.05	164.71	506.50	600.27	588.54	355.47	69.22	64.85

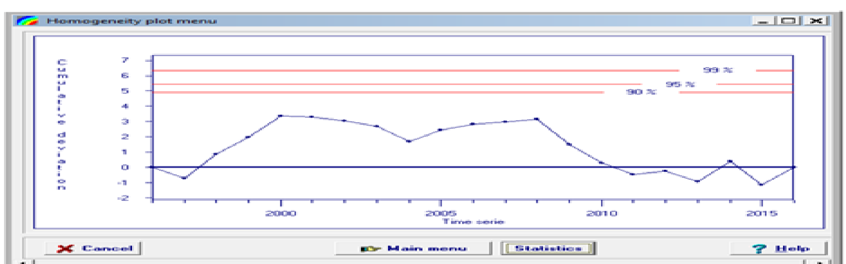
Appendix B: Homogeneity test using Ranbo software

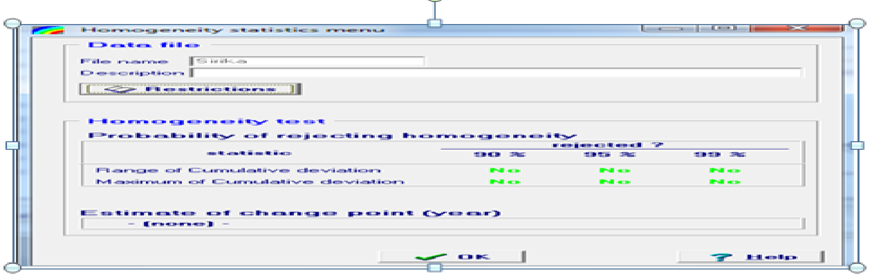
Ambamariam station



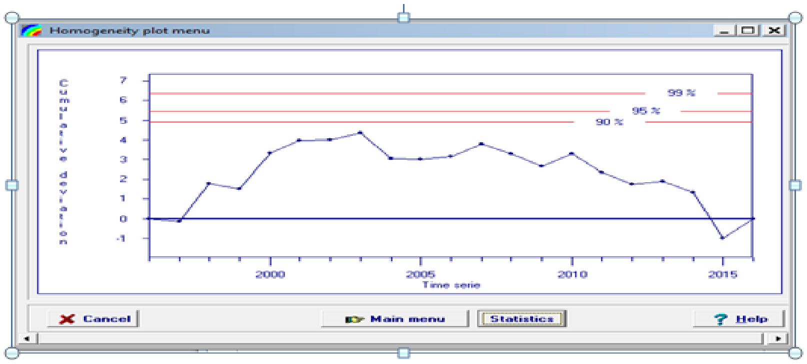


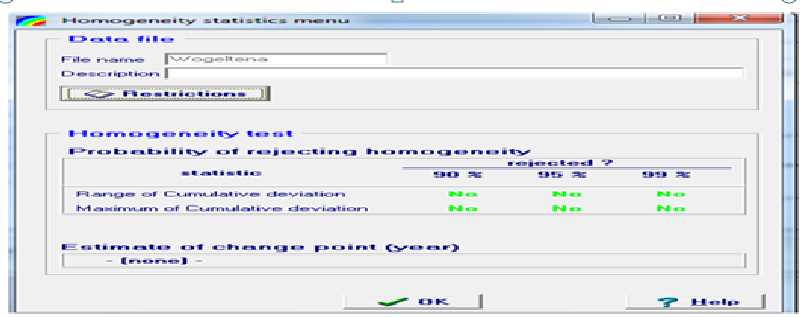
Sirika station



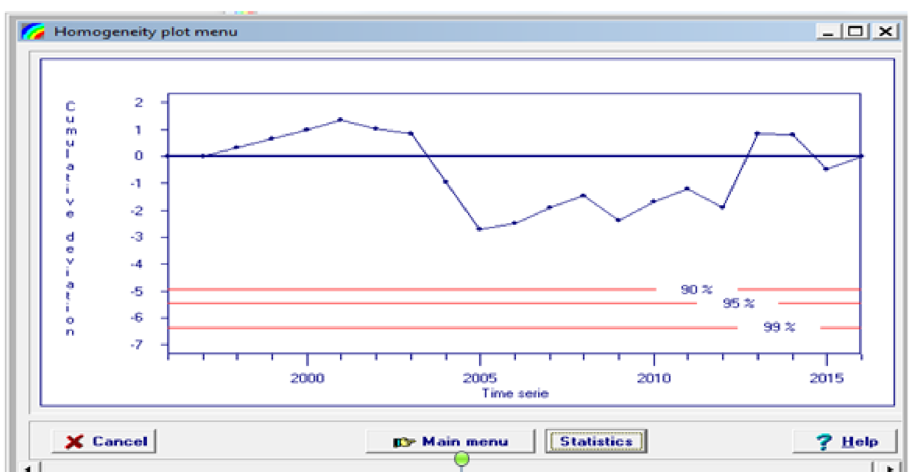


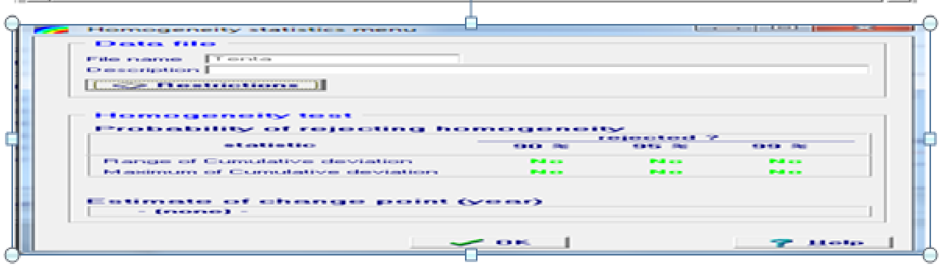
Wogeltena station



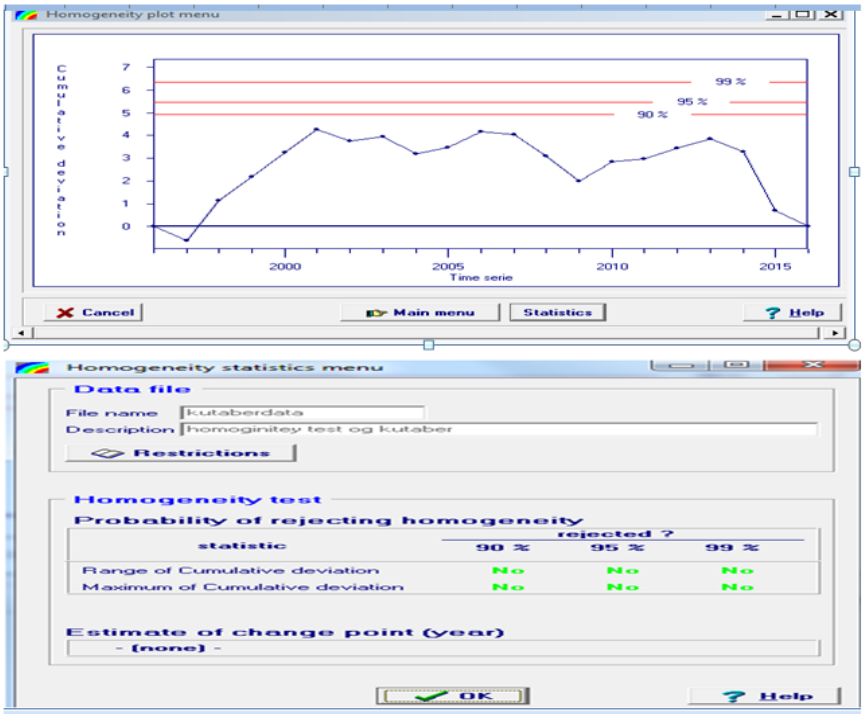


Tenta station





Kutaber station



Appendix-C: Location of Meteorological station in the study area.

ID	Name	x-cord	y-cord	Elevation
1	RAMBAM	512728.6	1244852	2990
2	RCOMBO	576448.07	1227015.73	1857
3	RSIRIKA	567138.875	1298418	1861
4	RWOGEL	523675.91	1280623.8	2952
5	RTENTA	530907.06	1263758.4	2605
6	RKUTAB	558212.27	1245405.84	2672

Appendix D: Mean Monthly Rainfall for different station

Station Name Ambamariam :-Monthly Total Rainfall (mm)

year	Jan	Feb	Mar	Apr	May	Jun	July	Agu	Sep	Oct	Nov	Dec
1997	27.4	6.7	60.9	77.2	20.7	86.9	277.8	265.3	32.7	30.3	32.3	2.3
1998	22.1	13.7	71.0	15.2	80.3	1.0	538.1	281.7	29.8	5.1	0.0	0.0
1999	35.7	0.0	72.3	17.8	1.2	35.2	424	281.5	109.5	16.1	0.0	8.8
2000	0	0.0	9.4	78.7	94.5	19.6	402.7	435	89.2	7.3	28.1	17.5
2001	0	10.0	88.4	16.9	77.2	30.7	436.6	419.8	81.5	0.0	0.0	11.3
2002	61.9	34.5	73.6	52.0	27.6	21.2	273.2	304.6	54.6	0.9	0.0	29.8
2003	24.3	33.4	128.1	47.1	17.9	49.5	220.7	314.1	75.2	0.0	5.7	16.3
2004	2.1	4.8	25.8	46.9	6.8	79.3	290.7	193.7	41	26.2	18.3	16.5
2005	11.3	0.3	169.4	101.6	137.9	30.9	316.4	248.5	242	191.3	157.7	154.4
2006	0.1	3.0	114.6	75.0	29.8	0.8	341.7	415.2	55.3	20.2	0.1	0.0
2007	31.7	32.3	12.8	39.2	18.1	130.5	270.5	252.9	92.7	0.0	6.9	0.0
2008	194	171.6	229.3	230.2	255.8	238.2	228.7	214.5	206.3	174.2	144.0	154.1
2009	14.1	10.4	69.3	7.7	3.7	48.2	375.3	190.6	48.6	48.6	4.3	36.0
2010	2.7	60.5	16.1	100.8	118.7	0.1	381.3	597.9	16.1	5.0	3.2	33.3
2011	31.2	0.1	91.9	58.6	92.9	32.9	240.5	195.3	27.7	4.4	2.8	0.0
2012	0	0.0	100.4	38.1	49.6	53.3	391.7	285	17.3	0.0	0.0	0.0
2013	14.2	5.0	35.7	77.2	5.2	46.7	397.1	321.6	45.5	2.4	1.7	0.0
2014	0.7	34.0	30.5	61.7	48.9	1.2	229.3	386	105.7	29.2	4.7	7.1
2015	0	5.4	33.5	0.0	86.1	97.9	51.8	253	42.8	0.0	3.4	46.9
2016	3.5	32.2	57.9	145.0	71.7	69.8	301.6	318.4	65.5	42.6	0.0	0.0

Station Name Sirinka :-Monthly Total Rainfall (mm)

year	Jan	Feb	Mar	Apr	May	Jun	July	Agu	Sep	Oct	Nov	Dec
1997	32.5	3.8	217.3	88	71.5	104	206.9	184.3	103.3	320.5	106	0
1998	119.8	109	114.3	63.5	36.1	0	367.5	361.3	73.5	59	0	0
1999	43.4	0	32	36.9	16.8	15.7	400.3	394.8	97.2	164.6	14.5	4
2000	0.3	0	15.9	69.7	33.9	35.2	356.8	357.7	130.1	76.6	49.7	145
2001	6.9	21.7	260.5	10.4	43.5	32.8	274.7	252.1	91.9	28.2	4.9	5.4
2002	87.6	6.2	47	73.8	0.6	7.6	229.5	295.3	134	17.7	0	94.7
2003	65.2	60.4	68.4	115.5	4.9	36.9	173.3	297	103.2	0	10.8	48.3
2004	22.1	11	37.9	119.4	4.2	36.5	166.4	225.6	68.7	73.8	86.6	17.9
2005	32	7.8	99	116.7	114.6	26.7	283.8	323.3	55.6	36.3	71.1	0
2006	1.6	35.6	145.2	244.2	40.4	8.3	157	283.7	117.8	38.2	2.6	26.2
2007	35.6	72.8	44.4	108.1	26.1	33.8	363.7	246.4	83.9	48.2	5	0
2008	42.8	0	0	27.1	33.9	46.9	132.5	464.3	135.3	48.8	132.7	1
2009	12.2	7.9	45.6	99.2	0	27.9	188.4	153.4	17.2	34.2	28.7	155
2010	2.8	32.7	98.6	84	103.4	0	0	148.5	92.1	8.1	54.4	10.8
2011	26	65.8	44.6	35.3	118.1	0	161.1	272.2	45	2.9	145.5	0
2012	0	0	85.1	154.1	39.3	70.6	384.7	252.9	76.7	10.4	0.4	0.6
2013	60.3	4.9	28	81.4	19.2	9.4	305.8	286.1	55.8	56.5	14.2	5
2014	25.2	21.8	79.7	115.7	196.1	7.8	242	273.5	165.6	78.3	51.8	3.2
2015	16	0.4	32.4	0	106.4	15	31.7	316.5	73.1	10.3	74.1	105
2016	19.3	49.7	98.4	160.3	122.5	30	268.7	351.8	97.1	1.9	32.7	0

Station Name Tenta:-Monthly Total Rainfall (mm)

year	Jan	Feb	Mar	Apr	May	Jun	July	Agu	Sep	Oct	Nov	Dec
1997	48.9	2.2	52.8	79.5	49.4	95.0	208.8	144.4	43.0	110.2	100.2	0.0
1998	23.2	6.2	102.8	48.0	70.2	74.8	346.6	264.7	123.7	121.9	19.3	0.0
1999	8.0	0.0	2.4	63.9	24.0	33.1	265.1	234.5	80.7	90.1	0.0	9.8
2000	0.0	0.0	12.5	127.8	43.6	84.0	286.1	185.0	113.6	74.7	36.5	9.0
2001	0.4	27.3	133.9	54.1	58.4	104.8	314.2	168.7	45.2	62.2	0.9	15.0
2002	55.3	14.8	65.6	38.6	41.5	57.1	276.6	212.5	91.0	0.0	7.1	28.1
2003	15.2	47.1	77.8	54.7	8.8	100.6	245.1	155.6	193.6	0.0	4.0	9.3
2004	0.8	0.9	29.4	44.6	21.3	95.9	184.2	181.5	51.7	64.2	3.3	0.0
2005	0.0	0.0	61.0	55.2	5.0	60.2	207.1	150.9	122.4	13.9	5.0	0.0
2006	3.0	0.0	60.5	85.5	86.7	53.9	234.3	250.5	115.0	40.6	21.1	18.1
2007	4.4	66.9	71.4	58.1	79.8	223.8	241.4	151.6	108.5	14.1	0.0	0.0
2008	19.6	0.0	0.4	32.5	62.6	100.6	322.8	210.3	90.9	84.7	76.3	0.4
2009	7.0	8.1	72.2	21.6	11.0	32.4	298.2	203.8	26.3	71.0	10.0	38.0
2010	14.3	9.7	35.8	111.9	133.5	56.8	318.1	253.7	85.9	1.5	10.5	4.6

2011	40.7	0.0	177.0	51.8	60.0	104.3	205.1	216.7	114.8	0.0	37.7	0.0
2012	0.0	0.0	74.1	70.5	86.7	100.6	175.4	224.6	95.0	6.2	0.0	2.1
2013	20.9	2.8	26.9	34.6	33.8	134.2	457.9	418.4	102.5	84.6	13.4	0.0
2014	0.0	54.6	35.3	72.0	121.6	60.6	186.6	230.2	143.6	19.5	9.8	0.0
2015	0.2	4.1	37.1	12.7	138.9	48.9	108.5	240.7	79.6	16.0	18.3	42.3
2016	42.3	34.6	55.9	101.2	154.5	122.7	176.3	228.8	80.7	8.5	0.0	0.0

Station Name Kutaber :-Monthly Total Rainfall (mm)

year	Jan	Feb	Mar	Apr	May	Jun	July	Agu	Sep	Oct	Nov	Dec
1997	34.8	0.0	46.1	44.8	96.4	90.5	318.7	179.9	15.7	33.3	4.6	0.0
1998	45.2	4.5	88.2	23.3	85.1	9.1	426.2	376.7	64.7	12.7	0.0	0.0
1999	13.7	0.0	23.1	12.4	24.8	14.9	549.0	440.6	71.3	0.0	38.0	3.0
2000	0.0	0.0	12.1	37.5	120.8	47.0	469.4	391.4	97.1	9.5	0.0	13.4
2001	0.0	6.2	113.4	12.1	67.8	31.2	607.9	310.9	23.8	0.0	0.0	10.7
2002	63.4	12.7	51.5	28.8	63.7	42.4	242.1	324.4	32.4	5.7	0.0	18.1
2003	26.7	19.8	43.4	56.6	116.4	60.1	328.8	254.2	79.4	0.0	2.2	38.0
2004	16.9	15.9	58.3	50.8	104.5	42.3	246.7	246.9	50.4	4.0	7.9	0.0
2005	38.6	0.0	79.9	41.1	175.4	38.5	340.4	294.1	35.7	0.0	0.0	0.0
2006	26.3	3.9	83.6	73.5	158.6	18.3	263.1	396.6	77.4	9.9	6.7	1.5
2007	11.8	32.3	12.6	32.0	66.4	80.5	314.9	315.8	99.2	0.0	0.0	0.0
2008	0.7	0.0	0.0	0.0	7.7	37.5	339.1	253.7	82.0	9.2	74.8	0.0
2009	14.4	0.0	22.0	0.1	6.3	32.9	349.3	234.7	41.7	8.1	38.0	25.4
2010	9.8	23.9	42.1	44.1	134.9	15.5	357.3	473.3	33.6	0.0	10.8	13.1
2011	9.7	0.0	73.7	36.8	166.8	35.5	268.3	336.6	76.1	2.5	1.5	0.0
2012	0.0	0.0	41.8	64.6	156.7	66.0	333.7	382.4	38.7	0.0	0.0	0.0
2013	0.0	0.0	31.6	5.7	16.4	56.4	497.7	359.6	43.4	50.7	5.3	0.0
2014	0.0	26.9	22.5	23.5	75.4	1.0	246.3	373.9	100.1	1.7	6.5	0.0
2015	0.0	4.0	17.1	0.0	27.5	46.5	65.2	230.8	87.7	0.0	3.3	5.7
2016	4.6	6.8	39.0	97.3	218.6	52.7	392.2		37.1	0.0	2.1	0.0

Station Name Kombolcha:-Monthly Total Rainfall (mm)

year	Jan	Feb	Mar	Apr	May	Jun	July	Agu	Sep	Oct	Nov	Dec
1997	34.8	0.0	73.5	76.0	16.9	119.5	243.7	192.9	52.0	154.6	87.0	0.0
1998	107.7	102.7	36.4	126.1	49.7	2.9	522.6	263.8	114.5	76.5	0.0	0.0
1999	54.4	7.3	33.2	19.0	5.4	16.3	374.3	318.4	109.1	129.3	0.0	2.0
2000	0.0	0.0	6.2	140.9	70.8	45.8	323.6	351.8	124.6	67.9	58.5	38.3
2001	4.4	2.7	137.4	39.2	42.9	46.8	353.6	236.9	119.1	7.1	0.8	8.9
2002	18.1	5.8	58.9	82.1	20.7	10.6	302.0	254.8	99.3	7.1	0.0	64.7

2003	71.4	29.5	75.0	86.4	5.8	48.6	214.9	274.9	151.8	0.2	12.9	60.2
2004	12.6	15.2	39.7	142.3	14.8	24.7	230.8	239.4	95.8	66.8	40.1	7.0
2005	19.0	4.5	76.1	67.0	86.4	20.9	356.9	321.6	40.8	25.7	6.7	0.0
2006	8.8	0.0	121.8	87.1	44.3	14.7	365.8	277.2	183.3	62.0	1.2	6.4
2007	40.5	34.0	52.3	115.0	14.9	37.1	320.7	175.5	90.3	21.6	6.6	0.0
2008	25.5	0.0	0.0	18.1	44.7	29.4	286.9	208.2	68.7	47.1	75.6	0.0
2009	20.6	11.4	17.0	13.4	6.4	34.6	370.1	320.3	58.4	63.2	11.5	32.4
2010	0.0	31.6	70.7	102.7	107.6	15.9	363.9	524.8	57.9	11.7	15.2	11.6
2011	15.0	0.0	50.4	25.5	130.9	20.4	278.0	338.6	90.5	16.6	41.4	0.0
2012	0.3	0.0	109.0	177.1	34.0	50.1	284.0	261.6	52.9	0.5	0.0	0.2
2013	36.8	0.3	54.2	55.2	40.0	1.8	336.3	284.9	67.2	132.7	0.6	0.0
2014	1.8	21.7	41.7	55.1	90.9	9.3	247.5	319.5	135.2	96.9	4.7	6.0
2015	13.0	0.0	71.1	0.0	102.2	18.6	42.7	342.8	107.9	12.2	0.0	14.6
2016	21.6	11.3	20.3	155.8	107.7	64.2	276.1	346.4	119.2	7.6	14.0	0.6

Station Name Kombolcha:-Monthly Total Rainfall (mm)

year	Jan	Feb	Mar	Apr	May	Jun	July	Agu	Sep	Oct	Nov	Dec
1997	10.5	0.0	46.5	50.1	32.9	94.4	242.1	166.3	42.5	36.3	60.6	0.0
1998	32.6	27.0	64.7	83.6	25.7	10.0	422.9	293.6	39.9	10.5	40.0	0.0
1999	19.0	0.0	0.0	0.0	1.4	25.9	351.0	277.8	62.9	23.7	0.0	5.0
2000	0.0	0.0	0.0	67.4	55.2	10.9	401.4	302.8	120.4	9.0	39.7	30.6
2001	0.0	15.3	109.5	42.2	52.3	50.2	315.8	234.4	50.3	7.4	0.0	4.6
2002	29.7	21.9	100.2	54.2	8.1	25.9	233.9	236.8	65.2	4.1	1.7	25.9
2003	0.0	50.6	75.0	72.9	23.8	42.8	191.9	321.2	52.3	0.0	5.1	11.3
2004	9.5	4.9	8.9	98.2	2.7	48.8	214.2	187.5	45.5	10.3	3.2	1.2
2005	14.1	0.0	57.9	79.4	83.2	22.4	283.6	218.6	23.1	3.6	14.2	0.0
2006	0.0	0.3	103.3	100.2	31.3	0.2	217.8	297.0	38.8	25.8	6.0	0.0
2007	40.7	37.6	30.9	41.4	6.7	116.4	269.6	239.4	98.8	1.9	0.6	0.0
2008	0.0	6.2	0.0	8.1	11.3	39.7	218.4	275.1	92.0	12.8	78.1	0.0
2009	5.6	9.4	23.3	33.5	2.5	20.0	270.5	159.1	40.3	14.7	4.0	12.8
2010	3.9	1.3	30.2	101.5	45.8	0.0	311.4	315.9	17.3	25.8	11.1	21.2
2011	8.4	3.0	77.1	36.5	65.3	16.9	196.6	226.4	24.7	0.5	24.2	0.0
2012	0.0	0.0	56.6	32.8	24.0	36.3	306.7	213.6	25.7	29.8	2.0	0.6
2013	2.3	0.1	18.8	33.2	24.2	31.4	355.7	289.0	18.9	44.7	0.0	0.0
2014	4.6	21.8	0.0	46.3	57.5	3.8	186.8	244.0	113.8	27.5	26.6	1.5
2015	0.0	11.7	46.6	0.0	53.6	46.6	52.1	207.7	32.2	0.0	20.9	36.8
2016	0.0	23.5	43.0	106.7	69.0	42.3	334.3	258.7	50.2	1.3	0.0	0.0

Appendix-E: Slope change from average tributary slope.

Sub basin	average slope of tributary channel(m/m)	increased by 5%	increased by 10%	increased by 15%
1	0.033	0.03465	0.0363	0.03795
2	0.078	0.0819	0.0858	0.0897
3	0.028	0.0294	0.0308	0.0322
4	0.147	0.15435	0.1617	0.16905
5	0.024	0.0252	0.0264	0.0276
6	0.056	0.0588	0.0616	0.0644
7	0.035	0.03675	0.0385	0.04025
8	0.039	0.04095	0.0429	0.04485
9	0.032	0.0336	0.0352	0.0368
10	0.04	0.042	0.044	0.046
11	0.029	0.03045	0.0319	0.03335

Appendix-F: Weather generator (WGEN) parameters used by the SWAT Model

Legend of the parameters used in the weather generation				
OBJECTID	1	2	3	4
STATION	WGAMBAMARIAM	WGKOMBOLCHA	WGSIRIK	WGWOGELTENA
RAIN_YRS	10.00	10.00	10.00	10.00
TMPMX1	19.96	25.02	23.48	20.01
TMPMX2	20.92	26.94	26.03	21.23
TMPMX3	21.02	27.62	26.65	21.28
TMPMX4	20.84	28.15	28.09	20.81
TMPMX5	21.03	29.53	30.23	21.31
TMPMX6	21.12	30.76	30.20	21.28
TMPMX7	17.57	28.16	27.68	18.18
TMPMX8	17.38	27.13	27.24	17.41
TMPMX9	18.36	26.81	26.46	18.44
TMPMX10	18.44	26.17	24.88	18.44
TMPMX11	18.77	25.44	24.02	18.48
TMPMX12	19.00	24.79	23.68	18.88
TMPMN1	6.80	10.43	11.66	5.04
TMPMN2	7.56	10.53	11.97	5.47
TMPMN3	8.22	12.65	13.73	7.02
TMPMN4	8.64	13.89	14.88	8.04
TMPMN5	9.05	14.45	15.63	8.74
TMPMN6	8.98	15.33	16.62	8.49

TMPMN7	8.13	15.27	16.01	8.44
TMPMN8	8.03	15.02	15.40	8.16
TMPMN9	7.88	13.97	14.46	7.29
TMPMN10	6.74	10.92	12.37	5.59
TMPMN11	6.00	9.24	11.13	4.58
TMPMN12	5.94	8.82	10.63	4.21
TMPSTDMX1	1.13	1.96	2.86	1.34
TMPSTDMX2	1.56	1.70	2.11	1.70
TMPSTDMX3	1.64	2.40	1.72	1.82
TMPSTDMX4	3.25	1.73	1.51	2.25
TMPSTDMX5	1.72	1.75	1.98	1.44
TMPSTDMX6	1.46	1.25	1.53	0.92
TMPSTDMX7	1.85	1.83	1.26	0.98
TMPSTDMX8	1.45	1.71	1.09	1.39
TMPSTDMX9	1.76	1.12	1.37	1.40
TMPSTDMX10	1.15	1.14	1.31	2.17
TMPSTDMX11	1.27	1.44	2.17	1.95
TMPSTDMX12	1.17	1.38	1.81	1.78
TMPSTDMN1	1.13	3.66	1.66	1.70
TMPSTDMN2	1.13	2.57	1.17	1.64
TMPSTDMN3	1.27	2.51	1.27	1.49
TMPSTDMN4	1.13	2.04	1.17	1.09
TMPSTDMN5	1.01	1.57	1.35	1.01
TMPSTDMN6	0.94	1.53	1.17	1.32
TMPSTDMN7	0.92	1.65	1.15	1.81
TMPSTDMN8	0.95	1.15	1.68	2.07
TMPSTDMN9	0.83	2.30	1.98	2.25
TMPSTDMN10	1.18	2.21	1.74	1.61
TMPSTDMN11	1.26	2.50	1.61	1.58
TMPSTDMN12	1.09	2.64	1.72	1.67
PCPMM1	14.44	25.39	32.58	9.03
PCPMM2	22.47	13.31	25.57	14.52
PCPMM3	69.28	63.36	79.71	51.90
PCPMM4	65.59	81.71	90.16	49.09
PCPMM5	29.83	44.62	56.58	30.55
PCPMM6	91.76	37.40	27.26	41.43
PCPMM7	367.11	320.40	235.08	280.96
PCPMM8	250.36	280.48	287.04	238.47
PCPMM9	43.92	90.37	90.85	43.09
PCPMM10	16.79	47.75	55.99	15.75

PCPMM11	13.77	17.60	44.28	14.21
PCPMM12	19.11	12.48	31.10	7.67
PCPSTD1	2.02	3.45	4.01	1.50
PCPSTD2	3.24	2.12	4.85	2.57
PCPSTD3	5.84	5.68	7.07	4.88
PCPSTD4	5.54	5.98	7.37	4.77
PCPSTD5	4.06	4.55	5.88	3.22
PCPSTD6	6.62	3.67	3.72	3.98
PCPSTD7	12.47	13.60	12.66	10.98
PCPSTD8	10.11	10.98	12.13	8.59
PCPSTD9	3.42	5.86	6.60	3.87
PCPSTD10	2.35	5.52	6.55	2.70
PCPSTD11	1.73	3.37	6.17	2.43
PCPSTD12	2.25	2.36	5.01	1.81
PCPSKW1	5.60	8.02	5.93	6.71
PCPSKW2	6.50	7.14	7.52	8.22
PCPSKW3	3.47	4.25	3.74	3.99
PCPSKW4	3.84	3.07	4.54	4.94
PCPSKW5	6.30	5.20	5.14	4.61
PCPSKW6	3.38	4.80	7.60	4.47
PCPSKW7	1.76	2.00	2.56	1.59
PCPSKW8	2.19	1.72	1.87	1.53
PCPSKW9	3.29	3.27	3.44	4.42
PCPSKW10	10.26	6.06	8.41	8.95
PCPSKW11	4.86	9.18	5.61	8.21
PCPSKW12	4.70	9.47	7.99	11.61
PR_W1_1	0.06	0.08	0.08	0.05
PR_W1_2	0.07	0.06	0.05	0.05
PR_W1_3	0.16	0.17	0.15	0.14
PR_W1_4	0.20	0.20	0.22	0.17
PR_W1_5	0.08	0.16	0.14	0.10
PR_W1_6	0.17	0.15	0.09	0.13
PR_W1_7	0.65	0.60	0.35	0.48
PR_W1_8	0.55	0.60	0.53	0.60
PR_W1_9	0.20	0.40	0.34	0.21
PR_W1_10	0.05	0.08	0.10	0.07
PR_W1_11	0.04	0.05	0.07	0.05
PR_W1_12	0.04	0.06	0.07	0.03
PR_W2_1	0.43	0.58	0.64	0.36
PR_W2_2	0.45	0.54	0.57	0.52

PR_W2_3	0.52	0.59	0.60	0.55
PR_W2_4	0.57	0.66	0.53	0.51
PR_W2_5	0.43	0.45	0.41	0.49
PR_W2_6	0.72	0.55	0.41	0.58
PR_W2_7	0.88	0.83	0.73	0.86
PR_W2_8	0.81	0.82	0.76	0.83
PR_W2_9	0.46	0.58	0.51	0.48
PR_W2_10	0.58	0.64	0.56	0.39
PR_W2_11	0.67	0.49	0.57	0.44
PR_W2_12	0.65	0.51	0.59	0.54
PCPD1	2.90	5.45	6.25	2.50
PCPD2	3.45	3.40	3.15	2.70
PCPD3	8.15	9.35	8.70	7.50
PCPD4	9.75	11.60	9.95	8.65
PCPD5	4.30	7.50	6.20	6.00
PCPD6	11.60	7.85	4.40	7.45
PCPD7	26.95	24.90	17.90	24.60
PCPD8	24.25	24.95	22.40	25.20
PCPD9	8.90	15.55	13.25	9.50
PCPD10	3.60	6.25	6.40	3.75
PCPD11	3.20	2.55	4.15	2.75
PCPD12	3.45	3.35	4.50	2.05
RAINHHMX1	0.49	0.50	1.05	0.57
RAINHHMX2	0.89	1.03	1.13	0.75
RAINHHMX3	0.83	0.72	1.74	1.00
RAINHHMX4	0.86	1.04	1.32	0.59
RAINHHMX5	0.99	0.75	1.09	0.80
RAINHHMX6	1.83	1.53	2.08	1.18
RAINHHMX7	1.40	1.27	1.70	1.13
RAINHHMX8	0.46	0.90	0.98	0.81
RAINHHMX9	0.86	1.26	2.18	0.61
RAINHHMX10	0.36	0.99	1.28	0.73
RAINHHMX11	0.41	0.71	1.28	0.62
RAINHHMX12	1.31	1.24	1.24	1.44
SOLARAV1	20.21	18.45	17.32	21.10
SOLARAV2	21.87	18.69	21.88	21.98
SOLARAV3	22.49	22.64	22.34	20.18
SOLARAV4	22.59	23.73	20.63	20.31
SOLARAV5	22.96	22.63	21.28	23.02
SOLARAV6	20.26	21.54	16.43	20.44

SOLARAV7	17.85	20.49	17.24	17.95
SOLARAV8	18.84	20.05	21.99	18.92
SOLARAV9	21.12	21.89	20.06	21.56
SOLARAV10	22.19	19.69	22.34	23.64
SOLARAV11	21.01	22.30	21.99	22.77
SOLARAV12	20.04	20.93	21.27	22.06
DEWPT1	2.74	9.73	12.78	3.31
DEWPT2	2.02	9.37	11.89	2.90
DEWPT3	4.11	11.42	12.93	5.54
DEWPT4	5.60	10.18	13.41	6.12
DEWPT5	4.74	8.32	12.52	5.27
DEWPT6	4.53	11.98	10.84	5.54
DEWPT7	9.18	14.45	14.67	9.81
DEWPT8	9.27	13.95	16.01	9.90
DEWPT9	7.27	12.29	14.36	7.89
DEWPT10	5.08	11.04	11.61	6.02
DEWPT11	3.48	9.57	11.01	4.66
DEWPT12	2.51	9.75	11.20	2.82
WNDAV1	1.31	1.24	1.24	1.44
WNDAV2	1.50	0.84	1.38	1.82
WNDAV3	1.52	0.83	1.36	1.89
WNDAV4	1.66	0.81	1.30	2.25
WNDAV5	1.56	0.85	1.29	2.38
WNDAV6	1.34	0.96	1.44	2.04
WNDAV7	1.02	0.91	1.26	1.17
WNDAV8	0.89	0.85	1.09	1.02
WNDAV9	1.01	0.55	0.94	1.44
WNDAV10	1.41	0.47	0.91	1.91
WNDAV11	1.41	0.55	1.03	1.59
WNDAV12	1.31	0.66	1.16	1.38