# Addis Ababa University School of Civil and Environmental Engineering

## Assessment of Sediment Inflow in Dire Dam Reservoir and Sediment Reduction Method Using SWAT Model, Dire Catchment, Ethiopia

A thesis submitted in partial fulfillment of the requirement
For the degree of masters of Science in Hydraulic Engineering

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## APPROVAL

This thesis entitled with assessment of sediment inflow dire dam reservoir and sediment reduction method using swat model, dire catchment, Ethiopia has been prepared by Yared Tadesse /GSE/6995/10.We the members of the Examining board and Advisor approved in the partial fulfilment of the Master of Science in Hydraulic Engineering.

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## CERTEFICATION

I certify that I have read and recommend for acceptance by Addis Ababa University a thesis entitled as “assessment of sediment inflow to dire dam reservoir and sediment reduction method using swat model” for partial fulfilment of the requirement of Degree of Master of Science in Civil Engineering.

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## STATEMENT OF THE AUTHOR

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## LIST OF ABBRIVATION

| | |
|---|---|
| PBIAS | Percent bias |
| ASCE | American Society of Civil Engineers |
| DEM | Digital Elevation Model |
| EMA | Ethiopian Map Agency |
| GIS | Geographic Information System |
| HRU | Hydrologic Response Unit |
| MUSLE | Modified Universal Soil Loss Equation |
| NMAE | National Meteorological Agency of Ethiopia |
| SCS | Soil Conservation Services |
| CUP | Calibration and Uncertainty Programs |
| ARS | Agricultural Research Service |
| SUFI-2 | Sequential Uncertainty Fitting version 2 |
| WLMI | water and land management institute |
| SWAT-CUP | SWAT calibration of uncertainty program |

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## ABSTRACT

Soil erosion or sedimentation is a major problem of reservoir operation in Ethiopia. Deforestation, overgrazing and poor land management practice are some which accelerate the rate of erosion. The topography of Ethiopia in general is full of ups and downs and local farmers commonly cultivate on the hilly sides causing easy topsoil wash away. Hence, this study has tried to determine the sediment yield at the dire dam reservoir, identify the high sediment source sub basin and check the applicability of SWAT model on the dire dam watershed. To go through this objective, SWAT model was applied with methodology of collecting hydro metrological data, sediment data, topographic, land use and soil map data by overlaying mechanism, the SWAT model run.

Simulation was carried out using metrological and spatial data by dividing the watershed in to 9 sub basins with 103 hydrological response unit (HRUs) at outlet of dire watershed. Based on the availability of data the model calibration period (1988-1999) and validation period (2000-2006) were performed for monthly flow and sediment data using Sequential Uncertainty Fitting (SUFI-2) with in SWAT calibration uncertainty program (SWAT-CUP). The model was found applicable in this watershed with the performance evaluation statistics (Nash-Sutcliffe model efficiency (ENS), coefficient of determination ($R^2$)) *in the acceptable range, ($R^2$in the range of 0.74 to 0.78, ENS in the range of 0.73 to 0.77). From the model simulation output, sub basin 1, 2, and 6 were found the top three severely eroded sub basin with average annual sediment yield of 19.01 t/ha,34.26t/ha and 27.31t/ha respectively. While sub basin 7 and 9 were found the least sediment source sub basin with annual average sediment yield of 8.06t/ha and 7.22t/ha respectively. Generally,the annual averaged sediment inflow in to dire dam reservoir was 1850 t/km$^2$/yr.*

Three watershed management scenarios were simulated to compare their effectiveness of sediment yield reduction from the existing baseline condition. The result shows that the mean annual sediment yield at the outlet can be reduced by 34.14% by applying filter strips, 57.12% by applying grassed waterway, and 70.06% by applying terracing. To generalize, applying terracing is relatively effective to reduce the mean annual sediment yield for the proposed dam.

***Key words**: SWAT, SUFI-2, SWAT-CUP, sediment yield, sub basins, dire dam reservoir*

# CHAPTER ONE

## INTRODUCTION

### *1.1 Background*

Deposition of sediment in reservoirs can cause serious problems. They reduce the storage capacity of the reservoir and they can cause serious problems concerning the operation and stability of the dam. The construction of a dam and the creation of an impounded river reach are ausually change the stream natural conditions. Concerning the sediment logical aspect, the dams cause a reduction on the flow velocity, thus causing the gradual deposition of those sediments carried by the stream resulting in the sedimentation, gradually diminishing the reservoir storage capacity. Therefore, it may come to hinder the reservoir operation, besides causing several kinds of environmental problems. Environmental and economic damage arising out of the sediments deposition in reservoirs may be hard to solve, especially in arid and semi-arid regions (Ansal, 2014).

The rates of soil erosion and land degradation in Ethiopia are high. Ethiopia loses about 1.3 billion metric tons of fertile soil every year and the degradation of land through soil erosion is increasing at a high rate (Hurni, 1988). Soil is eroded due to rainfall and wind, resulting in sediment movement in to watercourses by flood and storm waters. The soil particle, which is detached from the parent material by the impact of raindrop can be transported through the processes of sheet, rill, and gully erosion. Some part of the eroded materials left over and deposited as alluvial along river channels and across flood plains. The other portion is transported through the stream network to some point of interest such as reservoir is referred to as the sediment yield. Therefore, the amount of sediment inflow to a reservoir depends on the sediment yield produced by the upstream watershed (Kondolf et al, 2014). Sediment production of a watershed is highly influenced by weathering effects caused by climatic factors like temperature variation, action of rain and chemical action from elements contained in the soil and water (ASCE, 1975).

As a result of runoff from rainfall soil particles on the surface of a watershed can be eroded and transported through the processes of sheet, rill, and gully erosion. This total amount of onsite sheet, rill and gully erosion in a watershed is known as the gross erosion. However, not all of thiseroded material enters the stream system. Some of the material is deposited as alluvial fans along river channels and across flood plains. The portion of the eroded material that is transported through the stream network to some point of interest such as reservoir is referred to as the sediment yield. Therefore, the amount of sediment inflow to a reservoir depends on the sediment yield produced by the upstream watershed (Morris, 1991). Sediment production of a watershed ishighly influenced by weathering effects caused by climatic factors like temperature variation, action of rain and chemical action from elements contained in the soil and water. But to design and manage the life span of the project there should be intensive study related to the hydrology of the watershed like surface runoff amount and sediment inflow to the reservoir and sedimentation of the inflow sediment. Sedimentation is affecting the dam in many ways such as influencing the operational life of the reservoir that is the loss of effective water storage capacity and also damages the structural integrity of the dam walls.

The Dire dam reservoir is one of the source of water supply for the city of Addis Ababa city, which has a live storage capacity of 19 $Mm^3$. But the storage volume of this reservoir is threatened by the soil erosion and subsequent sedimentation from the upstream of the Dire dam basin. Soil erosion from the upstream of the basin and the subsequent sedimentation in the downstream area is an immense problem threatening the existing and future water resources development in the Dire basin.

In watershed, poor land use practices, inappropriate management systems and lack of suitablesoil and water conservation measures have play a major role causing soil erosion, land degradation and sedimentation problems in the basin (Krishna, 2014). Soil erosion intensity has strong correlation with land use, soil type and slope of the watershed (Garcia-RuizJ, 2008).

Consequences of soil erosion in watershed especially on agricultural land are the redistribution of soil within a field, the loss of soil from a field, breakdown of soil structure, the decline in organic matter and nutrients result reduction of cultivable soil depth, decrease of soil fertility and loss of productivity which eventually may lead widespread food shortages (Ruiz, 2008). A river does not only convey water, but also transports erosion products from the watershed. Therefore, a comprehensive understanding of hydrological processes in watershed isa prerequisite for successful land and watershed management and environmental restoration.

The estimation of sediment yield from the catchment is useful for reservoir sedimentation, river Morphology, soil and water conservation planning, and also estimation of concentration and load of chemical adsorbed to sediment particles. 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

This study consider major cause of storage capacity change was estimating sediment inflow from the upstream catchment of the dam and that caused by sediment deposition, recommend appropriate reduction sediment yield under different scenarios and assessing the 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 analyzed with models.

### *1.2 Problem Description*

Silt deposits in Dire reservoirs reduced their live storage capacity, while the buildup of suspended solids in Dire Reservoir has affect the raw water quality thus increasing the treatment prices. Siltation of water reservoirs has a significant influence on the reservoir operation. It decrease storage volume and amount of the harvested water that in return produced water lack for the rapidly increasing Addis Ababa City residents .The suspended solids in the eroded material increased the turbidity of the raw water (i.e., water becomes muddy and physically dirty), which increased the water treatment costs. According to AAWSA reports, the cost of water treatment increased from 7.7 million in 1993 to 21.4 million in 2001 due to the increasing rate of reservoir sedimentation. On the average, the state incurs water treatment cost of 12.6 million birr.

The Dire watershed, which covers large area agrarian doings 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 dire reservoir.

### *1.3 Research Questions*

- What is the sediment load in dire dam reservoir?
- What was the spatial variability of catchment affected sediment yield?
- What are the catchment areas of the rivers flowing into the reservoir?
- What are best mitigation methods to the erosion exposed areas?

### *1.4 Objectives*

#### 1.4.1 General Objective

The main aim of this study is to assess the quantity of sediment inflow in dire dam reservoir using the SWAT model and to take appropriate sediment reduction measures

### 1.4.2 Specific Objective

- To assess sediment inflow to Dire Reservoir using SWAT
- To recommend appropriate mitigation measure to reduce sediment yield of watershed

## *1.5 Significance of The Research*

Sediment transport replicas are being advanced to assist state and local resource agencies for the purpose of developing appropriate management plans to reduce/control sedimentation problems in the watersheds. Use of models in identifying areas with high sediment yield that can be of dredging concern. Monitoring sediment loads wants knowledge and quantitative assessment of soil loss and the sediment transportation process. A number of issues such as Climate, land use/land cover, drainage area size, basin slope affect residue delivery processes. In general, this study expected to help concerned sectors in planning, developing and handling water reserve project in the learning part and be an input for individuals who are interested to further research in related field and other area of study.

## *1.6 Scope and Limitation*

This study focus on to assess the quantity of sediment inflow in to Dire dam reservoir using SWAT model and to take appropriate sediment reduction measure. The aim of the study to predict sediment inflow to dire reservoir; identify the most erodible sub catchment and to recommend appropriate sediment reduction measure. During data collection, there is a limitation of sediment data because of not enough gauging station and I use sediment-rating curve to fill gap on the research so it is better to increase the number of record time and number of hydrological station to get better result

## *1.7* Thesis Layout

This thesis layout in to five chapters.

**Chapter One** outlines the statement of the problem, specific aims and objectives of the present study. The chapter also provides some background information on the problems caused by sediment accumulation in reservoirs.

**Chapter Two** briefly reviews the theory of sediment transport and erosion in rivers and reservoirs.

**Chapter** the location of study area and general catchment characteristics of the Dire catchment. Outlines the research methodology employed in this study. An overview of some of the erosion and sedimentation models is given. The use of the selected erosion model (SWAT) to dire catchment dealt with here.

**Chapter Four** Concentrates on SWAT model simulation results and discussion.

**Chapter five** summarizes the entire study by way of outlining the main conclusions, and recommendations.

# CHAPTER TWO

## LITERATUREREVIEW

### *2.1 Concepts of Erosion and Sedimentation*

Soil erosion starts with the dispassion of soil subdivisions from the exposed area, continues with the transport of those detached particles with the help of water and ends with deposition in another new location (Wakindiki and Yegon 2011). The force developed when the rain falling on bare or sparsely vegetated soil separates the soil subdivisions, which can be easily transport by generated runoff (Fitzpatrick et al. 2017). Sheet flow transports the soil particles that have been detached by splash erosion. A collection of these sheet flows develops deeper concentrated flow on the soil superficial and creates a rill (cutting grooves) into the soil surface which able to both detach and transport the soil particles (Assessment 2013). Soil properties include atom size delivery, texture, and configuration affect the soil particles susceptibility to being move by flowing water.

The inter-rill and rill erosion, which developed from a collection of sheet erosion from different sides according to the grade of the land are join to form and flow through the nearest gullies. According to (Maestas et al. 2018), gullies are define as relatively deep recently formed eroding channels where no distinct channel before occurred. (Fitzpatrick et al. 2017) also defined Gullies as small channels that cannot removed by normal tillage practice. Runoff cuts rill deeper and wider or when the flows from several rills come togetherand form a gully erodes as well as transports the collected soil material towards the channel or streams.

Once the soil particle detached, it becomes part of the flow and transported from the point of detachment to the point of interest (Briske et al. 2017). The sediment load from rill through the accumulation of large quantities of runoff and channel bed material detached during gully formations has a chance to join the river. The transported load may be either bed load or the suspended weight. The bed load typifies grains rolling lengthways the bed while suspended load mentions to grains upheld in suspension by commotion. The division is, however, sometimes random when both loads are of the similar material. The transport capacity is less than the amount of eroded soil material available, then the amount of residue exceeding the transport capacity gets deposited (Gilley 1985). Residue harvest is the amount of residue transferred by a watershed in excess of a period of time, which will ultimately enter a lake, reservoir or pond situated at the downstream edge of the watershed (Vanmaercke et al. 2014). The most shared discourse on sediment difficulties has been that of enlarged erosion and sediment loads from weak land use and growth of human impacts on previously undisturbed areas (Walling and Collins 2005).

Most approaches available to predict erosion processes and sediment yield potential of watersheds require detailed quantitative information. Analysis of the governing factors of sediment yield also needs quantitative data of suitable temporal and spatial scales related to watershed attributes. Acquiring information related to together rates of sediment admission and watershed attributes is difficult and, when acquired, may have a questionable accuracy.

Sediment flow data collected over a time and periodic reservoir review information are some properties demanding methods for approximating sediment yield rates at a watershed level. Some workers have suggested that an excellent sediment-rating curve could be construct from detailed sediment flow data of the short period of sampling programs (Summer et al., 1992). Besides, other researchers such as (Ndomba, Mtalo, and Killingtveit 2008) have cautioned that such relationships should be use in the watershed where no significant landforms, land use and sediment supply source change are expected

### *2.2 Soil Erosion Factor*

The chief issues moving soil erosion are climate, soil erodibility, topography, land use/coverand management factors (Renard and Foster 1985)

### 2.2.1 Climate

Climatic factors affecting soil erosion includes wind, rainfall, wind, temperature, solar radiation and humidity (Eguale et al. 2020). Rainfall is the major climatic factor, which takes large part in governing soil erosion by water. According to (Eguale et al. 2020), initial causes for surface erosion is heavy rainfall since the impact energy of raindrops breaks up soil aggregates and causes detached particles to move laterally with splash action. When rainfall is strong and rapid runoff occurs, in addition to sheet, rill erosions, deep gullies may form, and large volumes of water and soil may be removed away The peak strength sustained over an lengthy period are the two most significant features of a storm for determining its erosivity (Resources, Service, and Standard 2003).

### 2.2.2 Soil Erodibility

Clay, because of its stickiness, binds soil particles together and makes a soil resistant to erosion. However, they may travel a greatdistance without settling if fast flowing water or heavy rain erodes the fine particles. The existence of organic matter that consists plant and animal litter in various decomposition stages decreases the erosion susceptibility of the soil by improving soil structure and increasing permeability, soil fertility and water holding capacity (Mahajan, Saravanan, and Chang 2009).

The existence of organic matter that consists of animal and plant litter in various decomposition stages decreases the erosion susceptibility of the soil by improving soil structure, increasing permeability, fertility and water holding capacity. Soils have high in clay content low erodibility values, because they are resilient to disinterest. Coarse surfaced loams, for example dirty soils also have little erodibility values, because of little transportability but they are simply removable. Usual surfaced soils, for example silt loam soils, have a reasonable erodibility values, because they are abstemiously vulnerable to disinterest and they harvest moderate runoff. Soils having great silt gratified are the most erodible of all soils as they reason a reduction in penetration (Sy, Côté, and Saavedra 2005).

### 2.2.3 Topography

Soil erosion would be expected to rise with rise in topographic factor (slope length and steepness) as consequence of respective rises in velocity and volume of external runoff (Deore, 2005). Gabriel's (1998) experiment also concluded that soil loss increases with an increase of slope length and slope steepness. Steeper terrain slopes cause advanced runoff velocities, more squelches downhill, faster flow, and therefore contributes greater soil erosion. Smearing soil and water preservation actions like terracing decreases slope distance and sharpness which results decreases of the erosion velocity and surface runoff.

### 2.2.4 Land Use Factor

Land use/land cover can have a significant role in the erosion of the terrestrial superficial sediment.Vegetation cover is able to reduce the effect of precipitation on soil erosion. The change in land cover such as the clearance of the dense forest into agricultural land has caused the acceleration of erosion and increased sediment yield at the outlets (Morgan, Kingston, and Sproule 2005).

The cover management factor (C), one of the terrestrial usage factor of erosion, characterizes the resultof plants, soil biomass, ground cover, and soil disturbing activities on erosion (Witchmeier & Smith, 1978; (Srinivasan et al. 2012). The C factor is related to both erosivity of the erosive agents and the erodibility of the soil.(Naarden and Corbee 2020)indicate the effect of erosivity of raindrop impacts and the surface cover can affect surface runoff. Additionally, plant canopy also reduces the erosivity of the raindrop impact by intercepting raindrops and reducing rainfall energy. The erosion- control practice factor (P), accounts for the belongings of preservation rehearsal liketerracing, strip cropping, and contouring for controlling erosion. P-factor is the percentage of soil damage with a given repetition to earth damage by conventional raw farming similar to the slope.

### *2.3 Estimating Sediment Yield*

Sediment harvest mentions 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 consume remained rummage-sale for sizing storage reservoirs and estimating reservoir life (Schellenberg et al. 2017). Precise approximation of sediment harvest is very significant in order to plan a reservoir and efficiently manage its sediment so that the reservoir container encounter 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 since of little overflow and yield in wetter areas is limited by the protective soil cover and reduced erodibility of humid zone soils (García 2008).

### *2.4 Sediment Transport Equations*

Sediment transport equations are used to control the sediment conveyance volume for a specific set of flow condition. The primary stage in evaluating sediment transport is to select single or additional 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 divan weight and suspended weight 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 better than those originate 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.

MUSLE is a modified version of the USLE develop by Smith (1965)

Sed =1.292ElUSLE *KUSLE *CUSLE*PUSLE*LUSLE*CFRG

Where, Sed 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.)),

KUSLE is the USLE soil erodibility factor (0.013 metric ton m2 hr./ (m3-mertic ton cm)),

CUSLE is the USLE concealment and organization issue, PUSLE is the USLE provision repetition factor,

LSUSLE is the USLE topographic factor and

CFRG is the coarse piece issue.

Sed = 11.8 (Qsurf * qpeak * Aeahru) $^{0.56}$ * KUSLE *CUSLE*PUSLE*LUSLE*CFRG

Where, Q surf is the surface runoff volume (mm), q peak is the highest excess degree (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.

### *2.5 Flow-Duration, Sediment-Rating-Curve Procedure*

The flow-duration, sediment-rating-curve procedure requires a flow-duration curve, a sediment rating curve, and knowledge of the characteristics of the sediment; both the flow-duration and sediment rating curves must be developed from on-site measurements, usually measurements made as part of a historic record at sites within the watershed. A flow-duration curve is the graphical relationship between the flow rate and the duration of time that the movement is equaled or exceeded; flow-duration data can be computed and plotted as a flow-frequency curve. Construction of a sediment evaluation curve requires records of both average daily discharge and sediment loads. The assessment bend is developed by constructing a "best fit" line through a conspiracy of the regular everyday movement and the corresponding sediment improve the accuracy of computed sediment yields. The sediment harvest can be projected by integrating the flow duration and sediment rating curves

### *2.6 Reservoir Sedimentation*

Reservoirs are built to serve many functions that include storage facility for domestic and irrigation water supply, power generation enhanced navigation and flood attenuation. Discounting long term damaged the structural reliability of the dam walls, the main factor influencing the operational life of a tank is the loss of effective water storage capacity due to sediment deposition. However, storage capacity loss is only one of several sediment related problems such as: delta deposition (increasing flooding of infrastructure and agricultural lands, and reducing navigational clearance beneath bridges); navigation impairment due to sediment accumulation; air pollution due to erosion and transport by wind of desiccated deposit (creating a nuisance and health

Hazard to nearby communities); earth quake hazard due to the presence of sediment against the dam. Abrasion of hydraulic machinery (reducing its efficiency and increasing maintenance costs); obstruction of bottom outlets; reduction of energy generation; and ecological problems affecting species composition and both recreation and subsistence fishing (Petkovsek and Roca 2014).

Reservoir sedimentation process that differs with catchment sediment generation, speed of transport and form of deposition.

### *2.7 Modified universal soil loss equation*

RUSLE is a computerized form of the USLE.It incorporates enhancements in numerous of the factor estimations, including a new procedure to calculate cover factor, new algorithms to reflect rill to inter-rill erosion in slope distance and sharpness factors. Further-enhanced Windows form of the software, identified as RUSLE2, was recently released for guiding upkeep preparation, inventory erosion rates, and estimate sediment transport.

In 1985, the USDA initiated the WEPP model for soil erosion prediction. This model is used in loam and water upkeep planning and assessment (Foster & Lane, 1987). The WEPP model is a process-based, distributed parameters, capable of doing both single-event and continuous simulation erosion prediction. This model relies on the fundamentals of stochastic weather generation, infiltration theory, hydrology, soil physics, plant science, hydraulics and erosion mechanics USDA-Agriculture Research Service (ARS) 1995). Although this model does not implement the USLE for parameter estimation, it can predict soil erosion, sediment transport, and deposition across the landscape by using a steady-state sediment continuity equation for predicting and corrosion processes.

The European Hydrological System (De Figueiredo and Bathurst 2002), MIKE SHE (Refsgaard and Storm 1990) is a comprehensive, distributed, and physically based model that simulates water, sediment, and water-quality parameters in two-dimensional overland grids, one-dimensional channels, and one-dimensional unsaturated and three saturated flow layers. Asthe CASC2D model, MIKE SHE can perform both single-event and long-term continuous events.

### *2.8 Hydrological Modeling*

Modeling is clear as the process of organizing, synthesizing, and integrating component parts into a realistic representation of the prototype.(Elizabeth Frazão 1999). Lists the following benefits of modeling: Models help sharpen the definition of hypotheses, define and categorize the state of knowledge, provide an analytical mechanism for studying the system of interest, and container remain rummage-sale to simulate experiments instead of conducting the experiments on the watershed itself. Even though, guesses of sediment harvest are required in a wide spectrum of practical studies for the planning, design, action and care of water resources structures, the measurement and sampling of sediment transportation is very lengthy and costly. So that it requires other optionsto challenge such problems of sediment estimation in water resources development. One of the options is usage of hydrological models. Most of runoff - sediment modeling is uses physically based models or/and empirical models. The sediment yield from any drainage system is calculated by averaging the data collected over a period of years. It is, therefore, an average of the results of many different hydrologic events.

Hydrological models are characterizations of the actual world system. Modeling of the rainfall runoff processes of hydrology is needed for many different reasons the main reasons being limited range of hydrological measurement techniques and limited range of measurements in space and time (Campling et al. 2002). Therefore, it is essential to advance a means of extrapolating from those available measurements in space and time to ungauged catchments and into the future to assess the likely impact of future hydrological changes. The researchers use a extensive variety of hydrological models, however, the applications of those models are highly dependent on the purposes for which the modeling is made. (Campling et al. 2002), stated that many rainfall-runoff models are carried out purely for research purposes as a means of enhancing knowledge about hydrological systems. He also added that other types of models are developed and employed as tools for simulation and prediction aiming ultimately to allow decision makers to improve decision making about hydrological problems. Before developing the hydrological models, it is very important to understand how the catchment responds to rainfall under different conditions

### 2.8.1 Types of Hydrological Model

According to(Communities 2000), stochastic and deterministic models are often consider to be at the top level of the classification tree, in accordance with the way they treat the randomness of hydrologic phenomena. Stochastic models use local hydrometric data to predict flows. These models allow for some randomness that, result in different outputs and based on analysis of past events, commonly rainfall and river discharge (Samuel Antwi1 2008). Deterministic models generally produce a solitary production of runoff for a given rainfall under identical physical environments.

**Lumped models**: lumped hydrologic model simulation evaluated only at outlet of the basin that is without explicitly accounting for the reply of separate sub basins and parameters do not differ spatially within the basin.. Water Balance model (WATBA), Snowmelt Runoff Model (SRM), Identification of unit Hydrograph and Components from Rainfall, Evaporation and Stream flow data (IHACRES) are examples of lumped hydrological models

**Distributed models**: distributed hydrological model parameters are fully allowed to differ in space at a resolution frequently selected by the operator. Distributed modeling tactic attempts to integrate data concerning the longitudinal difference of limits together with computational algorithms to evaluate influence of this distribution on simulated precipitation-runoff behavior. Distributed models require big quantities of information for parameterization in each grid cell (Beven 2000). However, the governing physical processes are modeled in detail, and if properly applied, they can provide the highest degree of accuracy. For instance, HYDROTEL, MIKE11/SHE and WATFLOOD are distributed models.

**Semi-distributed models**: parameters of semi-distributed models are partially allowed to vary in space by separating the basin hooked on a amount of lesser sub basins. Semi-distributed model structures are more physically based than the arrangement of lumped models and less demanding input data than fully distributed models. Semi-distributed model can be grouped Kinematic Upsurge philosophy models and probability distributed models. According to Beven (2000), the Wave theory replicas are easy versions of surface and/or the subsurface movement reckonings of substantially grounded hydrologic models. In the case of the probability distributed models, spatial resolution is considered by using probability distributions of input parameters across the basin. Examples of semi-distributed models are SWAT (Arnold et al., 1993), HEC-HMS (US-ACE, 2001), HBV (Bergström 1976), and TOPMODEL(Cunderlik and Simonovic 2007).

### 2.8.2 Hydrological Model Selection

The choice of a suitable hydrological model depends on the function that the model needs to serve. There are several hydrological models simulating the hydrological process at different spatial and temporal scales. There are various criteria which can be used for choosing the proper hydrological model for a specific problem. Further, some criteria are also user-dependent and subjective, such as the personal preference for graphical user interface, computer operation system, input-output management and structure and clarity for users.

The selection of hydrological model taking into consideration the following four fundamental selection criteria (Cunderlik and Simonovic 2007):

- Does the model forecast the variables essential by the project?
- Is the model capable of simulating single-event or continuous processes?

For this study, SWAT model was selected since it fulfills the above criteria. Besides, the model was selected because, it is physically based, semi-distributed and belongs to the public domain, computationally efficient and it requires specific information about weather, soil properties, topography, vegetation, and land management practices occurring in the watershed.

## *2.9 Soil erosion and Sediment Reduction Measure*

### 2.9.1 Introduction

Soil and water preservation actions are classified into structural measures (check dams, terracing, contouring, stone bunds and graded channel), agronomic measures (mulching, strip cropping, contour farming, mix cropping) and vegetative measures such as grassed waterways, filter strips and reforestation (Douglas-Mankin, Srinivasan, and Arnold 2010). According to (Srinivasan et al. 2012) Soil and water protection actions are classified into two groups such as structural (grassed waterways, terraces, contouring and filter strips) and non-structural (no tillage, contour farming, conservation tillage, strip tillage). For this study the selected sediment management practices and the studies conducted by different researchers were discussed below.

Land administration and management issue is a key factor to be addressed in the dire dam Reservoir sedimentation is a significant problem in dire dam reservoir. In many water supply reservoirs, the original storage capacity is occupied by sediments and reduce the quantity of water supply to the community. Sediment accumulation on the reservoir reduce the useful life of the dam and diminish benefit from the dam When dual purpose dam constructed on dire dam to assist in reducing sedimentation, as well as harvesting additional quantities of water. The dam is supposed to prevent large part of the sediments from entering the reservoir, thus lengthening its life span and at the same time increasing water harvesting efficiency. The silt trap dam has a catchment area could be 8.3 km2; a reservoir volume of 1.1 MCM The dam is located at the northwest part of the catchment. The location is could be good for the construction of a small dam. Foundation conditions are very good and the bed rock is visible in both embankments and the river bed. The reservoir will probably not create any significant problems to the nearby communities and no cultivated land was identified during the site visit. Constructing silt trapping structure needs high amount of invest, so the silt-trap zone is good to prevent silt transported with water that originates from the catchment close to the reservoir and from the silt-trap-zone itself to enter the reservoirs. The two basic approaches for reservoir sedimentation control are controlling soil erosion through watershed management, and handling sediment where it creates the problem, namely, in the reservoir.

### 2.9.2 Grassed Waterways

Application of grassed waterway in critical sub basins reduces the sediment yield on the channel outlet by increasing sediment trapping efficiency and reducing flow velocity ; Arabi et al., 2008). During sediment simulation in SWAT model, the model calculates the maximum sediment yield that can be conveyance as a purpose of peak flow channel velocity (Neitch et al., 2011). Studies shown that implementing grassed waterways reduce sediment yield by protecting channel erosion and intercepting the sediment particles collected and transported through channels and streams.

The study of Mwangi et al. (2015) reveals application of grassed waterway can decrease the sediment yield of Sasumua watershed, Kenya, at the outlet with 54%. Study conducted by (Eguale et al. 2020), showed that introducing grassed waterway to Kesem Dam watershed, one of the tributaries of Awash River, can reduce the regular yearly sediment harvest rate of the treated sub basins by 57.34% from the baseline condition. The study of (Amaru Ayele and Gebremariam 2020) also shows the applying grassed waterway on proposed middle Awash Dam watershed for critical sediment source sub basins reduced 76% of regular yearly sediment harvest

### 2.9.3 Vegetated Filter Strips

Vegetated sieve floorings necessity install along the edge of the channel segment to reduce the entrance of sediment, nutrients, pesticides, and bacteria in surface runoff (Kondolf et al. 2014). A filter strip is represented by width of the edge of field filter strips.(Anon 2008), vegetated filter strips are designed to treat sheet flow from adjacent surfaces and slowing runoff velocities and filtering out sediment and other pollutants.

According to(Amaru Ayele and Gebremariam 2020), application of filter strips proposed middle Awash Dam watershed, Ethiopia using SWAT model has reduced regular yearly sediment harvest at outlet by 25.8%. The study of Andualem and Gebremariam (2015) conducted on Gilgel Abbay watershed, Ethiopia; found that applying filter strips on the study watershed can reduce 23.74% of the regular yearly sediment harvest at the outlet. Also, the study of Betrie et al. (2011) on Bluenile Sink by means of SWAT model reports, applying filter strips has also reduced the regular yearly sediment harvest at the outlet by 44%.

### 2.9.4 Terracing

When the slope steepness and slope length reduced by the application of terraces, the highest overflow degree and erosive power of runoff are reduced consistently (Parajuli and Acharya 2012). A promenade is an ground ridge, built crossways the field slope usually on the contour (Sanchez, Couto, and Buol 1982). To simulate terracing conservation practice in SWAT model, (CN_II), USLE practice (USLE_P) factor and the slope length (SLSUBBSN) could be adjusted based on cover type, hydrologic condition and hydrologic soil groups (Srinivasan et al. 2012).

Studies of (CN and FM 2015) assessment of agricultural upkeep practices on ecology services in

Sasumua crunch, Kenya by means of SWAT model shows the application of parallel terracing reduced residue harvest for the critical affected sub basins by 85%. Study conducted by Maharjan. Simulates five different land management practice case using SWAT model. The study decided that application of terracing on the critically affected sub basins is the most effective land management practice to decrease residue harvest with an average of 78.6%. Another study conducted by (Amaru Ayele and Gebremariam 2020) using SWAT model on proposed middle Awash Dam watershed applying terraces reduced 83.3% of regular yearly sediment harvest for the critically affected sub basins.

### 2.9.5 Contouring

Application of contouring can minimize the formation of rills and reduce erosion by reducing surface runoff and giving a chance to infiltrate by impounding water in a small depression (Srinivasan et al. 2012). According to (Srinivasan et al. 2012), contouring tillage and contour planting provides protection against erosion from storms of low to moderate intensity, but little or no protection against occasional severe storms that causes excessive break-overs of contoured rows.

The study of (Kim and Gilley 2008) shows contouring can reduce at least 50% of regular yearly sediment harvest for treated sub basins. The study conducted by (Amaru Ayele and Gebremariam 2020) shows applying contouring on proposed middle Awash Dam watershed can reduced 61.1% of regular yearly sediment harvest for critical sediment source sub basins.

### 2.9.6 Engineering works for sedimentation control and water harvest in to dire dam

To obtain additional water and to prevent silt to enter the reservoirs, the following other alternatives are proposed (besides dual-purpose dams) should be implemented:

- Regulation of Rivers, Streams and Tributaries
- Diversion of Natural Streams
- Mechanical removal of sediment from the reservoir
- Enlarging the impounding volume of existing reservoirs
- Buffer Strip

#### 2.9.6.1 Regulation of Rivers, Streams and Tributaries

Riverbed regulation would assist in reducing that part of sediment migration caused by river bed erosion and would also serve as well to lower flood water levels in the valleys along rivers, streams and tributaries. Regulation will become imperative when the price of the cultivated land

and agricultural products are sufficiently high to justify it. At present, regulation is justified only if it is less costly than other means to minimize reservoir sedimentation.

River/stream regulation would consist of excavating the river bed to the design cross-section to enable conveyance of the design flood and protect the riverbed from erosion. The latter would be achieved either by moderating the longitudinal slope (by installing drops) and reducing the flow velocity, or by protecting the cross-section from erosion by vegetation, where the velocity permits, or by riprap or other costly means, where the velocity is too high.

It should be noted that while erosion and sediment load would be reduced following river regulation, sediments that currently settle in the river floodplain would be conveyed downstream in the regulated stretches. Usually grass is used to protect the wetted perimeter up to velocities of 2.2 -2.5 m/sec. The permitted velocity depends on the type of soil and the grass protection. Since regulation will change the geometry of the river by enlarging the cross-section, it is possible that land requisitioning will be required

### 2.9.6.2 Diversion of Natural Streams

The possibility of diverting natural streams by constructing diversion canals, in order to divert a part of the sediments flowing to the reservoirs during the rainy season. This measure should be commenced after the reservoir is full of water. The following diversions were examined. Siltation in the recently commissioned Dire reservoir should be measured to check the rate of sedimentation and then to take the required decisions. stream diversions only the Hurufa and Bosena rivers could be diverted but the design of such a diversion would has to take into account the nearby relocated villages.

There are rivers and streams in the dire reservoir watershed, whose diversion might assist in reducing siltation of the reservoir. These are the, Sekoru, Fule, Dabe, Sendafa and Southeastern Tributary. Diversion of any given river/stream would have to start at a point that is sufficiently upstream (thus ensuring a downward slope) to reach a given point outside the catchment where the floodwater of the river/stream would be discharged.

### 2.9.6.3 Mechanical Removal of Sediments from the Reservoirs

Mechanical removal of silt/sediment from reservoirs is a costly operation. But on the other hand it is a measure to maintain the operational volume of reservoirs free of sediments if no other alternatives exist. Two ways of removal, excavation and dredging.

A large amount of sediments from incoming floods when reservoir water levels are high settle in the flooded area at the upstream end of the reservoir. During the dry season, when water levels drop due to supply and losses, the sediments at the upstream end will dry up and it will be possible to excavate them by heavy earthmoving equipment, working in a downstream direction. The excavated material would be disposed of or spread in areas nearby (in order to lower the cost of disposal).

Dredging of the reservoir bottom can be done throughout the year, although it might be much more expensive during the wet season.

The nature of the dredged material, namely liquid mud, is such that it cannot be spilled freely and should be impounded in settling basins/reservoirs where sediments will settle, while excess water will flow back to the reservoir.

After complete silting-up, the settling basin/reservoir can be used for cultivation or afforestation. Sediments could also be used for other purposes such as raw material for the tile/ceramics/brick industry, improvement of inferior agricultural lands, etc. If such solutions are adopted it is better to determine possible users/uses from the beginning in order AAWSA to share the cost with others.

Because of the high cost of dredging, it is recommended that sediments/silt settled in the reservoirs be excavated during the dry season, when the water level in the reservoirs is low.

In any case the excavation and certainly much more the dredging are very costly solutions. We consider that implementing very costly methods like the mechanical removal of sediment from the reservoirs in not a necessity for AAWSA at the moment. If the sediment rates be increased in the future, maybe that kind approach could be reconsidered.

#### 2.9.6.4 Enlarging the Impounding Volume of Existing Reservoirs

In dire reservoir there is a significant inflow from the catchments which cannot be retained by the existing reservoirs and overflows downstream. Specific engineering works must done in order to enlarge the impounding volume of the existing reservoirs. These works are could be done by raising the height of the dam and diversion of surplus water from dire reservoir.

**Diversion of Surplus Water from Dire Reservoir**

There is an expected average surplus of approximately 23 MCM of water annually from the Dire reservoir.

The following alternatives are used for the diversion of surplus water from the Dire reservoir:

- Diversion from a point upstream of the reservoir.
- Open earth channel diversion from the Dire reservoir directly to Lege Beri river.

- Direct open earth channel diversion from Dire river downstream of the reservoir spillway outlet.
- Diversion by concrete canal/conduit instead of earth channel according to either of the above alternatives

**Diversion from a Point Upstream of the Reservoir**

This alternative is not recommended because of the high cost to construct a 4 km long canal, the required relocation of villages, land expropriation and silt problems during flood flows

**Diversion from Dire reservoir to Lege Beri river**.

Following this alternative the overflow from the dam is diverted to Lege Beri river from an outlet on the eastern side of the reservoir. The period available for diversion will be short, mainly when the reservoir is full, when it will presumably be easier to determine whether diversion to Legedadi Reservoir is necessary and feasible. The diversion is possible from the hydraulic point of view, since there is a difference in elevations between the N.W.L. of Dire and Legedadi reservoirs. The optimal canal alignment would be selected so as to minimize the need for relocation of the local population and for land expropriation. The length of the diversion canal up to the western upper tributary of Lege Beri is about 1.0 km.

The diversion will require the development of a sophisticated operation program taking into consideration the water level in the Dire reservoir, as well as inflow discharges, water supply needs and reservoir losses from evaporation and infiltration.

**Direct open earth channel diversion from Dire River downstream of the reservoir spillway outlet**.

In this alternative a canal from Dire river downstream the spillway outlet to Legedadi reservoir is proposed, but not recommended, due to the higher cost of the previous direct diversion.

**Diversion by Concrete Canal/Conduit**

In this alternative it is proposed that if any of the above diversions should be examined in a next stage, an alternative of constructing a canal or regulating an existing stream using concrete should be consider, since the dimensions of the concrete canal will be considerably smaller than those of an open earth canal, due to the much lower roughness factor and the possibility of using higher conveyance velocities. A carefully planned concrete canal alignment may prove to be economically feasible despite the higher unit cost of concrete.

#### 2.9.6.5 Buffer Strips

buffer strips will act to serve several purposes including: denying entry of livestock to the reservoirs in order to reduce the animal waste deposited in the reservoirs; preventing sediments generated by catchment erosion and small stream erosion from reaching the reservoir directly, Preventing the local inhabitants from reaching the immediate vicinity of the reservoir and reducing farming activities to reduce chemical runoff into the reservoir. Excessive fertilizer use may increase algae blooming induce growth of large amounts of higher order aquatic plants with a resultant increase in the organic matter content of the reservoirs, and generate anaerobic conditions with consequent bad oduor and taste of the water. The three type of buffer strip are exclusion zone, area of minimum activity and supervised zone.

**Exclusion zone**

Separation of water body from any kind of human and animal activity. This roughly 25m wide buffer strip will consist of: a fence, a protection canal, and a green area are best for this zone

**Area of minimum activity**

This is the second buffer strip and allow only minimum activity 400m wide starting from the exclusion zone consist of hard grass

**Supervised zone**

Trees and small shrubs will be planted in this area with natural vegetation or fodder plant to be harvested by cut and carry methods. Shrubs and grass in staggered pattern are acceptable in this zone.

### 2.9.7 Reservoir operation policy

Large amount of sediment enter the reservoir during the rainy season**.** Lowering pool levels during flood season further increases the efficiency of the operation. Reservoir sedimentation is considered as a serious problem, the flow releases from the bottom outlets should be considered in dam design together with a reservoir operation that helps in maximizing flow-through of the incoming sediment. The outlets also help in drawing down reservoir levels during emergencies and repairs Implement established routine reservoir operation and management practices as specified in the professional manuals.

## *2.10 SWAT Model*

### 2.10.1 Overview

The Earth and Aquatic Valuation Instrument model (Srinivasan et al. 2012)is a river basin model developed by USDA-ARS in Temple, Texas. The SWAT classical is a physically based, long term simulation, deterministic, and originated from agricultural models with spatially distributed parametersand operating on a daily time step (P. W. Gassman et al. 2007).

To simulate watershed processes, such as sediment yield, sediment transport, surface runoff, streamflow, subsurface movement, and nutrient filling, amongst others the model uses watershed-exact evidence like weather, topography, soil, vegetation, and land use practices. Basedon their topographic situation the model spatially divides the entire watershed into smaller sub basins. The main structure of the working orderof the program is initially computing fluxes for each HRU, then aggregating the results to sub-basin outputs based upon the fraction of the HRUs, and finally routing sub-basin outputsthrough a river reach within the channel network.

Overland flow is computed using the curve number method and the modified rational formula. The curve number approach is used to determine the runoff volume and SCS TR- 55 or the modified rational method is used for peak flow computation. In the case of subsurface flow, which joins the river before reaching the ground water, the Kinematic storage model (Sloan and Jackson 2012) is used, whereas for ground water flow empirical relationsare used. Movement in a station is determined using Manning's equation and routed based eitheron the variable storage coefficient method or the Muskingum method. The overland sediment movement is estimated using MUSLE.The main factor controlling sedimentyield, in general, is the transport capacity of runoff (Ryu and Roh 2016). Sediment conveyance in the channel system is a function of degradation and aggradation (Neitsch *et al.,* 2011. The modeling method is applicable to the temporal and spatial analysis of sediment yields, and the results are essential for reservoir management strategies.

### 2.10.2. Previous application of SWAT model

Sediment Yield Modeling Using SWAT Model on Case of Changjiang River Basin in china. Indeed, for the monthly time step application, the relative error of the model to the runoff simulation was fewer than 10.21% in the calibration period and the validation period. The correlation coefficient(R2) and Nash-Sutcliffe (Ens) were higher than or equal to 0.91, and The relative error of the model to the sediment simulation was lower than 25.0% in the calibration period and the validation period, R2 and Ens were greater than 0.76. The monthly sediment is obtained and compared with the measured sediment in the figure 2.1

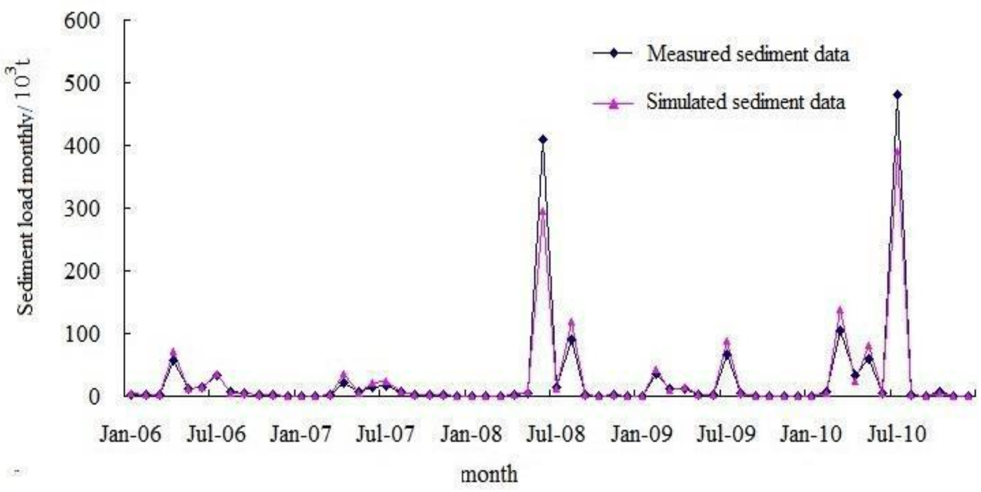


*Figure 2. 1 Observed and measured sediment transport on Changijing River*

Estimating sediment yield at Kaduna watershed, Nigeria using SWAT the dam sustainability, because of the nearness of erosion prone basins to the dam

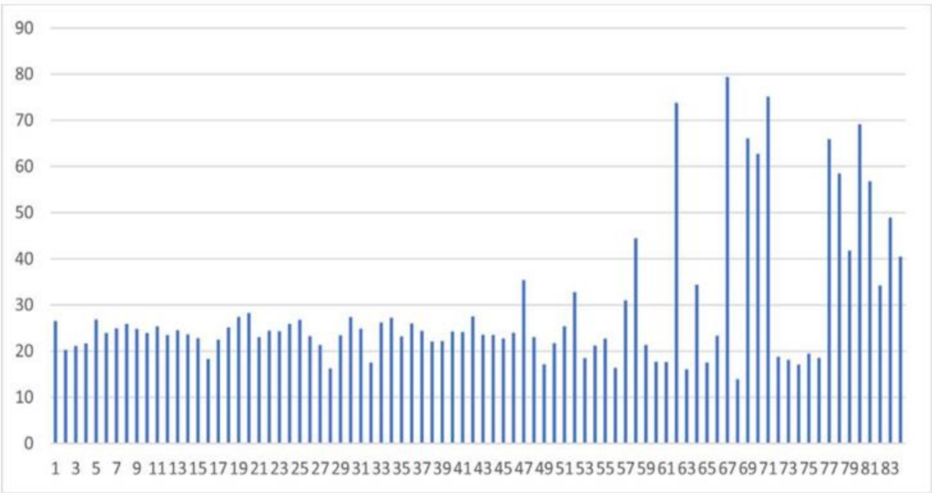

*Figure 2. 2 Simulated and annual sediment yield each of sub basin in the stud part*

Abebe Gebremariyam also done the research on modeling runoff and residue harvest of Kesem dam basin, a wash basin, Ethiopia .

Sub basin 12 (812.4 mm and 24.08 t/ha) and 13 (866 mm and 28.37 t/ha) are in the highest sediment yield and runoff distribution

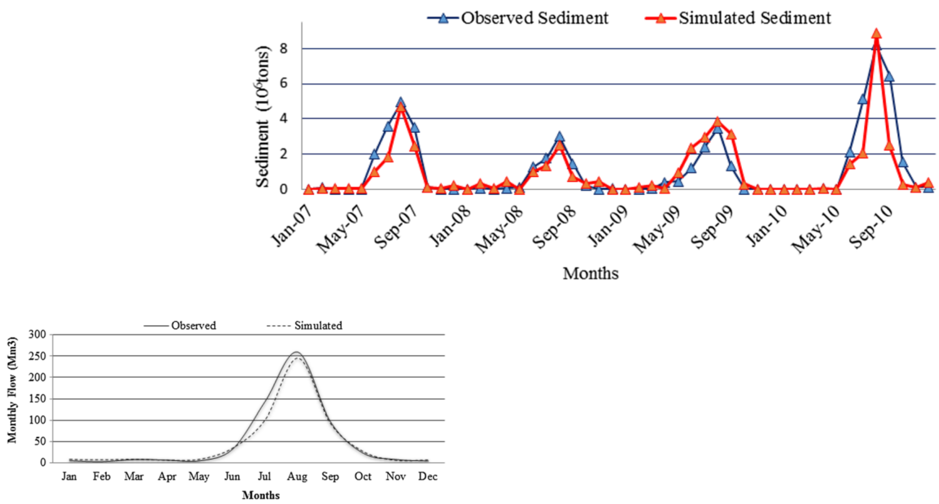


*Figure 2. 3sediment yield hydrograph of validation at kesem dam*

22,252 m3/year is linear yearly siltation rate of the Gefersa reservoir Based on the 1979 and 1998 bathymetric surveys. For 1966 (the time when Geffersa III started to serve as Silt-Trap) is 6.94 MCM, comparing the reservoir volume for period of 1966 to the 1955 volume shows on 46,400 m3/year siltation for the period that the reservoir did not armed with silt trap. Silt accumulation in the period 1976 to 1998 declined by more than half to 22,250 m3/year. This decline is accounted for by the smaller contributing area (with the same rate of 1200-ton//km2/year) due to the construction of the Geffersa III reservoir.

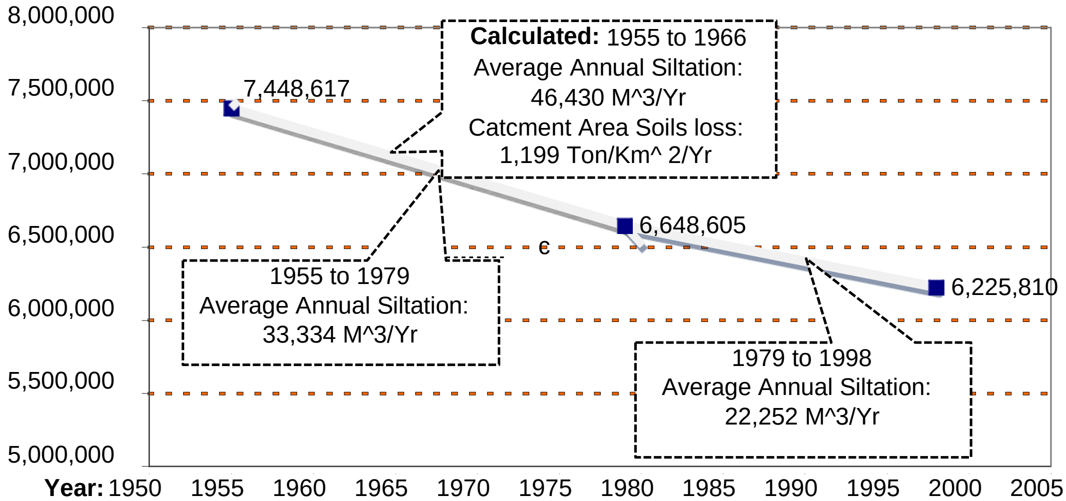


*Figure 2. 4 Gefersa reservoir siltation rate*

### 2.10.3 Limitations of SWAT Model

SWAT model has the following limitations (Srinivasan et al. 2012):

- Movement and residue direction-finding equations used by SWAT are simplistic and the model assumes channel dimensions are static throughout the simulation (may be unrealistic since simulations may be made for 100 years or more). The simplistic description of channel bed does not account for cohesive, non-cohesive or armored channels.

- SWAT model is popular due to the multi-disciplinary coverage of processes representing the hydrology, soil science, sediment transport, crop growth, in-stream water quality and the agricultural management, but it has limitation on its non-spatial representation of the HRU inside each sub catchment.
- The user is responsible for ensuring that any physical parameters entered are correct and meaningful since model is not talented to check meaningfulness of values entered by user.
- Sensitivity analysis, manual and auto-calibration tools in the SWAT perfect is time demanding when modeling complex catchments with several HRUs. This tool should be upgraded at least with visual and objective functional representation of the results. The SWAT-CUP tool is significant improvement for the calibration procedures, however coupling SWAT and SWAT-CUP is needed to increase the efficiency of the modeling.

# CHAPTER THREE

## MATERIALS AND METHODOLOG

### *3.1 Description of the Study Area*

#### 3.1.1 Location of the study area

The Dire Dam is located in BerekWoreda in Oromia National regional state Ethiopia. The dam site and reservoir area are located on the perennial Legeddadi stream and within Dire-Sokoru kebele about 40km northeast of Addis Ababa-Dessie highway. Geographically the dam is located at 9° 46' 73.58" Northing and 38° 56' 49" Easting at an altitude of 2675m above mean sea level.

The area is characterized by moderate weather with average annual maximum Temperatures ranging from 22°C- 24°C while the average annual minimum temperature is ranging from 8°C-10°C and the mean annual rainfall of the watershed area is 1200mm. The Dire sekoru watershed is comprising different land use land cover that exists surrounding the reservoir area. The mainland use type that exists in the catchment area is characterized by high cultivated land (hill slope cultivation and valley cultivation**)**, forest mixed, barren land build area, and waterbody Reservoir) along the reservoir area..

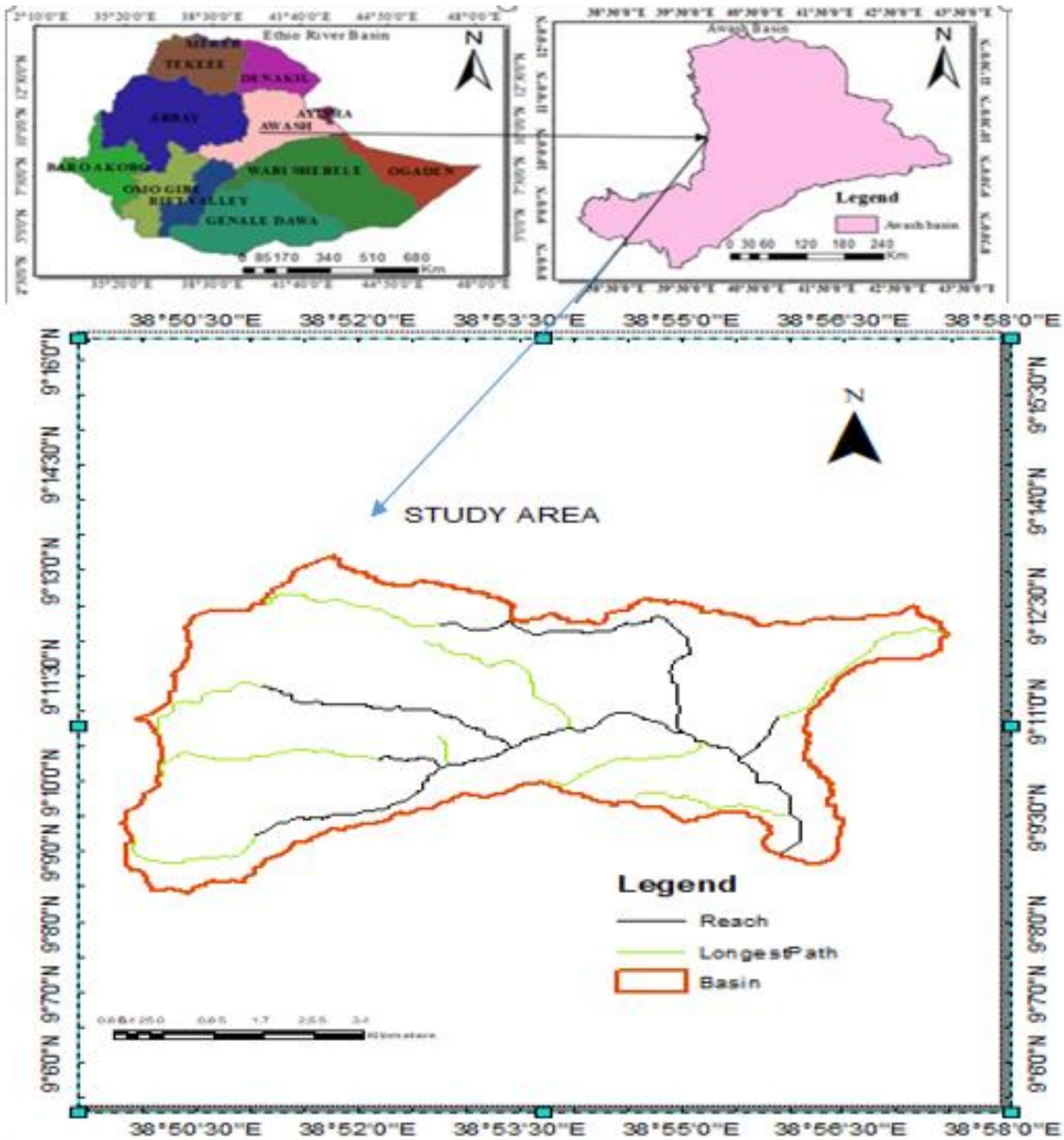


*Figure3. 1 Location of the study area*

### 3.1.2 Geographical Location

Dire-sokoru kebele lies between latitudes $9^0$ 46’ 73.59” North and between longitudes 380 43’ and $38^0$ 56’ 50” East. Its elevation ranges from 2676 masl in the North to about 2200 masl in the South. The Entoto mountain range, which rises to over 3000 masl, is the limit of the City development in the North

### 3.1.3 Topography

The topography of the barrek Woreda is constituting 70 % of flat land mass in the woreda. 20 % of the land is undulating and the remaining 10 % is classified as gorges.

*Table 3. 1 Altitude of the project area*

| No. | Description | Altitude (m.a.s.l) |
|---|---|---|
| 1 | Maximum | 3,228 |
| 2 | Mean | 2,284 |
| 3 | Minimum | 2,754 |

### 3.1.4 Climate

The Barrek woreda and the project area, like any other parts of Ethiopia, are characterized by four seasons. These are Bega (dry season, October-January), Kiremt (long rainy season from June to Septemer), Belg (small rainy season from February - May) and Meker from November to December.

*Table 3. 2 Climatic station with in and in the proximity to dire catchment station used as source of Precipitation data*

| No | Station name | Lat. | Long. | Elevation | Record period |
|---|---|---|---|---|---|
| 1 | A.A Observatory | $09^0$ 06’ 29’’ | $38^0$ 48’ 26’’ | 2386 | 1988-2018 |
| 2 | Sululta | $09^0$ 11’ 07’’ | $38^0$ 45’ 37’’ | 2610 | 1988-2018 |
| 3 | Intoto | $09^0$ 06’ 56’’ | $38^0$ 46’ 19’’ | 2903 | 1988-2018 |
| 4 | A.A Bole | $08^0$ 58’ 59’’ | $38^0$ 48’ 36’’ | 2354 | 1988-2018 |
| 5 | Dire gidib | $09^0$06’ 29’’ | $38^0$48’ 26’’ | 2560 | 1988-2018 |
| 6 | Sendafa | 9° 9' 7.8012" | 39° 1' 17.4" | 2558 | 1988-2018 |

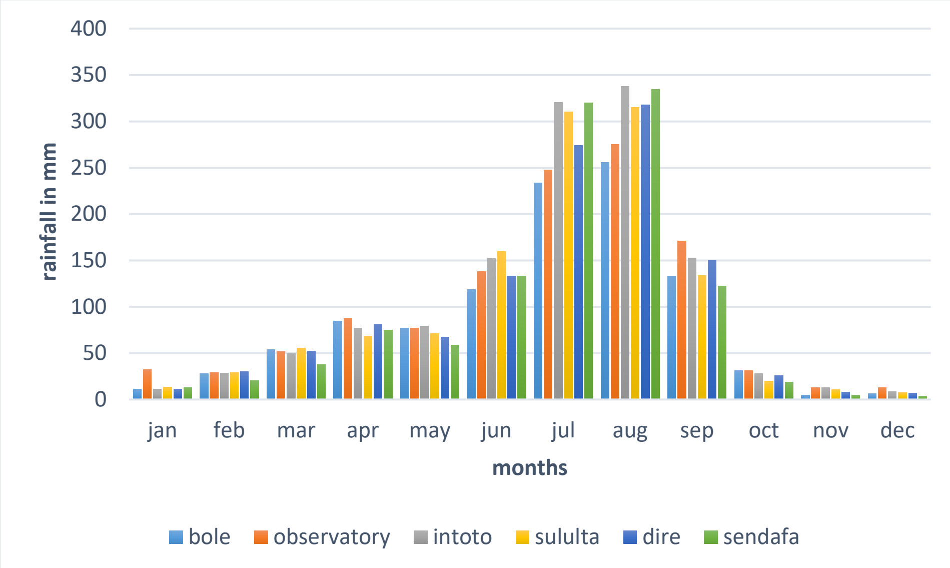


*Figure3. 2 rain fall station*

### 3.15 Temperature

The nearest meteorological station to the project area is dire dam station. Thirty-one year's temperature data obtained from NMSA measured at this station is analysed. The Thirty-one year's monthly average data is presented in figure below. As seen in the figure the maximum monthly average is obtained in March and April and recorded as about 26 Degree Celsius. The minimum average monthly temperature is recorded in December and the record is 6 Degree Celsius.

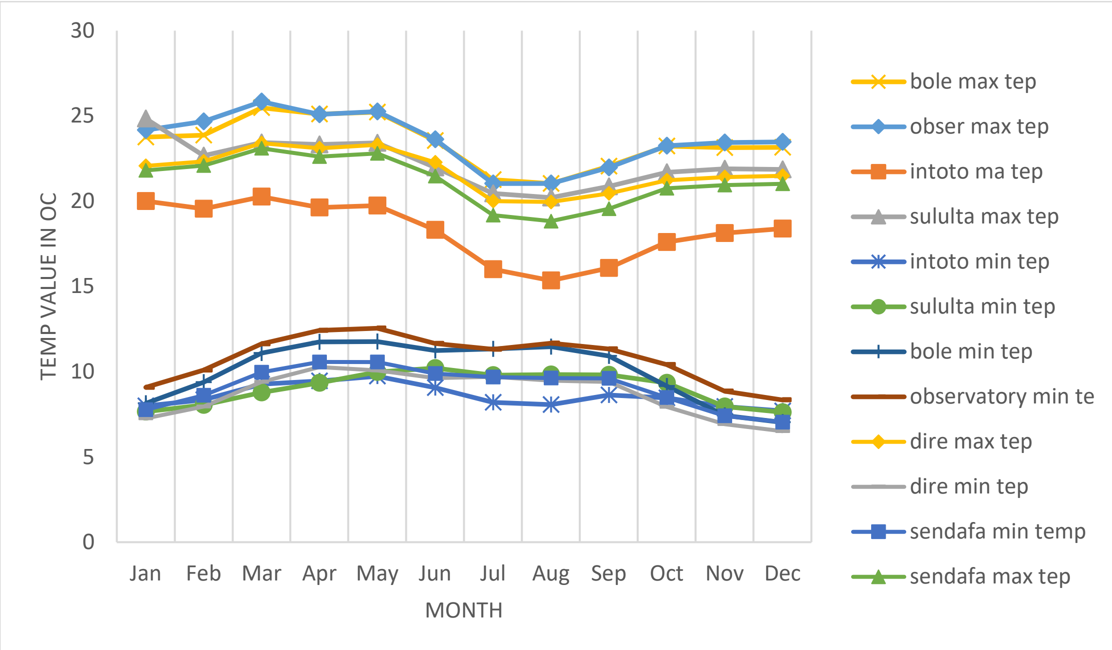


*Figure3. 3 minimum and maximum temperature of a satiation*

### 3.1.6 Land Use and Land Cover

Land use type and land cover types that were found in the catchment area are: cropland, grassland, plantation, and forest, open shrub, dense field river course, bare land, river side and a water body. Most of the catchment land in Barrek is agricultural land constituting 51 percent of the total woreda area. The area surrounding the reservoir is covered by grasses while the croplands are situated far from the reservoir area.

*Table 3. 3 land use land cover of the study area*

| No | Land use/ Land cover | % of cover |
|---|---|---|
| 1 | water | 2.09 |
| 2 | Forest-mixed | 22.55 |
| 3 | Forest-deciduous | 0.95 |
| 4 | Range-brush | 0.99 |
| 5 | Agricultural land generic | 58.90 |
| 6 | Range-grasses | 14.34 |
| 7 | Bare land | 0.19 |

### 3.1.6 Soil Type

With regard to the soil type, the data obtained in the **MoWIE,**describes the catchment have five soil type namely calcic zerosols, chromic luvisols, leptosols, ortho solonchaks and pellic vertisols woreda administration describes the woreda land as to be clay soil, sandy soil and Red soil

*Table 3. 4 soil type of the study area*

| No | Soil Type | % of coverage |
|---|---|---|
| 1 | Calcic xerosols | 12.51 |
| 2 | Chromic luvisols | 50.32 |
| 3 | leptosols | 1.01 |
| 4 | Orthic Solonchaks | 29.62 |
| 5 | Pellic Vertisols | 6.47 |

## *3.2 Methods*

### 3.2.1 General

Prior to dealing with any research, it is vital to make a strong search for the data and identify clear and efficient methodology that describes the procedural design and so as to provide enough detail, at which a competent worker can go through it. Data is a crucial input in hydrological modeling. Data preparation, analysis and formatting in the model input format is important and has influences on the model output. The relevant time series data used for this study includes daily rainfall data, stream flows, suspended sediment yield, temperature (minimum and maximum), relative humidity, wind speed ,solar radiation and Spatial data (DEM, soil map, land use map). Data were collected from the legal organizations, such as, Ethiopian Ministry of Water, Irrigation & Energy (MoWIE), water and land management institute and Ethiopian Meteorological Agency.

## *3.3 Conceptual Frame Work of the study*

The general methodology of this study is depending on the data, which are collected from different organization and also field observation. A field visit to the study area was conducted for duration of several days. The objective was to become familiar with the topography, foremost land-use and land cover of the study area and to have better sense of its hydrology during hydrological modeling. This methodology has two parts:

- The first part is the estimation of sediment yield in the watershed by using SWAT model
- The second part is introducing BMPs (best management practices) or mitigation measure for the sedimentation of the reservoir by using different scenario.

In order to understand how each section works within the modeling process, it is important to understand the conceptual framework of each step, as well as what data are used and how theyare integrated in to Arc SWAT. Therefore, the main steps of Arc SWAT preprocessing are going to be covered throrough.

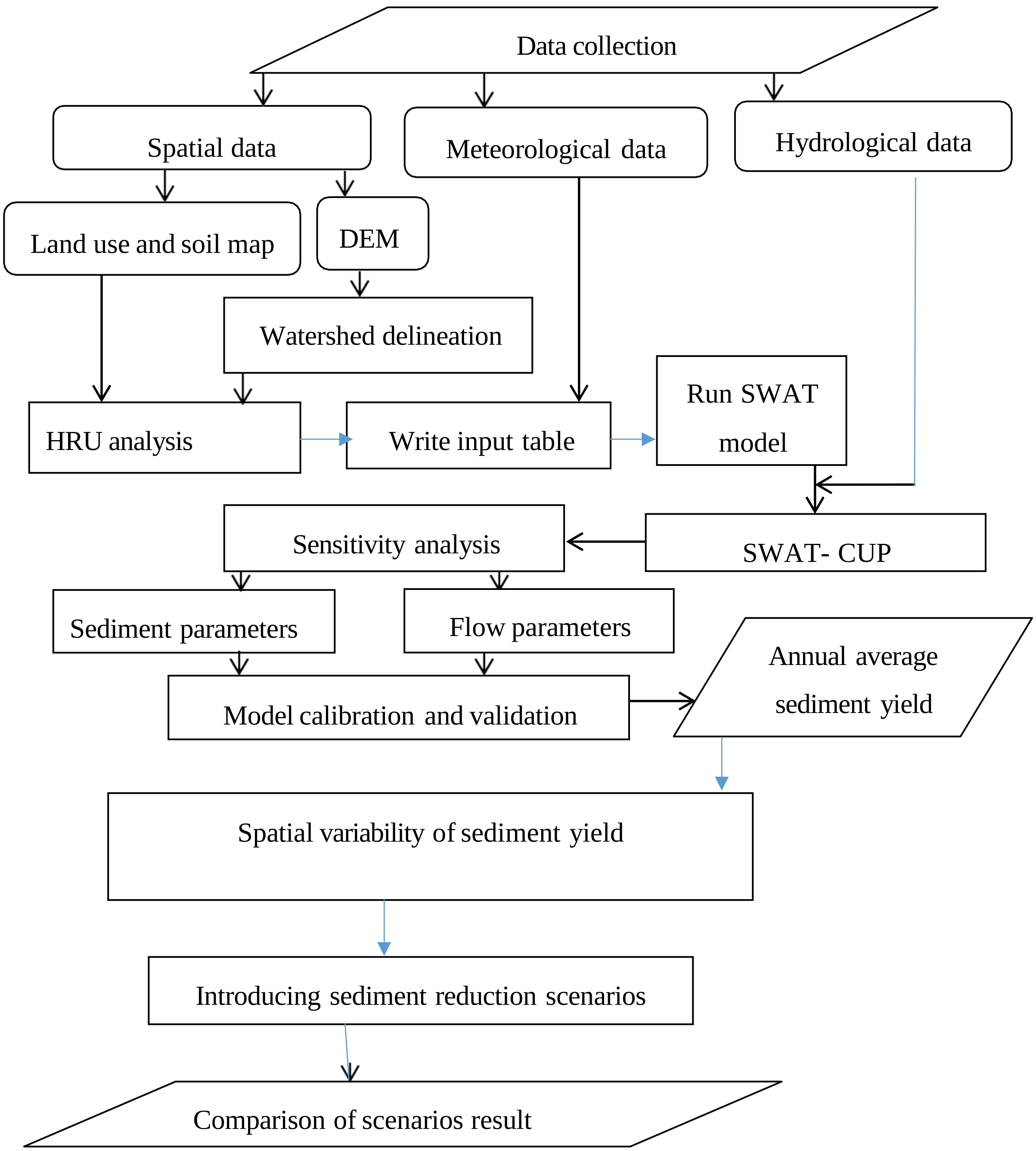


*Figure3. 4 overall process of the methodology*

### *3.4 Data Collection*

Collection of data include both desk and field investigation in order to achieve paper objective. The **deskwork** will carry out the essential literature review on modeling books, and previous work. The required data for sediment yield modeling in Dire dam

- Digital Elevation model
- Soil data
- Land use/land cover data
- Metrological Data
- Hydrological Data
- Sediment data and software application help for modeling like SWAT etc.

#### 3.4.1 Digital Elevation Model (DEM)

Digital Elevation Models (DEMs) are useful GIS layers that can be used for automatic delineation of flow, Stream networks and watershed analysis. They can be used to create terrain attribute maps, data and other stream characteristics.

For Dire dam, I will collect DEM data from water and land management institute and the study area can be delineated from DEM in ArcGIS – Arc SWAT interface where all the land use/land cover, soil and land slope data are clipped to it. In addition to these defining of the

The primary step in creating the model input is the watershed delineation accomplished using digital elevation data. DEM is the first input of SWAT model fordelineating the watershed to be modeled. Based on threshold specifications and the DEM, theArc View interface was used to delineate the crisis into sub basins. Subsequently, sub basinswere divided (HRU). DEM. All spatial data sets were projected to UTM 37 North.

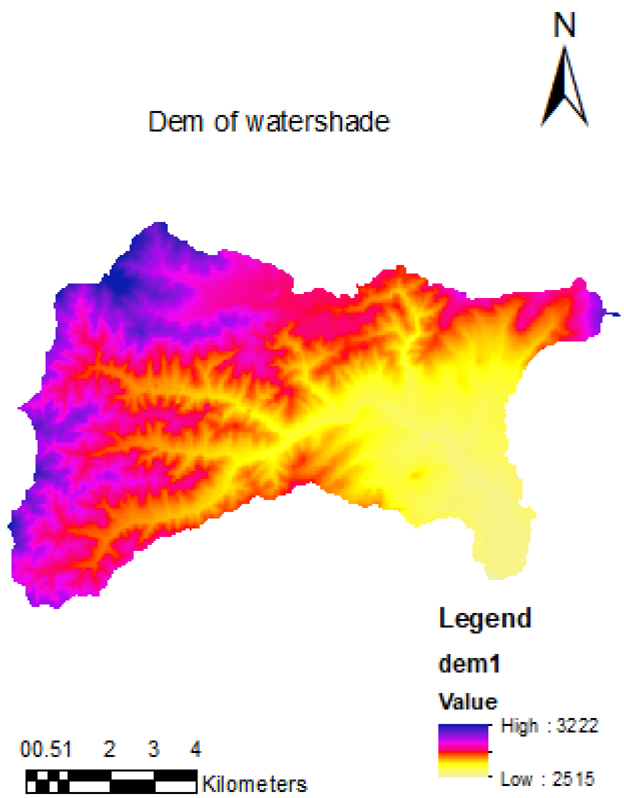


*Figure3. 5 digital elevation model of Dire dam watershed*

### 3.4.2 Soil data

SWAT model requires physico-chemical properties and different soil textural such as available water content, soil texture, bulk density, organic car-bon content and hydraulic conductivity for dissimilar coatings of apiece soil kind. Since the soils database defines the surface and upper subsurface of a watershed and is used to decide a water budget for the soil profile, daily overflow and erosion.

I will obtain soil data of Dire dam reservoir watershed from (MoWIE) and project using the raster projection in Arc Map before it is imported to Arc SWAT. In addition to this I will use high spatial resolution soil map since it increases the prediction accuracy of the model. Different soils have different soil edibility factor, hydraulic conductivity, infiltration capacity etc. This can affect the water balance and residue harvest from the watershed. The total area of the watershed is 73 $km^2$

*Table 3. 5 Soil percentage of dire catchment (source MoWIE  SWAT model HRU result)*

| NO | Soil Type | Area ( coverage)km$^2$ | % of coverage |
|---|---|---|---|
| 1 | Calcic xerosols | 9.45 | 12.51 |
| 2 | Chromic luvisols | 34.95 | 50.32 |
| 3 | leptosols | 1.78 | 1.09 |
| 4 | Orthic Solonchaks | 21.21 | 29.62 |
| 5 | Pellic Vertisols | 5.84 | 6.47 |

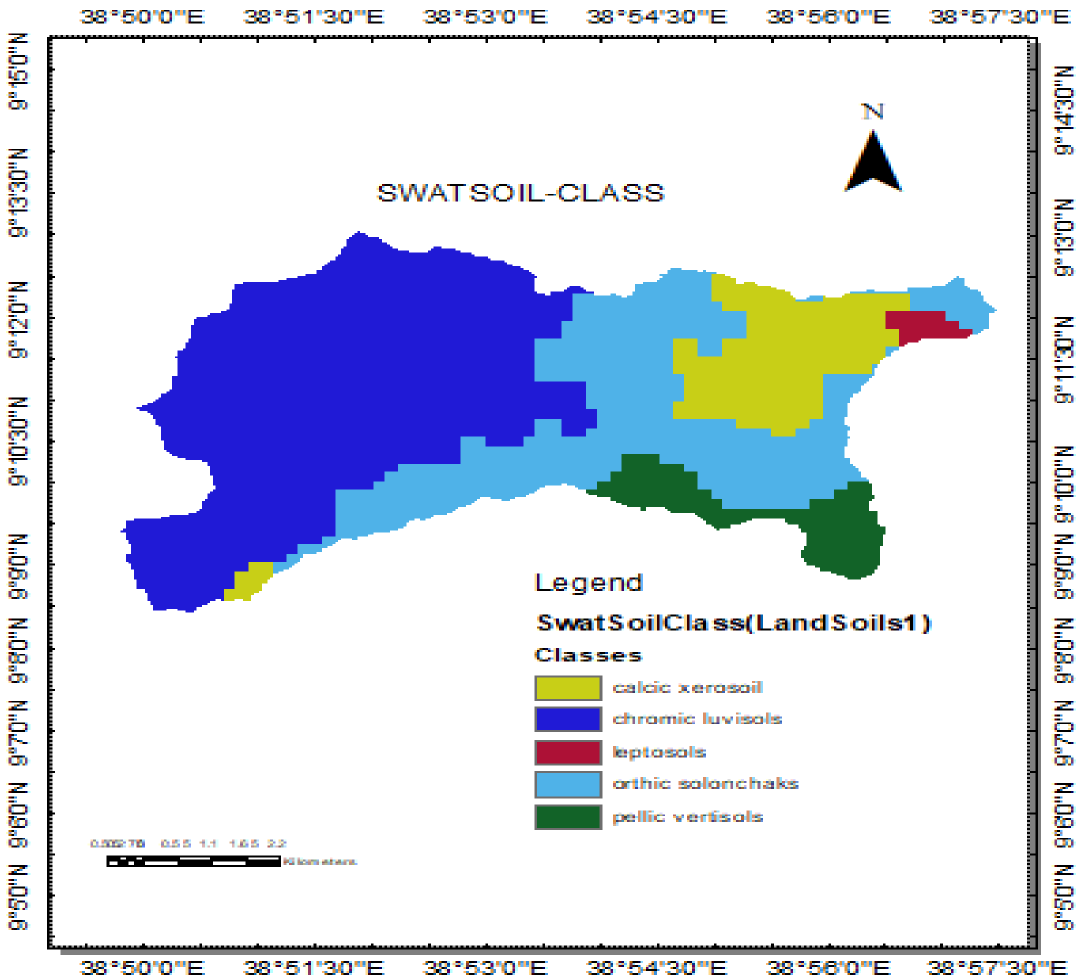


*Figure3. 6  soil map of Dire watershed*

### 3.4.3 Land Use Land Cover

Land use and cover data has also a significant effect on the hydrological modeling. As a result, it can affect runoff, evapotranspiration and surface erosion in a watershed. The land use map of the Dire dam reservoir area will be obtained from water and land management institute. In order to represent the land use according to the specific land cover types such as type of crop, pasture and forests, reclassification of land use map of the area based on the available topographic map, aerial photographs and satellite images will be done. The land use for Dire watershed will be projected using the raster projection in Arc Map before it is imported to Arc SWAT

*Table 3. 6 Coverage of land use in Dire catchment (Source WLMI 2016)*

| No | Land use/ Land cover | Swat Land | % of cover |
|---|---|---|---|
| 1 | water | WATR | 2.09 |
| 2 | Forest-mixed | FRST | 22.55 |
| 3 | Forest-deciduous | FRSD | 0.95 |
| 4 | Range-brush | RNGB | 0.99 |
| 5 | Agricultural land generic | AGRL | 58.90 |
| 6 | Range-grasses | RNGE | 14.34 |
| 7 | Bare land | BARR | 0.19 |

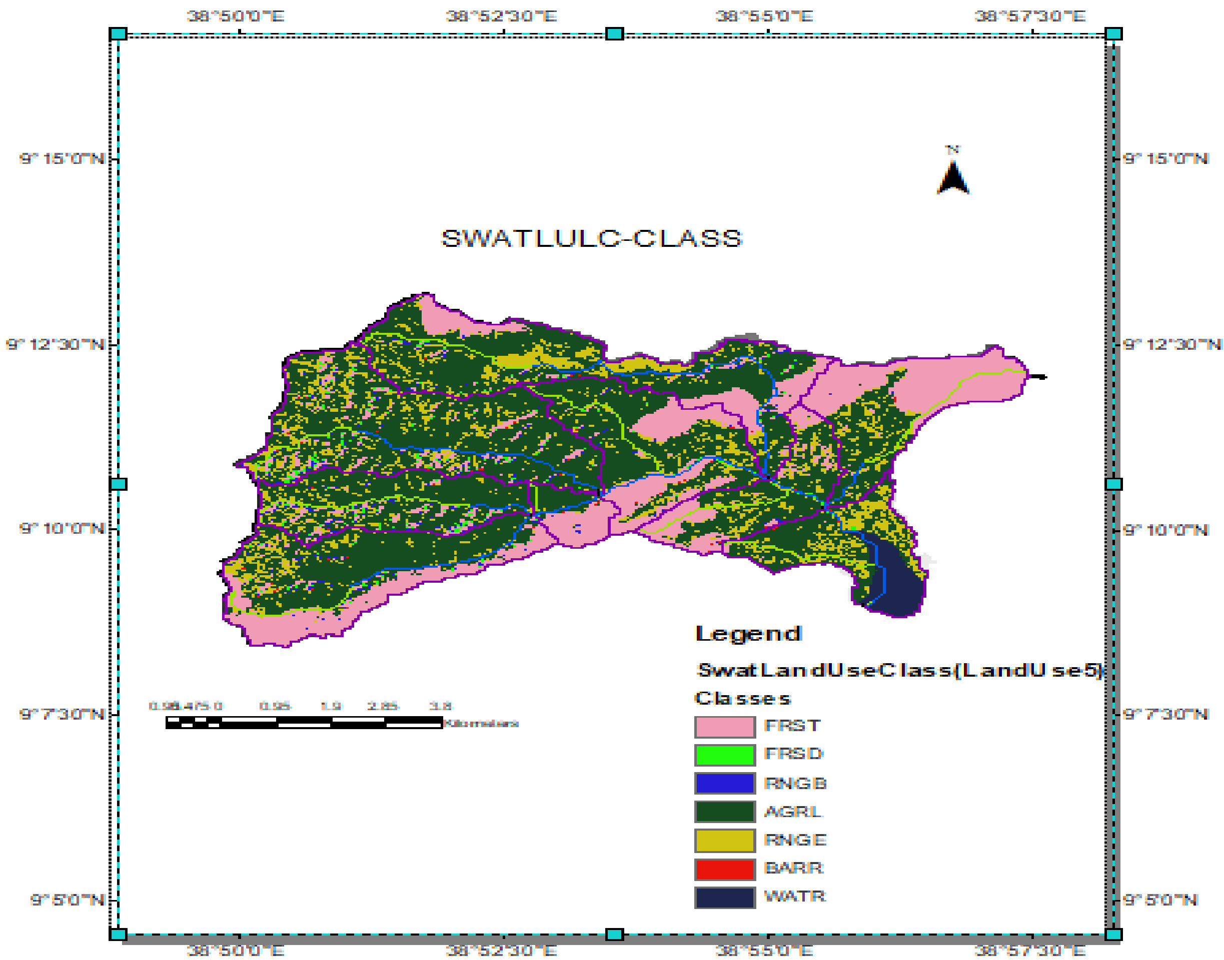


*Figure3. 7 land use land cover of Dire dam watershed*

### 3.4.4 Meteorological Data

SWAT requires daily meteorological data that could either be read from a measured data set or be generated by a weather generator model. These Weather data's are one of the basic input requirements for SWAT model which includes precipitation, maximum and minimum temperature, wind speed, relative humidity and solar radiation in daily basis since these variables are the most driving agents for hydrological balance. There were six namely Addis Ababa bole, entoto, Sululta and Addis Abeba observatory meteorological stations located outside the Dire watershed and dire dam metrological station located in inside of the watershed. The daily rainfall data of those positions are used in the model. The rainfall data for stations was available from 1988 to 2018.All these data will be prepared in suitable text format for each meteorological station with in Dire dam reservoir site so that the SWAT model can understand. I will obtain all these weather data from the National Meteorological Service Agency of Ethiopia (NMAE)

### 3.4.5 Hydrological data

Time series of runoff volume read from records of observed data and sediment yield are used to perform Sensitivity analysis, calibrate and validation of the Arc SWAT model. For Dire dam reservoir site the hydrological data mainly in the Dire basin and neighboring hydrological gauging station data will be collected from organizations which processes and files data namely: -

- Ministry of Water, Irrigation and energy (MoWIE),
- Adiss Ababa water and sewerage authority (AAWSA)

The quality of the studies is dependent on the quality of required elements and quantity or long term record of data. The most commonly observed problems are related to insufficient and in complete basic data. In most cases missing data should be filled using multiple station since the missing values may not be found as a whole only in one station, in such case the missed data will be filled using monthly mean of already available (if they are short period data's) or another regression will be done with another station which has a record on those months and years.

### 3.4.6 Sediment Data

SWAT CUP also uses this data values in comparing the observed values with simulated sediment data was formatted as to the requirement of the SWAT model and used for model validation and calibration. The sediment data also collected from MOWIE which recorded at different years at river station and used to compare with the sediment data that generated by the model during the validation period. The rating curve is to develop an equation between the relationship of flow and sediment.

**Sediment rating curve:** a sediment-rating curve expresses the average relation among

Postponed residue attentiveness and discharge for a certain place. The power function of discharge commonly represent sediment rating curve.

$$Qs = aQ^b$$

Where Qs is the suspended sediment transport (M tons/day)

Q is water discharge (m3/s)

a and b are regression coefficient and exponent respectively.

The sediment measurement at Keseme beke gauging station taken by MoWIE was not in continuous time step; so that by relating stream flow and measured sediment data it was required to generate sediment load data in continuous time step by using sediment rating curve. The raw data collected from the MoWIE was the sediment concentration. Thus, the data of sediment which was in concentration form have to change into sediment load in ton per cubic meter to create the sediment rating curve. This value was converted into sediment load by the time-series sediment rating curve computing technique (Morris and Fan, 1998)

S = 0.0864* Q * C

where S is the sediment load in (ton/day), Q is the flow of the stream (m3/s), C is the sediment concentration (mg/l) and 0.0864 is conversion factor.

Once the sediment load was calculated. The relation between the flow and sediment load for kesem beke gauging stations was with $R^2$ of 84.4%. The daily sediment harvest for the gauging stations was developed by using the rating curve equation which has obtained from the data plot $S= 11.446Q^{1.1956.}$

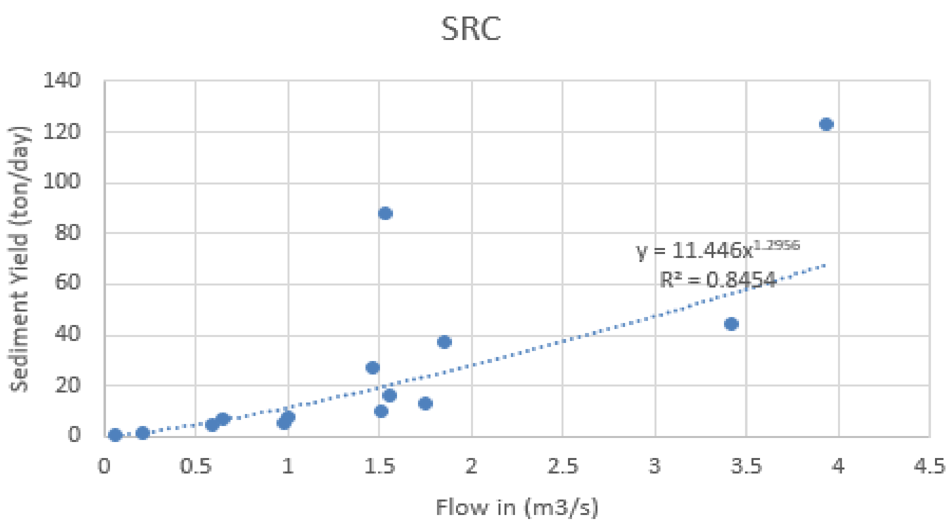


*Figure3. 8 sediment rating curve*

### 3.4.7 Stream Flow Data

Observed flow data was required for the SWAT calibration and validation. The observed stream flow data was available from 1988-2006 at kesem beke river downstream of Dire Reservoirs. The flow was determined for the Dire Reservoir which is located at the downstream of the watershed of study. This flow data was formatted as to the requirement of the SWAT model and used for model validation and calibration. The stream flow from 1988 to 1999 use for model calibration and the

2000 to 2006 flow data use for model validation. Here, it must be renowned that the efficiency of the model during calibration and validation depends on the accuracy of the calculation. Any error during calculation may cause significant problem in model calibration and validation.

### *3.5 Data Quality Control (Screening)*

Study depends on hydrological and meteorological data. These data must be consistent, homogeneous, and stationary after they are secondhand for incidence examines or to pretend a hydrological scheme. To regulate whether the data encounter these norms, we want a humble but well-organized screening technique statisticalerraticism. The rudimentary data-screening process presented here is based upon split-record tests forstability of the alteration and mean of such a time series. Hydrological data for water managementstudies should be consistent, homogeneous, and stationary once they are used in incidence analyses or system replications. A simple but well-organized process for broadcast these data is totest annual or periodic time series for nonappearance of trend and stability of mean and variance. I will follow basic data-screening procedure in order to check homogeneity, stationarity, consistency of the mean and variance of such a time sequence.

### *3.6 Filling Missing Rainfall Data*

Measured rainfall data are significant to numerous difficulties in hydrologic investigation and design. But, due to letdown of the spectator to make the essential visit to the gauge, Vandalism of recording gauges or instrument failure (by mechanical or electrical malfunctioning) may result inlost data. There are methods to estimate these missing values in the given stations. For this study missing values was estimated from other stations around the missed record station by considering the assumptions of at least three as close to and evenly spaced around the station with the missing record station as possible. Simple Arithmetic mean technique was used where the mean monthly precipitation of all the directory stations is within 10% of the station under consideration (station x) and calculated the missing data by equation 4.1. Whereas the mean monthly precipitation one or more of the adjacent (index) stations varies from that of station x by more than 10% then the normal ratio method was used by equation 4.2.

$P_K = 1/N\ (P_A + P_B + P_C + \cdots \ldots + P_N) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . .\ equation\ 4.1$

$P_K = Nx/n\ (P1/N1 + P2/N2 + P3/N3 + \cdots + Pn/Nn) \ldots \ldots \ldots \ldots \ldots\ldots .\ equation\ 4.2$

### 3.6.1 Test For Consistency

A period sequences of hydro meteorological data is relatively consistent if the periodic data are proportional to an appropriate simultaneous time series (Chang, Mingteh ,Lee and Richard, 1974). In this study double mass curve method is adopted for checking consistency of both meteorological and hydrological data When a significant change in the regime of the curve is observed, it reveals that rainfall data is inconsistent at that station and it should be corrected by using Equation .

$$P_{ck} = P_k * M_c / M$$

Where, $P_{CK}$ is the corrected precipitation at any time period, $P_K$ is the originally recorded precipitation at the time period, $M_C$ is correct (straight line) slope of the double mass curve and $M$ is the original slope of the double mass curve.

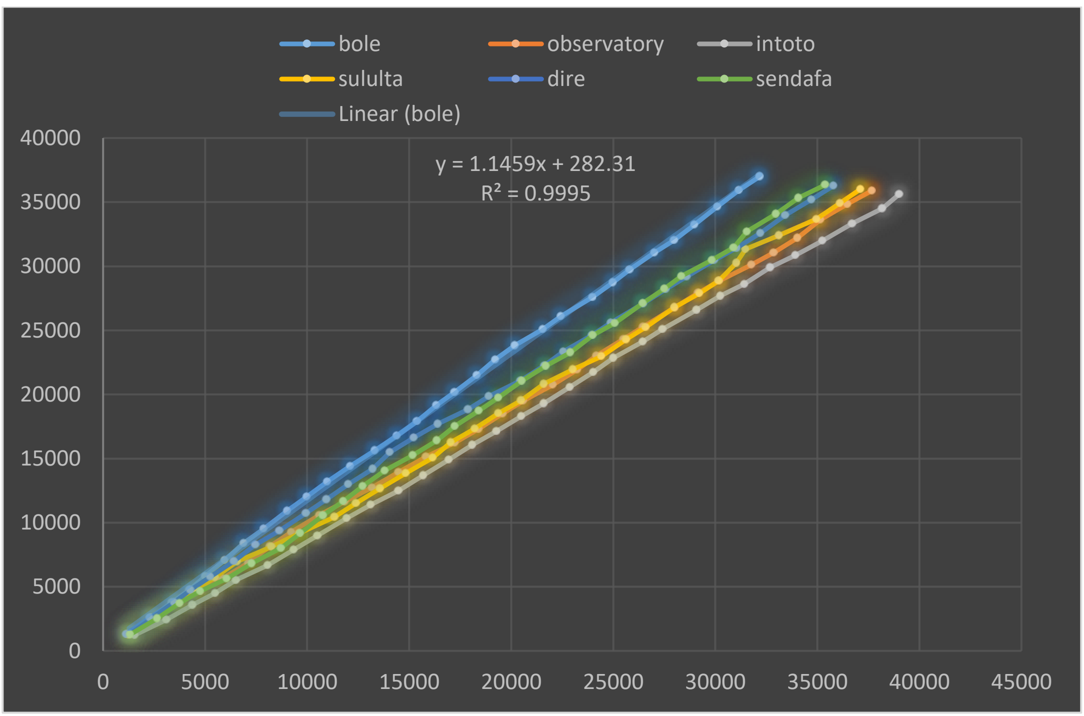


Figure3. 9 Double mass curve plot for six stations

*The double mass curve analysis (Figure3 .9) the stations used in this study have not undergone a significant change and the lines are fairly smooth with no station displaying a long-lasting breakin slope.*

### 3.6.2 Homogeneity test

The purpose of homogeneity test is to recognize a change in the statistical possessions of the time sequence data which is caused by either natural or artificial factors. These include alterations to land use and transfer of the observation station. The homogeneity test of time series may be classified into two groups as absolute method and relative method. In the absolute method, the test applies to each station separately. In the relative method, the neighboring stations are also used in testing (Wijngaard et al., 2003). According to Peterson et al. (1998), the recommended method to apply homogeneity has been tested with respect to neighboring stations that is supposedly homogeneous.

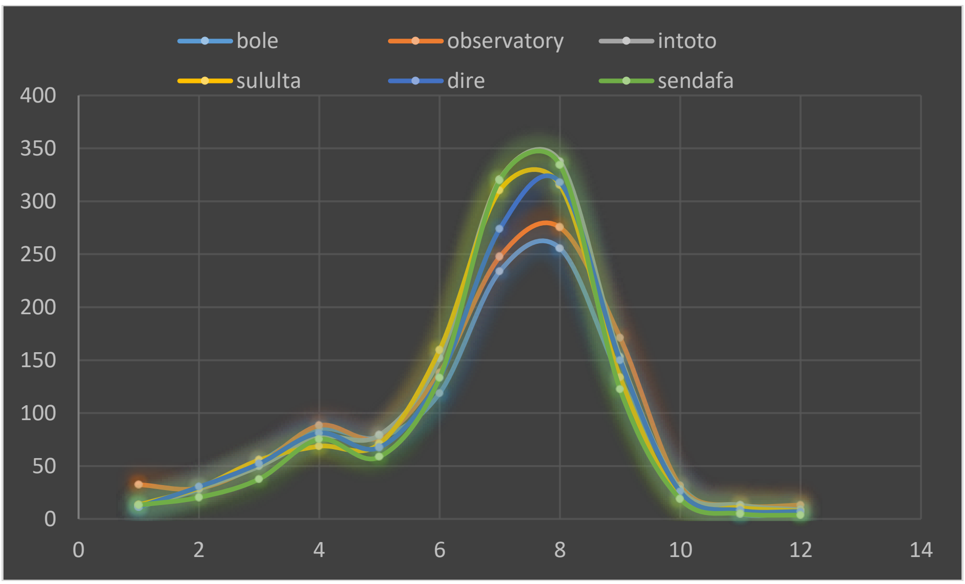


*Figure3. 10 homogeneity test for six stations*

### *3.6.3* Outlier test

Prior to performing frequency analysis based on the annual rainfall the outliers needs to be checked. Errors on data may occur during recording or reporting. The quality and consistency of data is checked by outlier test as depicted below. For checking the low or high outliers the relationship given below will be applied. For coefficient of skewness (Cs) of lower than -0.4, the data should be checked first for lower outlier test otherwise the checking will be done for higher outlier.

**Lower outlier**

$Y_{lo}=Y_{avg} - K_n*S_y$--------------------------------------------------------------------------

Where,

$Y_{lo}$: Low outlier,

$Y_{avg}$: Mean of samples converted to logarithmic value,

$K_n$: Coefficient of frequency and

$S_y$: Standard deviation.

Low outlier should check for lower value of less than $10^{Ylo}$

**Higher outlier**

$Y_{ho}=Y_{avg}+K_n*S_y$-------------------------------------------------------------------------

Where,

$Y_{ho}$: high outlier,

$Y_{avg}$: Mean of samples,

$K_n$: Coefficient of frequency and

$S_y$: Standard deviation.

| YR | Annua | LogX | KN | XH | XL | check for XH | check for XL | Lower Outlier | not lower outlie |
|---|---|---|---|---|---|---|---|---|---|
| 1988 | 1203 | 3.08012 | 2.5778 | 25.246 | 18.794 | not higher outlier | not lower outlier | higher outlier | not higher outle |
| 1989 | 1321 | 3.121 | 2.5778 | 25.246 | 18.794 | not higher outlier | not lower outlier | | |
| 1990 | 1125 | 3.051 | | | | not higher outlier | not lower outlier | | |
| 1991 | 1162 | 3.06528 | | | | not higher outlier | not lower outlier | | |
| 1992 | 1101 | 3.04195 | | | | not higher outlier | not lower outlier | | |
| 1993 | 1568 | 3.19532 | | | | not higher outlier | not lower outlier | | |
| 1994 | 1043 | 3.01808 | | | | not higher outlier | not lower outlier | | |
| 1995 | 1146 | 3.05903 | | | | not higher outlier | not lower outlier | | |
| 1996 | 1549 | 3.18991 | | | | not higher outlier | not lower outlier | | |
| 1997 | 952.4 | 2.97882 | | | | not higher outlier | not lower outlier | | |
| 1998 | 1338 | 3.12636 | | | | not higher outlier | not lower outlier | | |
| 1999 | 940.4 | 2.97332 | | | | not higher outlier | not lower outlier | | |
| 2000 | 1191 | 3.07595 | | | | not higher outlier | not lower outlier | | |
| 2001 | 1452 | 3.16197 | | | | not higher outlier | not lower outlier | | |
| 2002 | 1016 | 3.00694 | | | | not higher outlier | not lower outlier | | |
| 2003 | 1173 | 3.06941 | | | | not higher outlier | not lower outlier | | |
| 2004 | 1159 | 3.0639 | | | | not higher outlier | not lower outlier | | |
| 2005 | 1408 | 3.14849 | | | | not higher outlier | not lower outlier | | |
| 2006 | 1354 | 3.13168 | | | | not higher outlier | not lower outlier | | |
| 2007 | 1310 | 3.11716 | | | | not higher outlier | not lower outlier | | |
| 2008 | 1331 | 3.12408 | | | | not higher outlier | not lower outlier | | |
| 2009 | 1241 | 3.09363 | | | | not higher outlier | not lower outlier | | |
| 2010 | 1381 | 3.14026 | | | | not higher outlier | not lower outlier | | |
| 2011 | 1052 | 3.02218 | | | | not higher outlier | not lower outlier | | |
| 2012 | 1068 | 3.02873 | | | | not higher outlier | not lower outlier | | |
| 2013 | 1253 | 3.09808 | | | | not higher outlier | not lower outlier | | |
| 2014 | 1081 | 3.03375 | | | | not higher outlier | not lower outlier | | |
| 2015 | 1049 | 3.02093 | | | | not higher outlier | not lower outlier | | |
| 2016 | 1222 | 3.08711 | | | | not higher outlier | not lower outlier | | |
| 2017 | 1322 | 3.12117 | | | | not higher outlier | not lower outlier | | |
| 2018 | 1172 | 3.06882 | | | | not higher outlier | not lower outlier | | |
| | mean | 3.081 | | | | | | | |
| | stade | 0.057 | | | | | | | |

*Figure3. 11 outlier test*

## *3.7 SWAT Model Setup*

### 3.7.1 Watershed Delineation

The first step in creating SWAT model input is watershed delineation from digital elevation model. The SWAT model delivers three spatial stages: the sub basins, the watershed, and the (HRUs). Each level is represented by a limit established and contribution data. For modeling purposes, a watershed maybe partitioned into a amount of sub basins or sub watershed. Moreover, the selection and implementation of appropriate conservation measure can be aided by reliable predictions of watershed response under different land use scenarios. The watershed delineation was based on an automatic delineation procedure using a 30m x 30 m (DEM) setup, Stream definition, outlet and inlet definition, watershed outlet selection and calculation of sub basin parameters. Hence, definition of watershed, sub-basin boundaries and streams is decided by selecting a threshold area or the minimum drainage area to define streams.

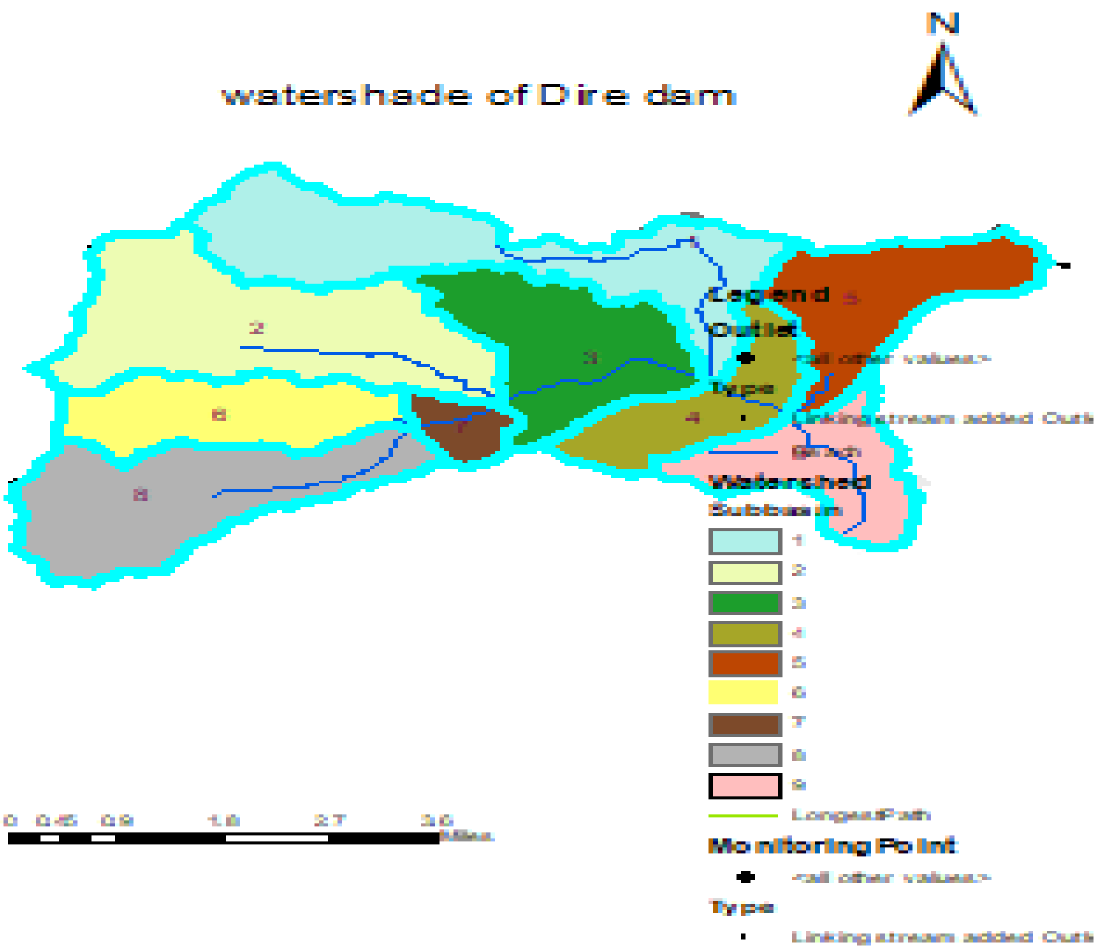


*Figure3. 12 Watershed of the study area*

### 3.7.2 HRU Analysis

After watershed delineation, the watershed was partitioned in to (HRU), which are unique occurrence of soil type, land cove and slope class combinations within in the watershed to be modeled. Any parcels of lands within one sub basin that share the same combination of these three features will be considered one HRU. HRUs are used in most SWAT runs since they simplify a run by lumping all similar soil and land use areas into a single response unit.
SWAT has predefined land use classes in its crop database. So it is necessary to prepare look up table, which refers land use land cover classes found in hand with SWAT land use land cover codes. Since in HRU definition the model refers the land use classes found in the SWAT model. So, well preparation of the lookup-table of the land use /cover types in the SWAT compatible way is basic for the loading of the land use/cover of the study area.

### 3.7.3 Slope

The slope is derived from DEM input so that the model uses this slope for the development of Hydrological Response Unit in addition to land use and soil input parameters. Arc SWAT allows the integration of land slope classes (up to four classes) when defining hydrologic response units. There are possibilities to choose simply a single slope class, or choose multiple classes. In this paper I prefer multiple classes and dived in 0-15, 15-30, 30-45 and above 45.

### 3.7.4 HRU Definition

(HRUs) Analysis tool in Arc SWAT helps to load soil and land use layers to the project. The outlined watershed by Arc SWAT and the prepared land use overlapped analysis in Arc SWAT includes divisions of HRUs by slope classes in addition to land use and soils. The multiple slope option (an option for considering different slope classes for HRU definition) 10%, 10% and 15% for Land use, soil and Slop class respectively was selected for this study .Based on the above classification, we have 103 HRU in the Dire catchment

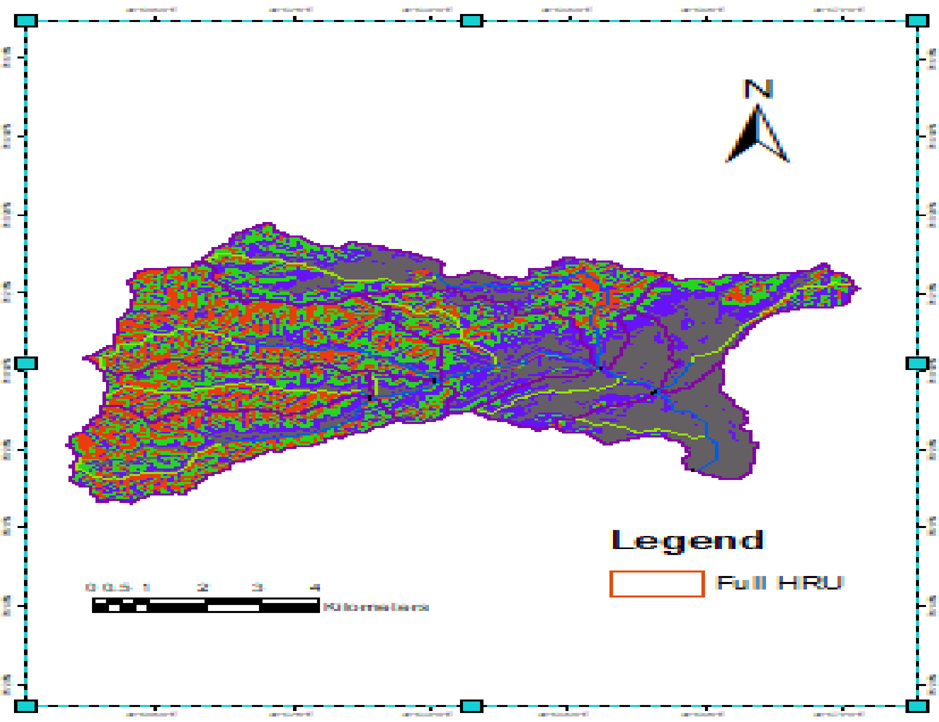


*Figure3. 13 Full HRU map of the Dire watershed*

### 3.7.5 Weather data definition and weather generator

Weather data’s are amongst the indispensable inputs for SWAT model. Accordingly weather data’s such as daily data’s of rainfall, temperature, Wind Speed, Relative humidity ,wind and solar radiation were analyzed and prepared according to the model inputformat requirement. By using Thiessen polygon method the weather data used represented from the six selected stations (Addis Ababa observatory, Addis Ababa bole, intoto, sululta, sendafa and dire dam). Here, it doesn’t mean that all the stations have all the weather data’s required by SWAT model,but, there is a method on the model itself to generate missing weather data of station x from the remaining nearby stations, called weather generator stations with known weather generator statistic variables even if, meteorological stations with full weather data can produce better efficiency to SWAT model. Unfortunately, there exists a lack of full and realistic long period of meteorological data in ourcountry, which will force as to use a Weather generator section of the model that solves the problem by generating data from the existing observed data. The weather generator requires the daily values of all climatic variables from measured data or generated from values using monthly average data over a number of years. To generate the data, weather parameters values were developed by using swat weather database.

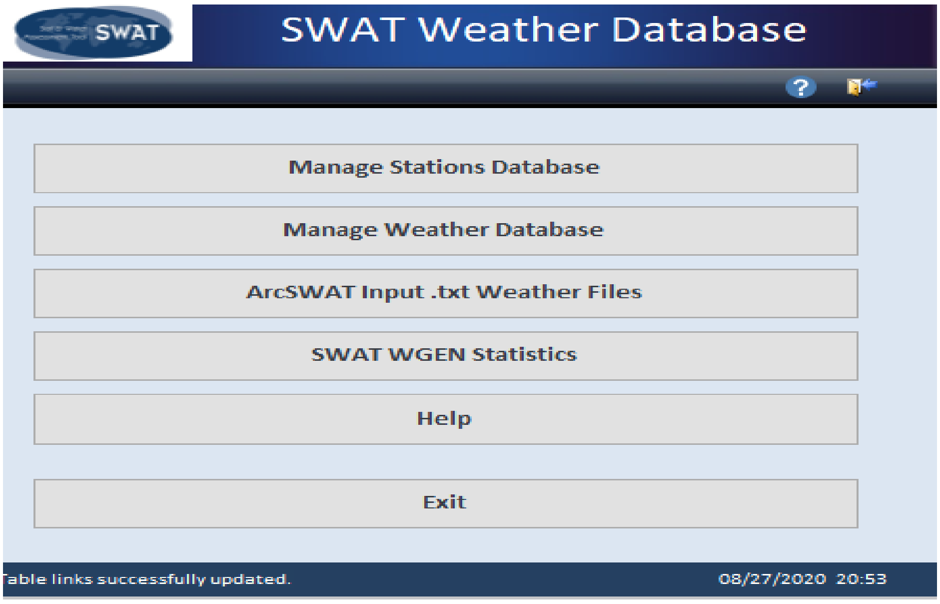


*Figure3. 14 weather database*

### *3.8 SWAT Simulation approach*

The ARCSWAT 2012 model was used in the watershed delineation process, which includes processing of DEM data for stream network delineation followed by sub watershed delineation. A total of nine sub watersheds were delineated for the entire Dire catchment . The Sub watersheds were then further subdivided into HRUs that were created for each unique combination of land use and soil. Thresholds vales of 10 % for land cover 10 % for the soil and 15% for slope area were applied to limit the number of HRUs in each sub watershed. SWAT was performed with the succeeding imitations choices: (1) For guessing shallow overflow from rainfall used the runoff curve number, (2) For approximating possible evapotranspiration group used Hargreaves method, and (3) For pretend station water steering used the variable storage method . A simulation period of 1988 through 2006 was selected for the sensitivity analysis. Several model runs were executed for each input parameter with a range of value, keeping simulation option and other parameter values constant. The analysis provided information on the most to least sensitive parameters for flow response of the watershed. Due to limitation of data, the model was calibrated for the period from 1988 to 1999 and validated for 2000 and 2006 .For sediment, we use the Bathymetric survey data for calibration from 1988 to 1999 and from 2000 to 2006 for validation on annual basis. Two statistical approaches were used to evaluate the model performance: ($R^2$) and Nash-Sutcliffe simulation efficiency ($E_{ns}$) The $R^2$ value is pointer of the forte of relation amid the experiential and replicated values; $E_{ns}$ directs how well the plot of observed versus simulated value fit the 1:1

line. If the $R^2$ price is close to zero and the ENS price is fewer than or close to zero, the model prediction is considered unacceptable. If the values approach one, the model predictions become perfect.

### 3.8.1 Sensitivity analysis

Sensitivity analysis is conduct to determine the influence of a set of parameters had on predicting total flow, sediment, and other model output of interest (James & Burges, 1982).It is a method of identifying the greatest delicate strictures that have a significant effect on model calibration or on model prediction (Dilnesaw, 2006). A model compassion examination can be obliging in understanding which model inputs are most important or sensitive and to understand potential limitations of the model. For large hydrological models like SWAT, which involve a extensive variety of data and parameters in the simulation process calibration is aquite complicated task. On the other hand, SWAT input parameters necessity be detained within a truthful uncertainty range since most of the parameters are process based. Therefore, willpower of the greatest sensitive parameters for a given sub basin or watershed.The modeler should be identifying sensitive parameters to allow the possible reduction in the amount of strictures that must be calibrated afterward reducing the computational time required for model calibration.

Several statistical methods are employed to perform uncertainty analysis, sympathy examination, calibration, and validation. From other developers include the methods (SUFI-2), Particle Swarm Optimization (PSO), Generalized Likelihood Uncertainty Estimation (GLUE), ParaSol (Parameter Solutions), Parameter Estimation (PEST), and Markov Chain Monte-Carlo (MCMC) (Gassman *et al.*, 2007; Abbaspour, 2014).

In this study, streamflow sensitivity analysis followed by sediment yield analysis was performed by SWAT_CUP using SUFI-2. The sensitivity analysis was carried out for a period of 10 years, which included both the calibration period from January 1$^{st}$, 1990 to December 31$^{st}$, 1999 and the warm up period from January 1$^{st}$, 1988 to December 31$^{st}$, 1989.

### 3.8.2 Model calibration

Model Calibration is the process whereby model parameter are adjusted to make the model output match with observed data. It is also a means of adjusting or fine tuning model parameters to match with the observed data as much as possible, with limited range of deviation accepted. There are three calibration approaches widely used by the scientific community. These are the manual calibration, automatic calibration and a combination of the two. Manual calibration is the most widely used approach. However it is tedious, time consuming, and success of it depends on the experience of the modeler and knowledge of the watershed being modeled. Automatic calibration involves the use of a search algorithm to determine best-fit parameters. Itis desirable as it is less subjective and due to extensive search of parameter possibilities can give results better than if done manually. This model use automatic calibration method. SWAT has two built-in calibration tools the manual calibration approach helps to compare the measured and simulated values, and then to use the expert judgment to determine which variable to adjust, how much to adjust them, and ultimately assess when reasonable results have been obtained.

Before calibration proceeds, the performance of the model was evaluated from the initial simulation runs with model default parameter values, field measured parameters and parameters collected from literature. The results of the model from the initial run was not worse and needs fine tuning of the most sensitive parameters until acceptable calibration statics was obtained. Therefore, the manual calibration was used in this study. For each calibration run and parameter change, the corresponding model performance statistics ($R^2$ and NSE ) were calculated. This procedure continued until the acceptable calibration statics recommended by SWAT developer for hydrology was achieved.

### 3.8.3 Model Validation

Model validation is testing of calibrated model results with independent data set without any further adjustment (Neitsch S. J., 2002) at different spatial and temporal scales. It is comparison of the model outputs with an independent dataset without further adjustments of the values of the parameters. In order to utilize any predictive watershed model for estimating the effectiveness of future potential management practices the model must be first calibrated to measured data and should then be tested (without further parameter adjustment) against an independent set of measured data. This testing of a model on an independent data set is commonly referred to as model validation. Model calibration determines the best or at least a reasonable, parameter set while validation ensures that the calibrated parameters set performs reasonably well under an independent data set. Provided the model predictive is phase, the used with some confidence for future predictions under somewhat different management scenarios. Flow and sediment validation was carried out at a station similar to the calibration. The statistical criteria (the R, NSE) used during the calibration procedure were also checked here to make sure that the simulated values is still within the accuracy limits. $R^2 > 0.6$,and $N_{ES} > 0.5$, (Santhi et al, 2001).

### *3.9 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 the graph 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.

#### 3.9.1 Coefficient of determination (R2)

$R^2$ measures the fraction of the variation in the measured data that is replicated in the simulated model results.

$R^2$ is defined as (Krause, Boyle, and Bäse 2005) the squared value of the coefficient of correlation and is given by equation below.

$$R^2 = \frac{\left[\sum_i (Q_{m,i} - \bar{Q}_m)(Q_{s,i} - \bar{Q}_s)\right]^2}{\sum_i (Q_{m,i} - \bar{Q}_m)^2 \sum_i (Q_{s,i} - \bar{Q}_s)^2}$$

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 is systematically over-or under-predicts all the time will still outcome in good $R^2$ values close to 1.0 even if all forecasts were wrong (Krause et al. 2005)

#### 3.9.2 Nash-Sutcliffe efficiency coefficient (NSE)

The Nash-Sutcliffe efficiency of coefficient (Nash and Sutcliffe, 1970) is used to measure the prognostic authority of the hydrological model. The value of NSE differs from 1.0 (perfect fit) to 0.0. An efficiency of lower than zero shows that the mean value of the experiential time sequence would have been a better predictor than the model (Krause et al. 2005)The NSE value of 0.0 indicates that the model predictions are as accurate as the mean of the observed data. (Krause et al. 2005) The major drawback of the Nash-Sutcliffe efficiency is the fact that the differences amid the experiential and replicated 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. This method is highly affected by a few extreme errors and it can be biased if a wide range of events is experienced The Nash-Sutcliffe efficiency (NSE) is calculated using equation below

$$NSE = 1 - \frac{\sum_{i=1}^{n}(O_i - S_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2}$$

# CHAPTER FOUR

# RESULTS AND DISCUSSION

SWAT model was calibrated and validated on a monthly basis to check its capability to model stream flow and sediment yield of Dire dam watershed using a time series dataset of 31 years from1988 to 2018. The first two years of the modeling period were used for "model warm- up". Data for the period 1988 to 1999 were used for calibration and the remaining part of the dataset was reserved for validation. The watershed was subdivided into 9 sub basins. The sensitivity analysis was done for both flow and sediment yield. The simulated flow and sediment yield were compared with the observed flow and sediment yields. Statistical model performance indicators checked model performance. Spatial variability of sediment yield evaluated; sediment reduction measures developed to highly sediment yielding sub basins and comparison of scenarios result was carried out.

## *4.1 Streamflow Modeling*

### 4.1.1 Sensitivity Analysis

Sensitivity analysis used to identify which model parameter is most important or sensitive. Flow sensitivity analysis was carried out for a period of 12 years, which includes both the calibration period (from January 1, 1990 to December 31, 1999) and two year of warm-up period (from January 1, 1988 to December 31, 1989). According to the results obtained from the sensitivity analysis using SUFI2, the ranks of the parameters was assigned depending on t - stat and p - value. P-value indicates the significance of the sensitivity andt- stat provides the measure of the parameter sensitivity (Abbaspour, 2014). Hence larger inthe absolute value of t - stat means the parameter is more sensitive, and a value of p – value closer to zero means the parameter has more significance

*Table 4. 1Result of sensitivity analysis of flow parameter in Dire dam watershed*

| Parameter Name | t-Stat | P-Value | rank | sensitivity | Description |
|---|---|---|---|---|---|
| SLSOIL | -6.836991980 | 0.000002889 | 1 | high | Slope length for lateral sub surface flow |
| CN2.mgt | -6.602669012 | 0.000004481 | 2 | high | Initial SCS CN II value |
| RCHRG_DP | -3.847543955 | 0.001290540 | 3 | high | Deep aquifer percolation fraction |
| SOL_Z | -3.751569555 | 0.001589498 | 4 | high | Depth from soil surface to bottom layer |
| CANMX | -2.320740075 | 0.032990452 | 5 | high | Maximum canopy storage |
| CH_K2 | -2.053887589 | 0.055697742 | 6 | medium | Effective hydraulic conductivity in main channel alluvium |
| EPCO | -1.804856863 | 0.088840799 | 7 | medium | Plant uptake composition factor |
| SOL_AWC | 1.774827550 | 0.093833413 | 8 | medium | Available water capacity of the soil layer |
| SOL_K | 1.605719694 | 0.126749827 | 9 | medium | Saturated hydraulic conductivity |
| USLE_K | -1.189314824 | 0.250662744 | 10 | medium | USLE equation soil erodibility |
| GWQMN | 1.173380881 | 0.256821613 | 11 | medium | Threshold depth of water in the shallow aquifer |
| ALPHA_BF | 0.832005477 | 0.416940608 | 12 | low | Baseflow recession constant (days) |
| SLSUBBSN | -0.695613645 | 0.496070917 | 13 | low | Average slop length |
| REVAPMN | -0.449318442 | 0.658877603 | 14 | low | Aquifer for revap to occur |
| ESCO | 0.186435162 | 0.854310198 | 15 | low | Soil evaporation component factor |
| GW_DELAY | 0.127496635 | 0.900043340 | 16 | low | Ground water delay |

These flow parameters are used to calculate the amount of flow from the catchment. Flow was found most sensitive to soil properties. In particular initial SCS curve number (Cn2), VSLSOIL.hru RCHRG_DP.gw SOL_Z .sol, was among the most sensitive parameters. The parameters related to surface runoff and ground water was found to be the major influencing factor for the stream flow in the watershed.

### 4.1.2 Calibration

The aim of calibration process is to create agreement between the simulated and observed value by adjusting the sensitive flow parameters in the recommended range. Flow calibration for the Dire watershed was conducted for the years 1988 and 1999. These years were selected based on the availability of data. The analysis of simulated result and observed flow data comparison was done on a monthly basis till the best match of the simulated result and its corresponding observed flow has attained, changing parameters or tuning process has continued with in the allowable range recommended by SWAT model developers. Among the three calibration approach (manual calibration, automatic calibration and a combination of the two), Due to its realistic representation in the users knowhow based for the watershed and its simplicity manual calibration was used in this study. Manual calibration is the most widely used approach. During calibration agreement between measured and simulated stream flow data on monthly basis was determined using different performance evaluation criteria. Moreover, the fit between monthly measured and simulated stream flow was checked graphically by plotting the runoff- duration curves and time series. General agreement between observed and simulated runoff- duration curves indicates adequate calibration over the range of the flow conditions simulated. Calibration resulted in, correlation coefficient (R2) of 0.77 Nash–Sutcliffe simulation efficiency (ENS) of 0.75 and showing a good agreement between measured andsimulated monthly flows.

*Table 4. 2monthly simulated and measured flow calibration*

| Calibration Time | Average Flow($m^3/s$) | | Model Efficiency(Monthly) | | |
|---|---|---|---|---|---|
| 1988-1999 | Simulated | Measured | $R^2$ | NS | P |
| | 1.83 | 1.72 | 0.77 | 0.75 | 0.66 |

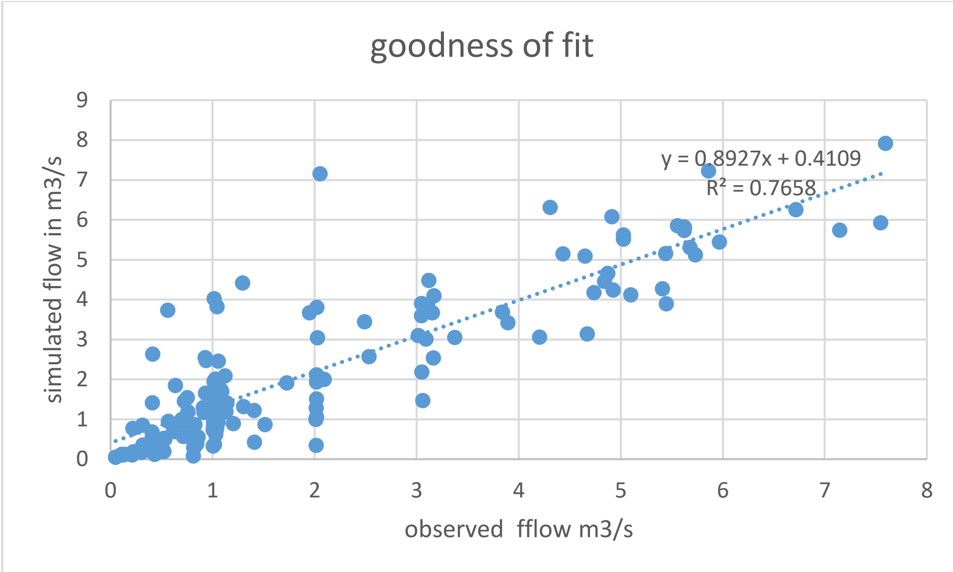


*Figure 4. 1regression plot of observed and simulated flow for calibration*

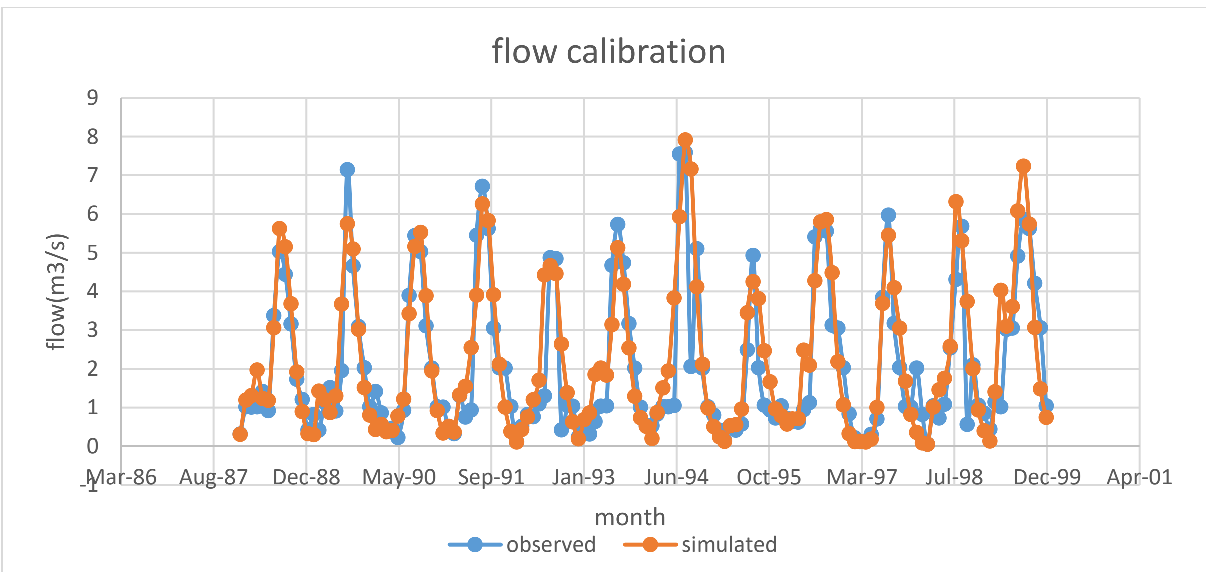


*Figure 4. 2monthly observed and simulated flow hydrograph during calibration*

### ***4.1.3 Validation***

After calibration, the model with calibrated parameters was validated by using an independent set of measured flow data which were not used during model calibration. Flow validation was carried out from January 1, 2000 to December 31, 2006 without further adjustment of the parameters of flows. Accordingly, good match between monthly measured and simulated flows in the validation period were demonstrated by the correlation coefficient ($R^2$) of 0.78, Nash - Sutcliffe simulation efficiency (ENS) of 0.77

*Table 4. 3 simulated and measured flow validation*

| Time | Average Flow($m^3/s$) | | Model Efficiency(Monthly) | | |
|---|---|---|---|---|---|
| 2000-2006 | Simulated | Measured | $R^2$ | NS | P |
| | 1.9 | 2.01 | 0.78 | 0.77 | 0.82 |

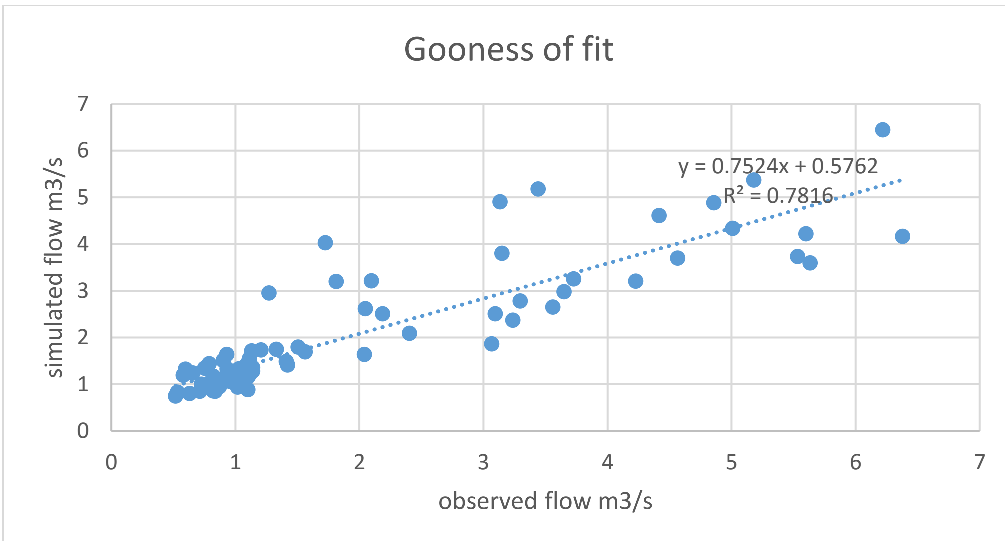


*Figure 4. 3 Regression plot of observed and simulated flow for validation*

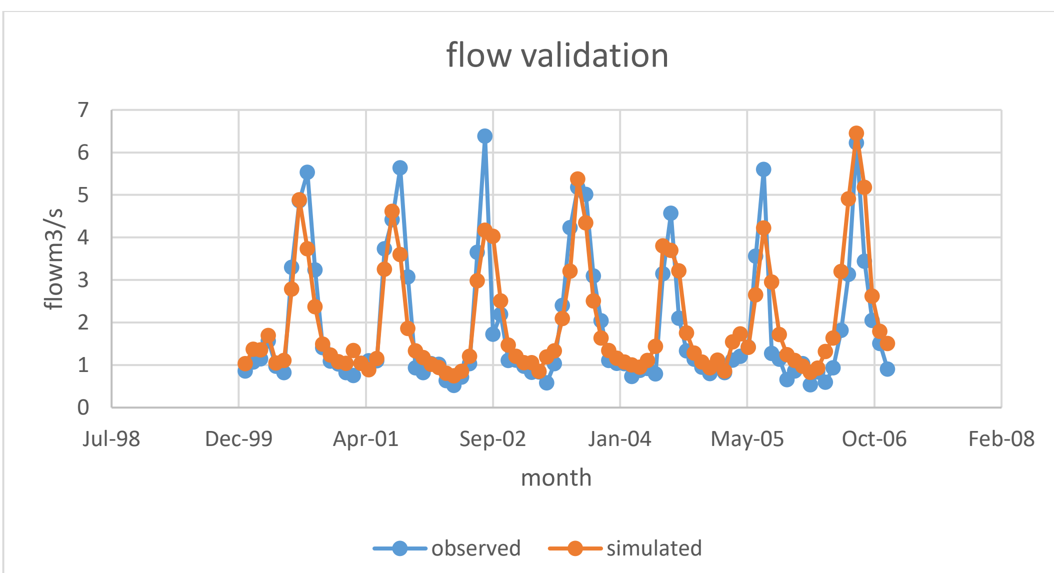


*Figure 4. 4 monthly observed and simulated flow hydrograph during validation*

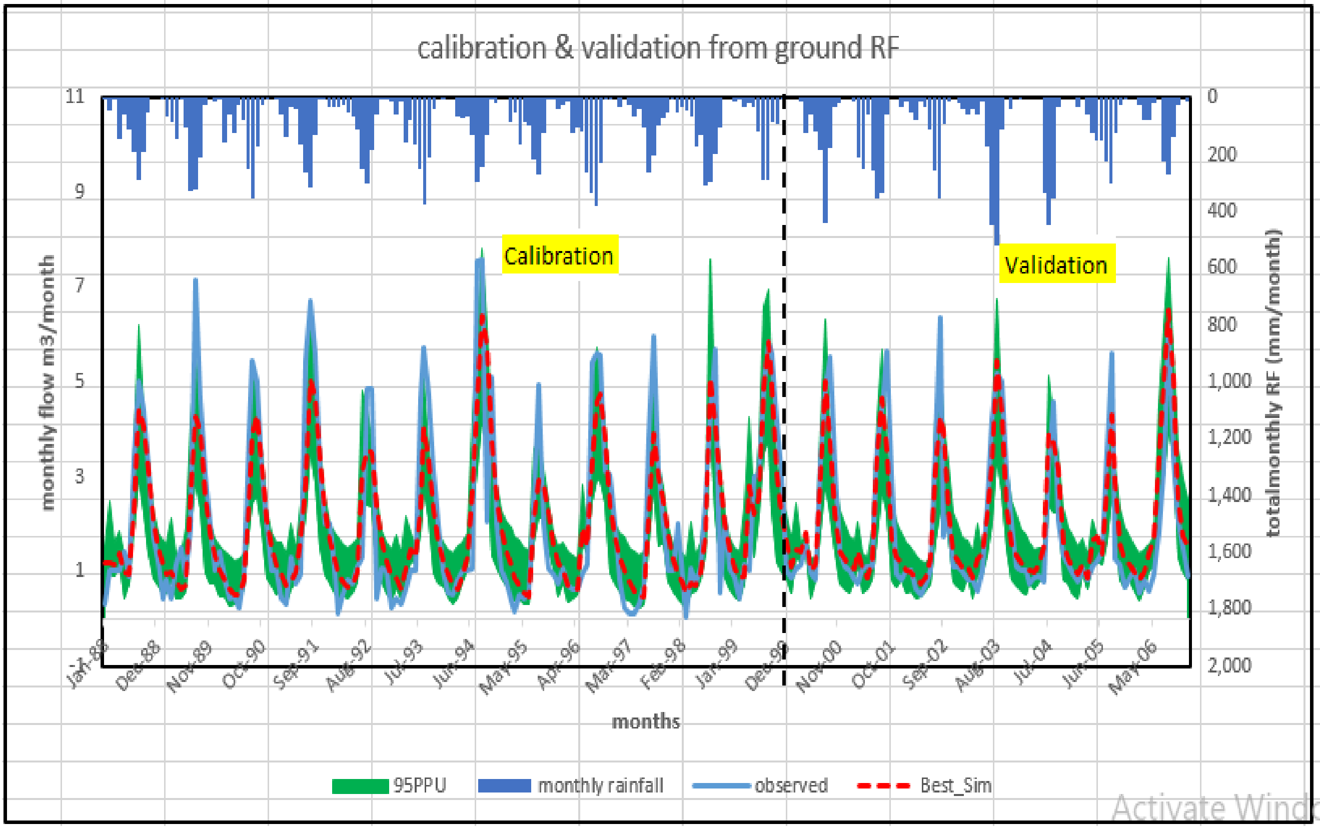


*Figure 4. 5 monthly observed and simulated flow hydrograph during calibration and validation period (1988-2006)*

## *4.2 Sediment Flow modeling*

### 4.2.1 Sensitivity analysis

Sensitivity analysis was carried out for sediment to identify parameters that affect sediment yield Once it is shown that the flow was accurately represented by the model the focus is shifted to the calibration of the model for sediments. This involves changing parameter values that control sediment generation within the model.. Sensitive parameters for sediment flow in the watershed includes CN2, GW_DELAY, LAT _SED was the most sensitive of all. These sediment parameters are used to compute the amount of erosion from the catchment and channel.

*Table 4. 4 Result of sensitivity analysis of sediment parameter in dire catchment*

| Parameter Name | t-Stat | P-Value | rank | sensitivity | Description |
|---|---|---|---|---|---|
| CN2 | 9.579693831 | 0.000000088 | 1 | high | Initial SCS CN II value |
| GW_DELAY | 0.986169936 | 0.339690863 | 2 | high | Ground water delay |
| LAT_SED | 0.914517008 | 0.374912326 | 3 | high | Sediment concentration lateral and ground flow |
| USLE_P | 0.679742550 | 0.507022882 | 4 | medium | USLE support practice factor |
| ALPHA_BF | 0.416826495 | 0.682709159 | 5 | medium | Baseflow recession constant (days) |
| SPEXP | 0.372333332 | 0.714852663 | 6 | medium | Exponential re-entrainment parameter |
| SOL_K | -0.052108487 | 0.959129869 | 7 | low | Saturated hydraulic conductivity |
| GWQMN | 0.036015039 | 0.971745287 | 8 | low | Threshold depth of water in the shallow aquifer |

### 4.2.2 Calibration

by comparing simulated stream sediment discharge against measured suspended Sediment determined from suspended sediment rating curve developed. The calibration of sediment yield of the watershed was done based on sediment sensitivity analysis that have identified sensitive parameters for sediment yield of the watershed and by varying iteratively within the allowable ranges of the parameters. sediment calibration for the dire watershed by comparing monthly model simulated sediment load against monthly measured sediment from kesem beke gauging station for the period January 1,1988 to December 31, 1999. Also two years (January 1, 1988 to December 31, 1989) was skipped for model initialization (warm-up period). Model calibrations were performed. According to model performance evaluation criteria the sediment simulation result for calibration show a good performance with $R^2$ of 0.74, $E_{NS}$ of 0.73. The overall performance of the model during calibration has been measured using D (the percent difference for a quantity) which is -0.05; means the model overestimate the average annual sediment by 5 %.

*Table 4. 5 Simulated & measured Sediment Calibration*

| Time | Sediment load(ton/year) | | Model Efficiency(yearly) |
|---|---|---|---|
| 1988-1999 | Simulated | Measured | D |
| | 23642.63 | 22453.22 | -5 |

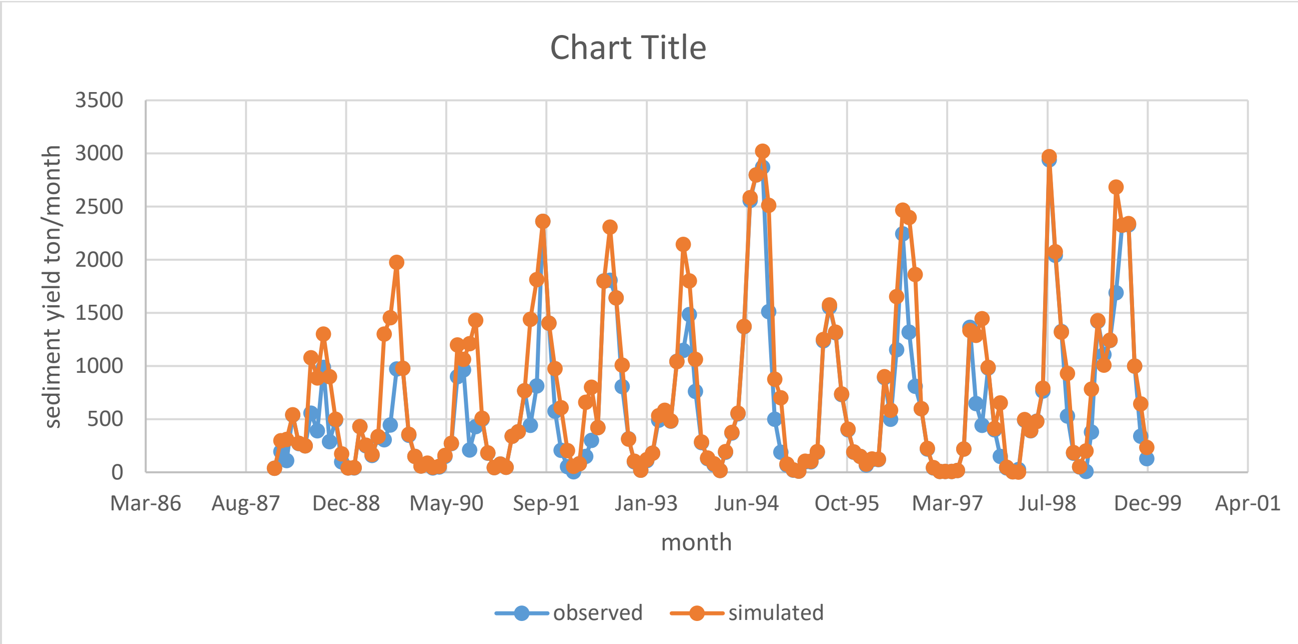


*Figure 4. 6 monthly observed and  simulated sediment hydrograph during calibration*

### 4.2.3 Validation

Like flow validation, validation of sediment harvest of the watershed was approved out for the ages January 1, 2000 to December 31, 2006. An independent sediment measurement data that was not used in sediment calibration was used to validate sediment yield with those parameters adjusted during calibration. In the validation period, good agreement between simulated and measured sediment was demonstrated by correlation coefficient ($R^2$) of 0.77, Nash-Sutcliffe model efficiency (NSE) of 0.77. The overall performance of the model during calibration has been measured using D (the percent difference for a quantity) which is -0.04; means the model overestimate the average annual sediment by 4 %.

*Table 4. 6 Simulated & measured Sediment validation*

| Time | Sediment load(ton/year) | | Model Efficiency(yearly) |
|---|---|---|---|
| 2000-2006 | Simulated | Measured | D |
| | 24852.4 | 23739.1 | -4 |

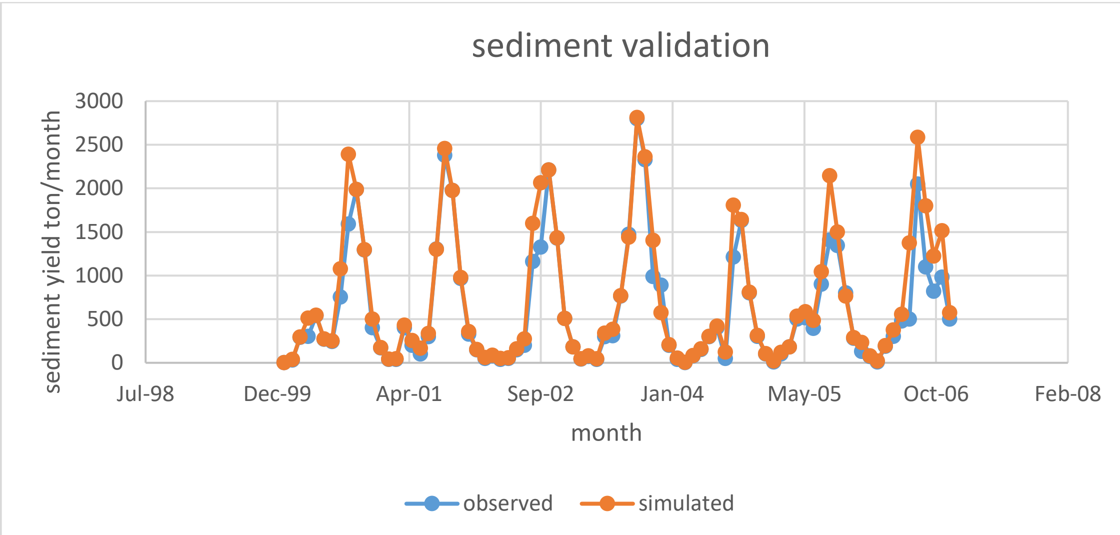


*Figure 4. 7monthly observed and simulated sediment hydrograph during validation*

### *4.3 Spatial Variability of Sediment Yield in the Watershed*

To get average annual sediment yield spatially with sub basins level, the SWAT model was run annually (1988-2018) for thirty-one years. Spatial variability of sediment yield for the dire watershed was identified from the simulated annual sediment yield and the result shows the ranges was between 7.22 to 34.26 tons/ha/yr. with average of 18.5 ton/ha/yr for the sub-basins.

According to Setegen et al (2008) the hot spot area identified based on the value of sediment -yield in ton/ha are classified as very low (0-9), low (9-17), moderate (17-30) and sever (30-65)

The sediment source map Figure on the next page was generated using the average annual sediment yield based on sediment yield potential. Sub-basins 2 were very sever sediment yielding (34 ton/ha/yr.), sub basins 1, 5, 6, and 8 were moderate (18 to 27 ton/ha/yr.), sub basins 3 and 4 were low (16 ton/ha/yr.), sub basins 7 and 9 were very low (7 to 8 ton/ha/yr.) sediment producing sub basins

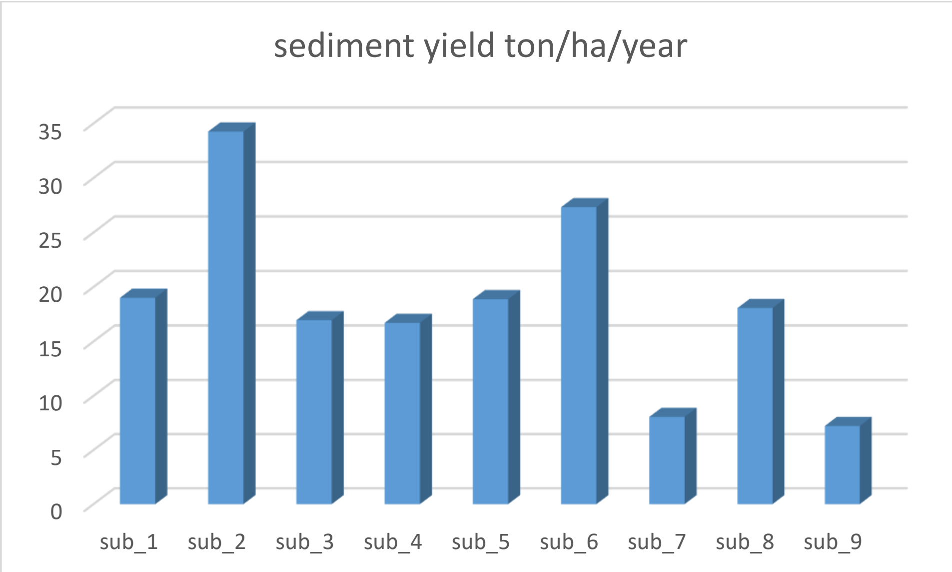


*Figure 4. 8  Sediment yield yield variability in the sub basin*

From the total 9 sub basins 5 sub basins which producing sediment yield from sever to moderate (18-34 ton/ha/yr.) with average sediment yield of 23.51 ton/ha/yr. were identified. As shown in Table, it is observed that 5 affected sub basins dominantly covered with intensively and moderately cultivated land, grass land, wet land which are the main sources for annual sediment yield of watershed. Classification base on land use land cover, soil and slope.

*Table 4. 7 sediment yield in each sub catchment*

| Sub_ Basin No | SYD (ton/ha/yr.) | SED_ CLASS |
|---|---|---|
| Sub_1 | 19.01 | moderate |
| Sub_2 | 34.26 | sever |
| Sub 3 | 16.95 | low |
| Sub 4 | 16.71 | low |
| Sub_5 | 18.88 | moderate |
| Sub_6 | 27.32 | moderate |
| Sub 7 | 8.06 | very low |
| Sub 8 | 18.07 | moderate |
| Sub_9 | 7.22 | very low |

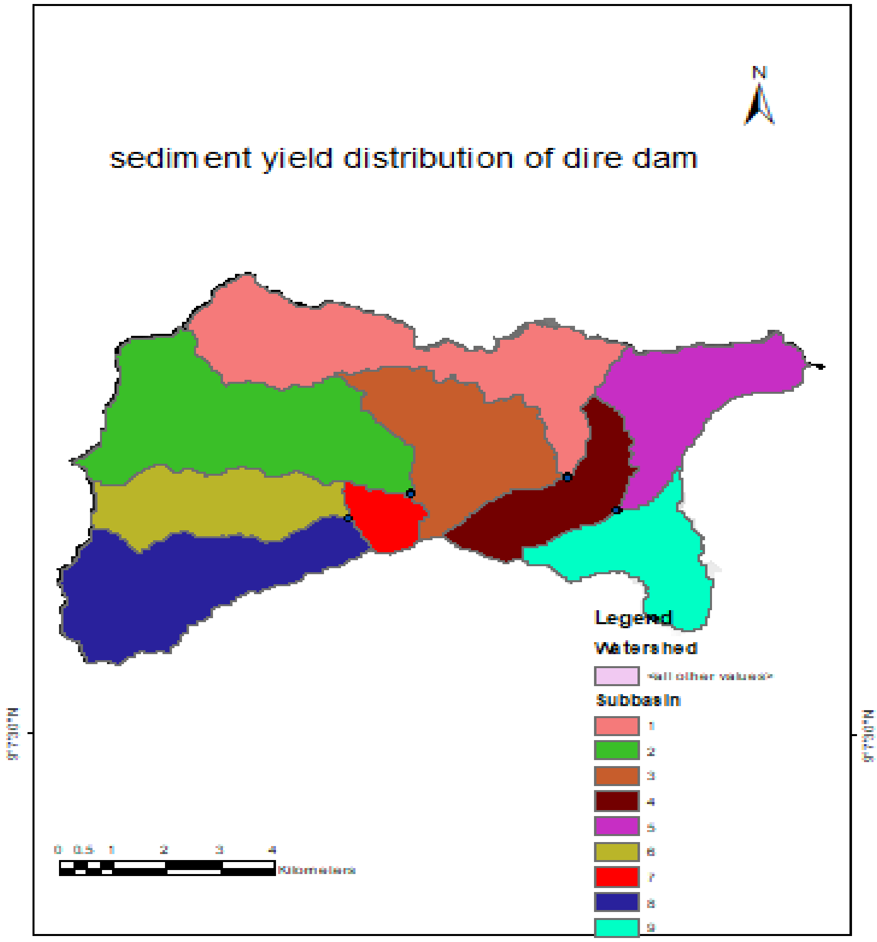


*Figure 4. 9 Spatial variablity of sediment yield for dire dam watershed*

### *4.4 Sediment Management scenario development*

Delineated dire dam watershed using ARC SWAT contain 9 sub basin. These Scenarios were setup to examine how Best Management Practices (BMP's) would affect sediment loadings to dire dam watershed. The best management practice used in this study were identified using swat model simulation result. During this study three different scenario (tracing, grassed_ waterway, filter strips) were developed and comparing according to the effectiveness of sediment yield reduction.

**Scenario – 0: Baseline Scenario**

A baseline scenario, the situation with no BMPs, assumed to reflect the current condition that was initially executed prior to performing the scenario simulations. In this simulation, the calibrated values of SWAT model were used without changing any modeling parameter.This simulated result used as a point of reference for understanding the effects of simulationresults of the following sediment reduction options.

**Scenario 1 (Grassed Waterways):** This practice reduces sediment yield by increasing sediment trapping efficiency and flow velocity Introducing grassed waterway for sediment prone areas reduces sediment yield by protecting channel erosion, intercepting sediment particles collected and transported through the channels and used for safe disposal of water to the streams. In this study applying grassed waterways for the critical sediment source sub basins Simulation on the selected critical sediment source sub basins by adjusting the GWATI (flag for the simulation of grass waterway),GWATN (manning n value for overland flow), GWATL (length of grass waterway), GWATW( average width grass waterway), GWATD(depth of grass waterway), GWATS(average slope of grass waterway channel) and GWATSPCON (linear parameter for calculating sediment in grass waterway) reduced average annual sediment yield from 20.05 ton/ha/yr. to 8.51 ton/ha/yr. which accounts 57% of sediment yield decreased and this scenario again minimizes the maximum up land sediment from 23.22/ha/yr. to 9.822 ton/ha/yr.

In this scenario all treated seven sub basins turned from the category of sever, high and moderate sediment yielding to the category of low and very low sediment yielding categories. Seen on figure below.

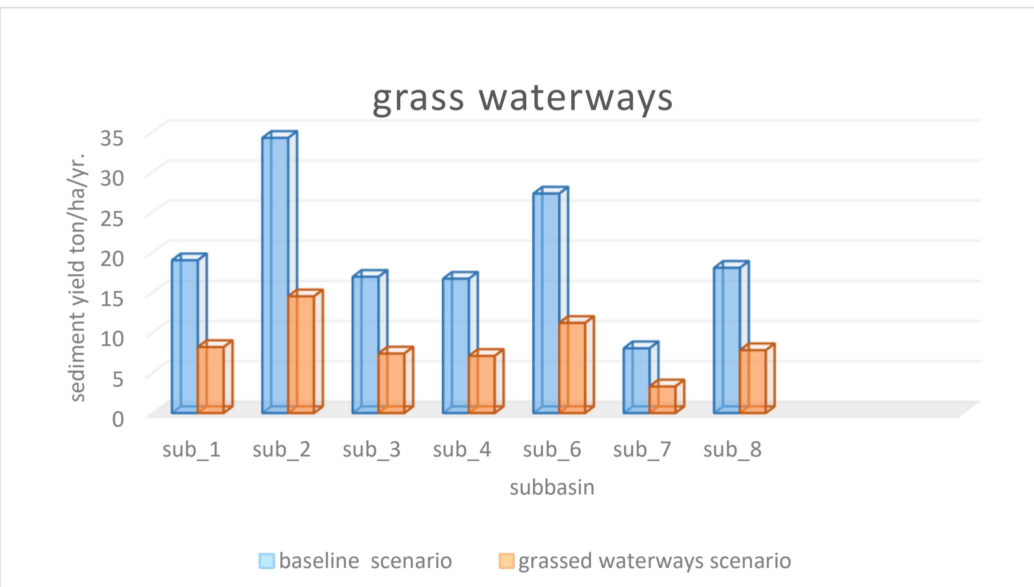

*Figure 4. 10 Reduction of mean annual sediment yield rate due to application of grassed waterway*

### *Scenario II Filter strip*

This management practices were placed on all agricultural HRUs that are combination of croplands, soils and all slope classes. The effect of the trips is that to reduce run off and trap sediment in a given plot (Bracmort et al., 2006). Simulation of filter strip on the selected critical sediment source sub basins by adjusting the VFSI, VFSRATIO, VFSCON, VFSCH Applying filter strips with 5m width for the seven sediment prone sub basins brought a slight reduction of average annual sediment yield by decreasing from 20.05 ton/ha/yr. to 13.20 ton/ha/yr. which accounts 34.14 % reduction. this scenario again minimizes the maximum up land sediment from 23.22/ha/yr. to 15.12 ton/ha/yr.. In this scenario all treated seven sub basins turned from the category of sever, high and moderate sediment yielding to the category of moderate, low and very low sediment yielding categories. Seen on below figure

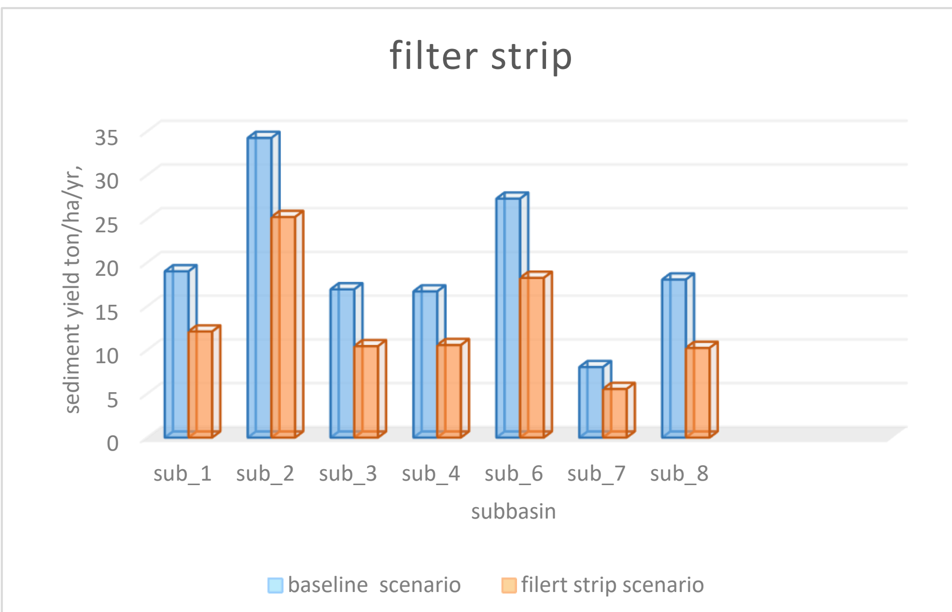


*Figure 4. 11 Reduction of mean annual sediment yield rate due to application of filter strip*

***Scenario III: Terracing***

Terracing practice used as part of a resource management system constructed to reduce erosion and sediment yield in the watershed by reducing slope length and steepness of sub basins. Simulation of terracing on the selected critical sediment source sub basins by adjusting the curve number (TERR_CN), USLE crop practice (TERR_P) and slope length (TERR_SL) significantly reduced average annual sediment yield rate by 70.06% (20.05 ton/ha/yr. to 5.88 ton/ha/yr.). this scenario again minimizes the maximum up land sediment from 23.22 ton/ha/yr to 6.56 ton/ha/yr. from this we can conclude from the three alternative scenario tracing is the best sediment reduction on the dire dam. In this scenario all treated seven sub basins turned from the category of sever, high and moderate sediment yielding to the category of very low sediment yielding categories. Seen on below figure


*Figure 4. 12 Reduction of mean annual sediment yield rate due to application of tracing*

Table 4. 8 summary of scenario

| Sub_ Basin | SYD (ton/ha/yr.) | Sediment values due to terracing (ton/ha/yr.) | Sediment values due to grassed water way(ton/ha/yr.) | Sediment values due to filter strips(ton/ha/yr.) |
|---|---|---|---|---|
| 1 | 19.01 | 6.23 | 8.2 | 12.13 |
| 2 | 34.26 | 9.18 | 14.5 | 25.22 |
| 3 | 16.95 | 5.48 | 7.4 | 10.45 |
| 4 | 16.71 | 5.16 | 7.1 | 10.58 |
| 6 | 27.32 | 7.63 | 11.2 | 18.26 |
| 7 | 8.06 | 2.16 | 3.3 | 5.56 |
| 8 | 18.07 | 5.35 | 7.8 | 10.25 |

Sub basin 3 and 4 are for baseline scenario and the three alternative scenario similar sediment loading condition due to similar characteristics of land use and cover.

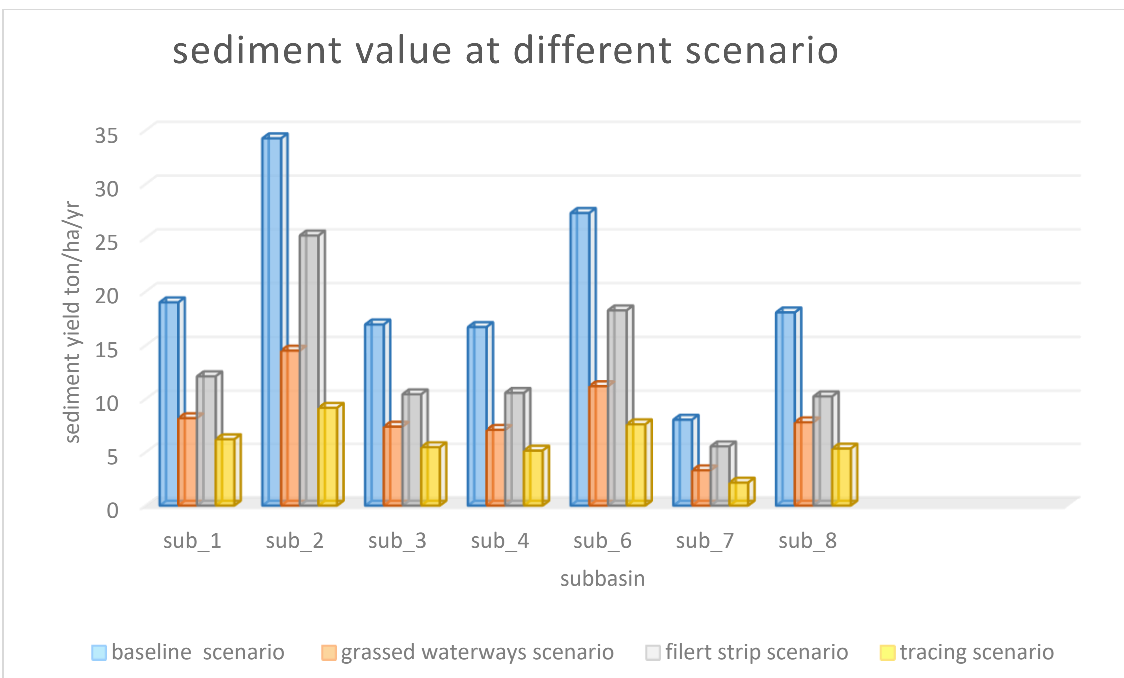


*Figure 4. 13 different scenario reduce sediment*

# CHAPTER FIVE

# 5. CONCLUSION AND RECOMMENDATION

## *5.1 CONCLUSION*

Soil erosion can expressively reduce the fertility and the productivity of agricultural land in the watershed and effects sedimentation problem at the outlet of watershed. The primary objective of this study was to determine the sediment yield from different sub basins of dire dam watershed in Ethiopia, and look the spatial variability of sediment yield evaluation, sediment reduction scenario and comparison of scenario result using SWAT model.

The SWAT model was used for modeling of the dire Dam watershed. The entirewatershed was subdivided into 9 sub basins spatially linked by stream networks. Overlaying slope (topographic data from DEM), land use and soils were performed to generate 103 HRUs from intersections. Climatic data from 1988 – 2018, reservoir physicaldata, outflow data and water abstraction data were inputs during simulation. The model wascalibrated from 1988 to 1999 and validated from 2000 to 2006 on a monthly basis using measured stream flow data and sediment load relations to examine its applicability for simulating flows and sediment yields using automatic calibration with Sequential Uncertainty Fitting (SUFI-2) in SWA_CUP.

During calibration for flow, SCS curve number (CN2), deep aquifer percolation (RCHRG-DP), (SLSOIL) and depth from soil surface to bottom of layer (SOL-Z) were relatively sensitive parameters and played a significant role for the simulation result agreed with the observed. Similarly, linear re-entrainment parameter for channel sediment routing ground water delay (GW_DELAY), SCS curve number (CN2) and sediment concentration lateral and ground water flow (LAT _ SED) were relatively sensitive sediment parameters played a significant role during the calibration process for sediment yield

The suitability and performance of the SWAT model was evaluated using calibration and validation statistics. A good agreement between measured and simulated monthly stream flow in the gauging station was demonstrated by correlation coefficient ($R^2$=0.77), Nash-Sutcliffe model efficiency (NSE=0.75) for calibration period and $R^2$=0.78, NSE= 0.77 for the validation period were observed

The monthly sediment yield simulation of SWAT model resulted in: $R^2$ of 0.74, NSE of 0.73 in the Calibration period of the model. For validation period, $R^2$ of 0.77, NSE of 0.77 was obtained. The 31 years simulation result indicates that the simulated annual average suspended sediment yield by SWAT model was 23.22 t/ha/yr. The sub watersheds that produce the highest sediment are 2, 6, 1, 5, and 8 in their order of importance contributing sediment yield exceeding the soil loss tolerable rates.

The model result showed the implementation of scenario has appreciable benefits in terms of sediment reduction. The annual sediment yield of the watershed at the outlet has reduced by 57%, 34.14%, and 70.06% due to the application of grassed waterways, filter strips, and terracing respectively. . Also at treated Thus, the result indicating that terracing was relatively more sediment reduction practice than other conservation measures on the majority of the affected sub basins in the study watershed. There are also additional option to prevent silt to enter the reservoirs of the dire dam are Enlarging the impounding volume of existing reservoirs, Mechanical Removal of Sediments from the Reservoirs, Regulation of Rivers, Streams and Tributaries, Diversion of Natural Streams and buffer strip.

The Dire dam reservoir is one of the source of water supply for the city of Addis Ababa city, which has a live storage capacity of 19 $Mm^3$. But the storage volume of this reservoir is threatened by the soil erosion and subsequent sedimentation from the upstream of the Dire dam basin.

### *5.2 RECOMMENDATION*

These research work mainly depends on the secondary data collected from the concerned offices and authorities as its input and simulation of final results. The qualities and representativeness may better to support with primary data. Therefore, for further studies of sediment yield in the study area, it is recommended that the use of primary data especially the data related with soil and suspended sediment will greatly refine the sediment yield modeling.

The study was modeling filter strips, grassed waterways, and terracing with scenario and also to prevent silt to enter the reservoirs are Enlarging the impounding volume of existing reservoirs, Mechanical Removal of Sediments from the Reservoirs, Regulation of Rivers, Streams and Tributaries, Diversion of Natural Streams and buffer strip with the objective of the effectiveness of only sediment reduction ability. Further studies could consider these or other land management options for the effectiveness of sediment reduction and economic feasibility for assessing optimized and economical sediment reduction options

The number of gauging station not enough and record small number of sediment data. Hence, it is better to increase the number of record time and number of hydrological stations to get better result.

The study can be further extended to similar neighboring sub basins and watersheds, as wellas can be used as a bridge to fill gaps for the researchers who want to study next in the sub basin level of this watershed or the whole basin

Finally, the study could help different stakeholders for plan and implementation of erosion and sediment yield reductions options on the study watershed. The analyzed and identified management scenario indicated as effective for sediment reduction.

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# APPENDIX

```
SWAT   model  simulation   Date: 05/21/2021 12:00:00 AM   Time: 00:00:00
MULTIPLE HRUs  LandUse/Soil/Slope OPTION            THRESHOLDS : 10 / 10 / 15 [%]
Number of HRUs: 103
Number of Subbasins: 9
```

| | Area [ha] | Area[acres] | |
|---|---|---|---|
| Watershed | 6932.0700 | 17129.4916 | |

| | Area [ha] | Area[acres] | %Wat.Area |
|---|---|---|---|
| LANDUSE: | | | |
| Forest-Mixed --> FRST | 1535.1753 | 3793.4949 | 22.15 |
| Agricultural Land-Generic --> AGRL | 4386.7534 | 10839.8869 | 63.28 |
| Range-Grasses --> RNGE | 856.5538 | 2116.5873 | 12.36 |
| Water --> WATR | 153.5875 | 379.5225 | 2.22 |
| SOILS: | | | |
| calcic xerosols | 813.7548 | 2010.8287 | 11.74 |
| Chromic luvisols | 3499.0798 | 8646.4011 | 50.48 |
| Orthic solonchaks | 2074.1510 | 5125.3308 | 29.92 |
| Pellic vertisols | 462.3139 | 1142.4007 | 6.67 |
| Leptosols | 82.7706 | 204.5303 | 1.19 |
| SLOPE: | | | |
| 45-9999 | 1009.4046 | 2494.2892 | 14.56 |
| 30-45 | 1906.5203 | 4711.1070 | 27.50 |
| 15-30 | 2177.2459 | 5380.0834 | 31.41 |
| 0-15 | 1838.8993 | 4544.0120 | 26.53 |

| | | | | | |
|---|---|---|---|---|---|
| SOILS: | | | | | |
| calcic xerosols | 180.5394 | 446.1220 | 2.60 | 14.50 | |
| Chromic luvisols | 674.1507 | 1665.8600 | 9.73 | 54.13 | |
| Orthic solonchaks | 344.7437 | 851.8789 | 4.97 | 27.68 | |
| SLOPE: | | | | | |
| 45-9999 | 88.3599 | 218.3417 | 1.27 | 7.10 | |
| 30-45 | 293.0779 | 724.2102 | 4.23 | 23.53 | |
| 15-30 | 409.9638 | 1013.0410 | 5.91 | 32.92 | |
| 0-15 | 408.0322 | 1008.2680 | 5.89 | 32.76 | |
| HRUs | | | | | |
| 1 Forest-Mixed --> FRST/calcic xerosols/45-9999 | 17.6817 | 43.6923 | 0.26 | 1.42 | 1 |
| 2 Forest-Mixed --> FRST/calcic xerosols/30-45 | 33.1531 | 81.9231 | 0.48 | 2.66 | 2 |
| 3 Forest-Mixed --> FRST/calcic xerosols/15-30 | 17.8922 | 44.2125 | 0.26 | 1.44 | 3 |
| 4 Forest-Mixed --> FRST/Chromic luvisols/15-30 | 31.4244 | 77.6513 | 0.45 | 2.52 | 4 |
| 5 Forest-Mixed --> FRST/Chromic luvisols/30-45 | 46.4535 | 114.7889 | 0.67 | 3.73 | 5 |
| 6 Forest-Mixed --> FRST/Orthic solonchaks/15-30 | 23.3752 | 57.7613 | 0.34 | 1.88 | 6 |
| 7 Forest-Mixed --> FRST/Orthic solonchaks/30-45 | 25.4801 | 62.9626 | 0.37 | 2.05 | 7 |
| 8 Forest-Mixed --> FRST/Orthic solonchaks/45-9999 | 29.6898 | 73.3651 | 0.43 | 2.38 | 8 |
| 9 Agricultural Land-Generic --> AGRL/calcic xerosols/0-15 | 34.6747 | 85.6828 | 0.50 | 2.78 | 9 |
| 10 Agricultural Land-Generic --> AGRL/calcic xerosols/30-45 | 34.4613 | 85.1555 | 0.50 | 2.77 | 10 |
| 11 Agricultural Land-Generic --> AGRL/calcic xerosols/15-30 | 42.6765 | 105.4558 | 0.62 | 3.43 | 11 |
| 12 Agricultural Land-Generic --> AGRL/Chromic luvisols/30-45 | 96.3369 | 238.0532 | 1.39 | 7.74 | 12 |
| 13 Agricultural Land-Generic --> AGRL/Chromic luvisols/0-15 | 170.5571 | 421.4552 | 2.46 | 13.70 | 13 |
| 14 Agricultural Land-Generic --> AGRL/Chromic luvisols/15-30 | 163.4838 | 403.9766 | 2.36 | 13.13 | 14 |
| 15 Agricultural Land-Generic --> AGRL/Orthic solonchaks/30-45 | 57.1931 | 141.3269 | 0.83 | 4.59 | 15 |
| 16 Agricultural Land-Generic --> AGRL/Orthic solonchaks/15-30 | 70.0615 | 173.1255 | 1.01 | 5.63 | 16 |
| 17 Agricultural Land-Generic --> AGRL/Orthic solonchaks/0-15 | 54.6194 | 134.9672 | 0.79 | 4.39 | 17 |
| 18 Agricultural Land-Generic --> AGRL/Orthic solonchaks/45-9999 | 40.9884 | 101.2843 | 0.59 | 3.29 | 18 |
| 19 Range-Grasses --> RNGE/Chromic luvisols/0-15 | 118.5505 | 292.9443 | 1.71 | 9.52 | 19 |
| 20 Range-Grasses --> RNGE/Chromic luvisols/15-30 | 47.3445 | 116.9905 | 0.68 | 3.80 | 20 |
| 21 Range-Grasses --> RNGE/Orthic solonchaks/0-15 | 29.6305 | 73.2185 | 0.43 | 2.38 | 21 |
| 22 Range-Grasses --> RNGE/Orthic solonchaks/15-30 | 13.7057 | 33.8676 | 0.20 | 1.10 | 22 |

| | Area [ha] | Area[acres] |
|---|---|---|
| Watershed | 6932.0700 | 17129.4916 |

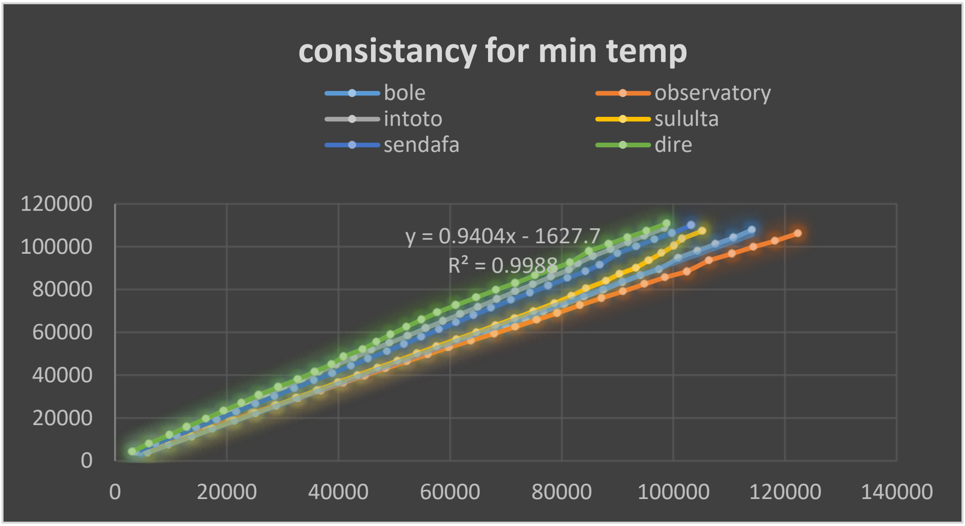
Number of Subbasins: 9

| | Area [ha] | Area[acres] | %Wat.Area |
|---|---|---|---|
| LANDUSE: | | | |
| Forest-Mixed --> FRST | 1592.9088 | 3936.1572 | 22.98 |
| Forest-Deciduous --> FRSD | 65.9225 | 162.8978 | 0.95 |
| Alfalfa --> ALFA | 67.7017 | 167.2942 | 0.98 |
| Agricultural Land-Generic --> AGRL | 4076.1459 | 10072.3604 | 58.80 |
| Range-Grasses --> RNGE | 965.7085 | 2386.3141 | 13.93 |
| Barren --> BARR | 13.2969 | 32.8572 | 0.19 |
| Water --> WATR | 150.3857 | 371.6106 | 2.17 |
| SOILS: | | | |
| calcic xerosols | 867.0121 | 2142.4302 | 12.51 |
| Chromic luvisols | 3488.1808 | 8619.4693 | 50.32 |
| Leptosols | 75.2865 | 186.0367 | 1.09 |
| Orthic solonchaks | 2052.9617 | 5072.9710 | 29.62 |
| Pellic vertisols | 448.6289 | 1108.5844 | 6.47 |
| SLOPE: | | | |
| 0-15 | 2057.3628 | 5083.8463 | 29.68 |
| 15-30 | 1958.3854 | 4839.2682 | 28.25 |
| 30-45 | 1720.0718 | 4250.3834 | 24.81 |
| 45-9999 | 1196.2500 | 2955.9937 | 17.26 |

| | | Area [ha] | Area[acres] | %Wat.Area | %Sub.Area |
|---|---|---|---|---|---|
| SUBBASIN # | 1 | 1245.3300 | 3077.2727 | 17.96 | |

LANDUSE:

Consistency check minimum temperature of all the station found around the study area




| YR | Annual RF | LogX | KN | XH | XL | check for XH | check for XL |
|---|---|---|---|---|---|---|---|
| 1988 | 8498.8 | 3.929358 | 2.577774 | 52.46451 | 49.9545 | not higher outlier | not lower outlier |
| 1989 | 8254.1 | 3.91667 | 2.577774 | 52.46451 | 49.9545 | not higher outlier | not lower outlier |
| 1990 | 8328.3 | 3.920556 | | | | not higher outlier | not lower outlier |
| 1991 | 8421.332 | 3.925381 | | | | not higher outlier | not lower outlier |
| 1992 | 8351.8 | 3.92178 | | | | not higher outlier | not lower outlier |
| 1993 | 8249.563 | 3.916431 | | | | not higher outlier | not lower outlier |
| 1994 | 8561.888 | 3.93257 | | | | not higher outlier | not lower outlier |
| 1995 | 8654.5 | 3.937242 | | | | not higher outlier | not lower outlier |
| 1996 | 8573.8 | 3.933173 | | | | not higher outlier | not lower outlier |
| 1997 | 8795.765 | 3.944274 | | | | not higher outlier | not lower outlier |
| 1998 | 8674.8 | 3.938259 | | | | not higher outlier | not lower outlier |
| 1999 | 8756 | 3.942306 | | | | not higher outlier | not lower outlier |
| 2000 | 8680.898 | 3.938565 | | | | not higher outlier | not lower outlier |
| 2001 | 8635 | 3.936262 | | | | not higher outlier | not lower outlier |
| 2002 | 8802.9 | 3.944626 | | | | not higher outlier | not lower outlier |
| 2003 | 8651.045 | 3.937069 | | | | not higher outlier | not lower outlier |
| 2004 | 8601.896 | 3.934594 | | | | not higher outlier | not lower outlier |
| 2005 | 8693.262 | 3.939183 | | | | not higher outlier | not lower outlier |
| 2006 | 8775.623 | 3.943278 | | | | not higher outlier | not lower outlier |
| 2007 | 8678.176 | 3.938428 | | | | not higher outlier | not lower outlier |
| 2008 | 8575.951 | 3.933282 | | | | not higher outlier | not lower outlier |
| 2009 | 8684.4 | 3.93874 | | | | not higher outlier | not lower outlier |
| 2010 | 8316.677 | 3.91995 | | | | not higher outlier | not lower outlier |

| | | | | |
|---|---|---|---|---|
| 2011 | 8544.015 | 3.931662 | not higher outlier | not lower outlier |
| 2012 | 8795.735 | 3.944272 | not higher outlier | not lower outlier |
| 2013 | 8663.608 | 3.937699 | not higher outlier | not lower outlier |
| 2014 | 8790.2 | 3.943999 | not higher outlier | not lower outlier |
| 2015 | 8904.391 | 3.949604 | not higher outlier | not lower outlier |
| 2016 | 8843.2 | 3.946609 | not higher outlier | not lower outlier |
| 2017 | 9007.711 | 3.954614 | not higher outlier | not lower outlier |
| 2018 | 8588.775 | 3.933931 | not higher outlier | not lower outlier |
| | **mean** | **3.935625** | | |
| | **stadev** | **0.009509** | | |

| LULC | HRU | HRUGIS | SUB | YEAR | MON | AREAkm2 | SYLDt_ha | USLEt_ha |
|---|---|---|---|---|---|---|---|---|
| WATR | 103 | 000090005 | 9 | 1992 | 7 | 1.5359 | 0 | 0 |
| FRST | 1 | 000010001 | 1 | 1992 | 8 | 0.17682 | 0.448 | 0.06 |
| FRST | 2 | 000010002 | 1 | 1992 | 8 | 0.33153 | 0.284 | 0.026 |
| FRST | 3 | 000010003 | 1 | 1992 | 8 | 0.17892 | 0.163 | 0.02 |
| FRST | 4 | 000010004 | 1 | 1992 | 8 | 0.31424 | 0.105 | 0.01 |
| FRST | 5 | 000010005 | 1 | 1992 | 8 | 0.46453 | 0.159 | 0.016 |
| FRST | 6 | 000010006 | 1 | 1992 | 8 | 0.23375 | 0.133 | 0.01 |
| FRST | 7 | 000010007 | 1 | 1992 | 8 | 0.2548 | 0.243 | 0.026 |
| FRST | 8 | 000010008 | 1 | 1992 | 8 | 0.2969 | 0.489 | 0.052 |
| AGRL | 9 | 000010009 | 1 | 1992 | 8 | 0.34675 | 8.17 | 0.916 |
| AGRL | 10 | 000010010 | 1 | 1992 | 8 | 0.34461 | 27.791 | 2.821 |
| AGRL | 11 | 000010011 | 1 | 1992 | 8 | 0.42676 | 13.891 | 1.588 |
| AGRL | 12 | 000010012 | 1 | 1992 | 8 | 0.96337 | 12.291 | 1.626 |
| AGRL | 13 | 000010013 | 1 | 1992 | 8 | 1.7056 | 3.374 | 0.632 |
| AGRL | 14 | 000010014 | 1 | 1992 | 8 | 1.6348 | 6.497 | 0.784 |
| AGRL | 15 | 000010015 | 1 | 1992 | 8 | 0.57193 | 19.5 | 2.336 |
| AGRL | 16 | 000010016 | 1 | 1992 | 8 | 0.70062 | 9.386 | 1.202 |
| AGRL | 17 | 000010017 | 1 | 1992 | 8 | 0.54619 | 4.196 | 0.822 |
| AGRL | 18 | 000010018 | 1 | 1992 | 8 | 0.40988 | 35.899 | 5.792 |
| RNGE | 19 | 000010019 | 1 | 1992 | 8 | 1.1855 | 0.106 | 0.015 |
| RNGE | 20 | 000010020 | 1 | 1992 | 8 | 0.47344 | 0.224 | 0.03 |
| RNGE | 21 | 000010021 | 1 | 1992 | 8 | 0.29631 | 0.221 | 0.027 |
| RNGE | 22 | 000010022 | 1 | 1992 | 8 | 0.13706 | 0.35 | 0.063 |
| AGRL | 23 | 000020001 | 2 | 1992 | 8 | 4.3926 | 15.793 | 2.006 |
| AGRL | 24 | 000020002 | 2 | 1992 | 8 | 2.9992 | 7.661 | 1.128 |
| AGRL | 25 | 000020003 | 2 | 1992 | 8 | 3.3354 | 27.845 | 2.656 |
| RNGE | 26 | 000020004 | 2 | 1992 | 8 | 0.5668 | 0.25 | 0.035 |
| RNGE | 27 | 000020005 | 2 | 1992 | 8 | 0.90183 | 0.361 | 0.051 |
| RNGE | 28 | 000020006 | 2 | 1992 | 8 | 0.95117 | 0.596 | 0.13 |
| FRST | 29 | 000030001 | 3 | 1992 | 8 | 1.1315 | 0.17 | 0.015 |