Addis Ababa University Institute of Technology School of Civil And Environmental Engineering Hydraulic Engineering Stream

Estimation of sediment yield to Chacha Dam Reservoir (case study, upper Abbay Basin Ethiopian)

A thesis submitted and presented to the School of Graduate Studies of Addis Ababa University in Partial fulfillment of the Degree of Masters of Science in Civil Engineering under Hydraulics Engineering

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CERTIFICATION

The under signed, certify that I have read and hear by recommend for acceptance by Addis Ababa Institute of Technology a thesis entitled "estimation of sediment yield Inflow to Chacha Dam reservoir (case study upper Abbay basin Chacha dam) in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering Specialization in Hydraulic Engineering stream.

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DECLARATION AND COPY RIGHT

I, Woldetinsay Sidelil, hereby declare that the work presented in this thesis is my own work and significant outside input is acknowledged properly.

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Abstract

Soil erosion is a major problem through the upper Blue Nile basin Ethiopia. This study is important to estimate sediment generate at chacha dam reservoir and evaluate its consequences on the reservoir through long term optimum management program. When the flow of river is obstructed and stored in reservoirs, the sediment settles, deposit and reduces its capacity. Sediment settle in a reservoir is a serious problem that threatens sustainability of the reservoir. The chacha dam site was located on Ajiba river (upper Abbay Basin) approximately at UTM coordinates of 1062926N and 549376 E particularly Angolela Tara Woreda north Showa zone Amhara region. The main objective of this study was to estimate sediment yield in the chacha dam reservoirs with SWAT model, to identify the spatial and temporal variation of sediment yield and to recommend appropriate sediment reduction measure. The Soil and Water Assessment Tool physically based semi distributed hydrological model is utilized for sediment yield estimation in the chacha watershed (after watershed delineated areas was 577.5km^2). The model is calibrated and validated for both flow and sediment and evaluation the model using Nash–Sutcliffe coefficient and coefficient of determination at chacha dam outlet (at area 577.5 km^2). Model calibration and validation were done after checking the performance of sensitive analysis. The first most sensitive parameters were saturated hydraulic conductivity (SOL_K) for flow calibration and urban BMP is applied (SED_CON) for sediment calibration. For flow calibration the coefficient of determination and Nash-Sutcliffe coefficient give as 0.85 and 0.84 respectively and flow validation the coefficient of determination and Nash-Sutcliffe coefficient give as 0.66 and 0.66 respectively. Sediment calibration the coefficient of determination and Nash-Sutcliffe coefficient give as 0.7 and 0.7 respectively. Sediment validation the coefficient of determination and Nash-Sutcliffe coefficient give as 0.74 and 0.74 respectively. Both the calibration and validation result indicated that good agreement between observed and simulated stream flow and sediment yield. The model simulated result shows that the average annual sediment yield is 144.28 ton/km2/year at the dam site. Spatial and temporal variation of sediment yield were performed. The spatial variation of sediment ranges from 0.66 ton/ha to 39.5ton/ha. Scenario was developed from HRU definition at land use refinement and HRU threshold for reduction of sediment yield using SWAT Model in the chacha dam reservoir.

Key words

SWAT model, Sediment Yield, Simulation, Calibration, validation, SWAT CUP

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Acronyms/Abbreviations

AAIT	Adiss Abeba Institution of technology
DEM	Digital Elevation Model
DGPS	Differential Global Positioning System
EMA	Ethiopian Mapping Authority
ET	Evapotranspiration
FAO	Food and Agricultural Organization
GIS	Geographic Information System
GWQ	Ground water flow (mm)
HRU	Hydrologic Response Unit
ITCZ	Inter-Tropical Convergence Zone
M.A.S.L	Meter above mean sea Level
mm	Millimetre
MoWIE	Ministry of water, irrigation and Electricity
MUSLE	Modified Universal Soil Loss Equation
PCP	Precipitation
NMSA	National Metrological Service Agency
RH	Relative Humidity
SCS	Soil Conservation Service
SURQ	Surface Runoff
SWAT	Soil and Water Analysis Tool
Tmax	Maximum Temperature
Tmin	Minimum Temperature
UTM	Universal Trans Mercator
USLE	Universal Soil Loss Equation
HYMO	Hydrologic Mode

1 INTRODUCTION

1.1 Background

Sedimentation is process of erosion which endangers and threatens the performance and sustainability of reservoirs. Estimation of sediment yield from the catchment is useful for reservoir sedimentation, river morphology, soil and water conservation planning, and also estimation of concertation and load of chemical adsorbed to sediment particles. When the amount of sediments accumulated on the reservoir, it reduces the effective flood control volume, presents hazards to navigation, changes water stage and affects operation of low-level outlet gates and valves and reduces stability, water quality, and recreational benefits. Sedimentation in a reservoir can be defined by trap efficiency which is the ratio of the deposited sediment quantity to the total sediment inflow. Trap efficiency is a function of the volume and grain-size distribution of sediment, outlet works, and method of reservoir operation (Eizel-Din et al., 2010). Reservoirs are often threatened, by loss of capacity due to sedimentation. Causes of reservoir sedimentation are many watershed, sediment and river characteristics are among the main natural contributing factors. Other important ones are reservoir size, shape and reservoir operation strategy. Manmade activities play also a significant role particularly in land use pattern.

Soil erosion is a natural process causing soil loss and generating sediment yield from catchment area even in the absence of human alterations of land cover. Soil erosion by water occurs in two phase process, consisting of the detachment of individual particles from the soil mass and their transport by erosive agents, and when sufficient energy no longer available to transport deposition occur (Morgan et al., 1998). Soil erosion not only the deposition of sediment transported by river into reservoir reduced the reservoir capacity, but also sediment deposition on river bed and banks causes widening of the flood plain during floods. As more and more sediments deposited in the reservoirs, its capacity decreases and ultimately will not be able to handle high flood. Sedimentation in irrigation canals will hamper and endanger proper irrigation management. To tackle all the aforementioned problems caused by erosion and sedimentation, identifying erosion prone areas and proper application of management options on those areas is crucial. The sustainability of water storage reservoirs requires a balance to be maintained between the volume of sediment deposited and the volume of sediment removed from the reservoir. In most cases it is difficult to achieve a complete sediment balance as sediment deposit in a reservoir is influenced by several factors. But it is possible to optimize services of the reservoirs through different sediment management strategies (Juracek, K.E., 2010)

Sedimentation is a complex hydro-morphological process which is difficult to predict. It has been underestimated in the past and perceived as a minor problem which can be controlled by sacrificing certain volume of the reservoir for accumulation of the sediment (dead storage). However, today's experience revealed that it is of paramount importance to take design and implementation of sediment control measures into consideration in the planning, design, operation, and maintenance phases, of the reservoirs (Siyam et al., 2005).

Since the major cause as (Noah et al., 2004) studies volume of stored material represents a reduction in storage capacity of 25.5%. However, our studies consider major cause of storage capacity change was estimating sediment inflow from the upstream catchment of the dam and that caused by sediment deposition since closure of storage dam, recommend appropriate reduction sediment yield under different scenarios and assessing the temporal and spatial distribution of sediment in the catchment. It is generally recommended to continue carrying out estimation of sediment yield by using SWAT (soil and water assessment tool) model, so that the quantity of sedimentation taking place can be assessed and analyzing with models.

1.2 Statement of problems

Sediment transport leads to degraded soil productivity that causes worldwide problems such as sedimentation in reservoirs. There are many reservoirs in existence today which cannot perform as designed because much of their storage has been filled by sediment. For any project scheme, any loss of live storage increases the risk of supply failure and this is often undesirable.

The decreases in surface area and storage capacity are the result of ongoing sedimentation. Since (Juracek, 2010), the reservoir has lost an estimated 42 percent of its conservation-pool storage capacity as of 2010. Sedimentation of a reservoir created by a dam constructed on a natural water course is inevitable. The problem of concern is the rate of sedimentation & the period of time which will elapse before the usefulness of the storage works is seriously impaired or destroyed. The silting of dam reservoirs is the most challenging problem in Ethiopia. Sedimentation adversely affects the reservoir capacity. Though the ultimate destiny of all reservoirs is to become filled with sediment, the length of time that this takes depends on the sedimentation rate and how well the problem is addressed both during the planning stage and while reservoir sedimentation is occurring.

In Chacha watershed, there is covering large area agricultural activities in the valleys of the main river and the tributaries which is the main source of sediment. There was also lack of systematic study of sediment and erosion control practice. These and other related problems increase the sedimentation of Chacha reservoir. Therefore, understanding the impacts of soil erosion and looking for solutions to minimize is essential. This study, focuses on estimating the sediment yield from Chacha watershed, recommend appropriate reduction measure of sediment yield with different scenarios and identify temporal and spatial variation of sediment in chacha watershed.

1.3 **Objectives**

1.3.1 **General objective**

The overall goal of this study is to model the hydrological processes to estimate the sediment Yield in to chacha watershed and identification of most appropriate sediment management strategy of this watershed by making use of the SWAT (Soil and Water Assessment Tool) model

1.3.2 **Specific objective**

To estimating sediment inflow from the upstream catchment to dam reservoir

To recommend appropriate reduction measure of sediment yield with different scenarios

To identify temporal and spatial variation of sediment yield on chacha catchment

1.4. Research question

- How much sediment yields be measured generated in to chacha dam reservoir?
- How does land use change affect sediment yield?
- What was the spatial and temporal variability of catchment affect sediment yield?
- From chacha catchment which one is the most erodible sub basin?
- How many sediment parameters are there the most sensitive?
- How to sediment recommend and identify scenarios analysis the sediment reduction measure?

1.5 Thesis outline

This thesis contained six chapter. Chapter one presented the introduction, statement of problem, objective that include general and specific objective and thesis out line. Chapter two describes literature review related to the soil erosion, sediment yield and SWAT model descriptions. Chapter three provides a description of the study area and data availability that include model input data collection and data analysis method presented in the detail. Chapter four deals with presentation of the research founding. The last chapter presented conclusion, recommendation, reference and appendix.

2 LITERATURE REVIEW

2.1 Erosion and sedimentation

2.1.1 Soil erosion processes

Soil erosion involves detachment, transport and deposition of soil particles (including plant nutrients and organic matter) by water or wind. The process may be natural or accelerated by human interference in the environment. Geologic erosion, usually referred to as natural erosion acting over long geological periods, occurs when the soil is in its natural environment. According (Wischmeier and Smith,1978) natural erosion rates exist under natural or undisturbed environmental conditions. Usually under natural geologic erosion rates, soil properties and soil profiles develop to approach an equilibrium condition. This type of erosion has contributed to the formation of soils and their distribution on the surface of the earth. This long-time eroding process caused most of the present topographic features.

Accelerated erosion is soil loss in excess of geologic erosion. It is normally associated with changes in natural cover or soil conditions and is caused primarily by water and wind. The forces involved in accelerated erosion are attacking forces which remove and transport the soil particles and resisting forces which retard erosion. Hereafter, accelerated erosion will be referred to as soil erosion or simply erosion.

Erosion by water is induced by the natural occurring events of rainfall or snowmelt, or artificially by irrigation and other types of sprinkler application of water to the surface. Detachment of individual (Julien, 1998) soil particles may occur when water strikes the surface by overcoming the interconnecting forces holding the soil particles together. This is commonly referred to as raindrop splash. As the inducing events of rainfall continue, water infiltrates into the soil at a rate controlled by the intensity of water hitting the surface and the infiltration capacity of the vertical soil profile. Water that is not infiltrated begins to pond on the surface. When sufficient depth is achieved at the surface, water flow will begin in the direction of the steepest slope that is unimpeded. This begins the hydrologic process referred to as overland flow or runoff (Julien, 1998)

2.2 Reservoir sediment transportation and deposition

The reservoir sedimentation involves entrainment, transport and deposition. They originate from the catchments area, river system and settled in the reservoir. As a river enters the reservoir, its cross section of inflow is enlarged due to the effect of the backwater curve. Thus, it causes a decrease in the water flow velocity; subsequently the sediment carrying capacity of water is reduced too. The major part, or all, of the sediment transported will deposit in the u/s part of the reservoir influenced by the back-water curve (Gassman eta l, 2007).

Reservoir sedimentation undergoes different processes of transportation and settling of sediment. This cusses the reservoir to possess different kinds of deposition at different positions. These differences are controlled by the effects of the sediment particle size, hydraulic condition and sediment transportation methods in the reservoir. Due to different behavior of sediment particles in transportation and deposition, they have different impacts on the reservoir sedimentation pattern and storage losses. Thus, it is important to treat each type separately, so as to understand how they are deposited and transported in the reservoir. This is hardly needed in analyzing the reservoir sedimentation problem and providing the best measures (Ahmed, 2009).

2.2. Types of reservoir sedimentation

The river flow usually carries a wide range of the sediment particle sizes and they are transported either as a bed load or as a suspended load. In general, the bed load material (coarse sediment particles) move near the bed and start to deposit in the beginning of the reservoir entrance in the form of the delta. The suspended sediments (fine sediment particle with lower settling velocities) are transported deeper into the reservoir either by no stratified flow forming a uniform deposition at the middle of reservoir, or by stratified flow depositing at lower part of the reservoir forming a muddy lake. Generally, the suspended load is divided in two parts; one comes from the bed of the river, and the other load from the catchments area as wash load. The reservoir sedimentation based on the location of deposition into three categories, with inclusion of the sedimentation in backwater reach as a part of the reservoir sedimentation (Juracek, 2010).

The position of each type of reservoir sedimentation can be seen in the longitudinal profile of the reservoir which is classified as Back water deposition, Delta deposition and Bottom set deposition. (Batuca, 2000) have classified the reservoir sedimentation based on the location of deposition into three categories, with inclusion of the sedimentation in backwater reach as a part of the reservoir sedimentation. The position of each type of reservoir sedimentation can be seen in the longitudinal profile of the reservoir which is classified as (Show fig 2.1) Back water deposition, Delta deposition and Bottom set deposition.

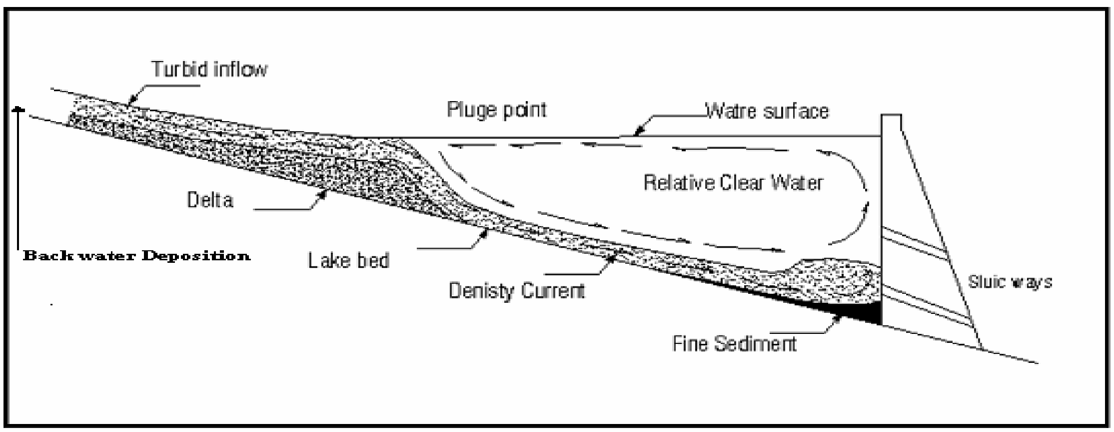


Figure 2.1 Back water deposition process (Batuca and Jordaan (2000))

2.2 .2 Sediment accumulation

Sediment accumulation in the reservoir is calculated using the bathymetric survey data collected. The base line was taken as the design storage capacity of the reservoir at the different levels in 1966. The storage capacity in the different bathymetric surveys compared to that of 1966 at different level enables estimation of sediment accumulation rates. Thus, the comparison between accumulated silt volumes deposited between the different surveys is obtained ((Ahmed, 2009)

2.3 Temporal and spatial variability in sediment yields

Sediment yield varies both in time and space. Knowledge of the extent of the temporal and spatial variability in sediment yields is significant in the context of resource allocation for sediment control measures. According to a study by Guyot et al., (1994) on sediment transport in the Rio Grande, the Andean river of the Bolivian Amazon drainage basin, it was found that most transport occurs during the three months of the year in which the river has high water flows. The period contributed up to 90% of the annual load. The determining factors for an increase or decrease in sediment yield with time depend on the site-specific conditions. In some circumstances, annual variability in sediment yield can just be a reflection of the variability in precipitation and runoff.

Batalla et al. (1994) reported about an investigation of the temporal variability of the suspended sediment load in a Mediterranean sandy gravel-bed river where marked temporal variability was caused by seasonal effects, progressive exhaustion of sediment available to be transported during sequences of storm events and extremely high sediment concentration during individual floods. A cumulative plot of the observed sediment load has the ability to indicate the temporal variability in sediment yield by inspecting the slope changes in the graph of the cumulative water discharge against cumulative sediment discharge. The same factors that have been reported to be responsible for the temporal variability of sediment yield have the ability to influence the spatial variability in sediment yield as long as there is possibility of spatial variability in the controlling variables within a catchment area. The temporal variation can be seasonally, annually and even inter-annually. It therefore emphasizes the need for longer term sampling records for a detailed understanding of the temporal variation in sediment yield and in order to draw realistic conclusions from observations (Hampson, 1997).

2.4 Impact of land use on erosion and sediment load

Forests are checkers of soil erosion. Protection is largely because of under story vegetation and litter, and the stabilizing effect of the root network. On steep slopes, the net stabilizing effect of trees is usually positive. Vegetation cover can prevent the occurrence of shallow landslides. However, large landslides on steep terrain are not influenced appreciably by vegetation cover. These large slides may contribute the bulk of the sediment, as for example in the middle hills of the Himalayas ((Bruijnzeel L. A., 1989).

Afforestation does not necessarily decrease soil erosion. Splash erosion may increase substantially when litter is cleared from the forest floor. The spectrum for the size of the drops that are formed by the canopy varies widely among different species, resulting in large differences in the potential of splash erosion (Calder, 1998). Deforestation may increase erosion. The actual soil loss, however, depends largely on the use to which the land is put after the trees have been cleared. Surface erosion from well-kept grassland, moderately grazed forests and soil-conserving agriculture are low to moderate. Road construction may be a major cause for erosion during timber harvesting operations. In the USA, forest roads are estimated to account for 90 percent of the erosion caused by logging activities (Brooks *et al.*, 1991).

In Ethiopian highlands soil erosion is a serious problem that increased sedimentation of reservoirs and lakes. Human activities (i.e. deforestation, ploughing, livestock grazing, removal of remnant vegetation, road building) led to an overall increase in erosion process intensity (Nyssen et al., 2008). Cultivated lands on average are five times more prone to erosion than bush–shrub lands. This emphasizes the importance of implementing appropriate soil and water conservation measures in critical sediment source areas prioritizing the steepest part of the watershed (Haregeweyn et al., 2013; Tibebe and Bewket, 2011). The sediment contribution of major watersheds within Lake Tana basin was estimated. On average annual sediment loss from the gauged part of the watershed is 32 t/ha. Accumulation of sediment in Lake Tana is taking place at an annual rate of 10 t/ha of watershed area with a small amount of outflow from the lake to the Blue Nile River (Zimale et al., 2016). To prevent or reduce land degradation, many programs have been initiated in northern Ethiopia for soil erosion control and land rehabilitation (Haregeweyn et al.,2012).3

2.5 Sediment transport equation

Sediment transport equations are used to determine the sediment transport capacity for a specific set of flow condition. The first step in evaluating sediment transport is to select one or more of available equations for use in solving the problem. The selection is not straight forward, since the result of different formulas can give drastically different results and it is usually not possible to determine the one providing best result. Additionally, some of the methods are considerably more complex than the other. According to (Bagnold,1962), the initial consideration is to decide what portion of sediment transport need to be estimated. If it is desirable to know the contribution of bed load and suspended load to the bed-material discharge, formula for each are available. Other formulas provide direct determination of bed material discharge. According with in ISO standard ((ISO, 2002.) Wash load consists of fine materials that are finer than those found in the bed. The amount of wash load depends mainly on the supply from the watershed, not on the hydraulics of the river. Consequently, it is difficult to predict the wash load based on the hydraulic characteristics of a river. Most total load equations are therefore, total bed material load equation

In Modified universal soil loss equation (MUSLE), the rainfall energy factor is replaced with a runoff factor. This improves the sediment yield prediction, eliminates the need for delivery ratios, and allows the equation to be applied to individual storm events. Sediment yield prediction is improved because runoff is a function of antecedent moisture condition as well as rainfall energy. Delivery rations (the sediment yield at any point along the channel divided by the source erosion above that point) are required by the USLE because the rainfall factor represents energy used in detachment only. Delivery ratios are not needed with MUSLE because the runoff factor represents energy used in detaching and transporting sediment. Erosion caused by rainfall and runoff is computed with the Modified Universal Soil Loss Equation (MUSLE) (Neitsch et al., 2011). MUSLE is a modified version of the Universal Soil Loss Equation (USLE) develop by Wischmeier and Smith (1965)

$$S_{ed} = 1.292 EI_{USLE} * K_{USLE} * C_{USLE} * P_{USLE} * L_{USLE} * CFRG$$

Where, S_{ed} is the sediment yield on a given day (metric tons/ha),

EI_{USLE} is the rainfall erosion index (0.017 m-metric ton cm/(m2 hr)),

K_{USLE} is the USLE soil erodibility factor (0.013 metric ton m2 hr/(m3-mertic ton cm)),

C_{USLE} is the USLE cover and management factor,

P_{USLE} is the USLE support practice factor,

LS_{USLE} is the USLE topographic factor and

CFRG is the coarse fragment factor

USLE predicts the average annual gross erosion as a function of rainfall energy. Whereas in MUSLE the rainfall energy is replaced with a runoff factor which improves the sediment yield prediction, eliminates the need for delivery ratios, and allows the equation to be applied to individual storm events. Sediment yield prediction is improved because runoff is a function of antecedent moisture condition as well as rainfall energy. Delivery ratios (the sediment yield at any point along the channel divided by the source erosion above that point) are required by the USLE because the rainfall factor used by USLE represents energy used in detachment only (Neitsch et al., 2011).

$$S_{ed} = 11.8\,(Q_{surf} * q_{peak} * Aea_{hru})^{0.56} * K_{USLE} * C_{USLE} * P_{USLE} * L_{USLE} * CFRG$$

Where, Q_{surf} is the surface runoff volume (mm), q_{peak} is the peak runoff rate (m / s ^{3}), hru Area is the area of the HRU (ha), and the other variables in the equation carries the same meaning as described in USLE equation

2.6 Sediment yield estimation of the watershed

Sediment yield refers to the amount of eroded sediment discharged by a stream at any given point over a period of time, which is also the amount which will enter a reservoir located at the downstream limit of its tributary watershed. The most common unit for sediment yield is tones/year. The specific sediment yield is the yield per unit of land area which is most commonly given in tones/km2/year. Long-term sediment yield estimates have been used for sizing storage reservoirs and estimating reservoir life (Morris and Fan, 2009). Accurate estimation of sediment yield is very important in order to plan a reservoir and efficiently manage its sediment so that the reservoir can meet its requirements. Sediment yield is affected by geology, slope, climate, drainage density and patterns of human disturbance and therefore, no single parameter or simple combination of parameters explains the wide variability in sediment yields. Sediment yield from drier areas tends to be limited because of low runoff and yield in wetter areas is limited by the protective soil cover and reduced erodibility of humid zone soils (Vanoni, 2006).

2.7 Sediment transport modelling

To better understand the parameterization process, some fundamental concepts and definitions on sediment transport will be covered briefly. The Brahmaputra is a braided river which is a pattern defined as flow paths constantly changing around smaller unstable or semi-permanent alluvial bars and islands (Campos, 2001). At low discharge levels the river is flowing in several smaller braided channels, while at high discharge levels it submerges most of the bars and is lands and is transformed into a few larger channels ((Vanoni, 2006). The number and size of the braided channels are therefore varying, with the exception for more stable node points where the riverbanks are made up by more consolidated material. To compensate for a changing width and still transport the same discharge, the scour depth is affected. When distributing the flow over several channels in a braided system, the wetted cross-sectional area of the combined channels should be equal to that of the nodal pointed. Braided rivers have evolved from combination of a relatively steep slope and an overabundance of sediment load (Vanoni, 2006). In contrast to a meandering river, a braided river has a lower sinuosity and does not scour on one bank and deposit on the other, it may affect both banks equally. Depositional processes can be summarized as various bed formations such as bars and dunes, and sedimentation in overbank areas during floods (Campos, 2001). Sediment transport within the channel is commonly divided into groups. Bed load is characterized by grains commonly larger than 0.1 mm that moves along the bottom of the channel by rolling, sliding and saltation. Suspended load is of smaller grain sizes that can be sustained by the flow without settling ((Meyer, 1969). The mobility of coarse non-cohesive grains, like sand and gravel, depends on the threshold of entrainment (i.e. the incorporation into the flow), and is also referred to as the dimensionless bed shear tress. The bed shear stress, and thus bed scouring, varies depending on factors such as bed slope, grain size and degree of immersion in sub layer. Due to this critical threshold, some grains are picked up and due to different settling velocities of the grain sizes, a sorting process is evolving. Thus, when bed erosion occurs, the finer grains on top are carried away first, while other potentially mobile fine particles may be trapped by coarser grains creating an armor effect. This leads to less material transported while the bed surface becomes rougher. Finer cohesive particles, like silt and clay, depend on bed processes such as electrochemical forces and are transported as composite particle aggregations (Meyer, 1969).

2.8 Description of swat model

The major components of SWAT include hydrology, weather, erosion, plant growth, nutrients, pesticides, land management, and stream routing. The program is provided with an interface in Arc GIS (Winchell et al., 2013) for the definition of watershed hydrologic features and storage, as well as the organization and manipulation of the related spatial and tabular data.

The SWAT watershed model is one of the most recent models developed by the USDAARS to predict the impacts of land management practices on water, sediment and agricultural chemicals yields in watersheds with varying soils, land use and management practices over long periods of time (Neitsch et al., 2005). The model is a physical based, semi-distributed, continuous time, and operating on daily time step (Neitsch et al., 2005). As a physical based model, SWAT uses Hydrological Response Units (HRUs) to describe spatial heterogeneity in terms of land use, soil types and slope with in a watershed. In order to simulate hydrological processes in a watershed, SWAT divides the watershed in to sub watersheds based upon drainage areas of the tributaries. The sub watersheds are further divided in to smaller spatial modeling units known as HRUs, depending on land use and land cover, soil and slope characteristics. For simulation, SWAT needs digital elevation model; land use and land cover map, soil data and climate data of the study area. These data will use as an input for the analysis of hydrological simulation of surface runoff and groundwater recharge.

2.8.1 SWAT model application Worldwide

The SWAT model has good reputation for best use in agricultural watersheds and its uses have been successfully calibrated and validated in many areas of the USA and other continents (Ndomba, 2002). The studies will indicate that the SWAT Model is capable in simulating hydrological process from complex and data poor watersheds with reasonable model performance statistical values ((Ndomba, 2002) was applied the SWAT model in modeling of Pangari River (Tanzania) to evaluate the applicability of the model in complex and data poor watersheds. In the Nile countries on the basis of performance indicators, the SWAT models in general produced satisfying or good results (Van Griensven et al., 2012). Applied the SWAT model for Nagwan watershed in India with the objective of identifying and prioritizing of critical sub watersheds to develop an effective management plan and the model was verified for both surface runoff and sediment yield. Accordingly, the study concluded that the SWAT model can be used in UN gauged watersheds to simulate the hydrological and sediment processes.

2.8.2 SWAT model application in Ethiopia

The SWAT model application was calibrated and validated in some parts of Ethiopia, frequently in Blue Nile basin. Through modeling of Gumara watershed (in Lake Tana basin), (Awulachew, 2008) indicated that stream flow and sediment yield simulated with SWAT were reasonable accurate. . In Ethiopia's Lake Tana Basin also report Nash- Sutcliffe model efficiency greater than 0.50, acknowledging that SWAT has the potential for use in assessing the relative impact of land use management decision on hydrologic response. The same study reported that similar long term data can be generated watersheds using the SWAT model. A study conducted on modeling to estimate of the chacha watershed sediment yield with SWAT model also showed that the SWAT model was successfully calibrated and validated (Setegn, 2008)

2.8.3 Selection of model

Even though, estimates of sediment yield are required in a wide spectrum of practical studies for the planning, design, operation and maintenance of water resources structures, the measurement and sampling of sediment transportation is very lengthy and costly. So that it requires other options to challenge such problems of sediment estimation in water resources development. Reason for the selection of SWAT model was: It is physically based, spatially distributed, identify vulnerable (erosion prone areas) and adopt best management practice for the watershed and belongs to the public domain and the model has been tested in different tropical watersheds (Tadele and Forch 2007). The performance SWAT summarized for discharge and soil loss shows very good results. With a P factor of 0.71 and R factor of 0.53 also the Validation of discharge data showed very good results. The hydrologic model SWAT has been applied to the ungauged and semi-ungauged watershed in different part of the country gets promising results (Gebrekristos, 2015).

3. MATERIAL AND METHODOLOGY

3.1 Study area disruption

3.1.1 Location and accessibility

Chacha watershed is located in Angolela Tara woreda north showa zone Amhara region**.** It also located 125 kms north of Addis Abeba capital city of Ethiopian**.** Chacha Earth Dam site is found in Ajiba River. The site is located at UTM coordinates of 1062926N and 549376 E and the elevation of watershed between 1700 and 3245m above sea level. The catchment has a shape of fern leaf type with a total size of about 577.5 km2. The mean annual precipitation is about 864.64mm and the annual minimum temperature and annual maximum temperature was 1.9^{0}c and 22.1^{0}c. The minimum monthly rainfall is 4.3mm in December and maximum 277.57mm in august /July. Similar mean minimum and maximum temperature is 6.1 and 19.7 respectively

According to the central statistical agency Debrebrehan branch 2004 study the Angolela Tara woreda land use and land cover percentage, agriculture land (perennial crop, irrigation and cereal crops), forest and bushland, pastureland, water body, roads and others land use practise in percentage 41.06%,14.139%, 13.55%, 0.015%, 1.32% and 29.93% respectively. The Chacha dam is a type of earth dam irrigation project. The Main Dam is zoned embankment dam with necessary provision of filter and drainage systems. The Dam embankment crest length is 377m and the maximum height above riverbed level is 45.5m. The reservoir capacity 70.09 million cubic meter of water. This dam will have an internal impervious core zone and upstream and downstream shoulder zones. It also comprises of upstream and downstream graded filter, upstream riprap and rock toe zones.

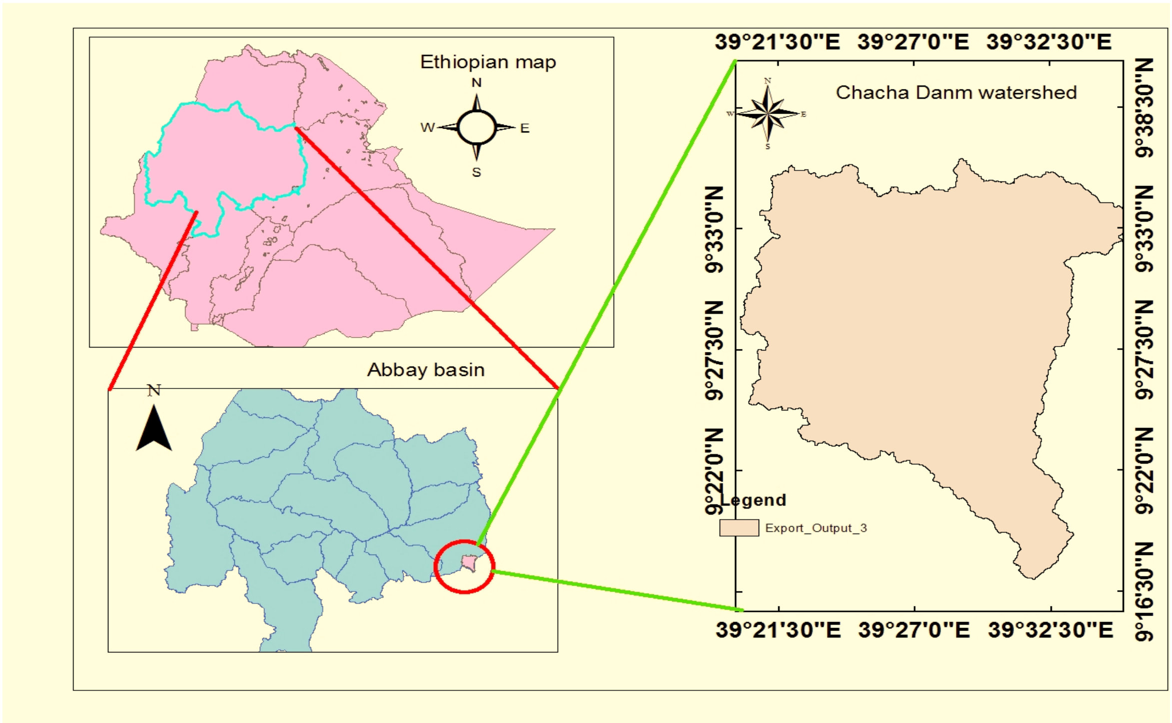


Figure 3.1 location of the study area

3.1.2 **Topography**

The chacha catchment is left out due to unstable soil, uneven topography and spares bush and large eucplouress tree from hill of the watershed. The slope analysis is important to classified the capability of land cover and land use planning and agriculture area. Generally, the majority of the chacha watershed is moderately steep slope land scape.

3.1.3 **Climate of the study area**

The climate of Ethiopia is mainly controlled by seasonal migration of inter-tropical convergence zone (ITCZ) and its associated atmospheric circulation but the topography has also an effect on the local climate. The traditional climate classification of the country ((Abebe, 2007) is based on attitude and temperature shows the presence of five climate zone, which were Wurch (cold climate at more than 3000m altitude), Dega (temperature like climate-high land with 2500-3000m altitude), Woina Dega (1500-2500m altitude), Kola (hot and arid type, less than 1500m in altitude), and Bereha (hot and hyper arid type) climate. According to Angulala woreda 2004 report data the chacha catchment climate in percentage, Dega 85%, Woina Dega 13%, and Kola 2%. Therefore, the classification of the chacha watershed ranges from semi-arid in winter season and humid in the summer season. Average Annual precipitation is 871mm/year all over the catchment. The mean annual precipitation is about 864.16mm with the minimum monthly rainfall of 1mm in December and maximum 277.57mm in July. Dependable rainfall varies 4.31 to 8.478mm during the dry season /December to February/ to 65.15 to 275mm/month during the period of wet season /June to August/. The rain falls of this area characterized by bimodal patter with maximum peaks July and August and during December and January in the low season. Seasonal variations are four namely, winter (dry season), summer (wait season), autumn (Small rain), and spring (a spell between rainy and dry season) where dry conditions with high rate off evapo-transpiration occur

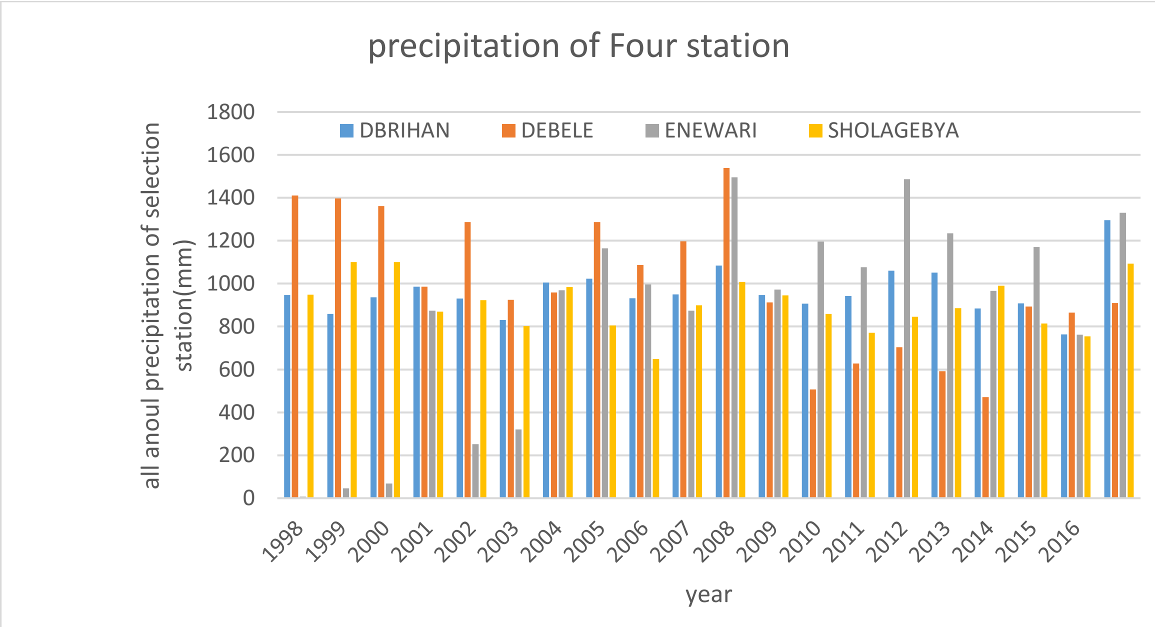


Figure 3. 2 Total annual precipitation of selection station at chacha catchment

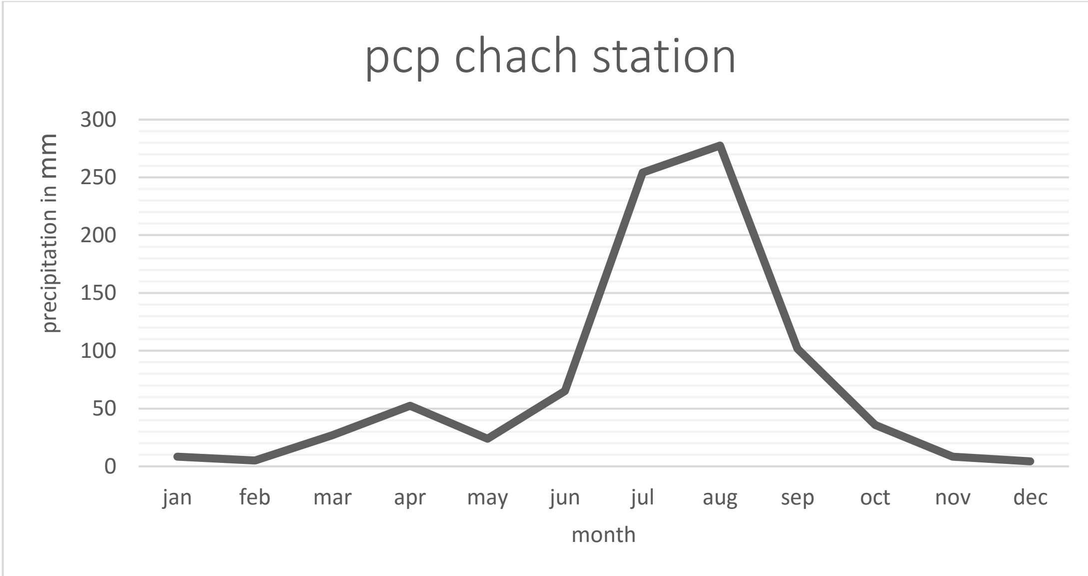


Figure 3.3 Total monthly precipitation of chacha station

3.2 Input data collection and analysis

SWAT is highly data intensive model that requires specific information about the watershed such as topography, land use and land cover, soil properties, weather data, and other land management practices. These data were being collect from different sources and databases.

3.2.1 Spatial data collection and analysis

3.2.1.1 Digital elevation model

The digital elevation model (DEM) data was used to delineate the sub-watersheds in the Arc SWAT interface. The DEM data with a resolution of 30mx30m was collected from MOWRIE, then using Global mapper 8 export as DEM. To delineate the watershed Digital Elevation Map (DEM) grid, mask grid and digitized stream network files were loaded using the watershed delineation tool. The projection of the DEM data was done using the Arc tool box operation in ArcGIS 10.4. The projected coordinate system parameters of Ethiopia (study area) are: UTM another GC Adindan UTM zone 37N.prj. DEM was used in the SWAT Model along with soil and land use/ land cover data to delineate the watershed and to further divided the watershed in to sub watershed and hydrologic response unit /HRU/.

The resolution of the digital elevation model (Gassman eta l.., 2007/ affects the watershed delineation stream network and sub basin classifications

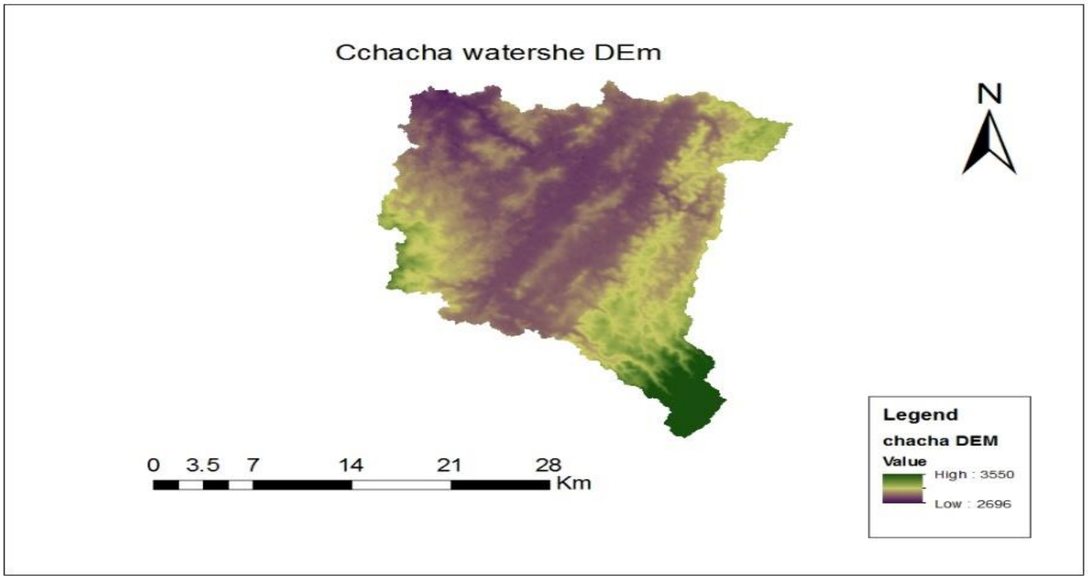


Figure 3.4 shows degital elevation model discription of chacha watershed

3.2.1.2 Land Use and Land Cover Mapping

The Land use and land cover change studies usually need the development and the definition of homogeneous land use and land cover units before the analysis is started. These have to be differentiated using the available data source such as remote sensing, any other relevant information and the previous local knowledge and previous research. The Chacha watershed is characterized by high cultivation along the valleys of the main river and the tributaries. The main land use types are Dominated cultivation, open grass, dense forest and bush land.

Table 3.1 land use/land cover

Land cover type	*SWAT land use*	*SWAT Code*	*Percentage of total area*
Durum Wheat	Durum wheat	DWHT	87.1633
Bush land	Range-Brush	RNGB	0.0221
Open grasses	Pasture	PAST	12.7286
Dense forest	Forest mixed land	FRST	0.08595

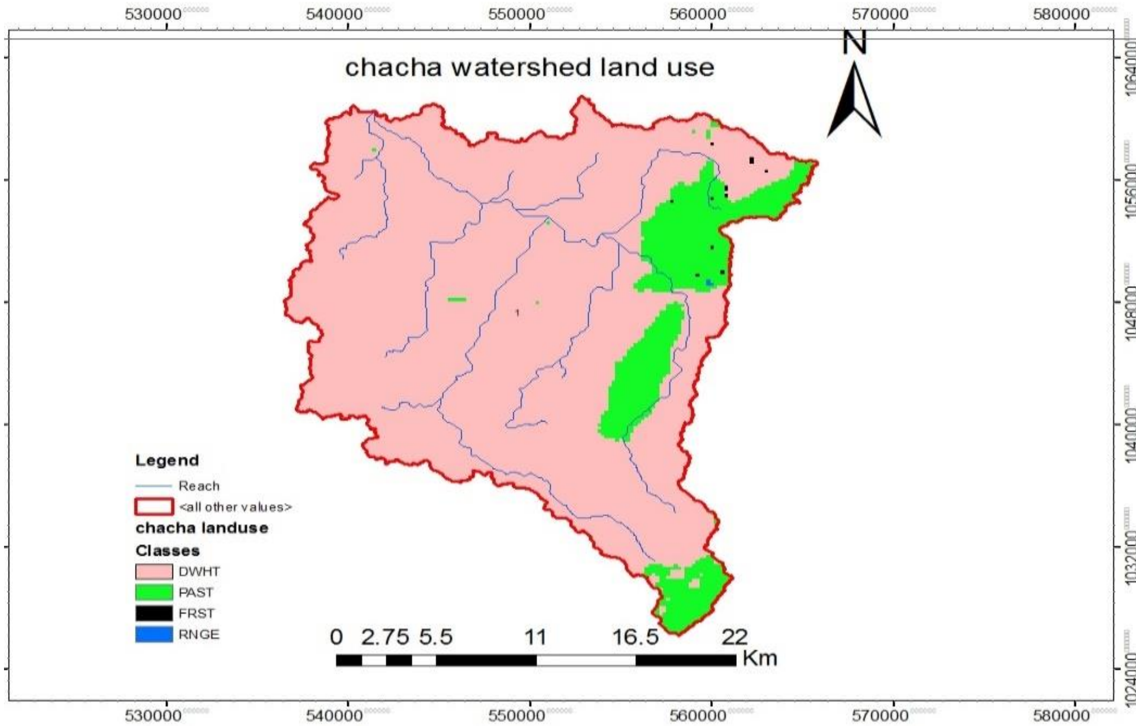


Figure 3.5 land use/ land cover of chacha watershed

3.2.1.3 Soil data

Soil data is one of the major input data for the SWAT model with inclusive chemical properties. The soil map of the study area was also obtain from Ministry of Water, irrigation and electricity of Ethiopia. The major soil type in the basin are Eutric Cambisols and Eutric Vertisols

Table 3.2 Soil type and percentage from total

Name of soil	*SWAT soil class*	*Hydrologic soil group*	*Percentage of total area*
Euritic Vertisoils	Be9-3c-26	C	3.9043
Eurtic Cambisol	Vp14-3a-286	C	96.0953

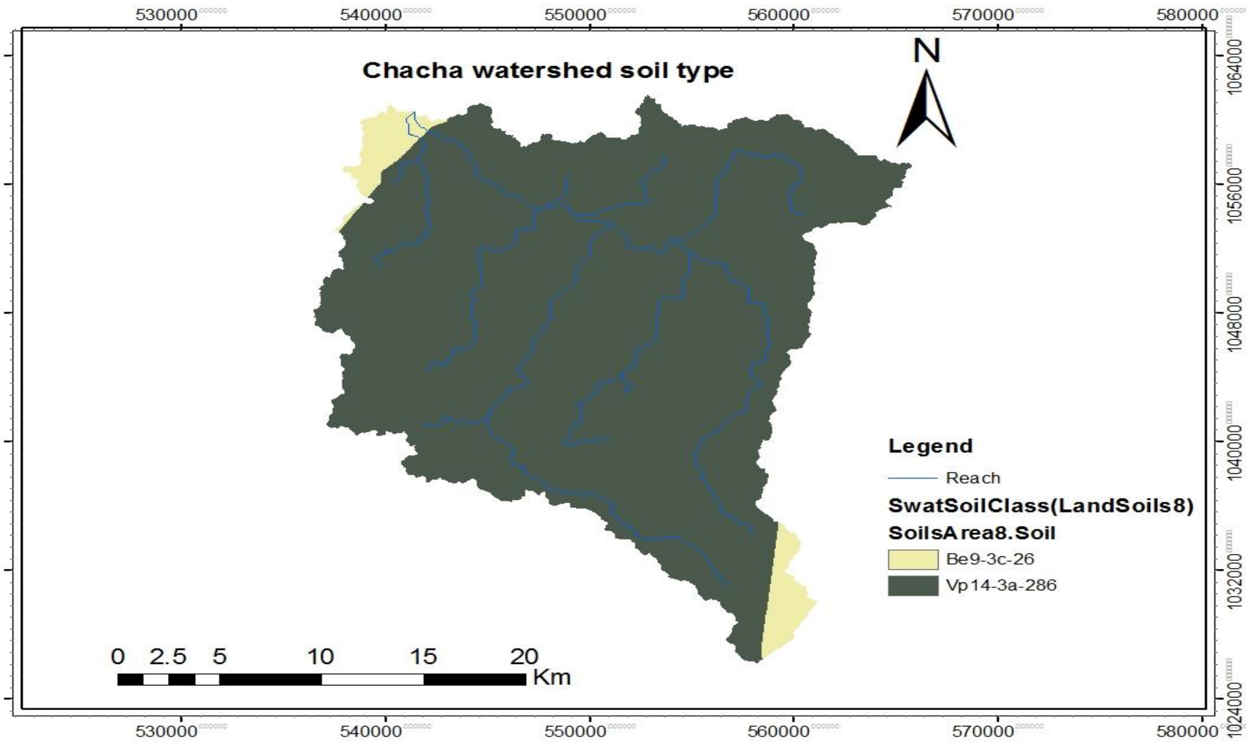


Figure 3.6 Soil Type of Cha-Cha Dam Catchment

The SWAT model requires different soil textural and physical-chemical properties such as soil texture, available water content, hydraulic conductivity, bulk density and organic carbon content for different layers of soil. These data were obtained mainly from the following sources: FAO –Global-soil and digital soil map from the Ministry of Water Resource. Physical soil property calculator was used to calculate the available soil moisture content, bulk density and saturated hydraulic conductivity and the default Value of the model. Whereas the soil edibility (K) factor was calculated according to (Williams J. , 1995) by using equation

$$K_{usle} = f_{csand} - f_{cl-si} - f_{org} - f_{hisand} \quad \text{(equation 3.1)}$$

Where

- fcsand is a factor that gives low soil edibility factors for soils with high coarse-sand contents and high values for soils with little sand,
- fcl-si is a factor that gives low soil erodibility factors for soils with high clay to silt ratios,
- forgc is a factor that reduces soil erodibility for soils with high organic carbon content, and

- fhisand is a factor that reduces soil erodibility for soils with extremely high sand contents. The factors are calculated by using equation (3.1-3.4)

$$f_{csand} = (0.2+0.3*\exp[-0.256*m_s(1-{m_{silt}}/{100})]) \quad \text{equation (3.2)}$$

$$f_{ci\text{-}si} = \left(\frac{m_{silt}}{m_{cl}+m_{silt}}\right)^{0.3} \quad \text{equation (3.3)}$$

$$f_{orgc} = \left(1-\frac{0.25*orgC}{orgC+\exp(3.72-2.95*orgC)}\right) \quad \text{equation (3.4)}$$

$$f_{hisand} = \left(1-\frac{0.7(1-\frac{m_s}{100})}{\left(1-\frac{m_s}{100}\right)+\exp\{-5.51+22.9*\left(1-\frac{m_s}{100}\right)\}}\right) \quad \text{equation (3.5)}$$

Where m_s is the percent sand content (0.05-2.00 mm diameter particles),

m_{silt} is the percent silt content (0.002-0.05 mm diameter particles),

m_c is the percent clay content (< 0.002 mm diameter particles),

orgC is the percent organic carbon content of the layer

3.2.1.4 Slope

The slop of chacha catchment derive from DEM input therefore, the model uses this slop for the development of hydrological response unit in addition to land use and soil input parameter. Arc SWAT allows to slop class when defining hydrological response unit. According to Belete et al.., (2013) Ethiopian slope classification was grouped in to six (0-3%, 3-8%, 8-15%,15-30%, 30-50% and above 50%), but SWAT model multiple slope classification maximum group was five. For this study consider slop class for chacha catchment class one 0-3%, class two 3-8% ,third class 8-15% , fourth class 15-30%and five class greater than 30% (table 3.3 & fig 3.7). The following table and figure are show that slop classification in the chacha Catchment

Table 3.3 show slop of chacha watershed

s.no	*Slop*	*Area(Ha)*	*Area percentage*
1	0-3%	9622.039	16.66
2	3-8%	24687.8	42.75
3	8-15%	16062.76	27.81
4	15-30%	6692.39	11.59
5	>30%	689.131	1.19

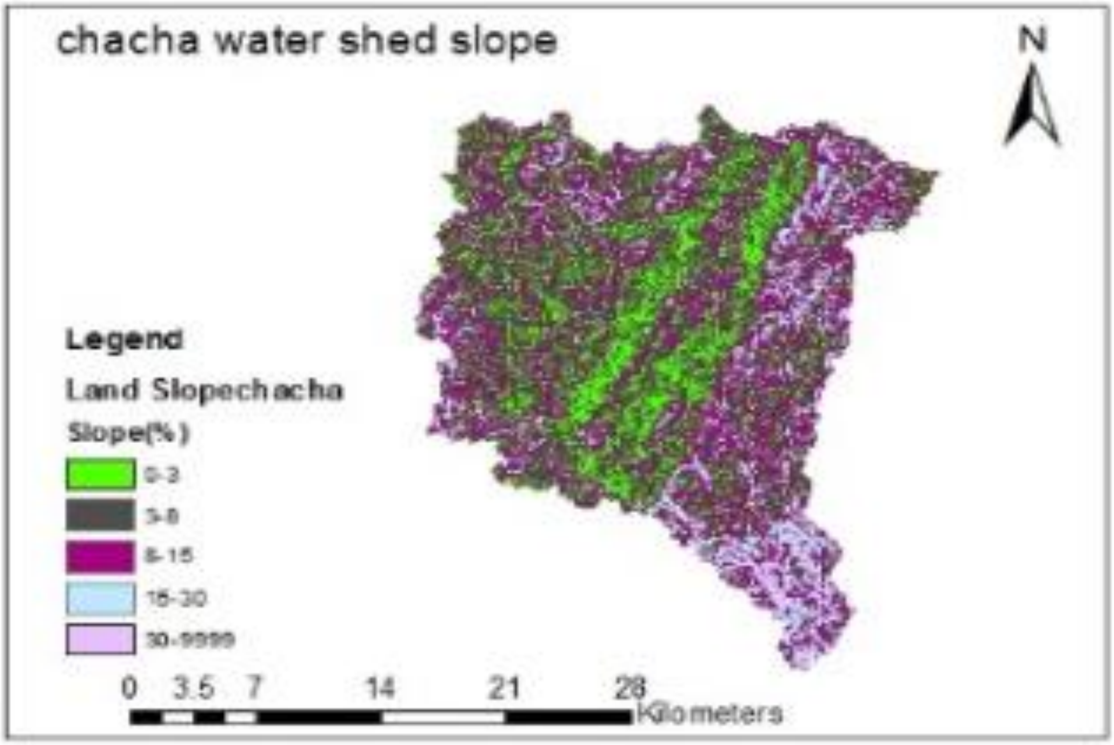


Figure 3.7 shows slop of chacha watershed

3.2.2 Meteorological data

The weather variables for driving the hydrological balance are precipitation, air temperature, solar radiation, wind speed and relative humidity. ArcSWAT requires daily data of precipitation when the SCS curve number method is chosen to model surface runoff. Maximum and minimum daily air temperature, daily solar radiations are also required. Most of the raw data are not complete; therefore, missing data are generated by weather generator. Climatic data was being generated in two instances: when the user specifies that simulated weather was been used or when measured data is missing.

The metrological input of the model was prepared first by analyzing, modifying, and entering in the right format which is Text (Tab delimited) of the daily data and secondly obtaining and analyzing the required monthly statistical weather parameters for the weather generator (i.e.

Debrebrihan station). The missing values within the meteorological input (i.e. Debele, Enewari and Sholagebeya stations) was been generated by the weather generator.

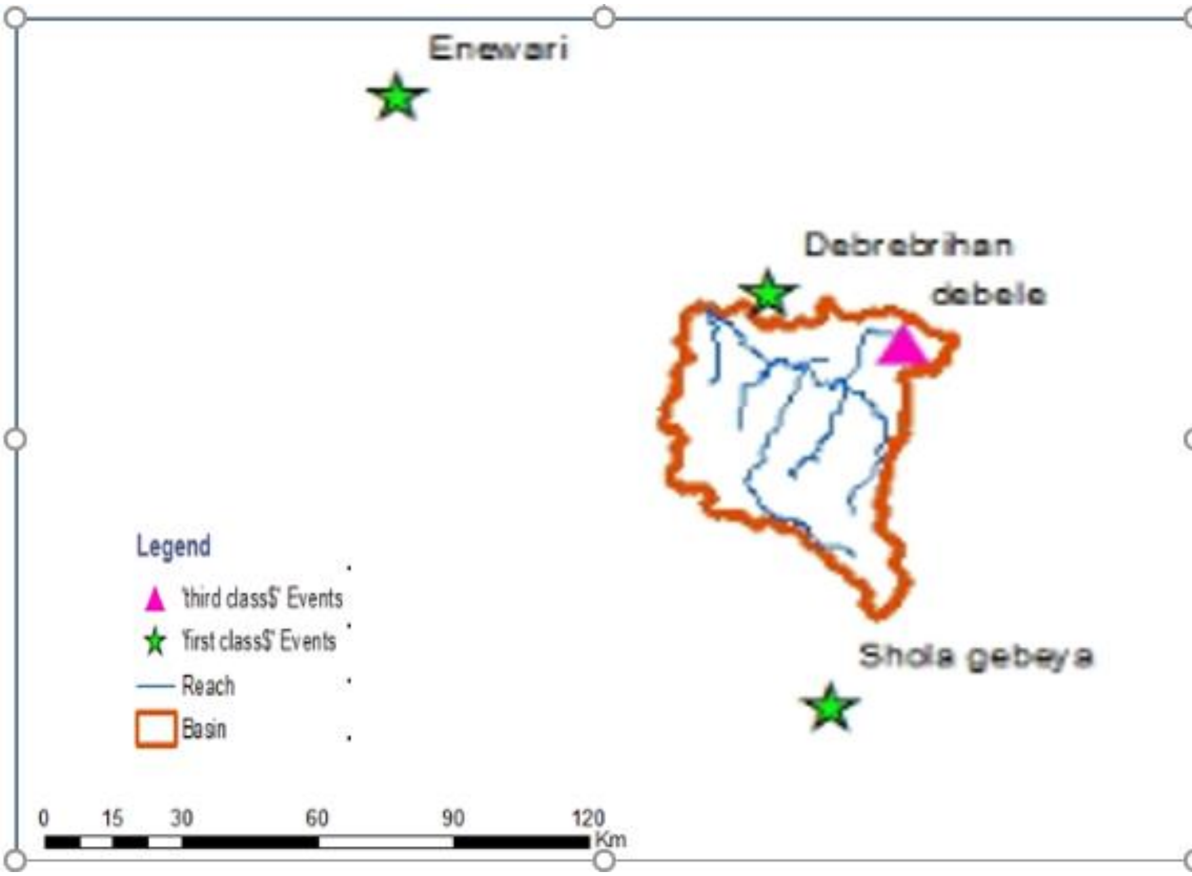


Figure 3.8 meteorological gauge station location

3.2.2.1 Weather data

Weather data are among the main demanding input data for the SWAT simulation. The weather input data require for SWAT simulation includes daily data of precipitation, maximum and minimum temperature, relative humidity, wind speed and solar radiation. These was obtained from the Ethiopian National Meteorological Agency.

3.2.2.1.1 Rainfall data

The rainfall data was obtained from the Department of Hydrology and Meterology (DHM). There were four meteorology stations located outside chacha watershed. But eniwari station are far from the watershed available data from these three station was was evaluted

Table 3.4 precipitation gauge station coordinate

Id	*station*	*XPR*	*YPR*	*Elivation*
1	Rdbrih	4382377	1077980	2750
2	Rdebela	4396800	1062227	3092
3	Rshola	4387924	1027143	2500
4	Reniwa	4343546	1095992	2561

These monthly statistical weather parameters for the weather generator were estimated by using empirical

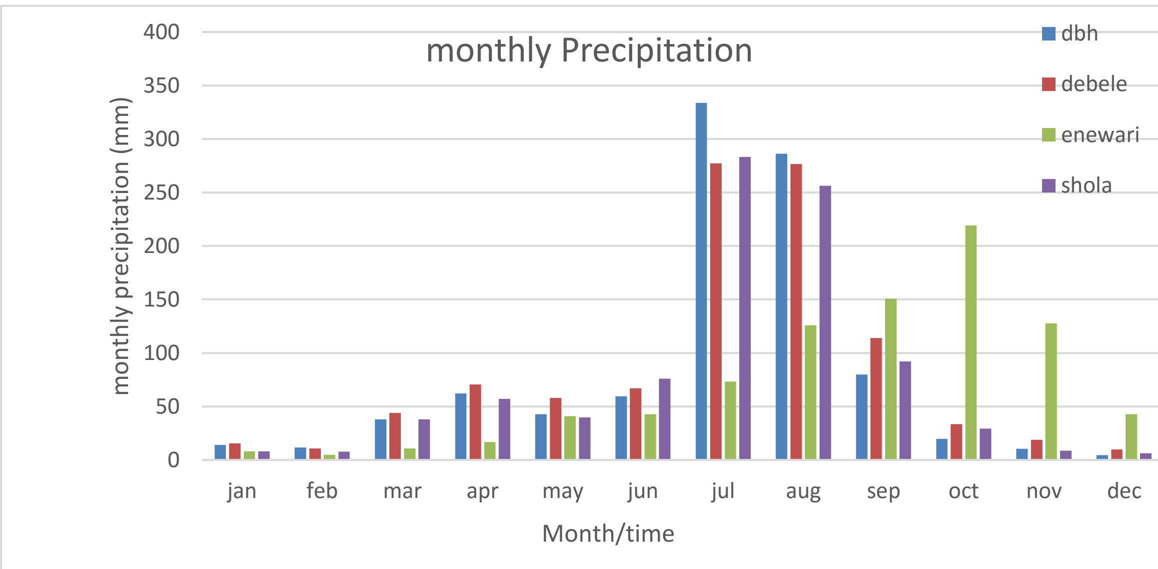


Figure 3.9 Monthly precipitation of all station of the study area

After the precipitation data was checked for quality and the appropriate station selected, the statistical parameters of precipitation data must be calculated before model set up. The statistical parameters for precipitation were calculated using the program pcpSTAT.exe. This program calculates the statistical parameters of daily precipitation data used by the weather generator.

Table 3.5 A Monthly Statistical Weather Parameters

Month	*PCP_MM*	*PCPSTD*	*PCPSKW*	*PR_W1*	*PR_W2*	*PCPD*
Jan.	14	2.3	7	0	0.4	2.5
Feb.	12	2.1	7.3	0	0.4	2.2
Mar.	40	3.5	4.5	0.1	0.6	8.1
Apr.	55	4.3	3.5	0.2	0.6	10.3
May.	43	4.2	4.4	0.1	0.5	7.2
Jun.	59	5.5	5.3	0.2	0.6	8.7
Jul.	334	11.6	1.6	0.6	0.9	26
Aug.	286	9.9	1.5	0.8	0.9	27.7
Sep.	80	5.5	4	0.3	0.6	14.9
Oct.	20	2.5	5.8	0.1	0.5	4.8
Nov.	15	1.9	10.5	0	0.8	4.8
Dec.	9	1.1	7.3	0	0.7	3.5

PCP_MM = average monthly precipitation [mm]

PCPSTD = standard deviation

PCPSKW = skew coefficient

PR_W1 = probability of a wet day following a dry day

PR_W2 = probability of a wet day following a wet day

PCPD = average number of days of precipitation in month

3.2.2.1.2 Temperature

The temperature in the basin is more visible than its seasonal variation. Average monthly temperature varies from 6 °C to 20 °C

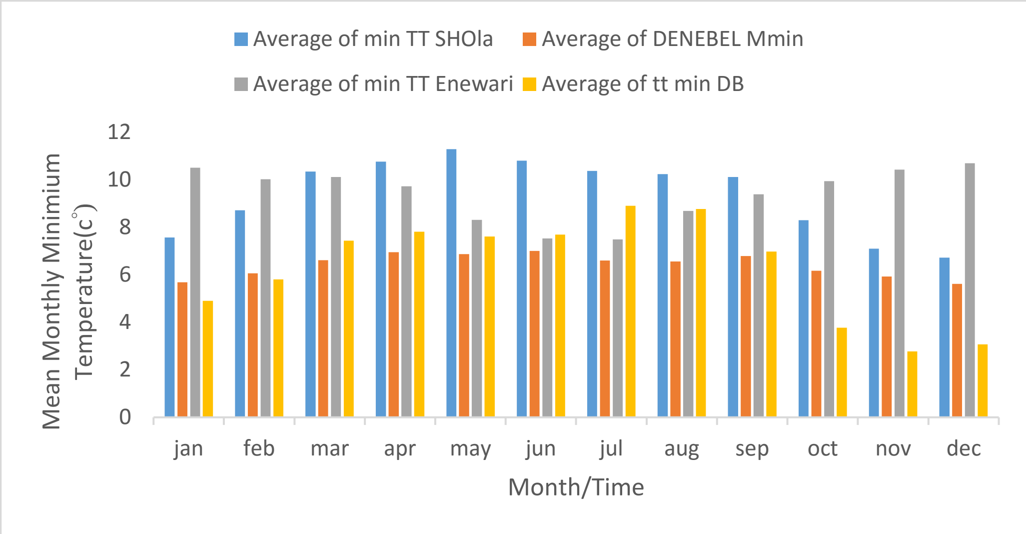


Figure 3.10 Minimum Temperature of All Station

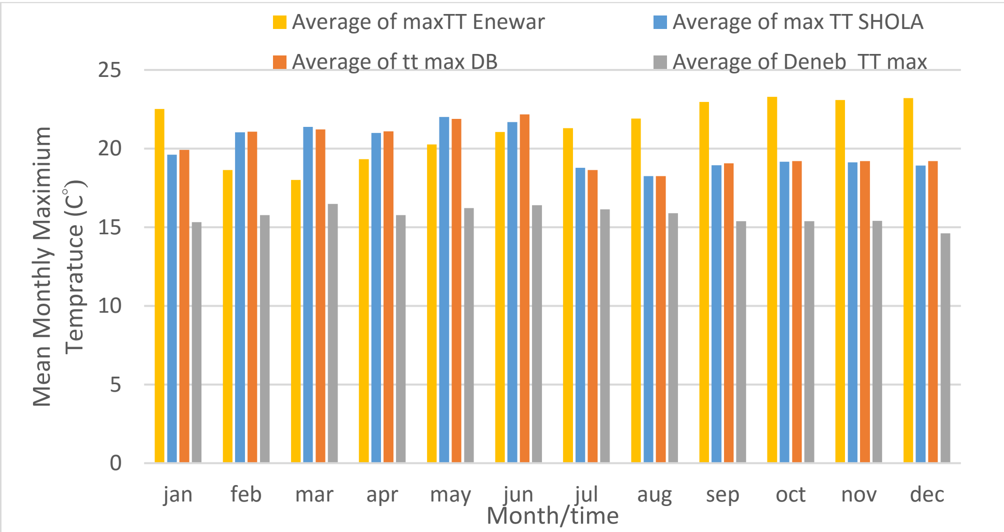


Figure 3.11 Maximum Temperature of All Station

The maximum and minimum temperature represented the basin was also collected for three station the average monthly maximum and minimum temperature each station shown in table 3.6 Average Daily Dew Point Temperature for Period (1997-2016)

Table 3.6 Average Dew Point Temperature

Month	tmp_max	tmp_min	Hmd	Dewpt
Jan	19.9	4.93	61.82	6.63
Feb	21.08	5.8	57.87	6.65
Mar	21.09	7.39	62.17	8.17
Apr	21.07	7.76	63.12	8.51
May	21.85	7.6	59.42	8.01
Jun	22.17	7.69	62.36	8.92
Jul	18.64	8.9	76.36	10.21
Aug	18.22	8.76	76.81	10
Sep	19.06	6.97	70.89	8.78
Oct	19.17	3.76	63.86	6.38
Nov	19.22	2.83	61.6	5.67
Dec	19.21	3.06	61.02	5.58

tmp_max = average daily maximum temperature in month [°C]

tmp_min = average daily minimum temperature in month [°C]

hmd =average daily humidity in month [%]

dewpt = average daily dew point temperature in month [°C]

This file has been generated by the program 'dew02.exe'

Input Filename = temprh.txtNumber of Years = 20

Number of Records = 7336

Number of No Data Values

tmp_max = 93

tmp_min = 92

hmd =1958

Formula in the ArcSWAT user manual, pcpSTAT and dewpoint software which were designed by Stefan Liersch in 2003. PcpSTAT calculates statistical parameters of average daily precipitation data. Dewpoint calculate the average daily dewpoint temperature per month using daily air temperature and humidity data. The weather generator first independently generates precipitation for the day. Then maximum temperature, minimum temperature, solar radiation and relative humidity are generated based on the presence or absence of rain for the day. Finally, wind speed generated independently.

3.2.2.2 Data quality control

The precipitation data must be checked for continuity and consistency before it is used for further analysis. The quality control can be done by filling of missing data if there is any, accumulated plot and double mass curve checking homogeneity of selection station by non-dimensional parametrization. This was help identify if there are any gaps or unphysical peaks in data series and correct them before the data is used or input to the model. Otherwise, using the erroneous data as input to the model was give erroneous output from the model.

3.2.2.2.1 Filling of missing data

All weather stations may have short breaks in the records due to absence of the observer or because of instrumental failures. Therefore, necessary to estimate or fill in this missing record. The missing precipitation of a station was estimated from the observations of precipitation at some other stations as close to and as evenly spaced around the station with the missing record as possible. Here, the station whose data was missing is called interpolation station and gauging stations whose data are used to calculate the missing station data are called index stations**.**

There are methods to fill in missing data that are arithmetic mean method, normal ratio method and inverse distance weighing method. Arithmetic mean method can be used to fill in missing data when normal annual precipitation is within 10% of the gauge/station for which data are being reconstructed. Debrebrihan and sholagebeya station identifying missing data with arithmetic method. The normal ratio method is used when the normal annual precipitation at any of the index station differs from that of the precipitation station by more than 10%. In this method filling data of Debela station and Enewari station. In the absence of normal annual rainfall for the stations inverse distance weighing method can be used to fill the missing data.

According to (Richards, 1998) the two formulas are described below.

1) Arithmetic mean method

$$P_x = \frac{(P_1+P_2+P_3+--P_n)}{N}$$ equation (3.6)

Where,

Px = the precipitation from the station with the missed record

P1, P2, P3 … Pn = the corresponding index station.

N = number of index station

2) The normal ration method is used when the surrounding gauged have the normal annual precipitation exceeded 10% consider gauged.

$$P_x = \frac{1}{n} \sum_{i=1}^{i=n} \frac{N_x}{N_i} * P_i$$ equation (3.7)

Where, P_x is the missing precipitation for any storm at the interpolation station x

P_i is the precipitation for the same period for the same storm at the i^{th} station of a group of index station

N_x is the normal annual precipitation for station x

N_i is the normal annual precipitation value for the i^{th} station

3.2.2.2.2 Double Mass Curve

To check for consistence of the recorded data, the cumulative of statin Debela, Sholagebeya, and Enewari was plotted against the Debrerihan station since Debrebrehan station has very few missing data to compared to the other three stations. Checking consistency use of the double mass curve for adjustment of slope ((Subramanya, 2008)

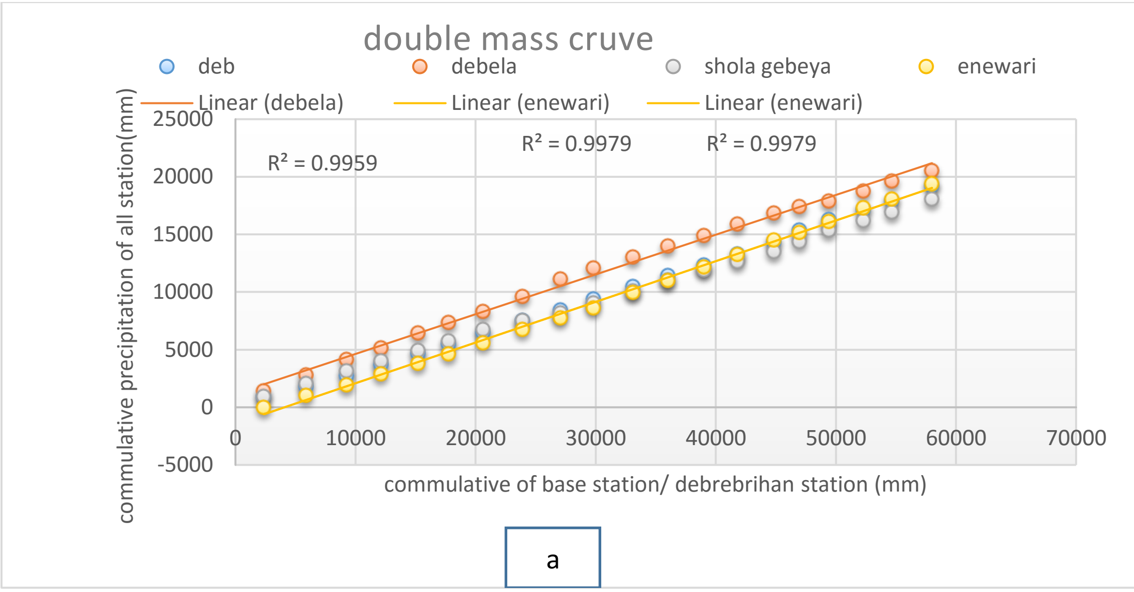
$$P_a = \frac{S_a}{S_o} * P_o$$ equation (3.8)

Where P_a = Adjusted precipitation

P_o = observed precipitation

S_a = slope of graph to which recording

S_o = slope of graph at time P_o was observed



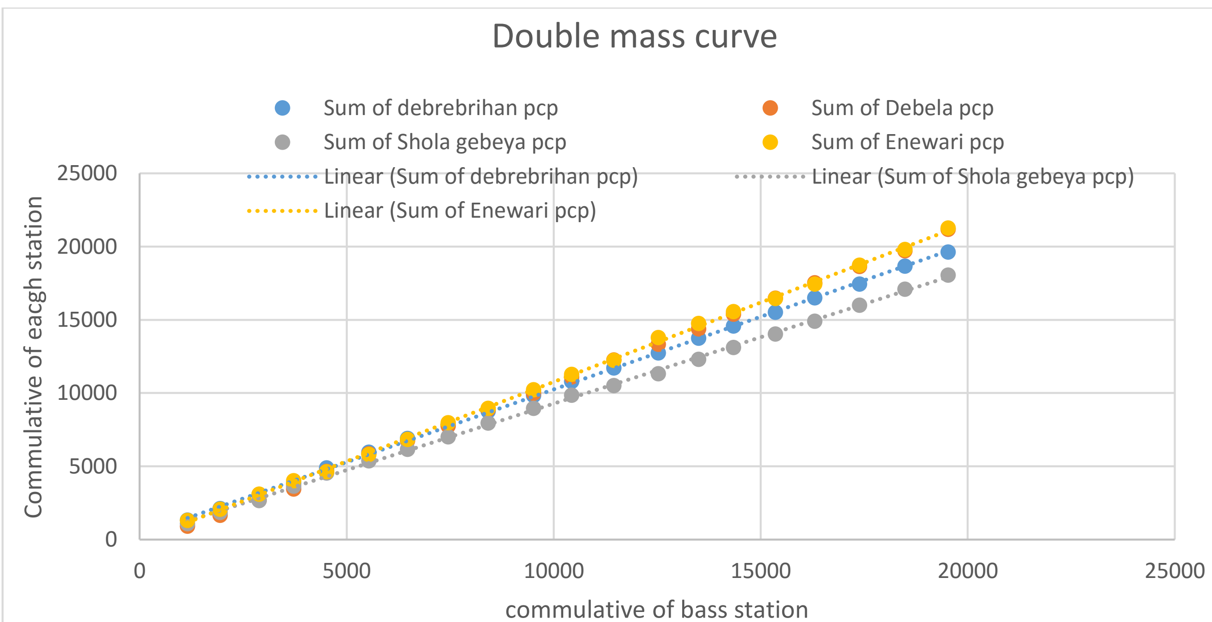


Figure 3.12 double mass curve before (a) and after adjusted (b) between cumulative precipitation and cumulative precipitation of selected metrological station

From, figure 3.12 we can see that there is inconsistency in the recorded data. There is some flat period in graphs in at early period for Enewari station and later for Debela station. Therefore, the precipitation recorded at station Debela, Shola gebeya and Enewari has a series problem as we can see it from the double mass curve and the percentage of missing data also leads to the same decision. Due to this reason the precipitation record at Debrebrihan station was used as input to the model for weather generate.

3.2.2.2.3 Checking homogeneity of selection station by non- dimensional parametrization

The homogeneity of parameters analysis is important to the variation of the statistical properties of the time series. The causes of variation can be either human or natural. These include alterations to land use and relocation of the observation station. This test is based on the assumption that precipitation amounts at the station being test all(station use) and some reginal average values are proportional to each other. This relationship is expressed interms of the raio P between the test station normalization values and those of a reginal time series defined as a weigth average of several neighboring reference station

Therefore, in order to select the representative meteorological station for the analysis of rainfall estimation, checking homogeneity of group stations are important and the homogeneity of the selected gauging stations monthly rainfall records were carried out by non-dimensional (Ozan Mert G¨okt¨urk, 2008)

$$p_i = \frac{\bar{p}_i}{\bar{p}} * 100 \qquad \text{equation (3.9)}$$

Where: Pi is non- dimensional value of precipitation for the month in the station i

P_i is over year's average monthly precipitation for the station

$\overline{p}$ is over year average yearly precipitation for station i

The selection station are plotted for compares for each other and the same- mode and pattern of the stations are observed and hence group station selected are homogenies.

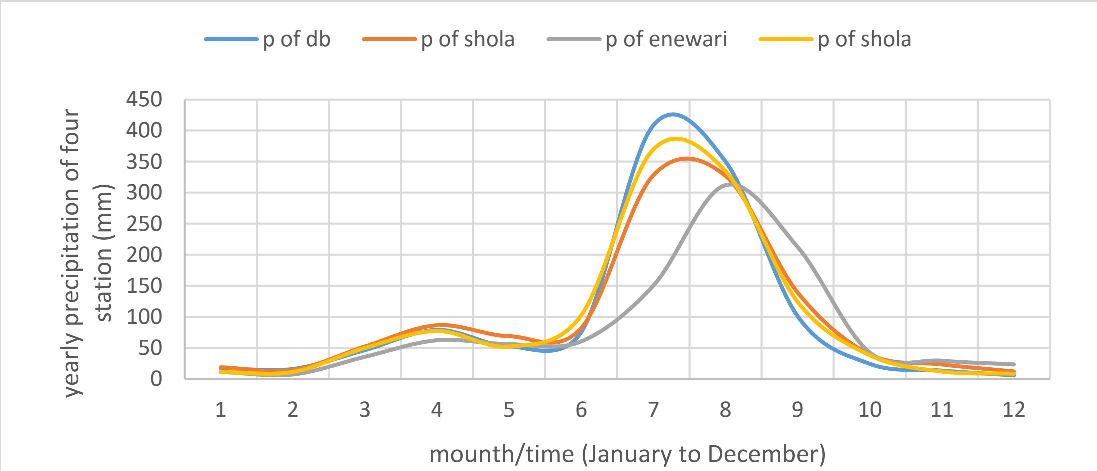


Fig 3.13 The Homogeneity Checking of Four Station of Precipitation

3.2.3 Hydrological data collection and analysis

3.2.3.1 Flow data

River flow data were required for performing sensitivity analysis, calibration and validation of the model. These data were also collected from Ministry of Water, Irrigation and Electricity of Ethiopia. The flow data at chacha gauged station were collected and arranged as per the requirement of SWAT model. It is used for the Soil and Water Assessment Tool (SWAT) calibration and validation. The observed stream flow monthly data included from 1995 to 2013, but for calibration and validation used from 2000 to 2009 and from 2010 up to 2013 used for validation. The other 1995 to 2000 does not used because the study area weather data starts from 1997. And from 1997 to 2000 these three years used for warm up period of SWAT simulation. The flow data shows strong serial correlation the value on one day is closely related to the value on the previous and following days especially during the period of low flow season November to February and heavy rainfall on June to August is the main cause of variation of flow in the study area. The gauging station has good stream flow records with a small number of missing data below 1%. Therefore, months with few days of missing data were filled by averaging from neighboring year data.

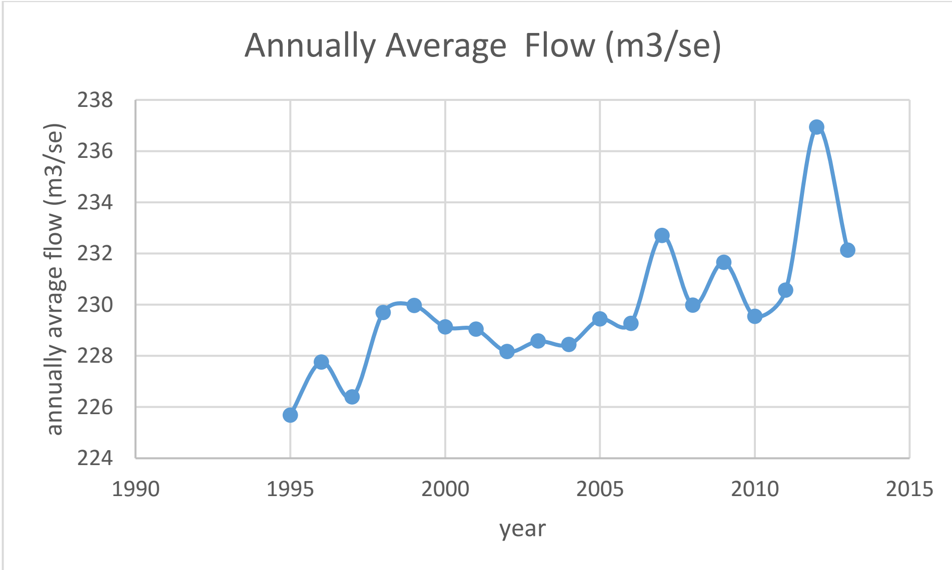


Figure 3.14 Annual Average Stream Flow of Chacha Dam Outlet

3.2.3.2 Sediment data

Sediment data collected from Ministry of Water Irrigation and Electricity ((MWIE, 2017) for hydrology department, but which recorded data of the station with different year had been missing data. To fill this gap, developed sediment rating curve is one of the options. Many researchers have also used sediment rating curve to estimate suspended sediment when measured data or not valid (Asselman, 2000.). Sediment rating curve expresses the average relation between river discharge and suspended sediment concentration for a certain existing data. The sediment rating curve usually express as a power function of discharge

$$Q_s = aQ^b \qquad \text{equation (3.10)}$$

Where: Qs is suspended sediment (ton/day), a and b is regression coefficient and exponent Q is river discharge.

The sample of suspended sediment measured by (mg/l) to convert sediment load (ton/day) by using the following formula.

$$\text{Qs} = 0.0864Cs * Q \qquad \text{equation (3.11)}$$

Where: Qs is sediment load (ton/day), Cs is sediment concentration (mg/l), Q river flow (m3/s) and 0.0864 conversion factor

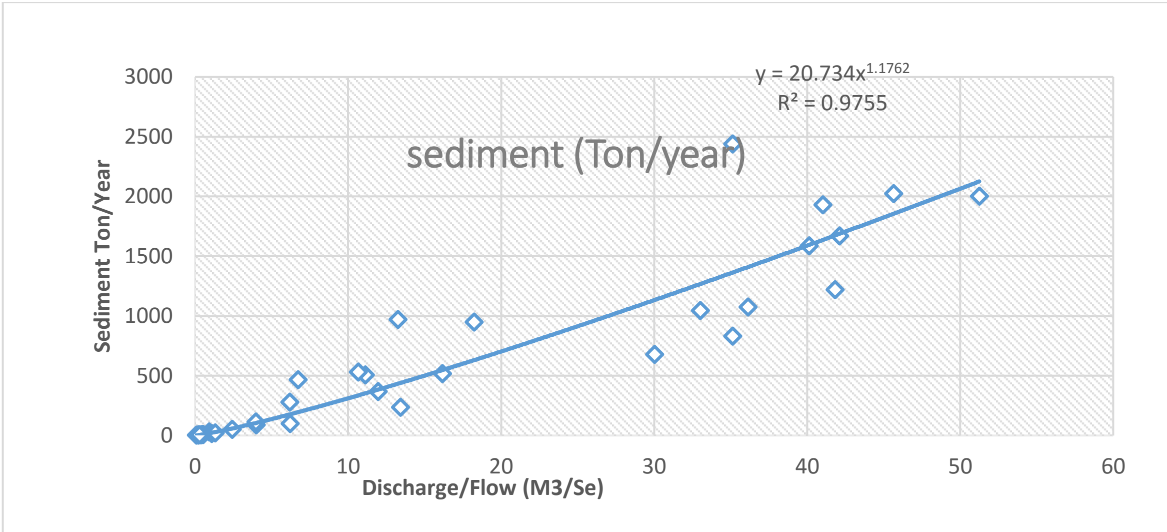


Figure 3.15 shows power function of sediment (ton/year) to discharge

3.3 Methodology

3.3.1 Introduction

The general methodology of this study was depending on the data which are collected from different organization and also field observation. In this methodology the first part is the estimation of sediment yield in the watershed by using SWAT model for determination of sediment yield at the outlet site and to characterize the sub basins in terms of sediment yield. The conceptual framework followed to accomplish this work can be described as follows. This is the driving force and the target to be accomplished during the course of the project work. For this specific project the SWAT (Soil and Water Assessment tool) model was selected. The reason for the selection of the SWAT model are that SWAT model is physically distributed and continuous time developed to estimate sediment inflow sediment from Chacha watershed and analyze the impact of land use change on sediment yield different scenarios and the best mitigation measure of the catchment. After the objective is set and the suitable model was selected, the necessary data required to run the model would be collected and prepared as to the requirement of the SWAT model format. The geospatial data including the digital elevation map, land use/land cover map, soil map and the hydro-meteorological data including the daily stream flow data, daily rainfall data, maximum and minimum daily air temperature data and sediment load/concentration data are all collected and processed as per the input requirement format of the model. The conceptual framework of the steps followed during the course of this project is shown below.

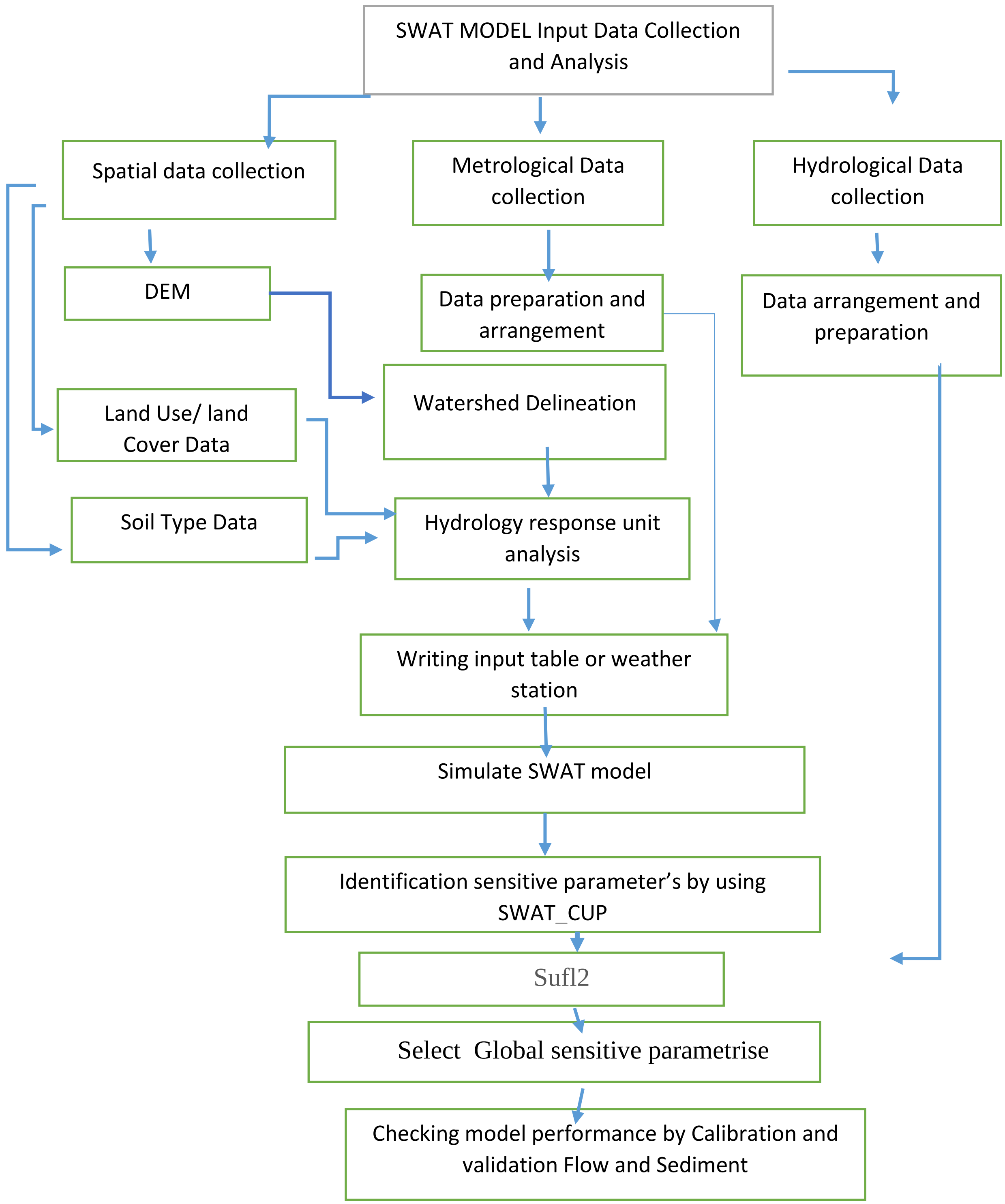


Figure 3.16 show data processing flow chart

Model sensitivity, calibration, validation, simulation of stream flow and sediment. After the model setup has been completed, the next step was run the model and analyze the simulation result. The applicability of the model for intended purpose was evaluated through the process of sensitivity analysis, calibration and validation for further analysis of the result. The objectives of this study are accomplished using available and newly collected information. Available information includes Topographic data (DEM), (90x90 resolution) and DEM 30 Land use and land cover data, soil data, (ministry of water, irrigation and electric city) Daily data of climatic variables (daily data of precipitation, maximum and minimum temperature, relative humidity, wind speed and solar radiation) (national metrological agency)

3.3.2 **Model set up**

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

3.3.3 Model input data collection and analysis

SWAT is highly data intensive model that requires specific information about the watershed such as topography, land use and land cover, soil properties, weather data, and other land management practices. These data were being collect from different sources and databases.

3.3.3.1 Digital elevation model

The digital elevation model (DEM) data was used to delineate the sub-watersheds in the Arc SWAT interface. The DEM data with a resolution of 30mx30m was collected from MOWRIE, then using Global mapper 8 export as DEM. To delineate the watershed Digital Elevation Map (DEM) grid, mask grid and digitized stream network files were loaded using the watershed delineation tool. The projection of the DEM data was done using the Arc tool box operation in ArcGIS 10.4. The projected coordinate system parameters of Ethiopia (study area) are: UTM another GC Adindan UTM zone 37N.prj. DEM was used in the SWAT Model along with soil and land use/ land cover data to delineate the watershed and to further divided the watershed in to sub watershed and hydrologic response unit /HRU/. The resolution of the digital elevation model ((Gassman, 2007) affects the watershed delineation stream network and sub basin classifications

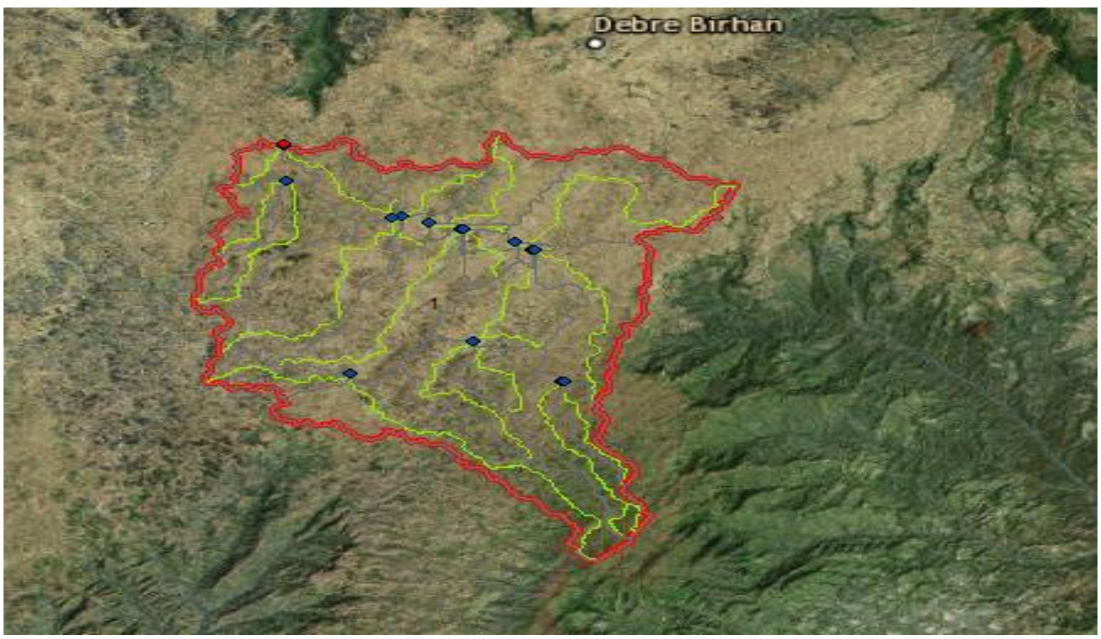


Figure 3.17 Chacha Watershed Digital elevation model map

3.3.3.2 Watershed delineation

The first step in creating ArcSWAT model input is delineation of the watershed from a DEM. Inputs entered into the ArcSWAT model were organized to have spatial characteristics. Before going in hand with spatial input data i.e. the soil map, Land use / land cover map and the DEM were projected into the same projection called UTM Zone 37N, which is a projection parameter for Ethiopia. A watershed was partitioned into a number of sub-basins, for modeling purposes. The watershed delineation process includes five major steps, DEM setup, stream definition, outlet and inlet definition, watershed outlets selection and definition and calculation of sub-basin parameters. For the stream definition the threshold-based stream definition option was used to define the minimum size of the sub-basin. The overall watershed was further classified into 23 sub-basins (fig.3.18) based on the algorithms provided by the SWAT model. Sub-basin defined as the hydrological area contributing to only one steam channel. The area coverage of chacha watershed from 23 sub-basins was 577.5 km2 for being delineated. The contributed area affected by the slop. The slop is increase from outlet to end of upstream catchment

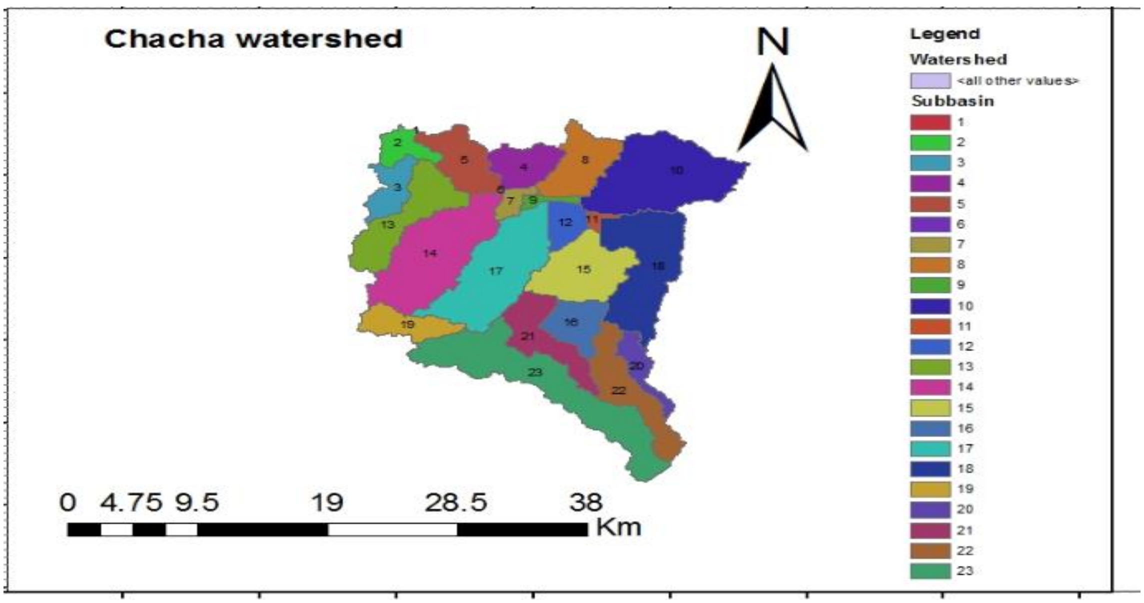


Figure 3.18 show watershed classification into 23 sub-basin

3.3.3.3 Hydrological Response Units (HRU)

The land area in a sub-basin was divided into HRUs. The HRU analysis tool in ArcSWAT helped to load land use, soil layers and slope delineation to the project. The delineated watershed by ArcSWAT and the prepared land use /land cover, soil was overplayed (show fig 3.19) 100 %. HRU analysis in ArcSWAT includes divisions of HRUs by slope classes in addition to land use and soils. The multiple slope option (an option which considers different slope classes for HRU definition) was selected. The land use / land cover, soil and slope map was reclassified in order to correspond with the parameters in the ArcSWAT database. After reclassifying the land use, soil and slope in ArcSWAT database, all these physical properties were made to be overlaid (show fig 3.18). Another step in HRU analysis was HRU definition.

The HRU distribution in this study was determined by assigning multiple HRU to each sub-watershed. In multiple HRU definition, a threshold level was used to eliminate minor land uses, soils or slope classes in each sub-basin. Subdividing the sub watershed into areas having unique land use, soil and slope combinations makes it possible to study the differences in evapotranspiration and other hydrologic conditions for different land covers, soils and slopes. The HRU distribution in this study was determined by assigning multiple HRU to each sub-base. The land use, soil and slope datasets were imported overland and linked with the SWAT 2012 databases. To define the distributions of HRUs multiple HRU definition options were tested. For multiple HRU definition 5% percent land use/land cover, 15 percent soil and 20 percent slope threshold were used

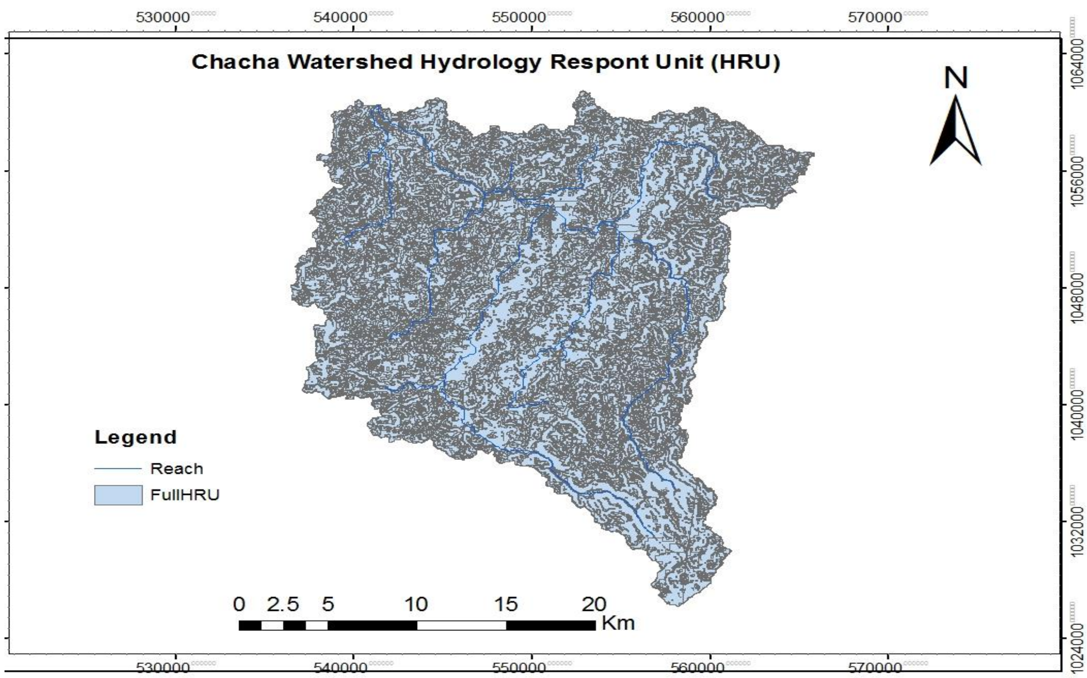


Figure 3.19 The hydrology response unit of chacha watershed

3.3.4 Hydrology modelling

As the rain descends, it may be intercepted and held in the vegetation canopy or fall to the soil surface. Water on the soil surface will infiltrate into the soil profile or flow overland as surface runoff. Runoff moves relatively quickly toward a stream channel and contributes to short term stream response. Infiltrated water may be held in the soil profile and later evapo-transpired or it may slowly make its way to the surface water system through underground paths (Neitsch S. L., 2011).

3.3.4.1 Surface Runoff/overland Flow

Surface runoff occurs whenever the rate of water application to the ground surface exceeds the rate of infiltration (Neitsch et al., 2011). When water is initially applied to a dry soil, the infiltration rate is usually very high. However, it was decrease as the soil becomes wetter. When the rate of application is higher than the infiltration rate, surface depressions begin to fill. If the application rate continues to be higher than the infiltration rate once the all surface depressions have filled, surface runoff was commence (Neitsch et al., 2011). SWAT provides two methods for estimating the surface runoff, the SCS curve number procedure (SCS, (1972)) and the Green and Ampt infiltration method.

The SCS curve number is a function of the soil's permeability, land use and antecedent moisture conditions (SCS, (1972))whereas the Green and Ampt infiltration method calculates infiltration as a function of the wetting front metric potential and effective hydraulic conductivity. SWAT uses the daily and hourly time steps to calculate surface runoff. For daily time steps, SWAT uses an empirical SCS curve number (CN) method and for daily time steps SWAT uses the Green and Ampt show as equation 3.12.

$$Q_{surf} = \left(\frac{R_{day}-I_a}{R_{day}-I_a+S}\right)^2 \qquad \text{equation (3.12)}$$

Where Q_{surf} is the accumulated runoff or rainfall excess (mm H2O)

R_{day} is the rainfall depth for the day (mm H2O)

I_a is the initial abstractions which includes surface storage, interception

S is the retention parameter (mm H2O

The retention parameter varies special due to change soil water content. The retention parameterize is defined as

$$S = 25.4\left(\frac{1000}{Cn} - 10\right) \qquad \text{equation (3.13)}$$

Where CN is the curve number for the day. The SCS curve number is a function of the soils

Permeability, land use and antecedent moisture conditions: 1 – dry (wilting point), 2 – average moisture, and 3 – wet (field capacity)

$$CN1 = CN2 - \frac{20*(100-CN2)}{(100-CN2+\exp(2.533-0.0636*(100-CN2)}$$ equation (3.14)

$$CN3 = CN2 * \exp(0.006373*(100-CN2)$$ equation (3.15)

3.3.4.2 Routing phase of the hydrologic cycle

Once SWAT determines the loadings of water, sediment, nutrients and pesticides to the main channel, the loadings are routed through the stream network of the watershed using a command structure similar to that of HYMO (Williams and Hann, 1972). In addition to keeping track of mass flow in the channel, SWAT models the transmission of chemicals in the stream and streambed.

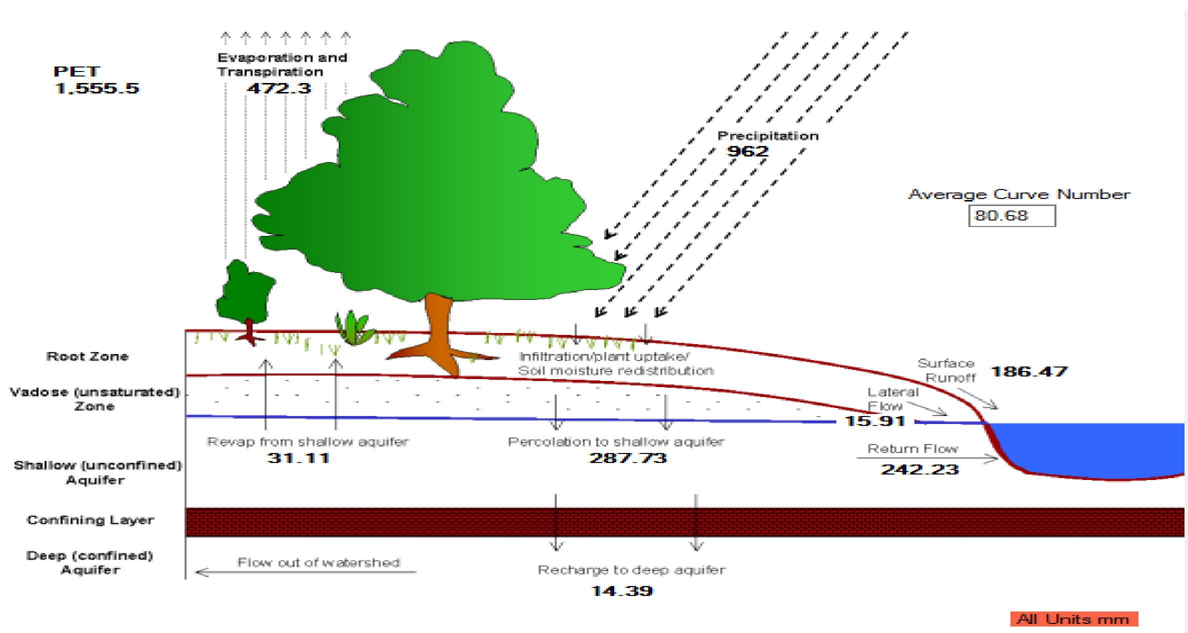


Figure 3.20 hydrology cycle of chacha watershed

SWAT routes water, sediment, nutrients and organic chemicals in the main channel. In this study attention had been given on the first two: water and sediment processes in the main channel. SWAT provides two methods routing (Neitsch et al., 2011) a)Variable storage method, and

b) The Muskingum river routing method

Both variable storage and Muskingum routing methods are variation of kinematic wave mode SWAT assumes the main channels, or reaches,have a trapezoidal shape. Therefore, Manning's equation for uniform flow in atrapezoidal channel was used to calcutate the rate and velocity of flow in arach segment for a given time step

A, Variable Storage Routing

The variable storage routing method was developed and used in the HYMO (Williams and Hann, 1972) and RTOT (Arnold et al., 1995) models.

$$V_{in} - V_{out} = V_{storag} \quad \text{equation (3.16)}$$

Where V_{in} is the volume of water inflow during the time step in (m^3) and V_{out} is the volume of water outflow during the time step(m^3), and V_{stored} is the change in volume of storage during the time step (m^3). The equation can be written as

$$V_{stored,2} - V_{stored,2} = \Delta t\left(\frac{q_{in,1}+q_{in,2}}{2}\right) - \Delta t\left(\frac{q_{out,1}+q_{out,2}}{2}\right) \quad \text{equation (3.17)}$$

Where Δt is the length of the time step (s), $q_{in,1}$ is the inflow rate at the beginning of the time step (m^3/s), $q_{in,2}$ is the inflow rate are the end of the time step (m^3/s) , $q_{out,1}$ is the outflow rate at the beginning of the time step (m^3/s) , $q_{out,2}$ is the outflow rate at the end of the time step (m^3/s), $V_{stored,1}$ is the storage volume at the beginning of the time step(m^3), and $V_{stored,2}$ is the storage volume at the end of the time step (m^3) Rearranging equation 3.16 so that all known variables are on the left side of the equation

Where $q_{in,average} = \frac{q_{in,1}+q_{in,2}}{2}$ equation (3.18)

$$q_{in,aver} + \frac{v_{stored,1}}{\Delta t} - \frac{q_{out,1}}{2} = \frac{v_{stored,2}}{\Delta t} + \frac{q_{out,2}}{2} \quad \text{equation (3.19)}$$

$$TT = \frac{v_{stored}}{q_{out}} = \frac{v_{storea,1}}{q_{out,1}} = \frac{v_{stored,2}}{q_{out,2}} \quad \text{equation (3.20)}$$

TT is the travel time (s). To obtain a relationship between travel time and the storage coefficient equation3.20 is substituted into equatin 3.19 and this simplifies to

$$q_{out,2} = \left(\frac{2*\Delta t}{2*TT+\Delta t}\right) * q_{in,ave} + \left(1 - \frac{2*\Delta t}{2*TT*\Delta t}\right) * q_{out,1} \quad \text{equation (3.21)}$$

This equation is similar to the coefficient method equatio

$$SC = \frac{2*\Delta t}{2*TT*\Delta t} \quad \text{equation(3.22)}$$

where SC is the storage coefficie

$$q_{out,2} = SC * \ q_{in,ave} + 1 - SC * q_{out,1} \quad \text{equation (3.23}$$

Equation 3.19 is the basis for the SCS convex routing method (SCS, 1972) and the Muskingum method (WMO, 1969). From equation(3.19), the storage coefficient in equation (3.22) is defined as

$$1 - SC * q_{out} = \frac{SC*v_{stored}}{\Delta t} \quad \text{equation (3.24)}$$

$$q_{out,2} = SC(q_{in,ave} + \frac{v_{stored,1}}{\Delta t}) \quad \text{equation (3.25)}$$

B Muskingum routing method

The Muskingum routing method models the storage volume in a channel length as a combination of wedge and prism storages in a reach segment (Chow et al., 1988). When a flood wave advances into a reach segment, inflow exceeds outflow and a wedge of storage is produced. As the flood wave recedes, outflow exceeds inflow in the reach segment and a negative wedge is produced. In addition to the wedge storage, the reach segment contains a prism of storage formed by a volume of constant cross-section along the reach length. As defined by Manning's equation the cross-sectional area of flow is assumed to be directly proportional to be discharge for a given reach segment. Using this assumption, the volume of prism storage can be expressed as a function of the discharge, k*q_{out} where K is the ratio of storage to discharge and has the dimension of time. In a similar manner, the volume of wedge storage can be expressed as K*x(q_{in} –q_{out}), where X is a weighting factor that controls the relative importance of inflow and outflow in determining the storage in a reach .Summing these terms gives a value for total storage

$$v_{stored} = k * q_{out} + k * x(q_{in} - q_{out}) \quad \text{equation (3.26)}$$

$$v_{stored} = k(x * q_{in} + (1 - x)q_{out}$$

The weighting factor, X, has a lower limit of 0.0 and an upper limit of 0.5. This factor is a function of the wedge storage. For reservoir-type storage, there is no wedge and X=0.0. For a full-wedge, X=0.5. For rivers, x will fall between 0.0 and 0.3 with a mean value near 0.2. The definition for storage volume in equation 3.26 can be incorporated into the continuity equation and simplified to

$$q_{out,2} = C_1 q_{in,2} + c_2 q_{in,1} + C_3 q_{out,1}$$ equation (3.27)

where $q_{in,1}$ is the inflow rate at the beginning of the time step (m^3/s), $q_{in,2}$ is the inflow rate at the end of the time step (m^3/s), $q_{out,1}$ is the outflow rate at the beginning of the time step (m^3/s), $q_{out,2}$ is the outflow rate at the end of the time step (m^3/s) (Chow et al., 1988)

$$\boldsymbol{C_1} = \frac{\Delta t - 2*k*x}{2*k*(1-x)+\Delta t}$$ equation (3.28)

$$\boldsymbol{C_2} = \frac{\Delta t + 2*kx}{2*k*(1-x)+\Delta t}$$ equation (3.29**)**

$$\boldsymbol{C_3} = \frac{2*k(1-x)-\Delta t}{2*k*(1-x)+\Delta t}$$ equation (3.30)

Where, $c_1 + c_2 + c_3 = 1$. To express all values in units of volume, both sides of equation 3.27 are multiplied by the time step

$$\boldsymbol{v_{out,2.} = c_1 * v_{in,2} + c_2 * v_{out,1} + c_3 * v_{out,1}}$$ equation (3.31**)**

To maintain numerical stability and avoid the computation of negative outflows, the following condition must be met

$$\boldsymbol{2 * k * x < \Delta t < 2 * k * (1 - x)}$$ equation (3.32)

The value for the weighting factor, X, is input by the user. The value for the storage time constant is estimated as:

$$k = coef_1 * k_{bunkfull} + coef_2 * k_{0.1bunkfuu}$$ equation (3.33)

Where K is the storage time constant for the reach segment (s), $coef_1$ and $coef_2$ are weighting coefficients input by the user, $K_{bankfull}$ is the storage time constant calculated for the reach segment with bank full flows (s), and $K_{bankfull}$ is the storage time constant calculated for the reach segment with one-tenth of the

$$k = \frac{100*l_{ch}}{c_k}$$ equation (3.34)

Where K is the storage time constant (s), ch Lis the channel length (km), and k c is the celerity corresponding to the flow for a specified depth (m/s). Celerity is the velocity with which a variation in flow rate travels along the channel. It is defined as

$$c_k = 5/3(R_{ch}^{\frac{2}{3}} * slp^{\frac{1}{2}}) \qquad \text{equation (3.35)}$$

$$= \frac{5}{3} * v_c$$

Where C_k is the celerity (m/s), R_{ch} is the hydraulic radius for a given depth of flow (m), Slp is the slope along the channel length (m/m), n is Manning's "n" coefficient for the channel, and V_c is the flow velocity (m/s).

3.3.4.3. Potential evapotranspiration (PET)

There are numerous methods that have been developed to calculate potential evapotranspiration (PET). The SWAT model provides three of those methods to estimate the potential evapotranspiration: The Penman-Monteith method (Lemma, 2015) and the Hargreaves method (Neitsch et al., 2005)

Among the aforementioned methods, Hargreaves method was selected for PET calculation in this study. The reason for this is that Hargreaves method requires only daily records of maximum/minimum air temperature to estimate PET. Since there is no measured solar radiation, wind speed and relative humidity for this watershed, Hargreaves method was found appropriate and used in SWAT to estimate PET. The other two methods need measured solar radiation, wind speed and relative humidity data to estimate PET.

$$\Delta Eo = 0.0023 * Ho(Tmx - Tmn)^{0.5} * (T av + 17. \qquad \text{equation(3.36)}$$

Where, λ is the latent heat of vaporization (MJ kg^{-1}), E_o is the potential evapotranspiration (mm d^{-1}), H_o is the extra-terrestrial radiation (MJ m^{-2} d^{-2}), mx T is the maximum air temperature for a given day (C o), mn T is the minimum air temperature for a given day (C^0), and av T is the me air temperature for a given day (C^o).

3.3.4.5 Landscape contribution to subbasin routing reach

From the landscape component, SWAT keep tracks of the particle size distribution of eroded sediments and routes them through ponds, channels, and surface waterbodies (Neitsch et al., 2011).

The sediment yield from the landscape is lagged and routed through grassed waterway, vegetative filter strips, and ponds, bushland is highter sediment yeild) if available, before reaching the stream channel. Thus, the sediment yield reaching the stream channel is the sum of total sediment yield calculated by MUSLE minus the lag, and the sediment trapped in grassed waterway, vegetative filter strips and/or ponds (Neitsch et al., 2011). There was no pond considered in this watershed of study.

3.3.5 Sediment modelling

For a watershed, identifying the source of erosion helps to apply different management practices to reduce the erosion rate. In addition to this, it is also very crucial to identify which erosion type is significant in the watershed of interest so that the correct and suitable erosion model can be applied. SWAT uses amodified universal soil loss equation (MUSLE) developed by (Williams J. , 1975) to simulate sediment yield from the up land watershed.

$$S_{ed} = 1.292 EI_{USLE} * K_{USLE} * C_{USLE} * P_{USLE} * L_{USLE} * CFRG \qquad \text{equation (3.37)}$$

Where, S_{ed} is the sediment yield on a given day (metric tons/ha),

EI_{USLE} is the rainfall erosion index (0.017 m-metric ton cm/(m2 hr)),

K_{USLE} is the USLE soil erodibility factor (0.013 metric ton m2 hr/(m3-mertic ton cm)),

C_{USLE} is the USLE cover and management factor,

P_{USLE} is the USLE support practice factor,

LS_{USLE} is the USLE topographic factor and

CFRG is the coarse fragment factor

The value of USLE EI for a given rainstorm is the product, total storm energy times the maximum 30 minutes' intensity (30 I). The storm energy indicates the volume of rainfall and runoff, while the 3 minutes' intensity indicates the prolonged peak rates of detachment and runoff (Neitsch et al., 2011).

$$S_{ed} = 11.8 (Q_{surf} * q_{peak} * Aea_{hru})^{0.56} * K_{USLE} * C_{USLE} * P_{USLE} * L_{USLE} * CFRG \qquad \text{equation(3.38)}$$

Where, Q_{surf} is the surface runoff volume (mm), q_{peak} is the peak runoff rate (m / s 3), hru Area is the area of the HRU (ha), and the other variables in the equation carries the same meaning as described in USLE equation. The equation for surface runoff and peak rate was discussed under hydrologic modelling topic earlier

3.3.6 Sediment routing

Sediment transport in the channel network is a function of two processes, deposition and degradation, operating simultaneously in the reach. There are two options in SWAT to compute deposition and degradation in the reach. The first and traditional way is to keep the channel dimensions constant so that SWAT was compute deposition and degradation using the same channel dimensions throughout the simulation and the second is to activate channel degradation and allow channel dimensions to change and updated us a result of down cutting and widening (Lemma, 2015). When channel down cutting and widening is simulated, channel dimensions are allowed to change during simulation period. Three channel dimensions are allowed to vary in channel down cutting and widening simulations: bank full depth, channel width and channel slope. In this study the former option was adopted in channel routing since the latter option is still in the testing phase.

3.3.6.1 Sediment routing in stream channels

Sediment routing is the function of peak flow rate and mean daily flow. When the watershed was delineated into smaller sub basin, each sub basins has at least one main routing reach. Therefore, the sediment from upland sub basins is routed through these reaches and then added to downstream reaches. To do this, SWAT uses the simplified version of Bagnold equation (Bagnold, 1977) and the maximum amount of sediment that can be transported from a reach segment is a function of the peak channel velocity (Neitsch et al., 2005).

$$Conc_{sed,ch,mx} = C_{sp} * (V_{ch,pk})^{spexp} \qquad \text{equation (3.39)}$$

Where, $Conc_{sed,ch,mx}$, is the maximum concentration of sediment that can be transported by water (ton/m^3) Kg/l, C_{sp} and spexp are coefficient and exponent of the equation defined by the user, and $V_{ch,pk}$, is the peak channel velocity (m/s) . The exponent spexp normally varies from between 1.0 and 2.0 and was set at 1.5 in the original Bagnold stream power equation (Arnold et al., 1995). But, in SWAT2012 the value of this exponent varies between 1.0 and 1.5.

$$V_{ch,pk} = \frac{q_{ch,pk}}{A_{ch}} \qquad \text{equation (3.40)}$$

Where, $q_{ch,pk}$, is the peak flow rate m^3/s and A_{ch} is the cross-sectional area of flow in the channel (m^2)

$$q_{ch,pk} = prf * q_{ch} \qquad \text{equation (3.41)}$$

Where, prf is the peak rate adjustment factor, and q_{ch} is the average rate of flow (m^3/s). The routing in the river reach starts off by comparing the maximum concentration of sediment calculated with Muskingu equation above to the concentration of sediment in the reach at the beginning of the time step, $Conc_{sed,ch,i}$. If $Conc_{sed,ch,i} > Conc_{sed,ch,mx}$, deposition is the dominant process in the reach segment and the net amount of sediment deposited is calculated as in equation 3.42 below

$$Sed_{dep} = \left(Conc_{sed,ch} - Conc_{sed,ch,mx}\right) * V_{ch} \qquad \text{equation (3.42)}$$

Where, Sed_{dep} is the amount of sediment re-entrained in the reach segment (metric tons), V_{ch} is the volume of water in the reach segment m^3. On the other hand, if mx $Conc_{sed,ch,i} < Conc_{sed,ch,mx}$, degradation is the dominant process in the reach segment and the net amount of sediment restrained is calculated as in equation (3.42).

$$Sed_{deg} = \left(Conc_{sed,ch,mx} - Conc_{sed,ch,i}\right) * V_{ch} * k_{ch} * c_{ch} \qquad \text{equation (3.43)}$$

Where, Sed_{dep} is the amount of sediment re-entrained in the reach segment (metric tons), K_{ch} is the channel erodibility factor (cm/hr/pa) and C_{ch} is the channel cover factor. The channel erodibility factor is conceptually similar to the soil erodibility factor used in the USLE equation (Arnold et al., 2012). Channel erodibility is a function of properties of the bed or bank materials. In general, values for channel erodibility are an order of magnitude smaller than values for soil erodibility. The channel cover factor can be defined as the ratio of degradation from a channel with a specified vegetation cover to the corresponding degradation from a channel with no vegetation cover. The vegetation affects degradation by reducing the stream velocity, and consequently its erosive power, near the bed surface (Neitsch et al., 2005).

Once the amount of deposition and degradation has been calculated, the final amount of sediment in the reach is determined by equation (3.44),

$$Sed_{ch} = Sed_{ch,i} - Sed_{dep} + Sed_{deg} \qquad \text{equation (3.44)}$$

Where, Sed_{ch} is the amount of suspended sediment in the reach (metric tons), $Sed_{ch,i}$, is the amount of suspended sediment in the reach at the beginning of the time period (metric tons),

Sed_{dep} is the amount of sediment deposited in the reach segment (metric tons), and is the amount of sediment re-entrained in the reach segment (metric tons). Thus, the amount of sediment transported out of the reach is calculated using equation (3.45)

$$Sed_{out} = Sed_{ch} * \frac{V_{out}}{V_{ch}} \qquad \text{equation (3.45)}$$

Where, Sed_{out} is the amount of sediment transported out of the reach (metric tons), V_{out} is the volume of outflow during the time step (3 m), and V_{ch} is the volume of water in the reach segment (3 m). SWAT incorporates a simple mass balance model to simulate the transport of sediment into and out of water bodies (ponds, wetlands, reservoirs and potholes) (Neitsch et al., 2011).

3.3.7 Sensitivity analysis, calibration and validation of swat model

3.3.7.1 Sensitivity analysis

A complex hydrologic model is generally characterized by a multitude of parameters (Holvoet et al., 2005). SWAT (Soil and Water Assessment Tool) is known to have a large number of parameters. Over-parameterization is a well-known and often described problem in hydrological models, especially for distributed models such as SWAT. SWAT input parameters are process based and must be held within a realistic uncertainty range. The first step in the calibration and validation process in SWAT is the determination of the most sensitive parameters for a given watershed or sub-watershed (Abbaspour, 2013). Therefore, methods to reduce the number of parameters via sensitivity analysis are important for the efficient use of these models (Van Griensven et al., 2006). Sensitivity analysis is a process of testing and identifying model parameters that affects most the output from the model when changed. In other words, sensitivity analysis is the process of determining the rate of change in model output with respect to changes in model inputs (parameters) (Abbaspour, 2013). A parameter sensitivity analysis provides insights on which parameters contribute most to the output variance due to input variability (Holvoet et al., 2005). Therefore, a parameter is considered sensitive when the change in that parameter causes large change on model output**.** In general, identifying sensitive parameters prior ((Eawag, 2015) to model calibration helps to allow the possible reduction in the number of parameters that must be calibrated thereby reducing the computational time required for model calibration. Once the sensitivity analysis is done calibration can be performed for limited number of influential parameters

The current version of SWAT model, SWAT2012, provides the algorithmic techniques for sensitivity analysis. Two types of sensitivity analysis are allowed when using SUFI2 (Sequential Uncertainty Fitting version 2). Global Sensitivity and One-at-a-time sensitivity analysis. The two aforementioned sensitivity analysis methods may yield different results since the sensitivity of one parameter depends on the value of other related parameters. In this study both local (OAT) and global sensitivity analysis were performed and the ranking of the parameters in both cases compared.

3.3.7.1.1 Local (one-at-a-time) sensitivity Analysis

The one-at-a-time (OAT) sensitivity analysis is performed for one parameter at a time only ((Eawag, 2015) by keeping the value of other parameters constant. OAT sensitivity analysis shows the sensitivity of a variable to changes in a parameter if all other parameters are kept constant at some reasonable value. This constant value can be the value of parameters from the best simulation (simulation with the best objective function value) of the last iteration. The objective function used in this project for ranking of the parameters based on OAT sensitivity analysis was the sum of the squares of the difference of the measured and simulated values after ranking (SSQR). The SSQR method aims at the fitting of the frequency distributions of the observed and the simulated series (Abbaspour, 2013).

3.3.7.1.2 Global sensitivity analysis

Global sensitivity analysis uses t-test and p-values to determine the sensitivity of each parameter. The t-stat provides a measure of the sensitivity (larger in absolute values are more sensitive) and the p-values determine the significance of the sensitivity. A P-value close to zero has more significance. A p-value less than 0.05 indicates that you can reject the null hypothesis (Eawag, 2015).

In other words, predictor that has a low p-value is likely to be a meaningful addition to your model because changes in the predictor’s p-value are related to changes in the response variable. The large p-value suggests that changes in the predictor are not associated with changes that changes in response. So that parameter is not very sensitive, p-value < 0.05 is the generally accepted point at which to reject the null hypothesis (i.e., the coefficient of that parameters different from 0). With a P-value of 0.05, there is 5% chance that results you are seeing would have come up in random distribution, so you can say with a 95% probability of being correct that the variable is having some effect. This type of sensitivity can be performed after an iteration. The main problem related to global sensitivity analysis is that it needs a large number of simulation (Abbaspour, 2013).

3.3.7.2 Model calibration and validation

Model calibration is an effort to better parameterize a model to a given set of local conditions, there by reducing the prediction uncertainty. Model calibration is performed by carefully selecting values for model input parameters (within their respective uncertainty ranges) by comparing model predictions (output) for a given set of assumed conditions with observed data for the same conditions (Arnold et al., 2012). Model validation is the process of demonstrating that a given site-specific model is capable of making sufficiently accurate predictions. This implies the application of the calibrated model without changing the parameter values that were set during the calibration, when simulating the response for a period other than the calibration period (Refsgaard, 1997).

The model calibration and validation process were conducted by using the SUFI2 (Sequential Uncertainty Fitting Version 2 programmer) in SWAT_CUP. SWAT_CUP is a computer programmer for automatic calibration of SWAT models. The programmer links SUFI2 procedures to SWAT. The auto-calibration procedure was supported by manual calibration for the values of parameters that were physically wrong. The values of parameters that are provided by SUFI2 during calibration as the best parameter value may not be physically correct or it may be outside recommended uncertainty range and needs to be adjusted manually to better match the existing situation. SWATCUP is an interface that was developed for SWAT, using this generic interface any calibration/uncertainty of sensitivity program can easily be linked to SWAT. Schematic of the linkage between SWAT and five optimizations programs is illustrated in Fig 3.21 below

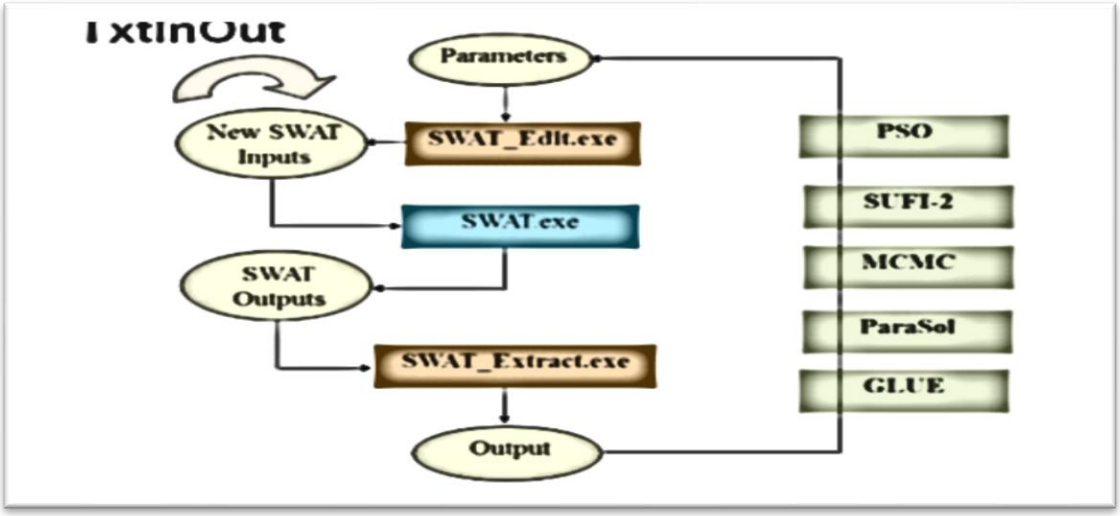


Figure 3.21 a Step by step process of SULf 12 cup calibration and Validation ((Eawag, 2015)Eawag , 2015)

3.3.8 **Efficiency criteria**

The systematic and dynamic behavior of the model can be visualized by plotting simulated flow and observed flow on the same coordinate system. By looking at the graph a modeler can understand whether the model over predicted or under predicted and also the timing of the rising and falling limb of the hydrograph and give subjective decision on the performance of the model. But, to quantitatively evaluate the model, we need mathematical measures of model performance.

Reasons to evaluate model performance (Krause et al., 2005),

1) To provide a quantitative estimate of the model's ability to reproduce historic and future watershed behavior;
2) To provide a means for evaluating improvements to the modelling approach through adjustment of model parameter values, model structural modifications, the inclusion of additional observational information, and representation of important spatial and temporal characteristics of the watershed;
3) To compare current modelling efforts with previous study results.

To assess the goodness-of-fit of the model, two methods were used during the calibration and validation periods. These are: coefficient of determination (R^2) and the Nash-Sutcliffe efficiency coefficient (NS). These two statistical parameters are used to measure the model performance.

3.3.8.1 Coefficient of determination (R^2)

The coefficient of determination **(R^2)** measures the fraction of the variation in the measured data that is replicated in the simulated model results. The coefficient of determination R^2 is defined as (Krause et al., 2005) the squared value of the coefficient of correlation and is given by equation 3.46.

$$R^2 = \frac{[\sum_i (Q_{m,i} - \bar{Q}_m) * (Q_{s,i} - \bar{Q}_s)]^2}{\sum_i (Q_{m,i} - \bar{Q}_m)^2 \sum_i (Q_{s,i} - \bar{Q}_s)^2} \quad \text{equation (3.46)}$$

Where, Q_m is the observed (measured) stream flow on day i (m /s $^{3)}$, Q_s is the simulated stream flow on day i (m /s ^{3}), and bars indicate averages. The value of R^2 ranges from (0-1) where a value close to 1.0 indicates good performance (good correlation) of the model and the value close to 0.0 indicates poor performance (poor correlation) of the model. The main drawbacks of R^2 is that it only quantifies dispersion. A model which systematically over-or under-predicts all the time will still result in good R^2 values close to 1.0 even if all predictions were wrong (Krause et al., 2005). To avoid this ambiguity, it is advisable to use additional information which can cope with that problem.

3.3.8.2 Nash-Sutcliffe efficiency coefficient (NS)

The Nash-Sutcliffe efficiency coefficient (Nash, 1970) is used to assess the predictive power of the hydrological models. The value of NS varies from 1.0 (perfect fit) to - ∞. An efficiency of lower than zero indicates that the mean value of the observed time series would have been a better predictor than the model. The NS value of 0.0 indicates that the model predictions are as accurate as the mean of the observed data. According to Krause et al, (2005) the major disadvantage of the Nash-Sutcliffe efficiency is the fact that the differences between the observed and simulated values are calculated as squared values. This leads to an over estimation of the model performance during peak flows and an under estimation during low flows. The Nash-Sutcliffe efficiency (NS) is calculated using equation 3.47

$$NS = 1 - \frac{\sum_i (Q_m - Q_s)_i^{\,2}}{\sum_i (Q_{m,i} - Q_s)^2} \quad \text{equation (3.47}$$

4 RESULT AND DISCUSSION

4.1 Sensitive parameters

The sensitivity analysis was done for flow and sediment separately since some parameters are sensitive to both flow and sediment, some sensitive to flow only and others sensitive to sediment only (Abbaspour et al.., 2007). Therefore, it was wise to test the sensitivity of the parameters for flow and sediment separately. Sensitivity analysis was carried out before calibrating the model to save time during calibration. Identifying sensitive parameters enables us to focus only on those parameters which affect most the model output during calibration since SWAT model has a number of parameters to deal with some parameters do not have any influence on the model output while some may have little effect,

4.1.1 Parameters sensitive to flow

The 18 parameters listed in table 4.1 and figure 4.1 were used in sensitiveity analysis . these parameters are used to calculate the amount of flow from the watershed. For calibration using the mounthly flow data from 2000 to 2013

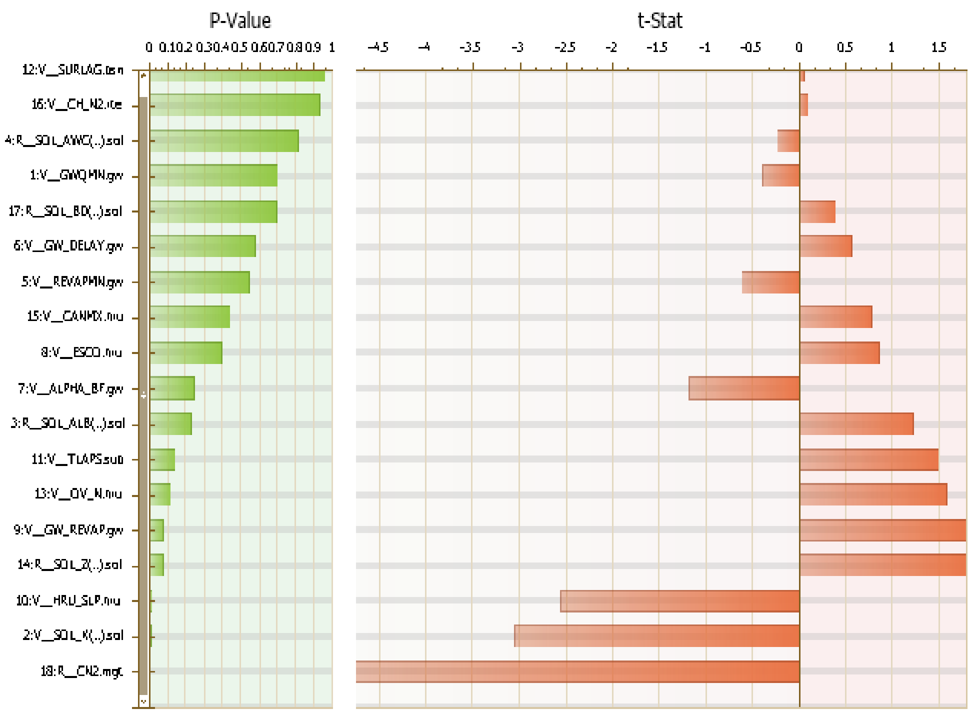


Figure 4.1 shows the all parameters and identifying sensitive parameters of flow

Table 4.1 Shows All Parameters of Flow

s.no	*Parameter*	*description of parameter*	*Rang*		*t-Stat*	*P-Value*	*Rank*
			Min	Max			
1	CN2	SCS runoff curve number	0.1	0.2	-4.8	0	1
2	SOL_K	Saturated hydraulic conductivity	0	92	-3	0	2
3	HRU_SLP	Average slop steepness	0	0.3	-2.6	0	3
4	SOL_Z	Depth from soil surface to bottom of layer	1.5	2.8	1.8	0.1	4
5	GW_REVAP	Ground water revamp coefficient	0	0.3	1.8	0.1	5
6	OV_N	Meaning n value for over land flow	10	23.4	1.6	0.1	6
7	TLAPS	Temperature lapse rate	-9.5	-0.9	1.5	0.1	7
8	SOL_ALB	Moist soil albedo	0.2	0.6	1.2	0.2	8
9	ALPHA_BF	Base flow alpha factor for bank of storage	0.22	0.68	-1.18	0.24	9
10	ESCO	Soil evaporation compensation factor	0	0.33	0.86	0.39	10
11	CANMX	Maximum canopy storage	0.16	1.84	0.78	0.44	11
12	REVAPMN	Threshold depth of water in the shallow	0.47	1.74	-0.61	0.54	12
13	GW_DELAy	Ground water delay	0	0.27	0.55	0.58	13
14	SOL_BD	Moist bulk density	1.17	1.79	0.39	0.69	14
15	GWQMN	Threshold depth of water in the shallow aquifer for return flow occur	0.916	1.797	0.385	0.701	15
16	SOL_AWC	Available water capacity on the soil layer	0.748	1	0.234	0.815	16
17	CH_N2	Base flow alpha factor for bank of storage	0.053	0.228	0.089	0.929	17
18	SURLAG	Surface runoff lag time	6.642	20.15	0.051	0.96	18

4.1.2 Global sensitivity analysis

Global sensitivity analysis was done for the parameters shown in Table 4.1. According to the result from the global sensitivity analysis, the curve number (CN2) was found to be the most sensitive parameter. Other parameters saturated hydraulic conductivity (SOL_K), average slop steepness (HRU-SLP), Depth from soil surface to bottom of layer (SOL_Z), Temperature lapse rate (TLAPS) and ground water revamp coefficient (GW_REVAP position as shown in Table 4.2 below. Here, t-stat provides a measure of sensitivity and hence larger in absolute values are more sensitive. On the other hand, P-value indicates the significance of the sensitivity and hence a value close to zero has more significance. Therefore, ranking in both cases (t-stat or P-value) give the same result i.e. a parameter will have the same rank whether it is ranked based on the t-stat or P-value.

Table 4.2 shows global sensitive parameters of fitted value of flow

s.no	*Parameter Name*	*parameter description*	*Fitted Value*	*Min value*	*Max value*
1	SOL_K	Saturated hydraulic conductivity	34.868	0.000	92.001
2	GW_REVAP	Ground water revamp coefficient	0.250	0.000	0.274
3	HRU_SLP	Average slop steepness	0.006	0.000	0.255
4	OV_N	Meaning n value for over land flow	20.546	9.975	23.407
5	SOL_Z	Depth from soil surface to bottom of layer	1.700	1.523	2.835
6	CN2	SCS runoff curve number	0.105	0.079	0.166

4.1.3 Parameters sensitive to sediment

The most sensitive parameters for erosion simulations were, sediment concentration in runoff, after urban BMP is applied (SED_CON), Base flow alpha factor for bank of storage (CH_N2), SCS runoff curve number (CN_2), Moist soil albedo (SOL_ALB), USLE soil erodibility factor (USLE_K) and Available water capacity on the soil layer (SOL_AWC). Other parameters included in the table below were also affecting the soil erosion simulation from a catchment (from upland) and from the channel (in stream sediment). The parameters that were used to evaluate the sensitivity to sediment are show into see which parameter is highly sensitive to sediment from the list show below table 4.3

Before calibrated and validated sediment, calibrated sediment by using monthly data from January 2000 to December 2013 to identifying sensitive parameter. As the sediment transport consists of landscape and channel components each transport component is affected by different factors. The parameters used in the sensitivity analysis are related to the corresponding transport component. Therefore, the parameters can be categorized in to upland factors which affect the landscape component of the sediments transport and factors which affect the channel component of the sediment transport. Occupy higher rank in the table that shows upland parameters are very sensitive in this case. The sensitivity parameter were base flow alpha factor for bank of storage (CH_N$_2$), SCS runoff curve number (CN$_2$), USLE soil erodibility factor (USLE_K), Sediment concentration in runoff, after urban BMP is applied (SED_CON), Available water capacity on the soil layer (SOL_AWC) and Moist soil albedo (SOL_ALB).

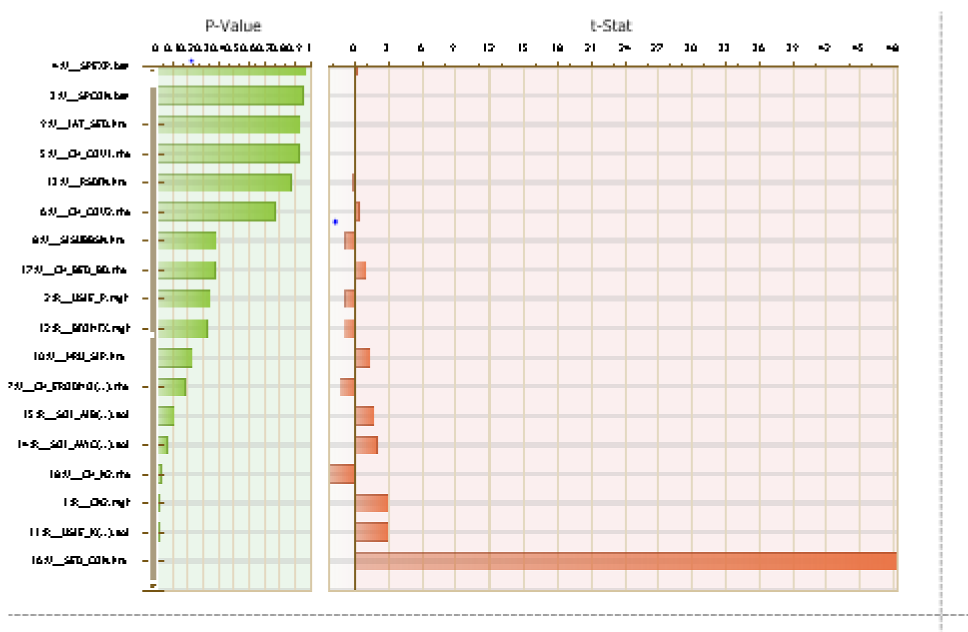


Figure 4.2 shows all parameters and identifying sensitivity parameters of sedimen

Table 4.3 shows the all parameters of sediment

s.no	Sediment SWAT CUP parameters	Description of parameter	Range		t-stat	P-value	rank
			Min	max			
1	SED_CON	Sediment concentration in runoff, after urban BMP is applied	252.2	340	52.67	0	1
3	USLE_K	USLE soil edibility factor	0	0.01	2.934	0.004	2
2	CN2	SCS runoff curve number	0.2	0.2	3.516	7.00E-04	3
4	CH_N2	Base flow alpha factor for bank of storage	0.16	0.16	-2.59	0.011	4
5	SOL_AWC	Available water capacity on the soil layer	1.15	1.44	1.979	0.051	5
6	SOL_ALB	Moist soil albedo	0.04	0.04	1.647	0.103	6
7	CH_ERODMO	Jan. channel erodibility factor	0.07	0.09	-1.353	0.18	7
8	HRU_SLP	Average slope steepness	0.79	0.87	1.228	0.223	8
9	BIOMIX	Biological mixing efficiency	0.01	0.01	-0.992	0.324	9
10	USLE_P	USLE support practice factor	0.15	0.18	-0.94	0.349	10
11	CH_BED_BD	Moist bulk density	1.04	1.09	0.913	0.364	11
12	SLSUBBSN	Average slope length	27.04	27.9	-0.897	0.372	12
13	CH_COV2	Channel cover factor	0.097	0.11	0.294	0.769	13
14	RSDIN	Initial residue cover	0.76	1.12	-0.15	0.884	14
15	CH_COV1	Channel edibility factor	0.129	0.15	-0.087	0.93	15
16	LAT_SED	Sediment concentration in lateral flow and groundwater flow	0.44	1.32	-0.08	0.938	16
17	SPCON	Linear parameter for calculating the maximum amount of sediment that can be restrained during channel sediment routing.	0.003	0	-0.057	0.954	17
18	SPEXP	Exponential re-entrainment parameter	1.55	1.6	0.04	0.968	18

Table 4.4 shows global sensitive parameters of fitted value of sediment

s.no	*Parameter Name*	*Description of parameter*	*Fitted Value*	*Min value*	*Max value*
1	CN2	SCS runoff curve number	0.199842	0.199731	0.201011
2	USLE_K	USLE soil edibility factor	0.008476	0.005998	0.009204
3	SOL_AWC	Available water capacity on the soil layer	0.9933	0.9000	1.000
4	SOL_ALB	Moist soil albedo	0.040189	0.03753	0.04191
5	SED_CON	Sediment concentration in runoff, after urban BMP is applied	344.12036	293.882629	379.1759
6	CH_N2	Base flow alpha factor for bank of storage	0.157837	0.155257	0.160115

4.2 **Model calibration and validation**

4.2.1 Flow calibration

SWAT 2012 model was calibrated and validated using measured stream flow data at Chacha gauged station. The flow data of chacha watershed was includede from the period Janaury 2000 to December 2013. These availability data was collected from MOWIE. From those total stream flow data two-third used for calibration purpose and one–third used for validation purpose. The calibration period was contains from January 2000 to December 2009, which was nine yeas and the validation period carried out four years from January 2010 to December 2013. The over all performance of the model during calibration has been measured using coefficient of determination (show table 4.5)(R^2) and Nash Sutcliff Efficiency (NS) value as 0.85 and 0.84 respectively. Figure 4.3 shows below the observed and simulated values after swat cup calibration process

Table 4.5 Monthly simulation and observed flow calibration output

Time	Average flow		Model efficiency	
Jan 2000-2009	simulated	observed	R^2	Ns
	6.12	4.98	0.85	0.84

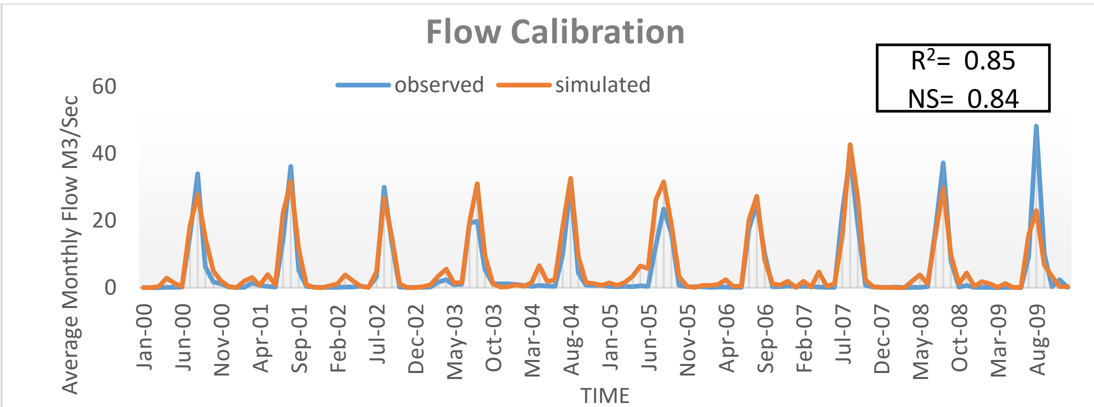


Figure 4.3 The Above Graph Shows Monthly Calibration of Observed and Simulated Flow

The graph fig 4.3 the calibration period of the observed and simulated of flow match overlap with monthly measured flow. Due to seasonal variability and monthly average discharge were generally at some points over estimated with low flow period and slightly over estimate when the period peak flow (for example august 2003 and august 2005). And highly underestimates the peak monthly flow in August 2009.

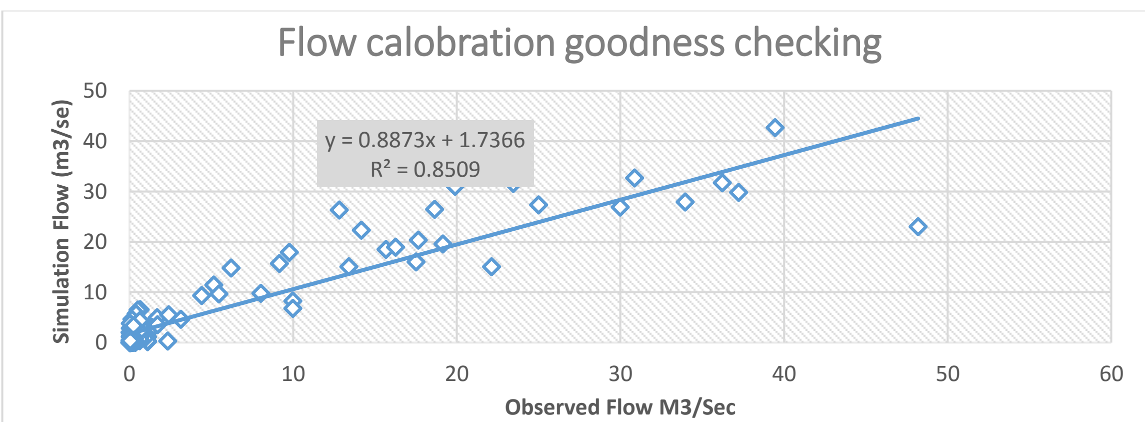


Figure 4.4 The Graph Shows Fit Line Observed and Simulated for Flow Calibration from 2000-2009

The observed and the simulated values of the flow calibration were plotted against each other to determine the goodness-of-fit criterion of the model sub-catchments (Fig 4.4)

4.2.2 Flow validation

Model validation results is necessary to increase user confidence. It involves re-running the model using the input data and without any adjustment of calibration parameters at different time period. Therefore, for this study the model validation carried out monthly flow from January 2010 to December 2013 from four-year data. Figure 4.5 shows below the observed and simulated values after swat cup validation process. The coefficient of determination as show table 4.6 (R2) is 0.66 and Nash Sutcliffe Efficiency (NSE) is 0.66.

Table 4.6 monthly simulation and observed flow validation output

time	*Average flow*		*Model efficiency*	
Jan 2010-2013	simulated	observed	R^2	Ns
	6.84	6.32	0.66	0.66

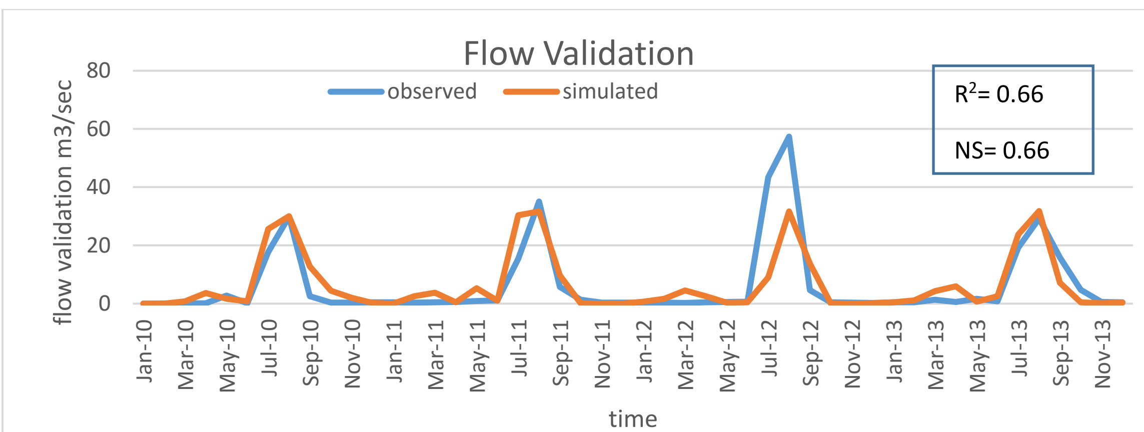


Figure 4.5 Graph Shows Monthly Validation of Observed and Simulated of Flow 2010-2013

The graph of the validation period of the observed and simulated flow in monthly estimation, the model slightly over estimates some of the low flows of the months, like in the September 2010 to May 2011, March 2012 and March 2013; and some of the month's peak flows of month were also under estimated by the model in the period between Jun 2012 to September 2012 of validation period. This result occurred from the quality of weather or flow data used as an input to the model. Some of the stations have many over missed recorded with comparing to other periods so that the model out put under or over estimated. Using estimated data may influence the simulation output. Additionally, mistake in measurement of flow and weather data may be another reason for the slight variation between measured and simulated flows at peak and under discharges.

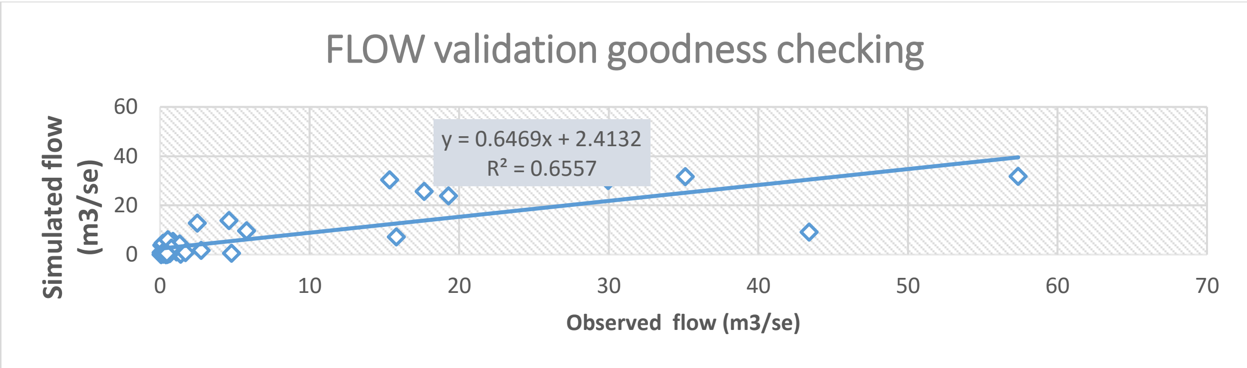


Figure 4.6 The Graph Shows Fit Line of Observed and Simulated for Flow Validation 2010-2013

The observed and the simulated values of the flow validation were plotted against each other to determine the goodness-of-fit criterion of the model sub-catchments (Figure 4.6). comparison for other thesis reports so that (Tesfa G, 2016) reported that SWAT model showed a good match between measured and simulated flow of Dedissa watershed both in calibration and validation periods with (NSE = 0.76 and R2= 0.80) and (NSE =0.7and R2= 0.79), respectively. Through modeling of Lake Tana basin (Shimelis et al., 2008) indicated that the average monthly flow simulated NSE =0.81 and R2=0.85 for calibration and NSE = 0.79 and R2 = 0.80 for validation periods. According to ((Tesfay, 2017) on Gefersa reservoir flow calibration and validation (NSE = 0.52and R2= 0.57) and (NSE =0.61 and R2= 0.65), respectively. This indicates that SWAT cans sufficiently reasonable result in the upper Blue Nile basin and hence the tool can be used in similar watershed.

4.2.3 **Sediment Calibration**

SWAT model were calibrated for monthly sediment yield where after calibration and validation of stream flow at the chacha dam gauged station. The observed sediment data based on the rating curve of chacha gauged station around the dam site. The modeling was comparing observed sediment with model simulated sediment for the calibration period from 2000 to 2009. The SWAT model performance evolution simulation monthly sediment yield at gauged station. The coefficient of determination show table 4.7 (R2) value is 0.7 and Nash-Sutcliff model efficiency (NSE) value is 0.7. The graphical comparison of measured and simulated sediment yield shown in figure (4.7)

Table 4.7 Monthly simulation and observed sediment calibration output 2000-2009

time	*Average Sediment*		*Model efficiency*	
Jan 2000 -	Simulated	observed	R^2	NSE
2009	6274.391	6087.378	0.7	0.7

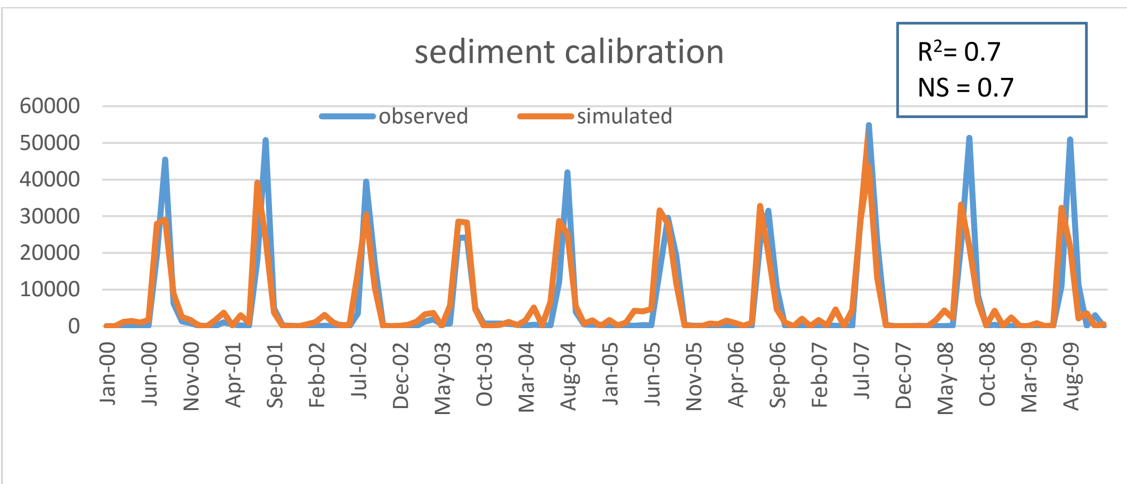


Figure 4.7 graph shows monthly calibration of observed and simulated sediment

87.basis shows the model slightly over-estimated some of low period monthly sediment yields of the watershed and when the period of peak slightly under estimate the sediment yield. Similarly, to flow calibration the peak monthly flow in August 2009 highly underestimates because the flow data using to calculating sediment rating curve.

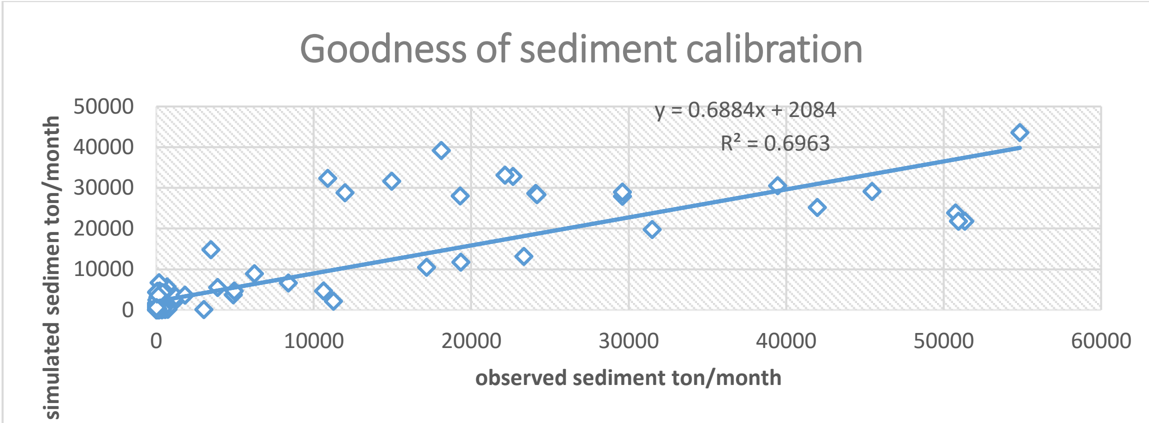


Figure 4.8 graph shows fit line of observed and simulated for sediment calibration from 2000-2009

The observed and the simulated values of the sediment yield were plotted against each other to determine the goodness-of-fit criterion of the model sub-catchments (Figure 4.8). The coefficient of determination show table 4.7 (R^2) and the Nash-Sutcliffe efficiency were found to be 0.7 and 0.7 respectively. Between 1.0 (perfect fit) and –ve infinitive. Since the NS coefficient is sensitive to extreme values (as it squared the difference of observed and simulated values), it might yield sub-optimal results when the dataset contains large outliers

4.2.4 Sediment validation

SWAT model monthly sediment validation was done after sediment calibration without further parameter adjustment. The model monthly validation period is different from the calibration period. Validation was performed for three years from January 2010 to December 2013. The correlation coefficient show table 4.8 (R^2) is 0.74 and Nash-Sutcliffe Efficiency (NS) is 0.74. Those value show that a good agreement between observed and simulated sediment. Fig 4.9 and 4.10 shows the model monthly observed and simulated for validation and the fitted line observed and simulated sediment for validation period respectively

Table 4.8 Monthly simulation and observed sediment validation output

Time	*Average sediment*		*Model efficiency*	
Jan 2010-2013	simulated	observed	R^2	Ns
	6881.377	6937.628	0.74	0.74

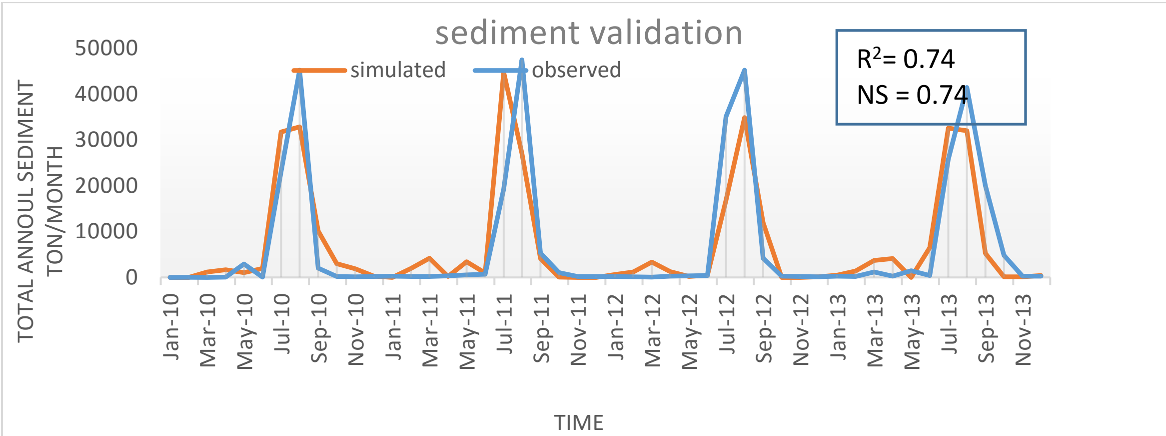


Figure 4.9 graph shows monthly validation of observed and simulated sediment 2010-2013

The observed and simulated sediment yield in monthly time step of the validation period shows that model slightly over estimate at low time periods, and under estimated at peak time period between Jun in low and medium periods the model simulation and the observed sediment yield were good fit but there was also in some months under estimation. This result occurred from the quality of weather or flow data used as an input to the model. Some of the stations have many missing weather data which were left to be estimated and filled by different data miss filling method

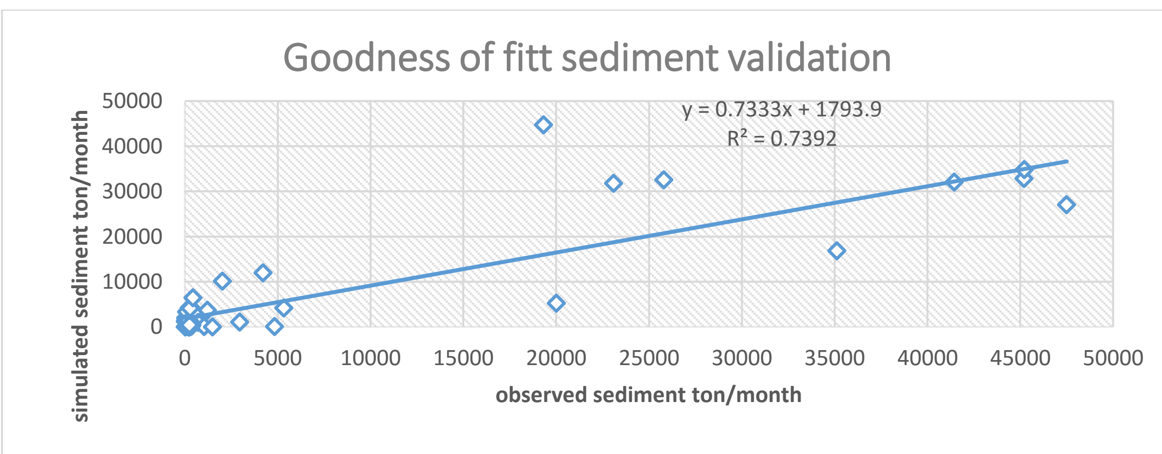


Figure .4.10 Graph shows Goodness fit of observed and simulated sediment validation from 2010-2013

The observed and the simulated values of the sediment yield were plotted against each other to determine the goodness-of-fit criterion of the model sub-catchments show fig 4.10. The coefficient of determination (R2) and the Nash-Sutcliffe efficiency were found to be 0.74 and 0.74 respectively. Between 1.0 (perfect fit) and –ve infinitive. Since the NS coefficient is sensitive to extreme values (as it squared the difference of observed and simulated values), it might yield sub-optimal results when the dataset contains large outliers.

From the above calibration and validation output of the total observed and simulated of sediment yield in the chacha catchment at the dam site of calibration from 2000 to 2013 is 1063491 ton and 1083233 ton respectively. Therefore, SWAT model is good result for the estimation of catchment sediment yield in the study area. The result indicated that the model simulation almost similar to the observed sediment yield.

The total annual sediment yield from catchment in to the reservoir during calibration and validation period was estimated using SWAT model is 83321.61 ton/year. Based on this result 83321.61 ton/year sediment enter into the reservoir. The total catchment area of the study area is 577.5 km2. Therefore, the annual specific sediment yield from the catchment can be calculated as the total sediment yield divided by the area of the catchment which is equal to 144.28 ton/km2/year.

4.2.5 Comparison with previous studies and estimates sediment yield from another reservoir

Before different SWAT model thesis calibration proceeds, the performance of the model was evaluated from the initial simulation with model default parameter values. The simulation results according to (Santhi et al., 2001 study daily time step the R2, NSE were 0.55 and 0.48 respectively. So, in the daily time step the estimation of sediment yield by the model were under the acceptance limit of the SWAT developer's recommendation (i.e. $R^2 > 0.6$ and NSE > 0.5 (The model over predicted the sediment yield from Chitlang Khola sub-catchment compared to the observed sediment yield.

On 19th of July the model predicted 358.3 tons of sediment yield whereas the measured sediment on the same date was only 2.9 tons per given hours while rainfall event on 19th of

July 2004 was 67.5 mm. Therefore, the model responded well for rainfall event. The coefficient of determination (R2) and the Nash-Sutcliffe efficiency were found to be 0.54 and 0.53 for Palung Khola and 0.40 and 0.1 for Chitlang Khola. The range of Nash-Sutcliffe efficiency varies between 1.0 (perfect fit) and Since the NS coefficient is sensitive to extreme values (as it squared the difference of observed and simulated values), it might yield sub optimal results when the dataset contains large outliers ((Lemma, 2015)

The sediment yield estimation ((Mengist, 2017) of Gelana catchment annual specific sediment yield from the catchment area (644.28km^2) was 89.14 ton/km2/year. The specific sediment yield for Palung Khola ((Lemma, 2015)sub-catchment of 62 km2 area was 137.4 tons/km2. The mean annual sediment load estimates by (USBR, 1964) and (BCEOM, 1999) for the Ribb dam site were 260,000 tons (363 ton/km2/year) and 490,000 tons (675 ton/km2/year) respectively. Design report of MoWE estimate 897 ton/km2/year based on the 1964 -2005 data it is higher than the above-mentioned estimates for the dam site. According to (Tensay, 2011) SWAT model estimate of Ribb Dam reservoir sediment load of 72.79 ton/km^2/year is very much less than the previous studies at dam site but very close to study of BCEOM (1999) for Upper Ribb River near Debre Tabor which is down stream of dam site and Sedimentation modeling for Ribb dam (catchment area 844km2), estimation of the average annual sediment yield is 72.79 ton/km2/year. Sediment management in Gibe I reservoir (catchment area 3602km2), estimation of average annual sediment yield is 106.178 ton/km2/year (TUfa, 2016).

4.3 Temporal and spatial variation of sediment in Chacha watershed

4.3.1 Temporal sediment variation

Sediment was affected the Seasonal variation throughout different years. The temporal variation of sediment yield characteristic of the entire sub-catchment has been computed with SWAT model. Catchment sediment yield is a function of catchment size, land use, soil type, slop and climate.

Table 4.9 The temporal variation of sediment in the chacha dam reservoir.

S.No	Year	Sediment Load (Ton)
1	2000	206551.3475
2	2001	212512.4817
3	2002	142676.8664
4	2003	209702.5914
5	2004	204459.8047
6	2005	291188.2626
7	2006	186379.5602
8	2007	313473.3633
9	2008	188237.6976
10	2009	162838.6909
11	2010	116926.5092
12	2011	190833.2722
13	2012	215480.1211
14	2013	151494.4589
15	2014	139516.0501
16	2015	125118.237
17	2016	277401.0309

The maximum sediment deposing recorded in the period of 2007 and 2016 (table 4.9) which value is 313473.3633 and 277401.03 respectively but the period 2010 and 2015 which value 116926.5 and 125118.237 respectively reduced sedimentation. Therefore, sediment yield varies from season to season due to wide spread of cultivated area and uneven distribution rainfall in the basin

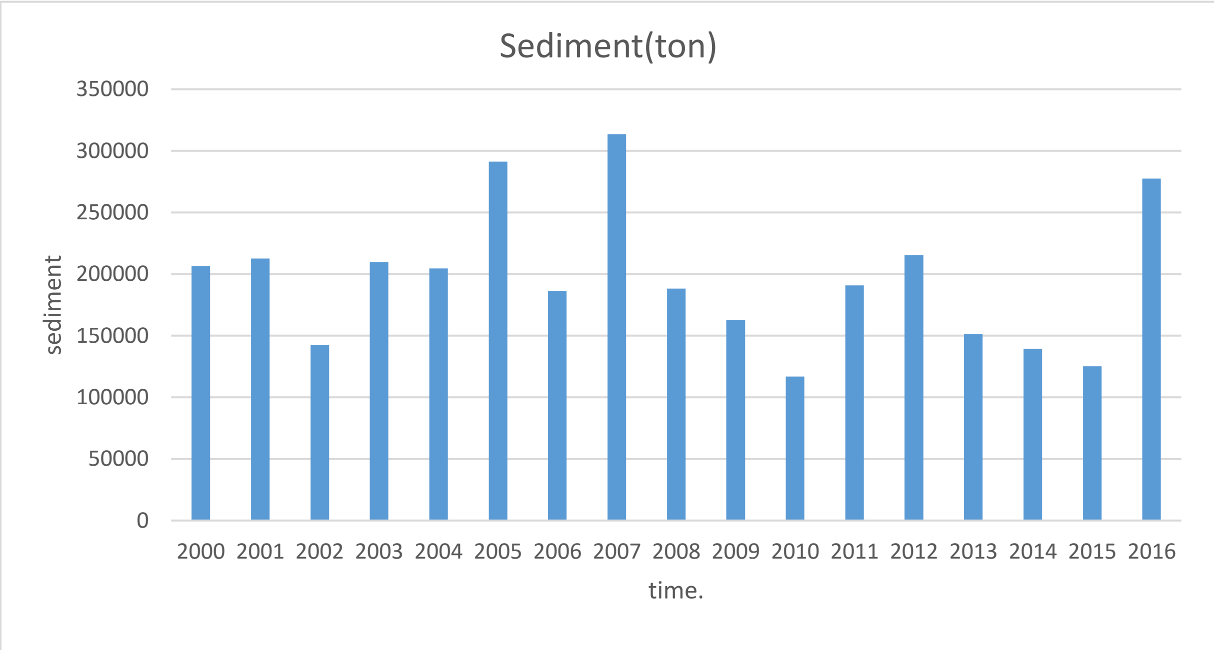


Figure. 4.10 graphical show of temporal variation of sediment

4.4 Spatial Distribution of Sediment

The spatial variability of sedimentation rate was identified and shown in figure 4.11 and based on which the potential area of intervention can identified. The average annual yield of sedimentation for each sub-basin was used to generate sediment source map shown in Figure 4.10. The output of SWAT model showed from 23 Sub-basin of chacha watershed the existing condition sub-basin 18 was generates a maximum annual average sediment yield of 39.51 ton/ha. It is the most erodible sub-basin in chacha catchment this was attributed due to the topographic slope and land use of this sub-basin. It was an agricultural land cover 44.32% and pasture land cover 55.2% from total area of catchments. And the minimum yield of 0.66 tons/ha was obtained for sub-basin 6, its land coverage was 100% agricultural land.

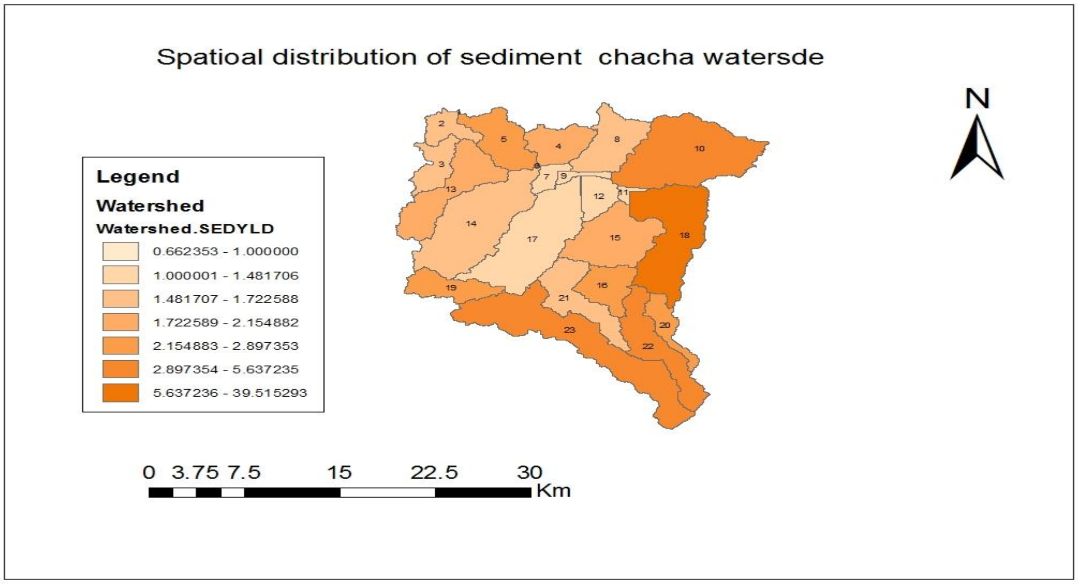


Figure 4.11 sediment yield spatial variation of in chacha sub-basin

Table 4.10 spatial variation of sediment in chacha watershed

sno	*Sub-basin*	*Yearly sediment (ton/ha)*	*s.no*	*Sub-basin*	*yearly sediment(ton/ha)*
1	1	1.3184	13	13	2.0231
2	2	1.7226	14	14	1.6736
3	3	1.6665	15	15	2.0062
4	4	2.1549	16	16	2.8974
5	5	2.3829	17	17	1.2534
6	6	0.6624	18	18	39.5153
7	7	1.4817	19	19	2.5377
8	8	1.6061	20	20	2.5166
9	9	1.2832	21	21	1.574
10	10	5.3694	22	22	5.6012
11	11	1.3608	23	23	5.6372
12	12	1.4042			

According to (Zelalem, 2016), the runoff sediment yield modeling using Soil and Water Assessment Tool for management planning of Mojo watershed Ethiopia, Shows the estimated soil loss rate from different sub-watershed ranges from 2 t/ha/year to 204 t/ha/year. The sediment yields for sub-catchment of this study was different; this is due to the combined effect of factors such as land use, soil type and slope. (Hurni, 1985) had conducted a research to estimate the rate of soil formation for Ethiopia and found that the range of tolerable soil loss level for various agro-ecological zone of Ethiopia from 2 to 18 tons/ha. The sediment yields for sub-catchment of this study was different; this is due to the combined effect of factors such as land use, soil type and slope. Table 4.10 and figure 4.11 show the spatial distribution of sediment in the chacha catchment.

4.5 Scenario development for appropriate reduction measure

As Watershed management intervention involves introducing of best management practices to reduce soil erosion and sediment transport. The SWAT model was applied to simulate the impact of best management practices on sediment yield reduction in the U.S. In the study area, as the information gathered from chacha basin woreda Agricultural office and visual observation, the study area has already physical soil and water conservation measures such as terraces, cut-off drain, soil bunds, water way, moisture harvesting structure(micro basin and deep trench), Gabion check dams, Gully treatment through biological and physical methods and check dams, these measures were not effective and many land areas have been damaged by runoff and failure of the structures where physical measures were practiced

According to the output from the model among the land use/cover of the area agricultural Land covers high amount of area and it is the source of the sediment of an area, and also the forest Deciduous, pasteurized and Range-Grasses covers small area and contribute little sediment to chacha Watershed. The important of SWAT model is the ability to build different scenarios. Scenarios are reasonable and often simplified description of how the future may develop based on coherent and internally consistent of assumption about key driving force and relationships. Scenario analysis is a process of evaluating possible future events through the consideration of alternative possible outcomes.

From model output HRU report 87.53 % of Chacha dam catchment is agricultural land. It is the most vulnerable area that affected by soil erosion and source of sedimentation. Therefore, to minimize soil erosion and sediment deposing in the chacha reservoir scenario development important for future plan. The solution was change agriculture land use to forest mixed to minimize sediment loading in to the reservoir. From those alternative agricultural land changed to forest mixed land is high amount of sediment reduction when compare to others. The second solution 12% of pastureland use changing to forest mixed land use. Therefore, scenario development was made by agricultural land changed to forest mixed cover by 10%, 20%, 30%, 40%, 50% and 60% .and the third solution is changing HRU definition at different land use, soil and slope level. The scenario is shown below step by step.

1 **The first scenario agricultural land change to mixed land**

So = Original land

Scenario1 (S1) = 10% Agricultural land change to forest mixed land

Scenario2 (S2) = 20% Agricultural land change to forest mixed land

Scenario3 (S3) = 30% Agricultural land change to forest mixed land

Scenario4 (S4) = 40% Agricultural land change to forest mixed land

Scenario5 (S5) = 50% Agricultural land change to forest mixed land

Table 4.11 scenario Agricultural land change to forest mixed land

Scenario	Annul Total Sed In (Ton)	Change Of Sed In Ton	Percentage
s0	3633436.325	0	0
s1	3193843.892	439592.4323	-12.099
s2	2949351.845	684084.4797	-18.827
s3	2638754.616	994681.7085	-27.376
s4	2550974.735	1082461.59	-29.792
s5	2403945.99	1229490.334	-33.838

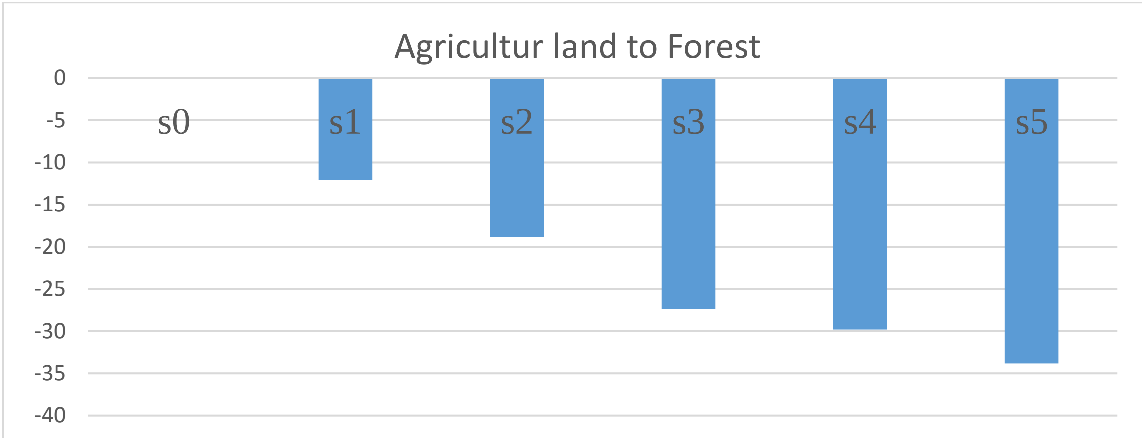


Figure 4.12 scenario of agriculture land change to forest mixed land

2 The second scenario pastureland use change to forest mixed land

So = Original land

Scenario1 (S1) = 20% pasture land change to forest mixed land

Scenario2 (S2) = 50% pasture land change to forest mixed land

Scenario3 (S3) = 70% pasture land change to forest mixed land

Scenario4 (S4) = 90% pasture land change to forest mixed land

Table 4.12 scenario pastureland use change to forest mixed land

Senario	*Annoul sediment in ton*	*change of sediment in ton*	*change in percentage*
S0	3633436.325	0	0
S1	3323437.48	309998.845	-8.532
S2	3306463.241	326973.0831	-8.999
S3	3292879.788	340556.5366	-9.373
S4	3280426.251	353010.0736	-9.716

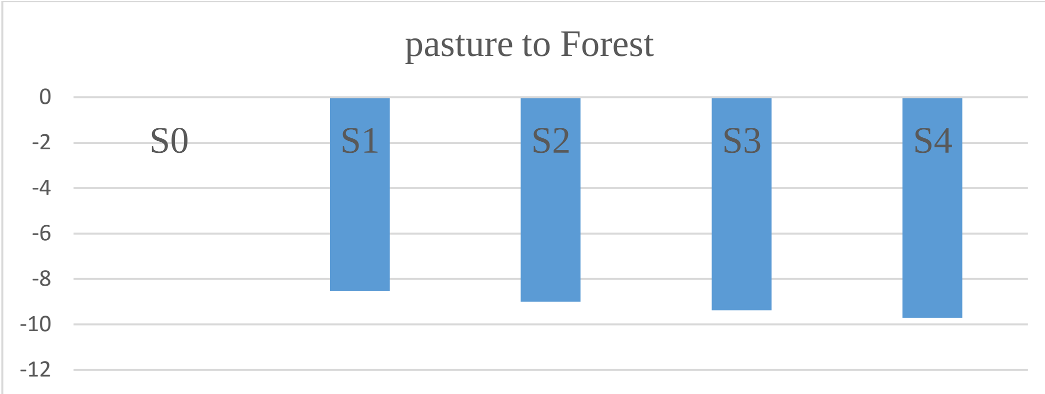


Figure 4.13 scenario of pasture land use change to forest mixed

3 Scenario development and analysis for HRU

The multiple slope option 5%, 15% and 20% for Land use, soil and Slope class respectively was selected in SWAT model as mentioned in methodology. But by changing this HRU definition the sediment load of the area is also changed

Table 4.13 Scenario Development and Analysis for HRU

scenario	***% of Land use/soil:/slop percentage***	***Total sediment load in ton***	***sediment change in ton***	***sediment change in percentage***
s0	5:15:20	3633436	0	0
s1	5:20:15	3364526	268910.01	-7.40
s2	5:10:15	3567803	65633.64	-1.81
s3	15:10:20	3349160	284275.87	-7.82
S4	10;20:20	3313336	320099.98	-8.81
S5	10:05:20	3562957	70479.58	-1.94
S6	10:10:15	3149822	483614.57	-13.31

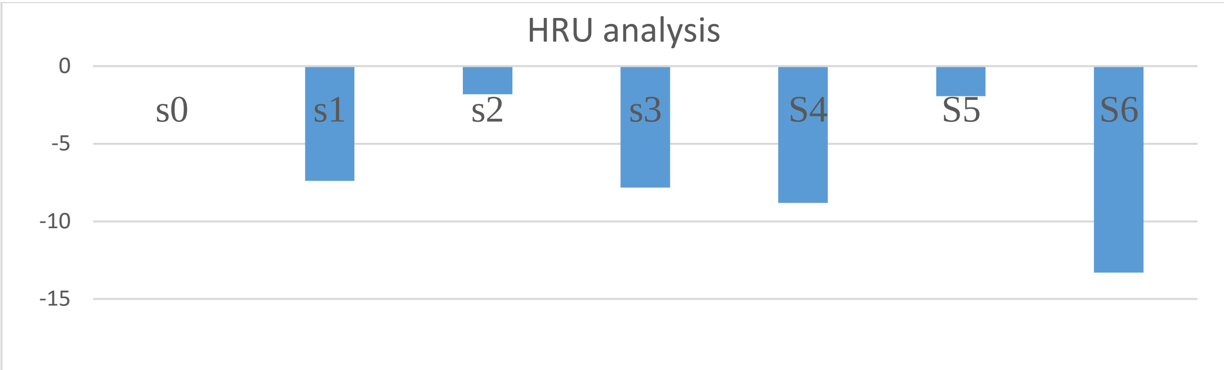


Figure 4.14 scenario of Analysis for HRU

4. **Scenario development and analysis for constructing terrace**

Terracing: a terrace is an embankment within a field designed to intercept runoff and prevent erosion. It is constructed across slope on a contour. Terracing in SWAT is simulated by adjusting both erosion and runoff parameters (Arnold, 2012). The USLE practice (TERR_P) factor, the slope length (TERR_SL) factor and curve number (TERR_CN) were adjusted to simulate the effects of terracing. The following five scenarios is special reducing sediment by constructing terrace

Table 4.14 scenario development by construction terrace

scenario numbe	TERR-P	TER-CN	TERR-SL	TOTAL SEDI(TON)	Reducised load	reducing percentage
s0	0.5	60	20	3633436.325	0	0
s1	1	60	20	3352809.258	280627	-7.7235
s2	0.5	90	25	3325726.315	307710	-8.4688
s3	1	82	25	3312365.042	321071	-8.8366
s4	0.5	80	25	3332052.324	301384	-8.2947
S5	1	82	20	3160623.473	472813	-13.0128

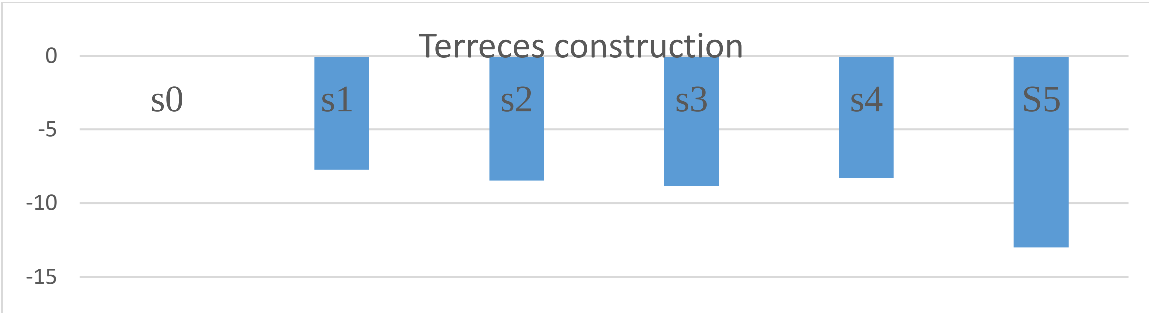


Figure 4.15 the graph shows terraces construction

5. **Scenario development and analysis for constructing filter strip**

Filter Strips: A filter strip is a strip of dense vegetation located to intercept runoff from upslope pollutant sources and filter it. Filter strips increase sediment deposition by reducing overland flow velocity before it joins the tributary and main channel. Filter strips in SWAT model adjusting VFSL (Flag for the simulation of filter strips), VESRATIO (Ratio of field area to filter strip area (ha2/ ha2), VESCON (Fraction of the HRU which drains to the most concentrated ten percent of the filters strip area (ha2/ ha2) and VFSCH (Fraction of the flow within the most concentrated ten percent of the filter strip which is fully channelized (dimensionless)) reduce sediment, nutrients, bacteria, and pesticides, but do not affect surface runoff in SWAT (Arnold, 2012). Like terrace the following five scenarios is special reducing sediment by constructing filter strip

Table 4.15 Scenario Filter Striping

scenario number	VFSL	VESRATIO	VFSCON	VFSCH	TOTAL SEDI(TON)	Reduced sed load	reducing percentage
s0	0	10	0.5	90	3633436.32	0	0
s1	0	30	0.25	80	3351574.43	281861.9	-7.7574
s2	0.5	20	0.75	100	3286566.17	346870.2	-9.5466
s3	0	25	0.5	90	3334781.32	298655	-8.2196
s4	1	10	0.25	100	3334774.17	298662.2	-8.2198

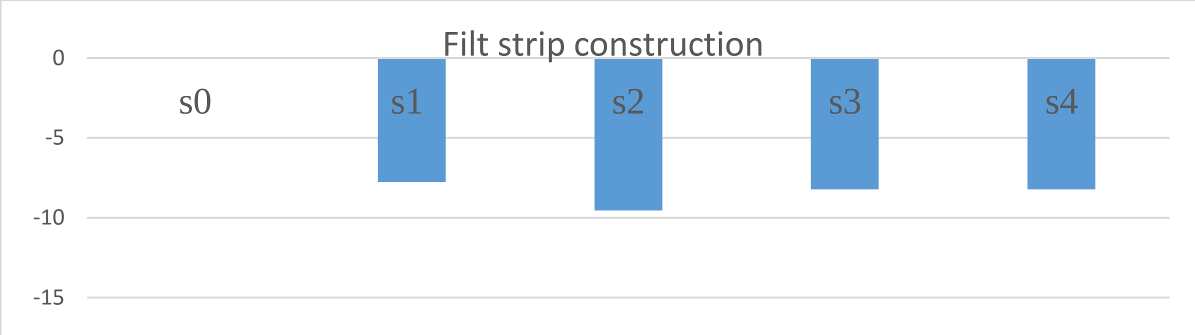


Figure 4.16 shows scenario of filte strip

The SWAT model prediction for the chacha sub basin was 144.28 t/km^2/year, this result is quite comparable with a study conducted where chacha sub-basins was found the highest sub-basins that yields high sediment yield loading from the sub catchments of Abbay Basin. However, running the model with different catchment management scenarios provide quit good results.

The selected critical sub basin level showed spatial variability on sediment reduction from baseline conditions as is shown above in Table (4.11, 4.12, 4.13, 4.14 & 4.15). The sediment reductions for selected critical sub basin ranged from 12% to 33.8% reducing sediment yield at changing 10% to 50% values of agriculture land to forest mixed land. Scenario. The second reduction solution as changing 20% to 90% postural lands to forest lands from this solution 8.5 to 9.7 % of sediment yield reduced. The third solution is changing HRU definition at different land use, soil and slope class reduction 1.8 to 13.3% of sediment yield. The fourth solution is construction of filter strip and terrace at different land use, soil and slope class reduction 7.7 to 13% for terrace and 7.75 to 9.54 for filter strip of sediment yield. Thus, from above scenario changing agriculture to forest mixed was more effective to reduce sediment than another scenario which is up to 33.8% with changing 50% of agriculture land use to forest. But, 50% of agriculture land change is difficult according to the basic need of farmer socio-economic activity. Thus, the best management practice is changing 30% of agriculture land to forest which reduces 27.3% of sediment yield.

5. CONCULUSION AND RECOMANDETION

5.1 Conclusion

SWAT mode for Chacha watershed was successfully estimate the sediment yield in the chacha and to reducing uncertainty and increasing user confidence Calibration and validation by using SWAT CUP, which makes the application of the model for decision making. SWAT model processed watershed delineation and simulated. The HRU analysis resulted 23 sub-basins and 80 HRUs based on 5% land use, 15% soil and 20% slop classification.

The important parameters were identified for calibration based on the sensitivity analysis using the SWAT CUP model. The most stream flow sensitive parameters are the curve number (CN2) was found to be the most sensitive parameter. Other parameters saturated hydraulic conductivity (SOL_K), average slop steepness (HRU-SLP), Depth from soil surface to bottom of layer (SOL_Z), Temperature lapse rate (TLAPS) Ground water revamp coefficient (GW_REVAP). and the most sediment sensitive parameters were , base flow alpha factor for bank of storage (CH_N2) SCS runoff curve number (CN2) USLE soil edibility factor (USLE_K), Sediment concentration in runoff, after urban BMP is applied (SED_CON). Available water capacity on the soil layer (SOL_AWC) and Moist soil albedo (SOL_ALB) Automatic model calibration was performed for stream flow and sediment yield at Tore gauged station. The steam flow calibration period 2000-2009and validation period 2010-2013. The model performance evolution during monthly stream flow calibration and validation period indicated that R2=0.85, NS=0.84 and R2=0.66, NS=0.66 respectively.

Sediment data taken from the rating curve equation for the period 2000-2013. The model calibration period is 2000-2009 and the validation period is 2010-2013. The model performance evaluation during monthly sediment yield calibration and validation period indicated that R2=0.7, NS=0.7 and R2=0.74, NS=0.74 respectively. The total observed and simulated of sediment yield in the chacha catchment at the dam site of calibration from 2000 to 2013 is 1083491 ton and 1103192 ton respectively. The total annual sediment yield from catchment in to the reservoir during calibration and validation period was estimated using SWAT model is 83321.61 ton/year. The annual specific sediment yield from the catchment can be calculated as the total sediment yield divided by the area of the catchment which is equal to 144.28 ton/km2/year. The maximum sediment deposing recorded in the period of 2007 and 2016 which value is 313473.3633 and 277401.03 respectively but the period 2010 and 2015 which value 116926.5 and 125118.237 respectively reduced sedimentation. The SWAT model output Sub-basin 18 was generates a maximum annual average sediment yield of 39.51 ton/ha, it indicates sub-basin 18 was most erodible than others. The best management practice is 30% of agriculture land change to forest which is 27.3% reducing sediment yield.

5.2 Recommendation

This study depends on the secondary data collected from different organizations and agencies as its input and simulation of the final model result. But the primary and representativeness of these data will be used for better result. Because of the quality of input data continues measuring of sediment data

The sediment data used for this study were generated from sediment rating curves developed from limited sediment measurement data. Therefore, possible discrepancy of actual sediment and sediment data derived based on rating curves. However, superior results can be obtained if detail suspended sediment data are used. Hence, responsible bodies should give due attention to the time and frequency of sampling, method of sampling and recording of reliable sediment data together with flow measurement.

The sub-catchment number 18 is produce the highest contributing sediment yield, this can be reduced by using sediment yield more emphasis and intervention strategies such as land slope stabilization, construction terraces, changing the land use of steep area and afforestation.

Reforestation of shrub lands, steep slope lands and some parts of agricultural lands mainly at upper parts of the watershed with other soil conservation measures should have to be implemented for further reduction of sediment

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Appendix

Appendix A

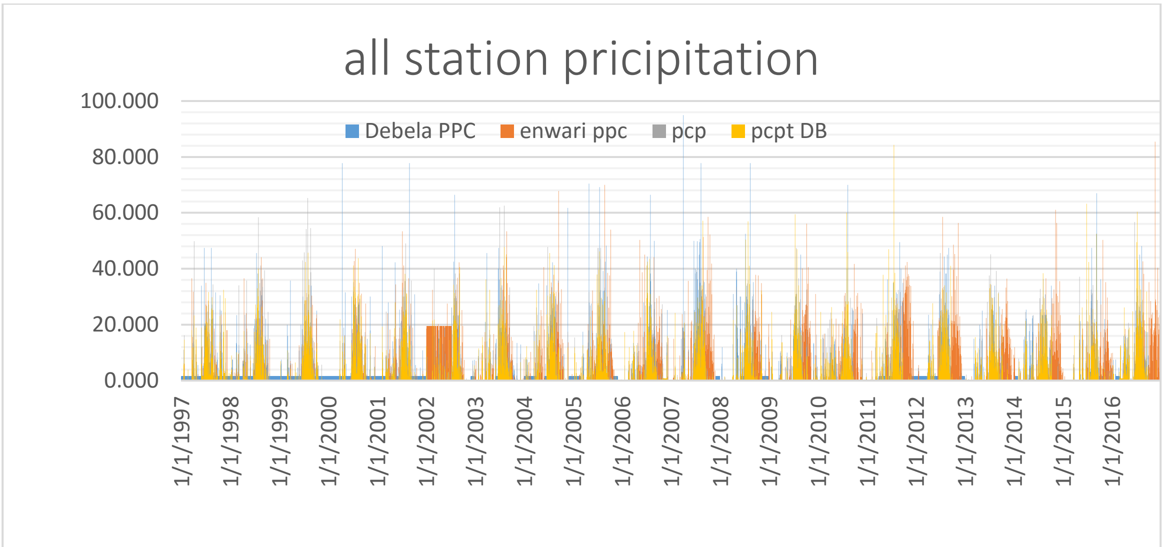


Figure A.1 graphical show of all station precipitation (1997 -2016

Appendix B

Table B.1 average daily precipitation of weather station (1997 -2016

Average daily prrecipitation in month weather generatet pcpstat out data												
Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1997	0.95	0.14	1.33	2.75	0.84	3.23	8.78	6.5	1.16	2.89	2.64	2.64
1998	0.75	0.47	0.48	1.64	1.39	0.45	10.9	9.3	2.35	0.17	0	0
1999	0.22	0	0.85	0.09	0.35	1.63	11.7	12	1.75	1.92	0.05	0
2000	0	0	0.84	1.58	1.2	1.53	11.4	10	3.51	0.92	0.63	0.22
2001	0	1.21	2.3	0.63	2.08	1.16	13.1	8.4	1.07	0.13	0	0.11
2002	0.58	1	1.95	1.54	0.59	0.97	6.92	9.5	3.64	0.1	0	0.27
2003	0.5	1.3	1.94	2.86	0.12	3.32	10.8	9.3	2.47	0	0	0.24
2004	0.79	0.33	0.96	3.78	0.18	3.32	10.8	9.7	2.63	0.45	0.39	0
2005	1.11	0.16	0.92	1.65	2.46	3.04	10	7.4	3.56	0.02	0.05	0
2006	0.56	0.87	1.97	1.28	0.64	1.17	14	7.2	1.99	0.28	2.64	0.85
2007	0.06	1.09	0.29	2.39	0.44	3.11	10	13	4.28	0.16	0.19	0
2008	0.01	0.06	0	1.15	2.22	2.21	12.8	7.6	2.55	0.32	1.82	0.04
2009	1.52	0	0.26	1.05	0.48	0.46	13.7	8.8	1.05	1.18	0.04	0.82
2010	1.52	0.77	1.8	3.98	1.36	1.18	7.82	10	1.79	0.01	0.28	0.13
2011	0.01	0.25	2.48	1.29	3.59	2.45	11.5	10	2.63	0	0.14	0
2012	0	0	0.17	3.11	1.87	1.87	11.3	13	3.08	0	0	0
2013	0.03	0	1.57	1.81	0.77	1.34	11.6	6.6	2.65	2.04	0.38	0
2014	0	0.57	2.18	1.47	1.51	0.56	8.4	9.4	3.67	1.8	0	0
2015	0	0	0.8	0	3.32	3.19	3.79	8	5.06	0.2	0.29	0.24
2016	0.41	0.12	2.64	2.64	2.13	3.48	16	8.6	2.35	0.13	0.24	0

Table B 2 total monthly precipitation of weather station (1997 -2016)

Total monthly precipitation of weather generated station pcpstat out data

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1997	29.5	4	41.2	82.4	25.9	96.9	272.1	200.6	34.8	89.7	79.29	81.94	1038.3
1998	23.1	13.2	14.9	49.3	43	13.5	337.3	289	70.6	5.2	0	0	859.1
1999	6.9	0	26.5	2.8	11	48.9	362.4	365.1	52.4	59.6	1.4	0	937
2000	0	0	25.9	47.3	37.1	45.8	352.4	317.5	105.2	28.5	18.8	6.8	985.3
2001	0	33.8	71.2	18.8	64.6	34.9	406.7	260.4	32.2	4.1	0	3.4	930.1
2002	18.1	28	60.6	46.1	18.4	29.1	214.4	294.8	109.1	3.1	0	8.4	830.1
2003	15.6	36.3	60.2	85.7	3.8	99.5	334.1	288.7	74.2	0	0	7.4	1005.5
2004	24.4	9.7	29.7	113.3	5.6	99.7	334.7	301.3	78.9	14.1	11.8	0	1023.2
2005	34.3	4.5	28.6	49.5	76.4	91.1	310.7	228.3	106.8	0.7	1.5	0	932.4
2006	17.3	24.4	61	38.3	19.8	35.2	432.6	224.2	59.8	8.6	79.29	26.3	1026.8
2007	2	30.4	8.9	71.8	13.6	93.2	309.9	414.6	128.5	4.9	5.7	0	1083.5
2008	0.3	1.7	0	34.6	68.9	66.4	397.7	234.8	76.6	9.9	54.6	1.2	946.7
2009	47.2	0	8.1	31.4	14.9	13.7	423.4	273.1	31.4	36.6	1.2	25.3	906.3
2010	47.2	21.6	55.7	119.3	42.2	35.4	242.3	312.2	53.8	0.3	8.5	3.9	942.4
2011	0.3	7	76.8	38.6	111.2	73.4	357.4	312.3	79	0	4.3	0	1060.3
2012	0	0	5.2	93.3	57.9	56	351.6	394.5	92.4	0	0	0	1050.9
2013	0.8	0	48.8	54.2	23.9	40.1	358.5	204.4	79.6	63.1	11.5	0	884.9
2014	0	16	67.7	44.1	46.9	16.8	260.3	291	110	55.9	0	0	908.7
2015	0	0	24.9	0	102.9	95.8	117.6	248.5	151.8	6.1	8.8	7.3	763.7
2016	12.7	3.4	81.94	79.29	66.1	104.3	496.5	267.1	70.5	3.9	7.2	0	1192.9

Table B.3 Statistical Analysis of Daily Precipitation Data (1997 -2016)

Month	*PCP_MM*	*PCPSTD*	*PCPSKW*	*PR_W1*	*PR_W2*	*PCPD*
Jan.	14	2.3	7	0	0.4	2.5
Feb.	12	2.1	7.3	0	0.4	2.2
Mar.	40	3.5	4.5	0.1	0.6	8.1
Apr.	55	4.3	3.5	0.2	0.6	10.3
May.	43	4.2	4.4	0.1	0.5	7.2
Jun.	59	5.5	5.3	0.2	0.6	8.7
Jul.	334	11.6	1.6	0.6	0.9	26
Aug.	286	9.9	1.5	0.8	0.9	27.7
Sep.	80	5.5	4	0.3	0.6	14.9
Oct.	20	2.5	5.8	0.1	0.5	4.8
Nov.	15	1.9	10.5	0	0.8	4.8
Dec.	9	1.1	7.3	0	0.7	3.5

Appendix C

Maximum and minimum temperature of study area station (1997 -2016)

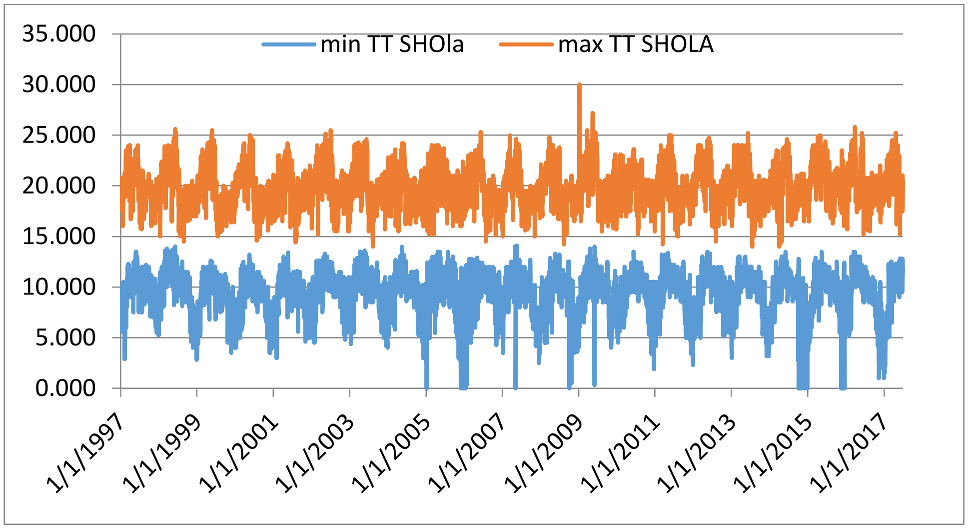


Figure C. 1 Sholagebeya maximum and minimum temperature station (1997-2016)

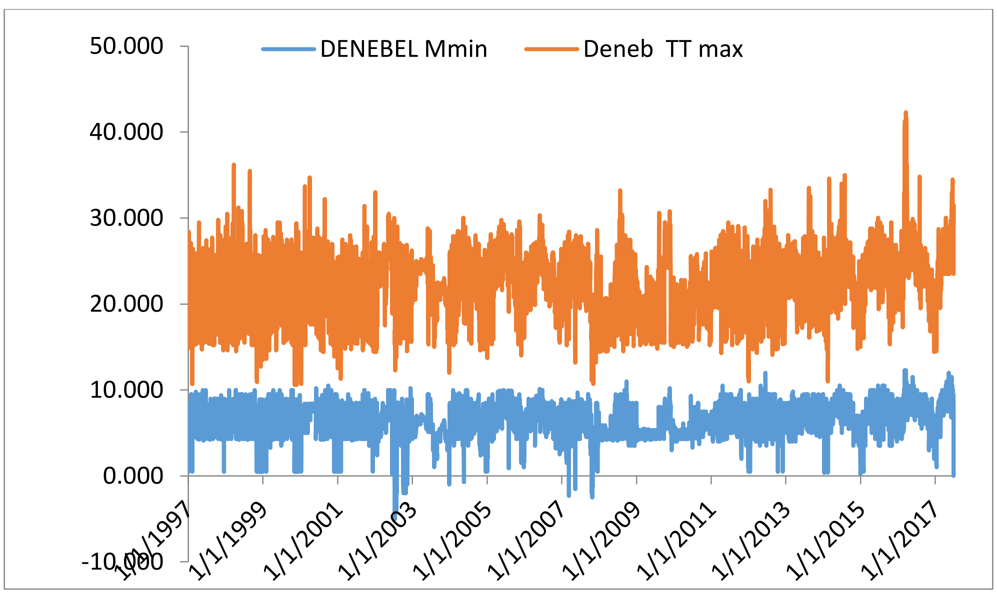


Figure C.2 Debela maximum and minimum temperature station (1997-2016)

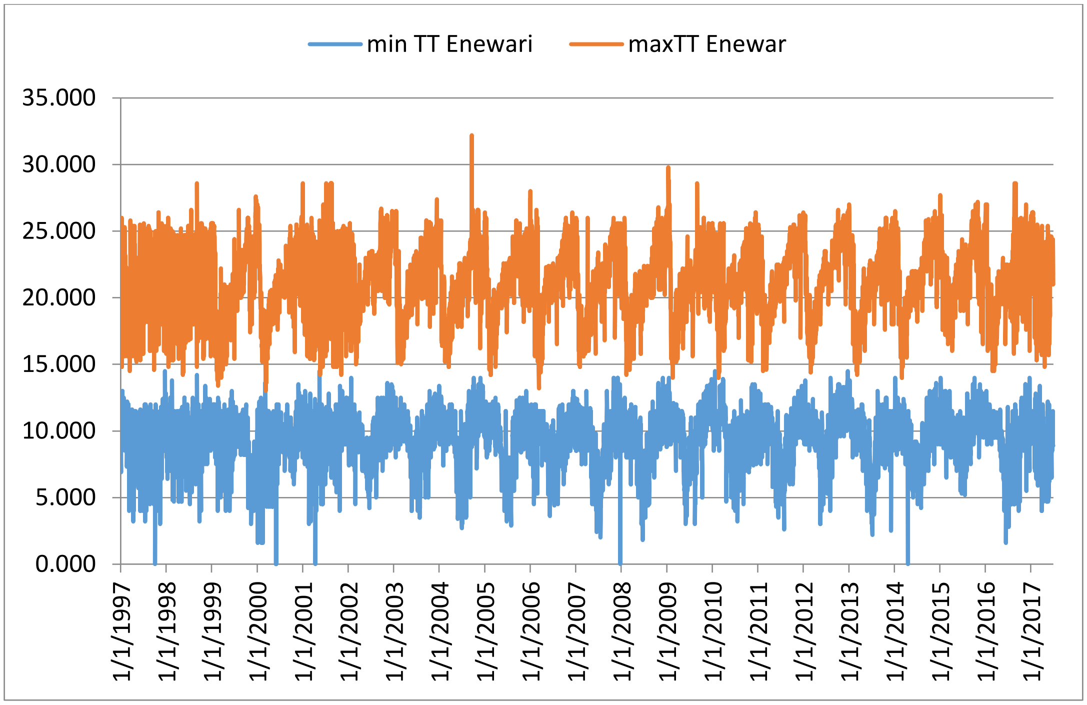


Figure C..3. Enewari maximum and minimum temperature station

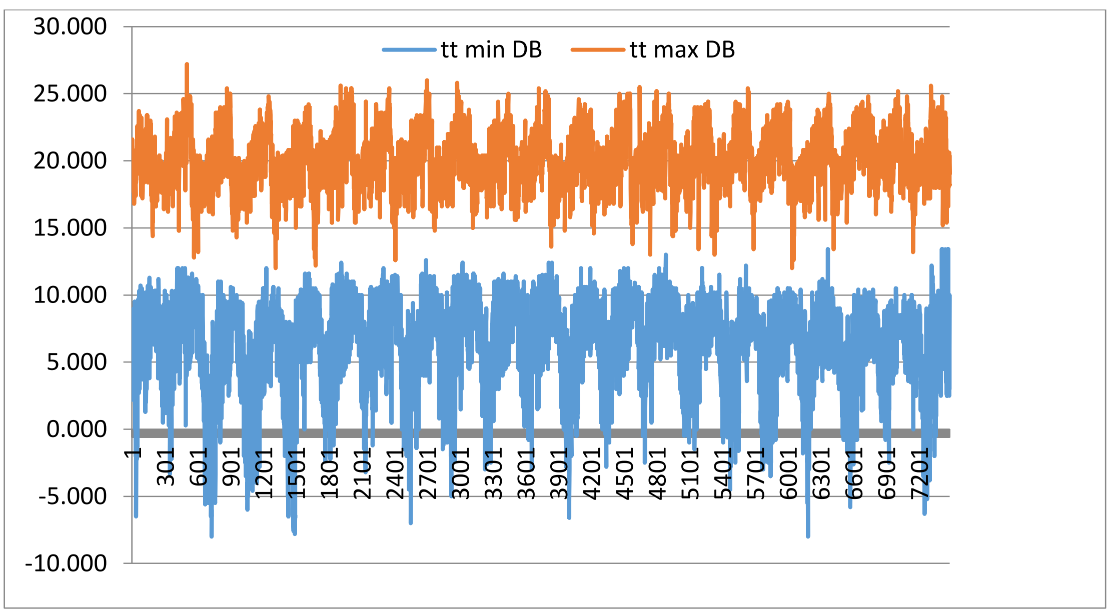


Figure C.4 Debrebrihan maximum and minimum temperature station

Table C Average Daily Dewpoint temperature for period (1997-2016)

Average Daily Dew Point Temperature for period (1997-2016				
Month	tmp_max	tmp_min	hmd	dewpt
Jan	19.9	4.93	61.82	6.63
Feb	21.08	5.8	57.87	6.65
Mar	21.09	7.39	62.17	8.17
Apr	21.07	7.76	63.12	8.51
May	21.85	7.6	59.42	8.01
Jun	22.17	7.69	62.36	8.92
Jul	18.64	8.9	76.36	10.21
Aug	18.22	8.76	76.81	10
Sep	19.06	6.97	70.89	8.78
Oct	19.17	3.76	63.86	6.38
Nov	19.22	2.83	61.6	5.67
Dec	19.21	3.06	61.02	5.58

tmp_max = average daily maximum temperature in month [°C]

tmp_min = average daily minimum temperature in month [°C]

hmd =average daily humidity in month [%]

dewpt = average daily dew point temperature in month [°C]

This file has been generated by the program 'dew02.exe'

Input Filename = temprh.txtNumber of Years = 20

Number of Records = 7336

Number of No Data Values

tmp_max = 93

tmp_min = 92

hmd =1958

Appendix D

Figure D Monthly Flow of chacha Dam reservoir

monthly flow in m3/se													
year	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	average flow(m3/se)
1995	0.12	0.127	0.175	0.16	0.13	0.13	5.891	22.061	4.754	0.194	0.158	0.113	2.834666667
1996	0.09	0.088	0.313	0.32	0.65	1.8	19.392	24.926	3.011	0.187	0.132	0.093	4.250083333
1997	0.15	0.146	0.164	0.28	0.14	0.31	10.32	18.556	1.191	4.493	2.006	0.442	3.183
1998	0.12	0.115	0.122	0.15	0.6	0.16	13.641	37.505	10.438	1.603	0.373	0.121	5.41175
1999	0.09	0.076	0.118	0.08	0.08	0.18	8.174	50.083	4.779	1.55	0.266	0.209	5.473666667
2000	0.04	0.031	0.026	0.06	0.07	0.17	15.679	32.33407	6.212	1.696	1.134	0.152	4.800006173
2001	0.07	0.081	1.371	0.7	0.39	0.2	13.92039	35.61487	5.162	0.326	0.184	0.095	4.84210496
2002	0.06	0.061	0.181	0.15	0.43	0.11	3.137	30.45911	13.406	0.15	0.072	0.106	4.025842262
2003	0.11	0.133	1.721	2.4	0.87	1.06	19.81903	19.897	5.473	1.114	1.112	1.11	4.56741954
2004	0.94	0.618	0.366	0.65	0.49	0.33	9.767	31.166	4.419	0.738	0.66	0.612	4.229583333
2005	0.38	0.273	0.348	0.28	0.52	0.4	12.817	24.08087	16.66814	0.636	0.305	0.268	4.748500794
2006	0.26	0.114	0.129	0.2	0.09	0.08	17.37897	24.4537	9.997	0.257	0.298	0.464	4.477138889
2007	0.37	0.399	0.353	0.15	0.08	0.12	21.40697	39.43696	18.656	0.648	0.146	0.041	6.816827469
2008	0.03	0.16	0.028	0.04	0.05	0.24	12.12912	35.67785	8.036	0.202	0.643	0.082	4.777080833
2009	0.07	0.07	0.029	0.04	0.04	0.03	9.167	48.195	9.986	0.251	2.349	0.047	5.855583333
2010	0.07	0.069	0.069	0.13	2.75	0.09	17.667	29.96	2.492	0.363	0.325	0.432	4.534166667
2011	0.48	0.375	0.423	0.59	0.87	1.1	15.357	34.56023	5.786	1.372	0.397	0.37	5.139769444
2012	0.35	0.299	0.193	0.48	0.6	0.65	43.73948	60.93071	4.607	0.454	0.385	0.216	9.40926642
2013	0.5	0.442	1.303	0.53	1.71	0.75	18.32393	29.237	15.805	4.773	0.526	0.46	6.196327778

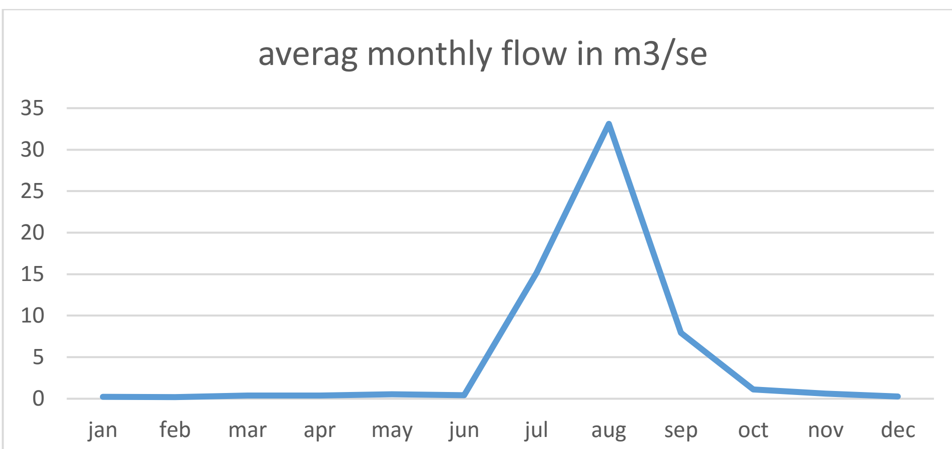


Figure D Graphical show of average monthly flow

Appendix E

1) Hydrology Response Unit (HRU)

```
SWAT   model  simulation   Date: 9/29/2018 12:00:00 AM   Time: 00:00:00
MULTIPLE HRUs  LandUse/Soil/Slope OPTION            THRESHOLDS : 5 / 15 / 20 [%]
Number of HRUs: 80
Number of Subbasins: 23
```

	Area [ha]	Area[acres]
Watershed	57754.1268	142713.3350

		Area [ha]	Area[acres]	%Wat.Area
LANDUSE:				
	Durum Wheat --> DWHT	50340.4279	124393.7142	87.16
	Pasture --> PAST	7351.2924	18165.4111	12.73
	Forest-Mixed --> FRST	49.6415	122.6667	0.09
	Range-Grasses --> RNGE	12.7650	31.5429	0.02
SOILS:				
	Be9-3c-26	2255.1445	5572.5748	3.90
	Vp14-3a-286	55498.9823	137140.7601	96.10
SLOPE:				
	0-3	9622.0386	23776.5384	16.66
	15-30	6692.3895	16537.2292	11.59
	30-9999	689.1310	1702.8772	1.19
	3-8	24687.8045	61004.7993	42.75
	8-15	16062.7632	39691.8910	27.81

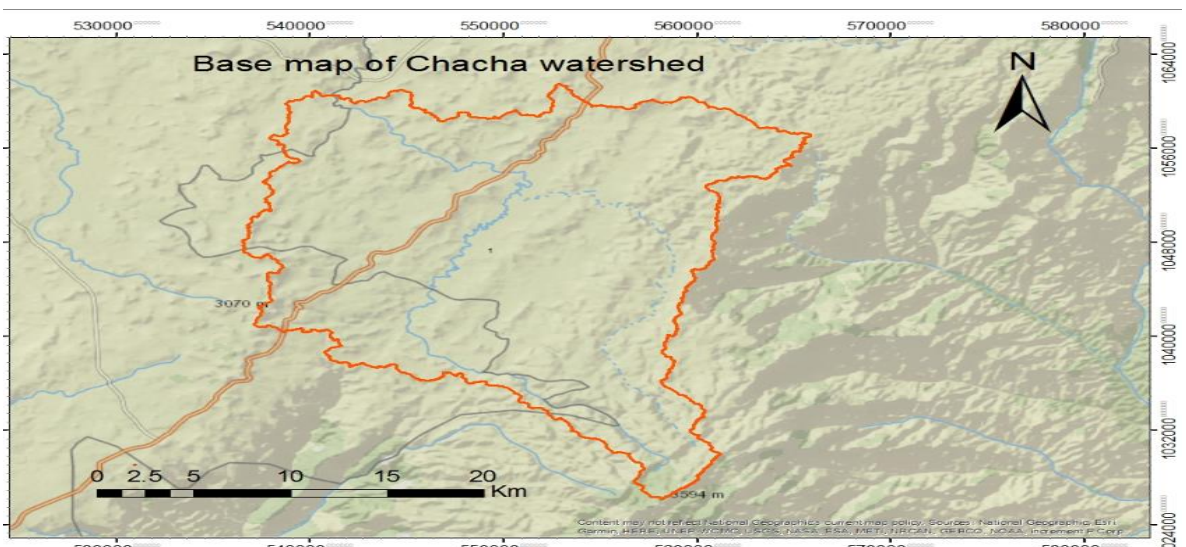


Figure. E .2 Base map of Chacha Watershed

Table .E Average monthly basin value

Mon	Rain (MM)	Snow Fall (MM)	SURF Q (MM)	LAT Q (MM)	Water Yield (MM)	ET (MM)	Sed. Yield (MM)	PET (MM)
1	11.45	0.00	0.50	0.10	2.03	12.74	0.05	143.50
2	12.31	0.00	0.38	0.12	1.43	15.42	0.03	154.14
3	40.79	0.00	1.61	0.27	2.62	44.65	0.11	157.24
4	63.36	0.00	2.64	0.63	3.87	83.72	0.26	145.93
5	47.92	0.00	2.03	0.65	3.48	60.86	0.25	156.07
6	64.24	0.00	2.15	0.54	3.55	34.83	0.15	139.50
7	317.56	0.00	80.47	3.78	88.12	44.59	2.27	76.20
8	280.48	0.00	76.59	5.67	140.53	54.37	2.09	80.03
9	91.94	0.00	17.12	2.93	108.09	56.14	0.78	118.65
10	16.62	0.00	1.82	0.83	65.58	31.30	0.06	134.61
11	9.54	0.00	0.97	0.26	31.90	19.82	0.13	123.81
12	5.95	0.00	0.16	0.13	7.79	14.21	0.02	129.61

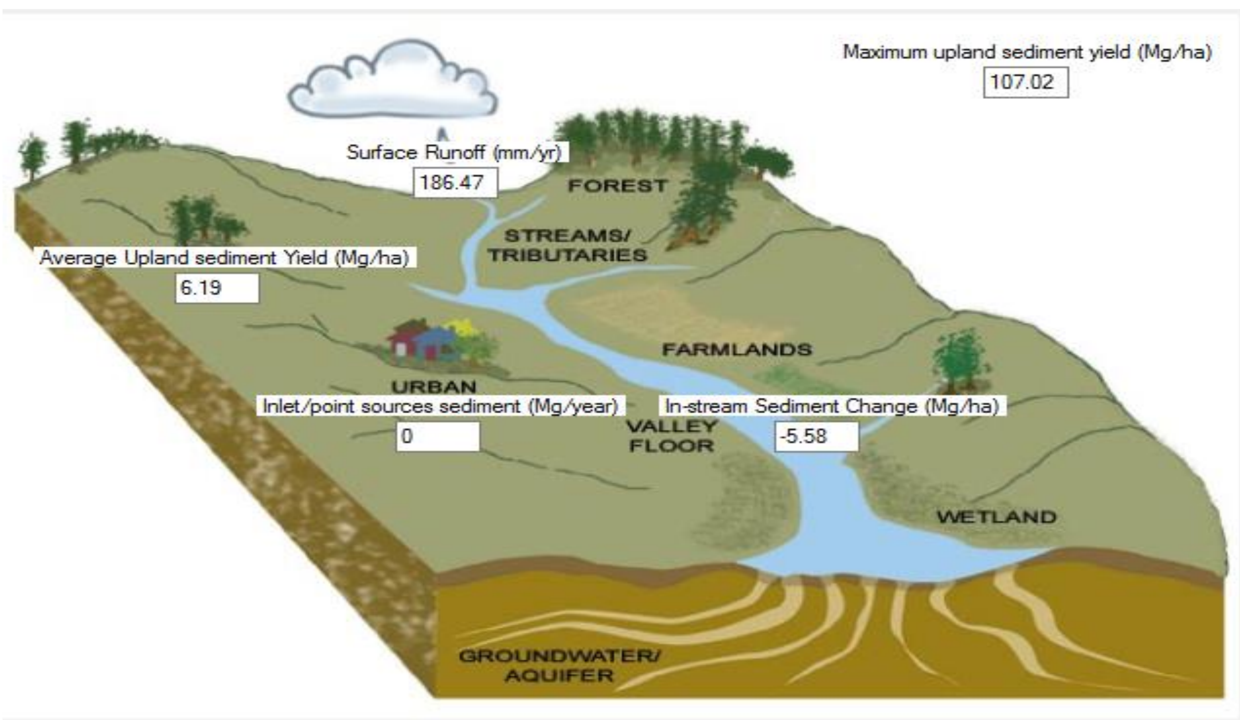


Figure E.2 Sediment processes figure

Appendix F

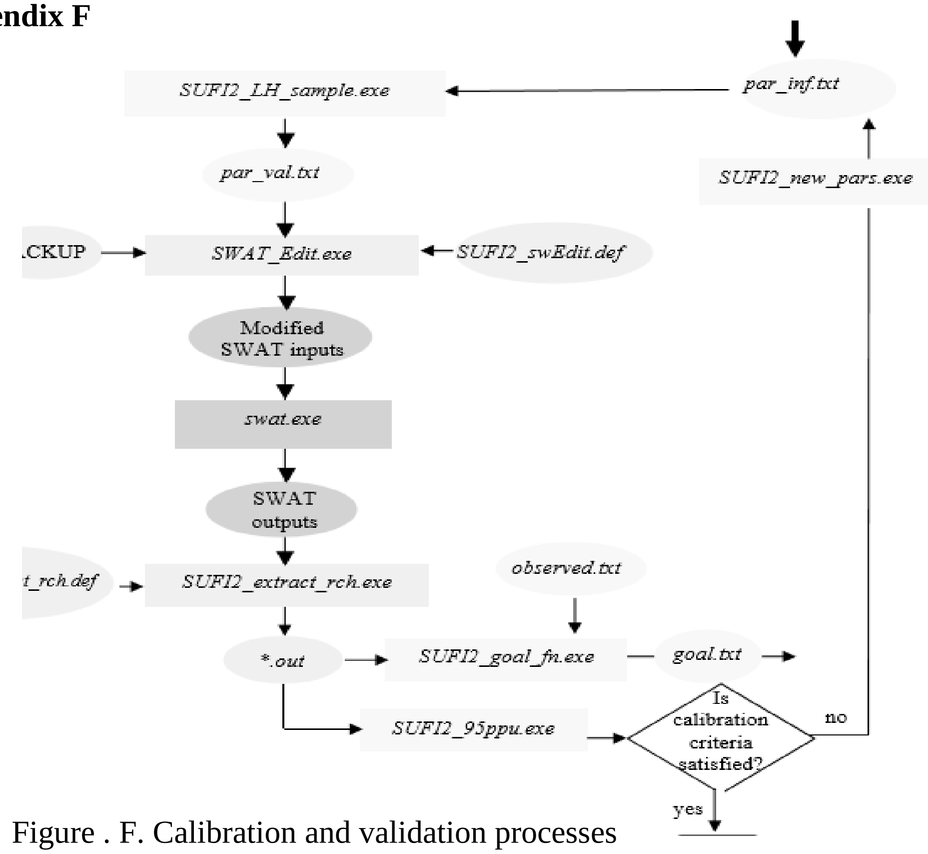
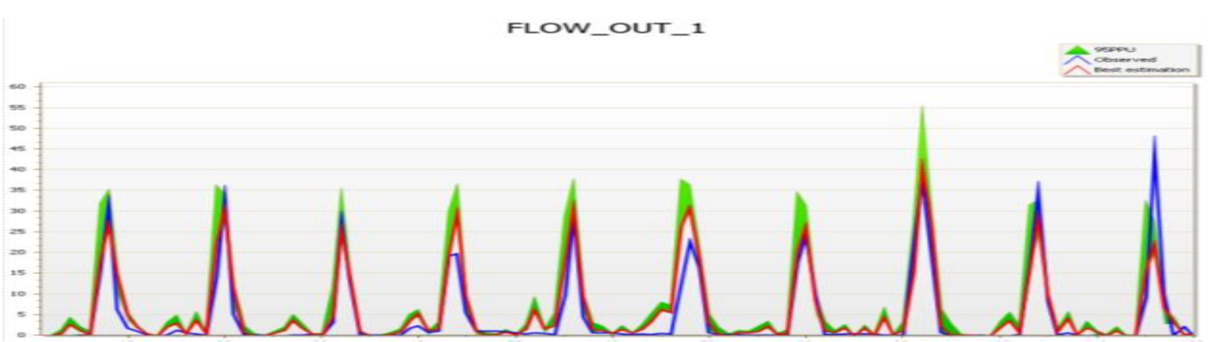


Figure . F. Calibration and validation processes

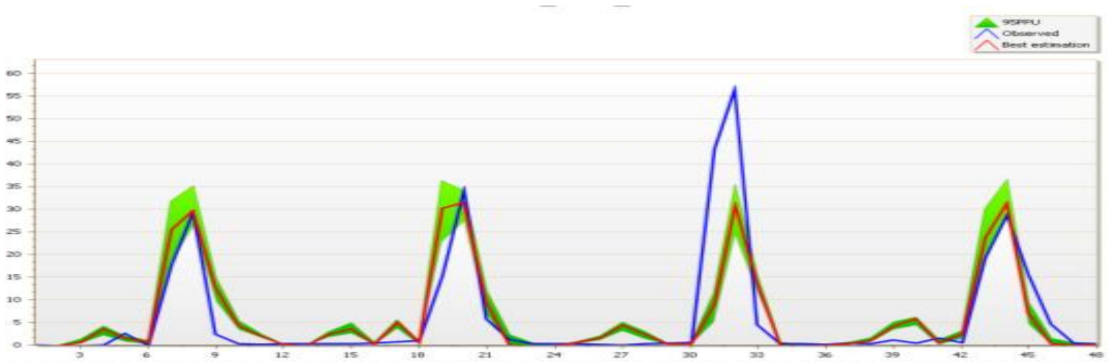
Appendix G



```
Goal_type= Nash_Sutcliff     No_sims= 500      Best_sim_no= 242      Best_goal = 8.351086e-001

Variable                  p-factor   r-factor   R2     NS      bR2        MSE         SSQR        PBIAS   KGE    RSR    MNS    VOL_FR
---   Mean_sim(Mean_obs)       StdDev_sim(StdDev_obs)
FLOW_OUT_1                0.32       0.31       0.85   0.84    0.7550     1.6e+001    5.3e+000    -23.6   0.75   0.41   0.67   0.81
6.16(4.99)                  9.48(9.86)
```

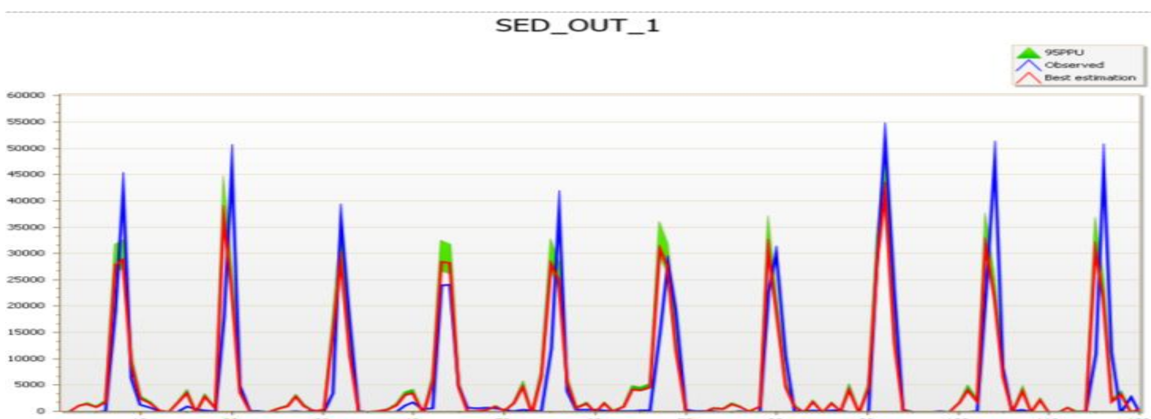
Figure G.1 SWAT-CUP flow calibration out put




```
Goal_type= Nash_Sutcliff     No_sims= 500      Best_sim_no= 391      Best_goal = 6.553357e-001

Variable              p-factor   r-factor   R2     NS      bR2        MSE         SSQR        PBIAS   KGE    RSR    MNS    VOL_FR
---   Mean_sim(Mean_obs)     StdDev_sim(StdDev_obs)
FLOW_OUT_1            0.27       0.22       0.66   0.66    0.4242     5.4e+001    2.1e+001    -3.2    0.72   0.59   0.57   0.97
6.47(6.27)              10.02(12.54)
```

Figure G.2 SWAT-CUP flow validation out




```
Goal_type= Nash_Sutcliff     No_sims= 50       Best_sim_no= 43       Best_goal = 6.960146e-001

Variable                 p-factor   r-factor   R2     NS      bR2        MSE         SSQR        PBIAS   KGE    RSR    MNS    VOL_FR
---   Mean_sim(Mean_obs)      StdDev_sim(StdDev_obs)
SED_OUT_1                0.05       0.10       0.70   0.70    0.4793     4.9e+007    1.3e+007    -3.1    0.76   0.55   0.59   0.97
6274.39(6087.38)            10518.56(12750.67)
```

Figure G.3 SWAT-CUP sediment calibration out

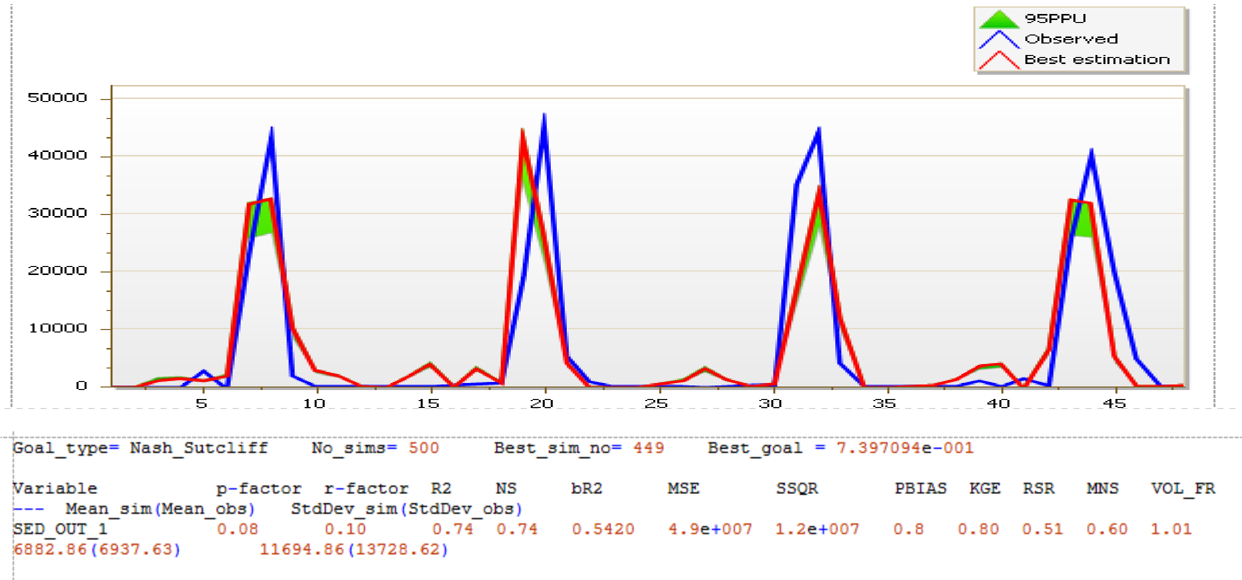


Figure G.4 SWAT-CUP sediment validation out

Appendix H

Dam site cross section