IMPACT OF LAND USE/LAND COVER CHANGE ON STREAM FLOW AND SEDIMENT YIELD USING SWAT MODEL, A CASE OF MELKA KUNTURE SUB- WATERSHED IN THE UPPER AWASH RIVER BASIN, ETHIOPIA

By: Aboneh Bezabih

A Thesis Submitted to the Department of Geomatics Engineering School of Civil Engineering and Architecture

Presented in Partial Fulfilment of the Requirement for Degree of Masters in Geoinformatics Engineering

Office of Graduate Studies

Adama Science and Technology University

Adama, Ethiopia

February, 2020

IMPACT OF LAND USE/LAND COVER CHANGE ON STREAM FLOW AND SEDIMENT YIELD USING SWAT MODEL, A CASE OF MELKA KUNTURE SUB- WATERSHED IN THE UPPER AWASH RIVER BASIN, ETHIOPIA

By: Aboneh Bezabih

Advisor: Daniel Alemayehu (PH.D)

Co Advisor: Tilahun Erduno (PH.D)

A Thesis Submitted to the Department of Geomatics Engineering School of Civil Engineering and Architecture

Presented in Partial Fulfilment of the Requirement for Degree of Masters in Geoinformatics Engineering

Office of Graduate Studies

Adama Science and Technology University

Adama, Ethiopia

February, 2020

APPROVAL OF THE BOARD OF EXAMINERS

We, the undersigned, members of the Board of Examiners of the final open defense by Aboneh Bezabih have read and evaluated his/her thesis entitled "IMPACT OF LAND USE/LAND COVER CHANGE ON STREAM FLOW AND SEDIMENT YIELD USING SWAT MODEL A CASE OF MELKA KUNTURE SUB- WATERSHED IN THE UPPER AWASH RIVER BASIN, ETHIOPIA "and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the Degree of Degree of Masters in Geoinformatics Engineering.

______________________________	______________________	____________________
Advisor	Signature	Date
______________________________	______________________	____________________
Co-Advisor	Signature	Date
______________________________	______________________	____________________
Chairperson	Signature	Date
______________________________	______________________	____________________
Internal Examiner	Signature	Date
______________________________	______________________	____________________
External Examiner	Signature	Date

DECLARATION

I hereby declare that this MSc Thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged. This Thesis has been submitted in Partial Fulfilment of the Requirement for Degree of Masters in Geoinformatics Engineering at Adama Science and Technology University and Adopted at the university library to be made available to borrowers under rules of the Library.

Name: Aboneh Bezabih

Signature: __________

This MSc Thesis has been submitted for examination with my approval as thesis advisor.

Name: Daniel Alemayehu (PH.D)

Signature: __________

Date of submission:………..

ADVISOR'S APPROVAL SHEET

To: Geomatics Engineering department

Subject: Thesis Submission

This is to certify that the thesis "IMPACT OF LAND USE/LAND COVER CHANGE ON STREAM FLOW AND SEDIMENT YIELD USING SWAT MODEL A CASE OF MELKA KUNTURE SUB- WATERSHED IN THE UPPER AWASH RIVER BASIN, ETHIOPIA" submitted in partial fulfillment of the requirements for the degree of Master's in Geoinformatics Engineering, the Graduate program of the department of Geomatics Engineering, and has been carried out by Aboneh Bezabih Id. No A/pr15313/10, under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby he can submit the thesis to the department.

____________________________	__________	__________
Name of major Advisor	Signature	Date
____________________________	__________	__________
Name of Co-Advisor	Signature	Date

ACKNOWLEDGMENTS

Above all and everything, I thank Almighty God who strengthened me throughout my life and helped me to achieve my dreams. Secondly, I wish to express my immense gratitude to my major advisor Dr Daniel Alemayehu for his unwavering guidance and professional expertise during the preparation of this thesis. Otherwise the thesis would not have been possible and completed on time. I am also grateful to my Co-Advisor Dr Tilahun Erduno for the devotion of his precious times to guide me on my project work.

I would like to thank the Department of Geomatics Engineering program for their kind cooperation in providing the required information and guidance especially Dr Roba Gemechu whom enabled me to pass through the official steps for the defense preparation.

I am grateful to the Ethiopian authorities, specifically the Ministry of Water Resources and the National Meteorology Service Agency for their willingness to provide me with the requested data elements.

I am forever grateful to my family especially my mother Aster Jemaneh to whom I owe my deepest gratitude for being constant sources of my strength and hope in every aspect of life despite their humble backgrounds. Their continuing support and deep love are the major drive for all my achievements.

TABLE OF CONTENTS

LIST OF TABLES viii
LIST OF FIGURES ix
LIST OF ABBRIVATIONS AND ACRONYMS x
1. INTRODUCTION 1
1.1 Background 1
1.2 Statement of the Problem 3
1.3 Research Questions 4
1.4 Significance of the study 4
1.5 Objective 5
1.5.1 General objective 5
1.5.2 Specific objectives 5
1.6 Scope of the Study 6
1.7 Organization of the Thesis 6
2. LITERATURE REVIEW 7
2.1 Land Use and Land Cover Changes 7
2.1.1 Land Use and Land Cover: Definitions and Concepts 7
2.2 Continuous Time Step Simulation Models 9
2.2.1 AnnAGNPS (Annualized Agricultural Nonpoint Source): 9
2.2.2 ANSWERS (Areal Nonpoint Source Watershed Environment Response Simulation): 9
2.2.3 HSPF (Hydrologic Simulation Program Fortran): 10
2.2.4 WEPP (Water Erosion Prediction Project): 10
2.2.5 SWAT (Soil Water Assessment Tool): 10
2.3 Criteria for Selection of Hydrological Models 11
2.4 Overview of ArcSWAT Model 11
2.4.1 Hydrological Component of ArcSWAT Model 12
2.4.2 Sediment Component of ArcSWAT Model 12
2.4.5 SWAT Model Limitations 12
2.5 Impact of Land Use Land Cover Change on Stream Flow and Sediment Yields 13
2.6 Sediment Yield Estimation in a Watershed 14
2.7. SWAT Model Application in Ethiopia 15

TABLE OF CONTENTS (*Continued*)

3. MATERIALS AND METHODS 16
3.1 Conceptual Framework of the Study 16
3.2 Study Area Description 17
3.2.1 Location 17
3.2.2 Geology 19
3.2.3 Physiography and Climate 19
3.2.4 Rainfall Pattern 21
3.2.5 Climate 22
3.3 Materials 25
3.3.1 Data and Data Source 25
Weather Data 26
Stream flow Data 26
Sediment Data 26
3.4 Methods of Data Analysis 26
3.4.1 Land Use Land Cover Mapping 26
3.4.2 Land Use Land Cover Change Detection 28
3.4.3 Modeling Stream Flow and Sediment Yield 30
3.4.3.3 SWAT Model Setup 32
3.4.3.6 Model Efficiency 35
3.4.3.7 Impact of Land Use Land Cover on Stream Flow and Sediment Yield 36
4. RESULTS AND DESCUSSOIN 38
4.1. Introduction 38
4.2 Land Use Land Cover Mapping 39
4.3 Land Use Land Cover Change Detection 40
4.4 Modeling Stream Flow and Sediment Yield 41
4.4.1 Sensitivity Analysis for Stream Flow Simulation 41
4.4.2 Sensitivity Analysis for Sediment Simulation 43
4.4.3 Stream Flow: Calibration and Validation 44
4.4.4 Sediment Yield: Calibration and Validation 48
4.4.5 Model Performance Evaluation for Stream flow Calibration and Validation 52

TABLE OF CONTENTS (*continued*)

4.4.6 Model Performance Evaluation of Sediment Yield Calibration and Validation........................53

4.4.7 Impact of Land use Land cover Change on Stream Flow..53

4.4.8 Impact of land use Land Cover on Sediment yield..55

4.3 DISCUSSION..56

4.3.1 Parameter Sensitivity for Stream flow and Sediment Yield Simulation...................................56

4.3.2 Melka Kunture sub watershed Stream flow and Sediment Yield status...................................56

4.3.3 Impact of LULC change on Stream flow and Sediment Yield in Melka Kunture Watershed...57

5. CONCLUSION AND RECOMMENDATION...58

5.1 Conclusion..58

5.2 Recommendation...60

REFERENCES...61

APPENDIX..66

LIST OF TABLES

Table 3.1: Selected meteorological station in study area (Source: NMAE, 2019) 21

Table 3.2: River gauging stations and sub-catchments in the Melka Kunture watershed (Source: MoWE, 2018) 23

Table 3.3: Data and data source 25

Table 4.1: LULC change detection Analysis. 40

Table 4.2: Result of sensitivity analysis for flow calibration. 42

Table 4.3: Result of sensitivity analysis for sediment calibration. 43

Table 4.4: Model performance evaluation for stream flow calibration and validation 52

Table 4.5: Model performance evaluation for sediment calibration and validation 53

Table 4.6: Impact of LULC on stream flow 53

Table 4.7: Impact of LULC on sediment yield 55

LIST OF FIGURES

Figure 3.2: Study area map 18
Figure 3.2: Physiographic map of the study area produced from DEM in 3D-view. 20
Figure 3.3: Distribution of agro-climatic zone map of the study area (Source: AWBA, 2018) ... 22
Figure 3.4: Mean annual flow characteristics of main river gaging station in Melka Kunture watershed 24
Figure 3.5: Flow chart of LULC change detection analysis 29
Figure 3.6: Flow chart of methods of data analysis for stream flow and sediment yield simulation. 37
Figure 4.1: LULC Map of 1986, 200 and 2010. 39
Figure 4.3: Simulated and observed daily flows generated from SWAT CUP during calibration. 44
Figure 4.4: Simulated and observed daily flows by excel during calibration. 45
Figure 4.5: Simulated and observed average monthly flows by excel during calibration 45
Figure 4.6: Simulated and observed monthly scatter plot for flow calibration 46
Figure 4.7: Simulated and observed daily flows generated from SWAT CUP during validation. 46
Figure 4.8: Simulated and observed daily flows by excel during validation. 47
Figure 4.9: Simulated and observed monthly flows by excel during validation. 47
Figure 4.10: Simulated and observed monthly Scatter plot for flow validation 48
Figure 4.11: Simulated and observed monthly sediment generated from SWAT CUP during calibration. 49
Figure 4.12: Simulated and observed monthly sediment by excel during calibration. 49
Figure 4.13: Simulated and observed monthly scatter Plot for sediment calibration 50
Figure 4.14: Simulated and observed monthly sediment generated from SWAT CUP during validation. 51
Figure 4.15: Simulated and observed monthly sediment yield 51
Figure 4.16: Simulated and observed monthly scatter plot for sediment validation 52
Figure 4.17: Mean monthly stream flow change due to LULC change. 54
Figure 4.18: Average monthly sediment change due to LULC change. 55

LIST OF ABBRIVATIONS AND ACRONYMS

AOI	Area of Interest
AWBA	Awash Basin Authority
ANNAGNPS	Annualized Agricultural non-point source
ANSWERS	Areal Non-point Source Watershed Environmental Response Simulation
CN	Curve Number
DEM	Digital Elevation Model
ET	Evapotranspiration
ETM	Enhanced thematic mapper
FAO	Food and Agricultural Organization
GIS	Geographic Information System
HRU	Hydrological Response Units
HSPF	Hydrologic Simulation Program Fortrun
Km	Kilometer
LULC	Land use land cover
M.a.s.l	Meter Above Sea Level
Mm	Millimeter
MLC	Maximum Likelihood Classification
MoWE	Ministry of Water and Energy
MUSLE	Modified Universal Soil Loss Equation
NMAE	National Metrological Agency of Ethiopia
NSE	Nash-Sutcliffe Efficiency
PBIAS	Percent Bias
PDRE	Peoples Democratic Republic of Ethiopia
R^2	Regression coefficient
RSR	Root Mean Square Error Observation Standard Deviation Ratio
RUSLE	Revised Universal Soil Loss Equation
SCS	Soil Conservation Service
SUFI2	Sequential Uncertainty Analysis Fitting Version 2
SWAT	Soil Water Assessment Tools

SWAT_CUP	Soil Water Assessment Tools Calibration and Uncertainty Program
TM	Thematic Mapper
UA	Upper Awash
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
WEPP	Water Erosion Prediction Project

ABSTRACT

Stream Flow and Sediment yield estimations are needed for studies of reservoir sedimentation, river Morphology and soil and water conservation planning. An understanding of hydrological processes is essential for investigating impacts of land use and land cover changes on water resources. The objective of this study is to estimate stream flow and sediment yield of Melka Kunture sub watershed by using hydrologic model SWAT and the study result will provide an insight to planners and decision makers regarding the status of stream flow and sediment yield so that appropriate management measure will be undertaken. The area of Sub Watershed was discretized into 7 sub catchments using ArcSWAT interface of the model. The Sequential Uncertainty Fitting (SUFI2) calibration process built in SWAT calibration and uncertainty program (SWAT-CUP) were used to calibrate the model parameters using time series flow and sediment load data of 2001 to 2005 and validated with the observed data from years 2005 to 2008. The performance of the model was evaluated through Sensitivity Analysis, Calibration and Validation. The coefficient of determination (R^2), Nash-Sutcliffe Efficiency (NSE) and Percent Bias (P_{bias}) values for the daily Stream Flow by using SUFI2 optimization technique was obtained as 0.85, 0.76 and -4.6 respectively for the calibration period and 0.76, 0.74 and 5.1 respectively for validation period. For monthly sediment yield R^2, NSE and P_{bias} for calibration was computed as 0.72, 0.78 and -13.5 respectively, and 0.71, 0.69 and -14.1 respectively for validation period. Simulation of effect of land use land cover change on stream flow and sediment yield, evidently indicated that average monthly stream flow and sediment yields were increased due to the reduction of Forest land and Increment of Agricultural land. Stream flow was increased by 7.78% from 1986 to 2000 and 4.84% from 2000 to 2010.similarly Sediment Yield also increased by 58.62% from 1986 to 2000 and 4.34% from 2000 to 2010. Average annual sediment yield of Melka Kunture watershed was estimated as 21.17 t/ha/y, 33.58 t/ha/y and 35.04 t/ha/y using LULC map of 1986, 2000, and 2010 respectively, which exceeds the average sediment yield of the Upper Awash sub-Basin. Therefore, Stakeholders must provide appropriate mitigation measures to reduce the stream flow and sediment yield of Melka Kunture Sub Watershed.

Keywords: *calibration; Validation; Stream Flow; Sediment Yield; SWAT-CUP; SUFI2;LULC*

1. INTRODUCTION

1.1 Background

Stream flow and sediment yield estimations is used in studying reservoir sedimentation, river morphology, soil and water conservation planning, water quality modelling and design of efficient erosion control structures. Sediment yield refers to the amount of eroded sediment discharged by a stream at any given point over a period of time, which is also the amount, which will enter a reservoir located at the downstream limit of its tributary watershed (Neitsch., 2011).

Sedimentation continues to be one of the most important threats to rivers around the world (Walling., 2003). Considering the risk of sedimentation and its impacts, it is necessary that appropriate management measures should be undertaken. Studies have shown that in Ethiopia, billions of tons of soil are lost annually. The average annual rate of soil loss in Ethiopia is estimated to be 12 tons/hectare/year (USAID, 200).Awash River Basin has faced a serious sedimentation problem. The average annual soil loss in catchments is in the order of 200-300 t/ha or 20,000-30,000 t/km^2 (PDRE., 1989).The existence of high rate of soil erosion in a watershed can be taken as an indication of unsustainable land management practices (Herweg, 1999).

An understanding of hydrological processes is essential for investigating impacts of land use and land cover changes on water resources. Land use and land cover influences watershed hydrological responses by partitioning rainfall between return flow to the atmosphere as evaporation and transpiration and flow to aquifers and rivers. However, techniques for the analysis of the impact of LULC change on stream flow and sediment yield are still very much at early stage (Schreier, 2003).

With the development of computer technology and the understanding of hydrological processes, modeling has become one of the most powerful tools for watershed management (Gassman, 2007). Information of sensitivity analysis, calibration, and validation are key factors in reducing output uncertainty and increasing user confidence in model abilities, which make the simulation more effective.

The basic requirement for a hydrological model is its capability to estimate stream flow adequately because the stream flow process affects the transport of sediments and agricultural chemicals. Knowledge on sediment yield from a catchment is also quite essential because it is often needed to estimate the quantity of sediment delivered to a downstream reservoir and then further estimate the amount of pollutants into the reservoir. There is a growing need for effective technologies for catchment management to control sediment transport for this kind of catchments. One possible choice is the use of a hydrological model coupled with Geographic Information System (GIS) and Remote Sensing (RS) techniques.

In order to choose a model for a particular watershed, the following factors should be considered: the level of application, purpose, required accuracy, space and time scale, and availability of data (Decoursey, 1988).Many Continuous time step simulation models Such as AnnAGNPS, ANSWERS, HSPF, WEPP including SWAT are used presently to model stream flow and sediment yield involved in the hydrological cycle. The applicability of these models had been evaluated under different conditions from different researchers in different part of the world and revealed that SWAT model is more accurate than the AGNPS, ANSWEAR, and HSPF model (Young et al., 1989; Donigian et al., 1995; Bouraoui and Dillaha, 2001). The WEPP model is accurate than the SWAT but it overestimates sediment yield in large watershed area but SWAT is accurate in both small and large areas and also it is better in assessing both spatial and temporal variability of the hydrological process (Arnold, 1998). So, the hydrological model SWAT was selected to model the stream flow and sediment yield of the study area.

SWAT model was calibrated and validated in many parts of Ethiopia, especially in the Blue Nile basin. Through modelling of Gumara watershed (in Lake Tana basin), Awulachew (2008) indicated that stream flow and sediment yield simulated with SWAT were reasonably accurate. A study conducted on modelling of Lake Tana basin with SWAT model also showed that the SWAT model was successfully calibrated and validated (Setegn, 2008). This study reported that the model can produce reliable estimates of stream flow and sediment yield for complex watersheds.

Therefore, the purpose of this study was to estimate stream flow and sediment yield of Melka Kunture Sub Watershed by using hydrologic model SWAT and the study result will provide an insight to planners and decision makers regarding the status of surface runoff and sediment yield so that appropriate management measure will be taken. The SWAT model was calibrated and validated for the stream flow and sediment. Following the calibration and validation of the model, the effect of land use land cover change with respect to stream flow and sediment yield was evaluated under different Land Use Land cover maps.

1.2 Statement of the Problem

Upper Awash (UA), part of Awash River Basin, is densely populated with large population growth as well as the expansion of development activities in the region is expected to put further pressure on the water and associated resources of the area (Gobena, 2010). Melka Kunture sub watershed is located at Upper Awash River Basin, upstream of Koka reservoir which about 180 square kilometer wide. Melka Lemma (2018) reported that the upper catchment of Koka reservoir station was affected by the land use land cover changes, and this changes causes for high erosion which reduces the capacity of reservoir and capacity of the channel that cause for the reduction of power. This reservoir has been facing a critical sedimentation problem resulting from the input of rivers such as Awash, Modjo and others that drain into it. The annual sediment deposition in the reservoir is estimated at 18Mg $ha^{-1}y^{-1}$ (Siyam., 2005), which indicates a very high off-site effect of soil erosion. Silt deposition in the Koka reservoir is an outcome of LULC changes and lack of appropriate soil and water conservation practices in the upper Part of Reservoir, including the Melka Kunture Sub watershed (Berhan., 2015).Therefore it is important to conduct stream flow and sediment yield analysis specific to the upper catchment of Koka reservoir station which is specifically Melka Kunture that helps to reduce the cost of conservation measures and infrastructure development.

A change in LULC is often the initial phase of accelerated surface runoff generation, soil erosion and land degradation (Bewket., 2003). Besides, the soil erosion model simulation result shows that cultivated lands replacing former vegetation covers were found to be on average five times more prone to erosion than bush–shrub lands in most parts of the Gindae catchment, northern Ethiopia (Haregeweyn., 2013). A LULC change analysis is a decisive requirement for the assessment of its potential environmental impacts (Leh., 2011).

There are, however, very few studies in the Ethiopian highlands context that assess long-term LULC change impacts on hydrological regimes. For example, studies by Legesse (2003) (South central Ethiopian), Bewket (2005) (Northwestern highlands) and Tadele. (2009) (Southern region of Ethiopia) evaluated hydrological responses to LULC changes. The findings of these studies confirmed that adverse impacts are observed on hydrological regimes including seasonal overland and streamflow variations; a reduction of infiltration rates, base-flow and groundwater recharge; and scarcity of water resource availability due to partly declining natural vegetation covers and a considerable expansion in areas under farmland, settlement and bare lands. Although LULC dynamics analysis is an important input for environmental monitoring to devise effective land use management and planning strategies (Leh, 2011), the availability of quantitative studies regarding the impact of spatio-temporal LULC changes on runoff generation and soil erosion is not widely and intensely discoursed in Ethiopia. Thus the present study was focused on the impact of land use land cover change on stream flow and sediment yield under different Land use land cover changes.

1.3 Research Questions

1. How to map and detect LULC change using time series satellite data?
2. What is the performance of SWAT model in simulating stream flow and sediment yield of Melka Kunture Sub-Watershed?
3. How stream flow and sediment yield Responding under changing LULC?

1.4 Significance of the study

Distributed hydrological models, mainly simulating processes such as stream flow and transport of sediment in a catchment, can assist decision-makers in dealing with these problems by providing systematic and consistent information on water availability, water quality and impact of human activities on hydrological regimes (Tripathi, 2005). Therefore, the present study will give essential information regarding the quantity and deposition of stream flow and sediment yield. In order to design efficient conservation strategies for the sustainable development, it is essential to know the patterns of land use change of the area over time and space and to quantify the extent to which these changes influence the hydrological processes of the watershed.

Knowing the effect of land use land cover change on stream flow and sediment yield, will help planers and decision makers to undertake appropriate management measures. Generally, the Following Stakeholders will be benefited from the Study:

Community and Farmers: The result of the project gives information to policy makers, water resource planners and local land use managers to provide a proper conservation measure to reduce rapid rate of deforestation and soil erosion which helps the farmers and community living over the area.

Land use Planners and Local Land Managers: the study provide base line information on issues of land use and land cover change and dynamics in relation to forest cover change in the study area. Basically, such information is vital for land use planners and local land managers to compare the past and present condition and predicts the future trends of the LULC change.

Hydrologist and Water Resource Planners: will also benefit from the information regarding the status of stream flow and sediment yield.

Researchers: The study identified the most sensitive parameters to simulate stream flow and sediment yield over the area. Scholars and researchers will use this information to other area which have similar watershed condition with Melka Kunture watershed.

1.5 Objective

1.5.1 General objective

The general objective of the study is to model the stream flow and sediment yield of the study area.

1.5.2 Specific objectives

1. To Analyze LULC change detection for three periods(1986,2000,2010)
2. To evaluate the performance of SWAT model in simulating stream flow and sediment yield.
3. To quantify stream flow and sediment yield under changing LULC (1986,2000,2010)

1.6 Scope of the Study

The potential for soil erosion varies from one watershed to the other depending on the nature of the watershed (type of topography and Slope), the soil characteristics, the local climatic conditions, and the land use and management practices implemented on the watershed. Therefore, the present study was intended to model the stream flow and sediment yield of Melka Kunture sub watershed, Awash River Basin, the catchment covering an area extent of 4230km^2. SWAT2012 which is an extension of ArcMap Software was used to Model the stream flow and sediment yield of the study area. SWAT_CUP software was also used for conducting sensitivity analysis, calibration and validation and the performance of model evaluation was carried out to show how the measured values were fit with simulated ones. Finally, the effect of Land use Land cover on stream flow and sediment yield was accessed from the year 1986-2010.

1.7 Organization of the Thesis

The thesis was presented in five chapters including conclusion and recommendations. The first chapter included an introduction regarding the study, general background, problem Statement, research question, significant of the study, and the general and specific objectives of the study, scope and organization of the thesis were illustrated under this chapter. On the second chapter, literatures such as Land Use and Land Cover Changes, Continuous time step simulation models, Criteria for selection of hydrological models, Overview of ArcSWAT Model, Model efficiency previous studies conducted on stream flow and sediment yield and the conceptual framework adopted to conduct the present study were included. Chapter three included description of study area such as location, Geological Setting, Physiography and Climate, Rainfall Pattern, temperature condition and Hydrology in the Watershed were inclustirated. Data and data source also included under these chapter. Chapter four were discussed about data analysis, results and discussion of the study which includes LULC mapping, swat model simulation for stream flow and sediment yield and impact of LULC change on stream flow and sediment yield. Finally conclusion and recommendation were discussed under chapter five.

2. LITERATURE REVIEW

2.1 Land Use and Land Cover Changes

2.1.1 Land Use and Land Cover: Definitions and Concepts

The International Geosphere-Biosphere Program, The International Human Dimension Program and the Land Use and Land Cover Change project have referred to 'land use and land cover change' as follows (IGBP-IHDP, 1999). ***Land cover*** refers to the physical and biophysical characteristics or state of Earth's surface and immediate, captured in the distribution of vegetation, water, desert, ice and the other physical features of the land, including those created solely by human activities e.g., settlements. ***Land use*** refers to the intended use or management of the land cover type by human beings. Thus, land use involves both the manner in which the biophysical attributes of land are manipulated and intent underlining that manipulation (the purpose for which the land is used e.g., agriculture, grazing, etc), which are more subtle changes that affect the character of the land cover without changing its overall classification. Definition of land use in this way establishes a direct link between land cover and the actions of people in their environment (FAO, 1998a).

Land Use and Land Cover Changes (LULC) is the shift in intent and/or management constitute land use and land cover. LULC can be classified into land use and land cover conversions, and land use and land cover modification. Conversion refers to change from one cover or use type to another, as is the case in agricultural expansion, deforestation, or change in urban extent.

Land use and land cover modification, on the other hand, involves the maintenance of broad cover or use type in the face of change in its attributes. Both conversion and modifications of land use and land cover have important environmental consequences through their impacts on soil and water, biodiversity, and microclimate, hence, contribute to watershed degradation (Lambin., 2003). LULC is always caused by multiple interacting factors originating from different levels of organization of the coupled human environment systems. It is the result of complex interactions between several biophysical and socio-economic conditions which may occur at various temporal and spatial Space, according to specific human-environment conditions. Understanding the underlying LULC drivers is an important input for planning and decision making (Xiuwan, 2002). Lambin (2003) described the fundamental causes of LULC as: (1) resource scarcity leading to an increase in the pressure of production on resources (population of resource users, labor availability, quantity of resources, and sensitivity of resources); (2) changing opportunities created by markets (market prices, production costs, transportation costs, and technology); (3) outside policy intervention (subsidies, taxes, property rights, infrastructure, and governance); (4) loss of adaptive capacity and increased vulnerability(exposure to external perturbations, sensitivity, and coping capacity), and (5) changes in social organization, in resource access, and in attitudes(resource access, income distribution, household features, and urban-rural interactions). As a result, information on LULC has an important role to play at local and regional planning and management natural resources (Kumar, 2004), quite often the study of LULC is necessitated by the need to know, in quantitative terms, the nature, extent and rate at which these changes advance and the problems or impacts they cause. Furthermore, some studies tried to comprehend the effect of changes in upstream land use and land cover, resulting alterations in the movement of water and water availability at the downstream. Increased consciousness of these impacts enhanced their estimating, forecasting and modelling at the regional scales.

However, quantifying impacts of LULC and managements practices at a watershed scale is still complex because of the inherent variability and complex interactions among the different factors. Thus, in order to provide foundations for effective management of natural resources, an understanding must be built on the variability in time and space of the resources and role of human cultures and institutions in bringing those variations (Thomas, 2001).

Comprehensive knowledge of LULC is useful for reconstructing past land use and land cover changes and for predicting future changes, and thus May help in elaborating sustainable management practices aimed at preserving essential landscape functions (Hietel, 2004). The primary drivers of LULC and their interrelationship with the hydrological regimes has to be identified to develop projections of future land use and management decision outcomes under a range of economic, environmental, and social scenarios.

Currently, improved understanding of processes of LULC has led to a shift from a view condemning human impact on the environment as leading mostly to a deterioration of earth system processes to emphasize on the potential for effective utilization of resources and ecological restoration through watershed management.

This change reflects an evolution of the research questions, methods, and scientific paradigm (Victor., 2000). As a result, general statements about impacts of LULC and land–water interactions need to be continuously questioned to determine whether they represent the best available information and whose interests they support in decision-making processes (Bewket., 2005).

2.2 Continuous Time Step Simulation Models

Continuous time step models are characterized by their capability of simulating stream flow and sediment fluxes on a long-term time basis. In the following, some of the most popular continuous time step simulation models are explained briefly.

2.2.1 AnnAGNPS (Annualized Agricultural Nonpoint Source): In the model, a watershed is represented based on homogeneity of land areas, river reaches and impoundments. The model can simulate hydrology, sediment transport and nutrient transport on a long term, daily or sub daily time steps.

Overland flow is computed by the runoff curve number method and the peak flow by the soil conservation service (SCS) TR-55 method, while subsurface flow is computed from Darcy's equation or Hooghoudts equation. Mannings equation, with a trapezoidal cross Section is used for the computation of runoff in channels for peak flow estimation by TR-55 method. Overland sediment transport is estimated from sheet and rill erosion generated by using the RUSLE equation. The rate of sediment deposition is based on the distribution of particle size and fall velocity. The sediment transport in a channel is estimated using the modified Einstein equation and the transport capacity of flow.

2.2.2 ANSWERS (Areal Nonpoint Source Watershed Environment Response Simulation):

This model has sediment detachment and sediment transport components. It is capable to simulate long-term processes based on daily time steps. The watershed is found based on a square grid with uniform hydrologic characteristics. Mannings and continuity equations are used to calculate the overland runoff of each grid cell. The subsurface flow is determined using Darcy's gravity flow equation. In a similar way to the overland flow, Mannings equation and the continuity equation are used to determine the runoff in the channels. Overland sediment flow is determined from the raindrop detachment, soil erosion and a sediment transport equation. The raindrop detachment is computed from rainfall intensity and the USLE factors.

Soil erosion is determined by unit width flow and the USLE factors whereas transport and deposition of sediments are computed using Yalins equation. However, the model does not simulate channel sediment separately.

2.2.3 HSPF (Hydrologic Simulation Program Fortran): This model is intended to simulate the water quantity and its quality in a watershed. In HSPF, pervious (agriculture) and impervious (urban) land areas represent a watershed. This model has the capability to simulate stream flow and sediment transport on a long term based for hourly time steps. The overland flow is computed using the empirical outflow depth to the detention storage relation and the Chezy-Mannings equation. Interflow, percolation and ground water flow are computed from different empirical relations. Channel flow is computed based on the continuity equation with the assumption that all flows enter the channel at one point in the upstream section. The outflow is determined based on the reach volume or user supplied demand. Overland sediment is estimated from the transport capacity function, which is based on rainfall splash detachment and wash off processes.

2.2.4 WEPP (Water Erosion Prediction Project): WEPP is a process based soil erosion estimation model. It incorporates the spatial variability of the topographic conditions, soil characteristics and different land management activities. The model can be used for estimation of sediment yield for small watersheds. Moreover, inter rill and rill erosion are considered. Inter rill erosion is the result of rainfall impact mainly the rainfall intensity and the sediment transport in the rill channels is as a result of inter rill runoff. For watershed sediment yield prediction, the model assumes that sediments are transportable if the channel flow shear stress exceeds the critical shear stress and the sediment supply to the channel does not exceed the channel sediment transport capacity. The spatially varied flow equation is used for computation of the flow shear stress in channels.

2.2.5 SWAT (Soil Water Assessment Tool): SWAT is also a nonpoint source pollution model with the capability of simulating hydrology, missing weather elements, sediment and pollutants transport. Temporally, it can simulate long term and daily time steps. It is capable to simulate long-term processes based on daily time steps. 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 case of subsurface flow, which joins the river before reaching the ground water, the Kinematic storage model (Sloan, 1983) is used, whereas for ground water flow empirical relations are used. Flow in a channel is determined using Mannings equation and routed based on either the variable storage coefficient method or the Muskingum method. Overland sediment movement is estimated using RUSLE (Williams, 1995).The sediment transport in channels is determined from the combination of stream power concept of Bagnold and the soil erodibility factor from USLE (Wischmeier, 1978.).

2.3 Criteria for Selection of Hydrological Models

In order to choose a model for a particular watershed, the following factors were considered: the level of application, purpose, required accuracy, space and time scale, and availability of data (Decoursey, 1988). SWAT is suitable in the following context: Watersheds with no monitoring data can be modeled, the relative impact of alternative input data (e.g. change in management practices, climate, vegetation, etc.) on water quality and other variables of interest can be quantified, variety of management strategies can be modeled without excessive investment in time or money and Enables user to study long-term inputs (Neitsch., 2005).

2.4 Overview of ArcSWAT Model

The Soil and Water Assessment Tool (SWAT) model is developed by USDA Agricultural Research Service (Winchell, 2013), which simulates the land phase of the hydrologic cycle in daily basis. SWAT predicts surface runoff using the Soil Conservation Service (SCS) curve number (CN) method and it used daily rainfall data as an input. The modified universal soil-loss equation is used to predict the sediment loss. The SWAT model is designed to route water and sediments from individual watersheds through the river systems. It can incorporate the tanks and the reservoirs/check dam off-stream as well as on-stream. The agricultural areas can also be integrated with respect to its management practices. The ArcSWAT ArcGIS extension evolved from AVSWAT2000 an ArcView extension developed for an earlier version of SWAT (Winchell, 2013).The interface requires the designation of land use, soil, weather, groundwater, water use, management, soil chemistry, pond, and stream water quality data, as well as the simulation period, in order to ensure a successful simulation.

The major advantage of the model is that unlike the other conventional conceptual simulation models, it does not require much calibration and therefore can be used on ungagged watersheds; it is physically based; it uses readily available inputs; it is computationally efficient to operate on large basins in a reasonable time; it is continuous time and capable of simulating long periods for computing the effects of management changes.

2.4.1 Hydrological Component of ArcSWAT Model

SWAT in the land phase simulates the hydrological cycle based on the water balance equation. Equation 3.1 used to determine the soil water content of the watershed.

$$SW_{t=}SW_0 + \sum_{i=1}^{t} \left(P_{day}\right) - Q_{surf} - AET - Q_{seep} - Q_{gw} \ldots\ldots\ldots\ldots \text{(1)}$$

Where *SW t* is the final water content in millimeters (mm), SWo is the initial soil water content on day i (mm), Pday is the precipitation on day i (mm), Qsurf is the surface runoff on day i (mm), AET is the actual evapo-transpiration on day i (mm), Qseep is the water entering the unsaturated zone from the soil profile on day i (mm), and Qgw is the return flow from the shallow aquifer and lateral flow on day i (mm).

2.4.2 Sediment Component of ArcSWAT Model

Erosion and sediment yield in SWAT are estimated for each HRU with the Modified Universal Soil Loss Equation (MUSLE). It uses the amount of runoff to simulate erosion and sediment yield. The hydrology module/component supplies estimates of runoff volume and peak runoff rate, which, with the sub basin area, are used to calculate the runoff erosive energy variable. The crop management factor is recalculated every day that runoff occurs. It is a function of above ground biomass, residue on the soil surface, and the minimum crop factor for the plant (Getnet., 2008).

2.4.5 SWAT Model Limitations

The popularity of the SWAT model is largely due to the multi-disciplinary coverage of processes representing the hydrology, soil science, erosion/sediment transport, crop growth, in-stream water quality and the agricultural management. Even though SWAT contains many processes, certain processes may still not be well represented. For example, Dumbo and van Griensven (2011) indicated in their paper that certain landscape elements, such as wetlands, are not well represented in the SWAT model, while they may have a huge impact on the hydrological and nutrient cycle.

One may also wonder whether the concepts behind the processes are represented in the SWAT model and are generally applicable all over the globe. Several of these processes have an empirical background whereby the equations were derived from large data sets in the US. They used curve number approach and the USLE soil loss equations are good examples.

While SWAT is a process-based model, it intentionally incorporates simplified representations of most processes so that many parameters can be obtained from readily available geospatial coverages. For upland generation of flow and sediment, SWAT relies on the well-tested, semiempirical approaches of the SCS Curve Number and MUSLE. The basic time step of the model is one day (although hydrology can be simulated at a finer scale using Green -Ampt infiltration); so actual flow hydrographs are not represented. The MUSLE approach is most applicable to the estimation of cumulative loads, rather than loads from individual events. It should also be noted that the default SWAT algorithm may yield unrealistic results from HRUs that contain a mix of urban pervious and impervious land cover because MUSLE is calculated with the peak flow.

2.5 Impact of Land Use Land Cover Change on Stream Flow and Sediment Yields

Quantifying the effects of land use and land cover change on sediment and runoff dynamics of a river basin has been an area of interest for hydrologists in recent years. In water resources planning and management, a study of the land use changes and their effects on stream flow and sediment yield patterns for a watershed is essential. Information on changing land-use within a watershed is vital for evaluating the hydrological impacts. Various studies in different countries showed that SWAT, a river basin scale model developed to quantify the impact of land management practices on water, sediment, and agricultural chemical yields, can adequately simulate the effects of land use on runoff volumes, sediment yield and stream flows.

In the earlier days, assessment of the impact of land use changes on Stream Flow was mainly done through catchment experiments and different results had been obtained, with some even opposing the findings of the others. (Langford, 1976), for example, found out that there is no significant increase in runoff because of burning down of a stand of Eucalyptus.

In contrast, after reviewing results from a number of catchment experiments, (Hibbert, 1967) concluded that there is clearly an increase in runoff volume due to reduction of forest cover, while he underlines on the unpredictability of the response. Bosch and Hewlett, (1982) argued on Hibbert's later conclusion, giving specific figures on the changes of runoff volume due to changes in the amount of vegetation cover of different types of vegetation. On the other hand, some studies have indicated that urbanization leads to an increase in runoff. After synthesizing a number of studies, (Hollis, 1975) concluded that while small frequent floods are increased many times by urbanization, large rare floods are not significantly affected. A study conducted by Nathaniel *et* al. (2009) in the selected Manipuai River sub watersheds with an aggregate area of 200 ha to simulate the effects of land use on runoff volumes, sediment yield and stream flows showed that Arc SWAT adequately predicted peak flows and temporal variation of runoff volumes and sediment yields. They reported that both runoff volumes and sediment yields were increased and a decrease in stream flows was observed when 50% of the pasture area and grasslands are converted to agricultural lands.

2.6 Sediment Yield Estimation in a Watershed

Sediment yield: Refers to the amount of eroded sediment discharged by a stream at any given point over a period of time, which is also the amount, which will enter a reservoir located at the downstream limit of tributary watershed (Neitsch., 2011).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/km^2/year. Accurate estimation of sediment yield is very important in order to plan a reservoir and efficiently manage its sediment so that the reservoir can meet its requirements. Sediment yield is affected by geology, slope, climate, drainage density and patterns of human disturbance and therefore, no single parameter or simple combination of parameters explains the wide variability in sediment yields (Morris, 2009). Sediment yield from drier areas tends to be limited because of low runoff and yield in wetter areas is limited by the protective soil cover and reduced erodibility of humid zone soils (Vanoni, 2006). The process of soil erosion involves detachment, transport and subsequent deposition (Meyer, 1969). Sediment is detached from soil surface both by the raindrop impact and by the shearing force of flowing water. The detached sediment is transported down slope primarily by flowing water, although there is a small amount of down slope transport by raindrop splash also (Walling, 1987). Once runoff starts over the surface areas and in streams, the quantity and size of material transported depends on transport capacity of runoff water. However, if transport capacity is less than the amount of eroded soil material available, then the amount of sediment exceeding the transport capacity is deposited and estimation of sediment load is required in practical studies for the planning, design, operation and maintenance of water resources structures. (Meyer, 1969)

Sediment yield by a stream or the stream sediment load is the total sediment delivered past a point of interest or the watershed outlet during any given time (Singh., 2012). The stream sediment load can be determined using either a short-term or a long-term analysis. The short-term analysis of sediment load is performed generally on a daily basis expressing often the magnitude and variability of sediment transport during rainstorm or snowmelt events (Julien, 1998). On the other hand, the long term sediment load analysis estimates the amount of sediment yielded by a stream. On an annual basis, it gives the mean annual sediment load of a stream (Julien, 2010).

2.7. SWAT Model Application in Ethiopia

SWAT model was calibrated and validated in many parts of Ethiopia, especially in the Blue Nile basin. Through modelling of Gumara watershed (in Lake Tana basin), Awulachew (2008) indicated that stream flow and sediment yield simulated with SWAT were reasonably accurate. A study conducted on modelling of the Lake Tana basin with SWAT model also showed that the SWAT model was successfully calibrated and validated (Setegn, 2008). This study reported that the model can produce reliable estimates of stream flow and sediment yield from complex watersheds. Gessese (2008) used the SWAT model to predict the Legedadi reservoir sedimentation. According to this study, the SWAT model performed well in predicting sediment yield to the Legedadi reservoir. The study further put that the model proved to be important in capturing the process of stream flow and transport of sediment in the watersheds of the Legedadi reservoir. In addition to the above, the SWAT model was tested for prediction of sediment yield in Anjeni gauged watershed by Setegn (2008). Study found that the observed values showed a good agreement at Nash-Sutcliff efficiency (ENS) of 80 %. In light of this, the study suggested that the SWAT model can be used for further analysis of different management scenarios that could help different stakeholders to plan and implement appropriate soil and water conservation strategies.

3. MATERIALS AND METHODS

3.1 Conceptual Framework of the Study

For the present study SWAT model was selected to model stream flow and sediment yield of Melka Kunture watershed. The SWAT model was chosen for physically based, uses readily available inputs, is computationally efficient, enable users to study long term impacts, capability for application to large-scale catchments (>100 km^2), and capability for interface with a Geographic Information System (GIS). After the suitable model was selected, the necessary data required to run the model were collected and prepared as to the requirement of the SWAT Model format. The geospatial data such as the digital elevation map, land use/land cover map, soil map and the hydro-meteorological data such as the daily stream flow data, daily rainfall data, sediment load/concentration data and other weather data used for generating the weather generator file such as maximum and minimum daily air temperature, wind speed, relative humidity and solar radiation data were collected and processed as per the input requirement format of SWAT model. After the necessary data preparation, the watershed was delineated based on the outlet of the watershed and the hydrological response unit of the area was generated by overlaying the slope, land use land cover and soil data.

Based the prepared weather file SWAT model was run using 2000 LULC map and the model sensitivity analysis was conducted using SWAT_CUP software to identify the most sensitive parameter to model stream flow and sediment yield. Model calibration and validation was performed by using the selected parameter in sensitivity analysis. Finally the performance of the model in predicting stream flow and sediment yield was evaluated by using standard model criteria's such as R^2, NS and P_{bias}. The impact of LULC change on stream flow and sediment yield were assessed by using LULC map of 1986 2000 and 2010

3.2 Study Area Description

3.2.1 Location

The Melka Kunture Watershed is located in the Ethiopian highland plateau, which is a part of South West and Western Shewa Zone of Oromia Regional State (Figure 3.1). The watershed is located in Upper Awash River Basin. The Wereda and their major town in the area includes Welemera Wereda (Holeta), Dendi Wereda (Ginchi), Ejere Wereda (Addis Alem), Alem Gena Wereda (Sebata, Tefki, Boneya), Becho Wereda (Debre Genet, Tulu bolo) and Tolle Wereda (Bantu liben). The watershed is cover a total surface area of 4340 km^2, which is bounded by 08˚06'30" N to 08˚40 45" N latitude and 37˚37'34" E to 38˚40' 10" E longitude and has located in an altitude ranging from 1950 to 3600m above sea level (m.a.s.l) (Figure 3.1 and 3.2).

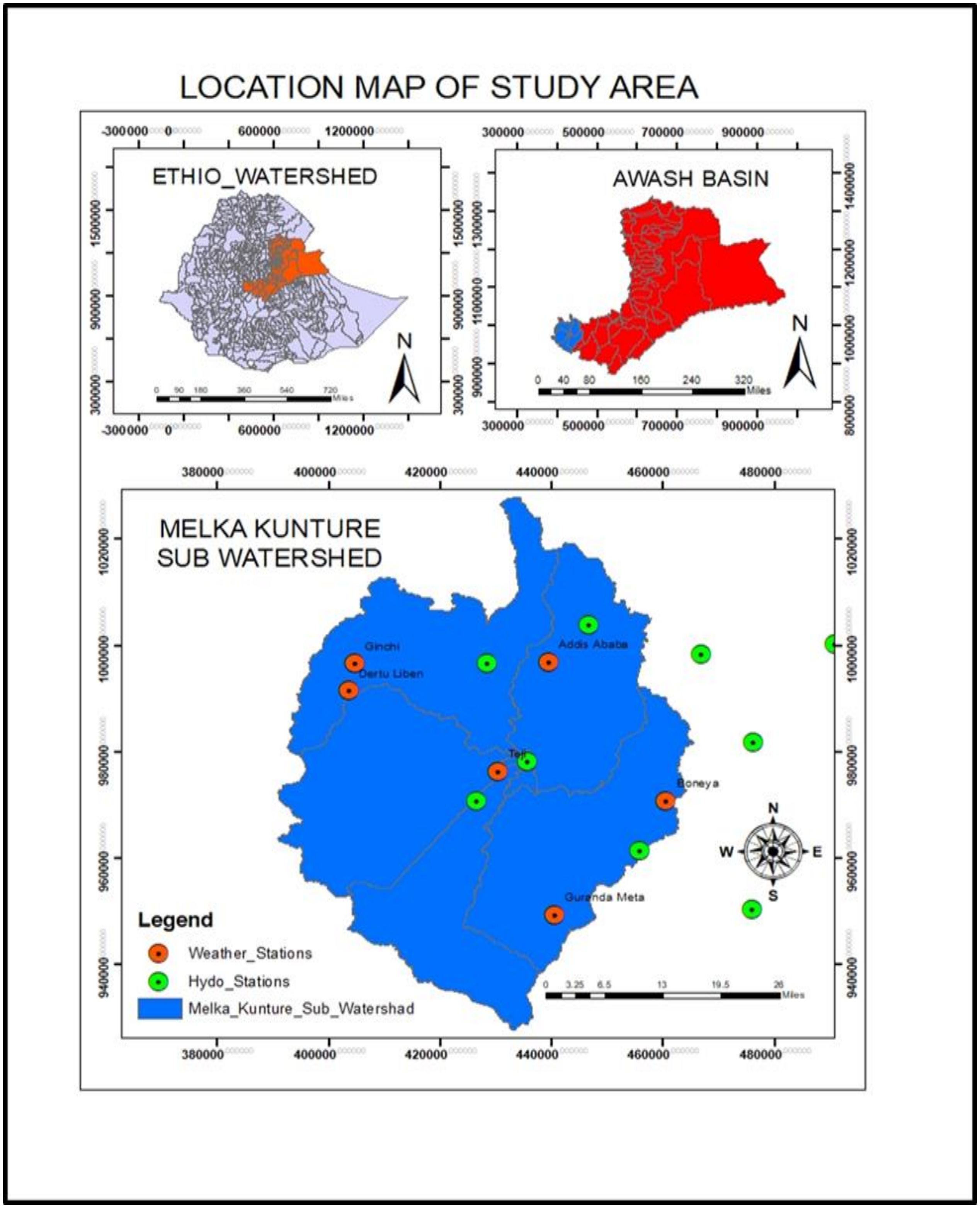


Figure 3.1: Study area map

3.2.2 Geology

Ethiopia can be divided into four major physiographic region, widely known as the western, plateau, southeastern plateau, main rift and afar depression. The Upper Awash River Basin is enclosed within the north-central plateau and adjoining escarpment and rift valley. The regional geology of Upper Awash River Basin is underlain by a wide range of high grade metamorphic rocks and situated to different rock categories that have different age of formation. From this Mesozoic Sedimentary successions, Tertiary and Quaternary age group of acidic, basic volcanic rock, Quaternary Lacustrine and Alluvial deposits compromise of the regional geology of the study area.

Melka Kunture Watershed is included the uppermost part of Awash Basin, which is composed from same geological formation of Upper awash Sub-Basin. According to geological Survey of Ethiopia studied by (OWWDSE, 2017) the major geological formations found in this study area are includes Addis Ababa Ignimbrite(Nadl), Central volcanics of Wechecha, Fur, and Yerer(NcvTy), Tarmaber Basalt(PNtbB), Weliso Ambo basalt(QwaB), Entoto becho-rhyolite(NebRy), Akaki basalt(NakB) and alluvial deposits(Qal). The main Ethiopia Rift (MER) fault systems trending the NE-SW, N-S and N-E directions. The structural setting of Upper Awash Basin is located at the intersection of two important structure NNE-SSW trending MER and the E-W trending Ababa-Nekemte volcanic lineament which is in the direction of NE-SW, E-W and NW-SE are subjected to large area faulting system.

3.2.3 Physiography and Climate

Based on physical and socioeconomic factor Awash Basin has been traditionally divided into Upland (all lands above 1500m), Upper valley and Middle (area b/n 1500m and 1000m), lower valley (area b/n1000m and 500m) and eastern catchment (closed sub-basin between 2500m and 1000m). Melka Kunture Watershed lies in Upland watershed because Upper Awash River Basin is a part of both Upland and Upper watershed. The Climate of the study area is characterized by long-term rainfall, temperature (Tmax/Tmin), relative humidity, wind speed and (long/short) sunshine hours.

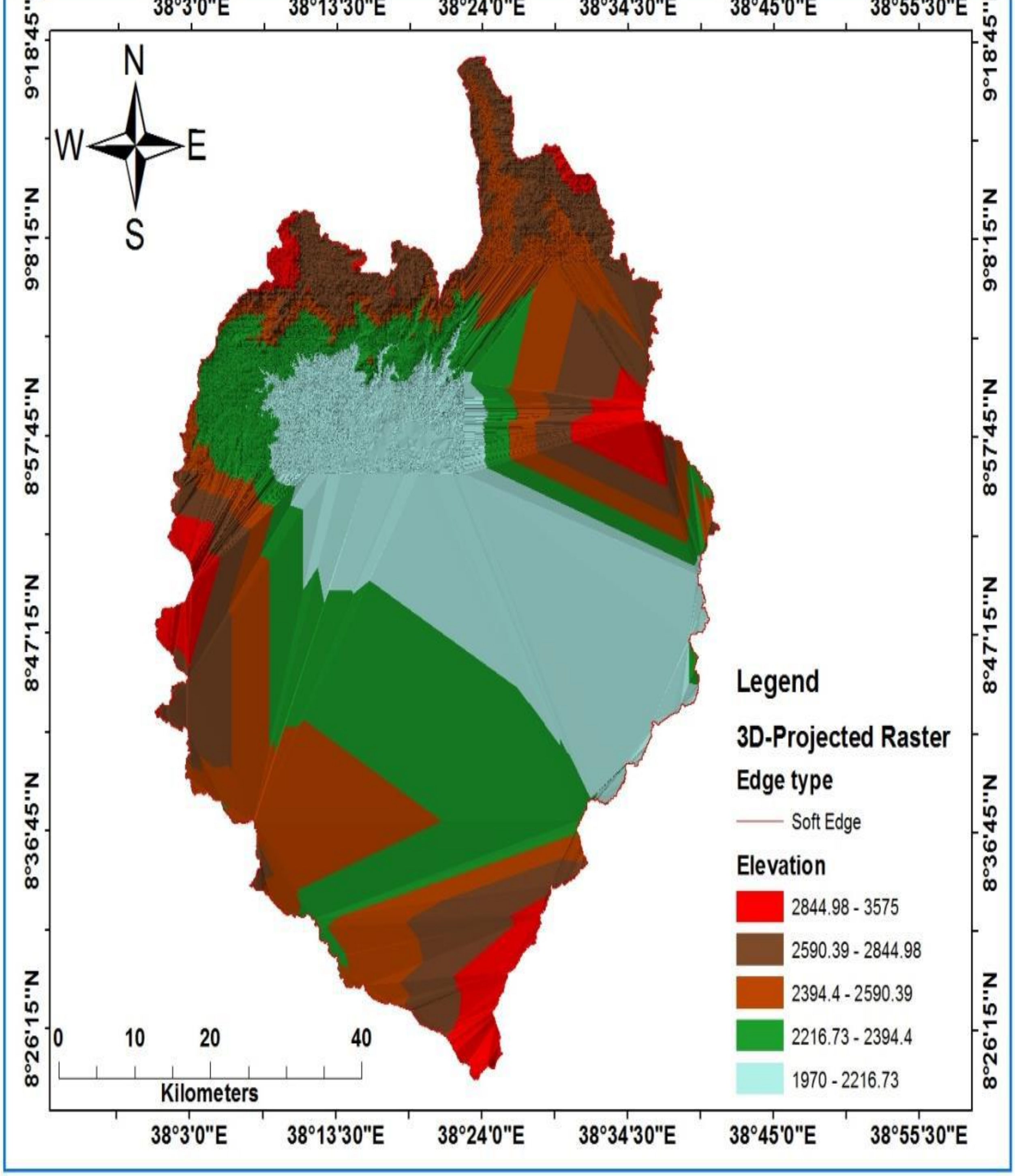


Figure 3.2: Physiographic map of the study area produced from DEM in 3D-View.

3.2.4 Rainfall Pattern

Rainfall is one of the most widely measured meteorological data in Upper Awash Basin as well in Melka Kunture Watershed. There are around 156 rainfall gauging stations in the whole Awash Basin. Among these total gauging stations, around 50 metrological stations were available in the Upper Awash River Basin to represent the rainfall distribution (Kiesel, 2006; Abel, 2017). From these 50 meteorological stations of Upper Awash Sub Basin, 6 meteorological stations were available in/around the Melka Kunture Watershed (Table 3.1 and Figure 3.3).

The mean annual rainfall of the area was calculated using arithmetic mean method from monthly long-term rainfall record of ten stations (1986-2010), namely Tulu Bolo, Boneya, Ginchi, Teji, Dertu Liben and Guranda Meta obtained from National Meteorology Agency of Ethiopia (NMAE).

Table 3.1: Selected meteorological station in study area (Source: NMAE, 2019)

STATION	**LAT(Decimal Degree)**		**LON(Decimal Degree)**	**ELEV**	**Year**	**MARF(mm)**
Tulu Bolo	8.65		38.21	2190	1986-2010	1087.44
Guranda Meta	8.59		38.46	2597	1986-2010	1070.55
Boneya	8.7845		38.64167	2251	1986-2010	811.14
Dertu Liben	8.97		38.1232	1991	1986-2010	809.16
Teji	8.8333		38.366667	2091	1986-2010	956.38
Ginchi	9.01667		38.1333	2132	1986-2010	1195.18
	Mean Annual Rainfall(mm) = $\frac{1}{N}\sum_{i=1}^{N=6}(p1+p2+\cdots pN)$					1008.72

3.2.5 Climate

The meteorological data of the study area shows that the monthly maximum temperature is in between 21˚C and 27˚C, and the monthly minimum temperature is in between 10˚C and 13˚C. There are three main agro-climatic zones found in Melka Kunture Watershed i .e “Wurch” “Dega” and “Weyena Dega” (Figure 3.3). Dega and Wurch climatic zones are found in the highland areas with altitude ranging between 2500-3000m and greater than 3000m m.a.s.l, respectively. Among these Agro-climate zone, the study area is mostly dominated by “Weyena Dega” which is found in an altitude range between 1900 and 2500m m.a.s.l altitude with optimum temperature.

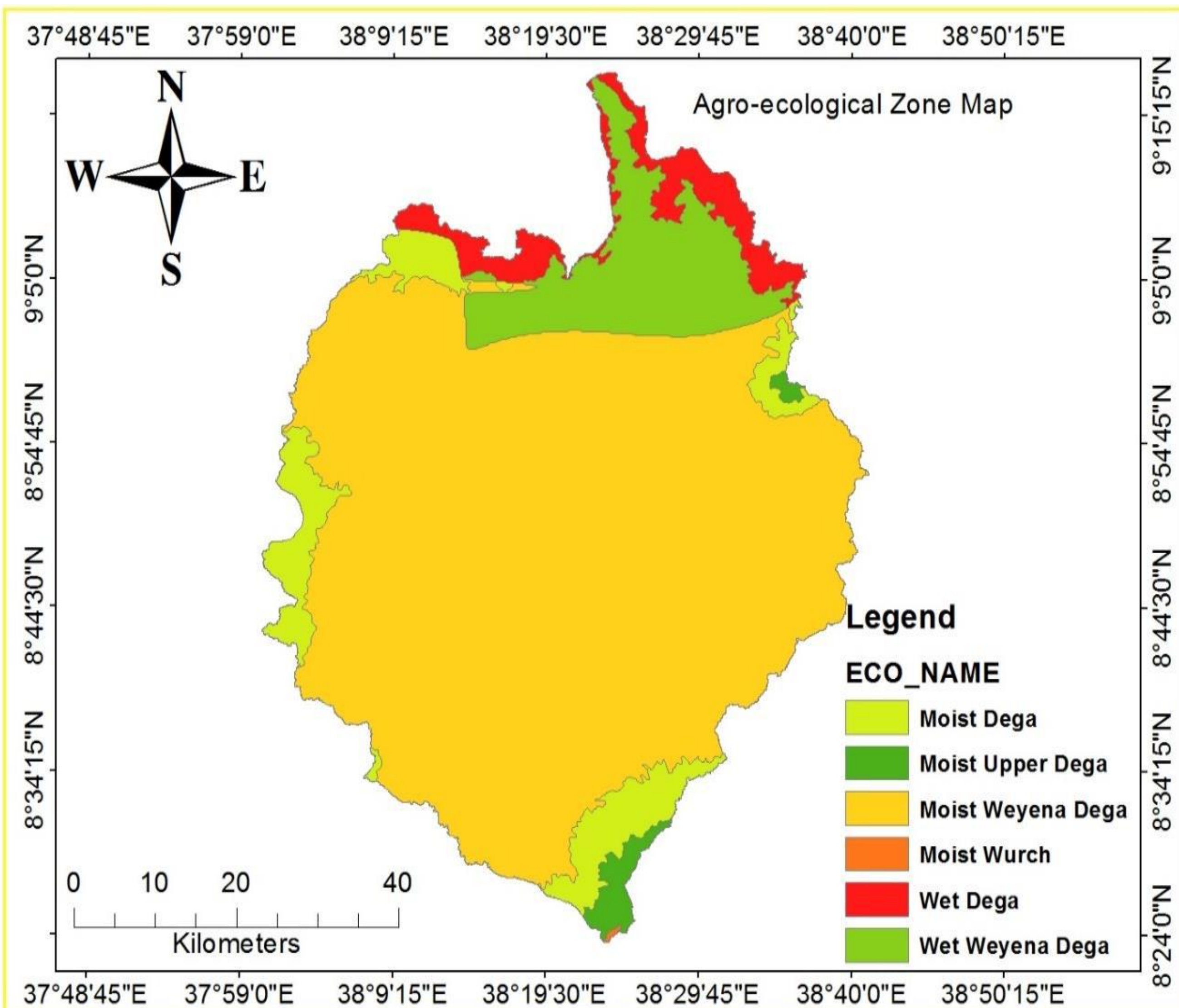


Figure 3.3: Distribution of agro-climatic zone map of the study area (Source: AWBA, 2018)

3.2.6 Hydrology

Awash River begins from the high altitude of 3000m in the western most region of the basin near Ginchi and flows in the west-east direction. Afterwards it is distributed into the Becho Plain which makes an alluvial plain with a regular altitude of 2,060m. Awash River and its streams flowing in to the larger river i.e. Awash River and its tributaries form dendritic drainage pattern and Awash River move steadily in a NW – SE general flow direction.

In the Awash basin there are about 76 river gauging stations, out of these 21 stations are found in the Upper Awash sub- basin particularly in the upstream of Koka Dam. From these, 21 rivers gauging stations in the Upper Awash River Basin, 7 stations are found in Melka Kunture Watershed (Table 3.2). Among these river gauging stations Bello, Melka Kunture, Melka Hombole, Mojo and Akaki stations have automatic water level recorder. Gauging station at the site of Awash Melka Kunture and Modjo are located in a very stable cross-section and hence have unique rating curve for the entire record (Sileshi Gobena., 2010).

Table 3.2: River gauging stations and sub-catchments in the Melka Kunture watershed (Source: MoWE, 2018)

S.No	Name of the station	River length (km)	Catchment Slope (%)	Catchment Area (km2)	Latitude N (UTM)	Longitude E (UTM)
1	Awash @ Ginchi	58.36	24	76	997173	404697
2	Berga Nr. Addis Alem	13.488	17	249	996668	428556
3	Holeta Nr. Holeta	14.97	76	119	1004010	446886
4	Teji @ Asgori	24.14	61	663	970876	426678
5	Awash @ Belo	32.38	35	2568	978231	435855
6	Jemjem Nr.Wolenkomi	26.43	25	781	970264	428720
7	Awash @ Melka Kunture	57.35	30	4456	961622	455998

The mean annual flow Characteristic and their distribution from 2000-2012 years in the main river gauging station are shown flow bar (Figure 3.4).

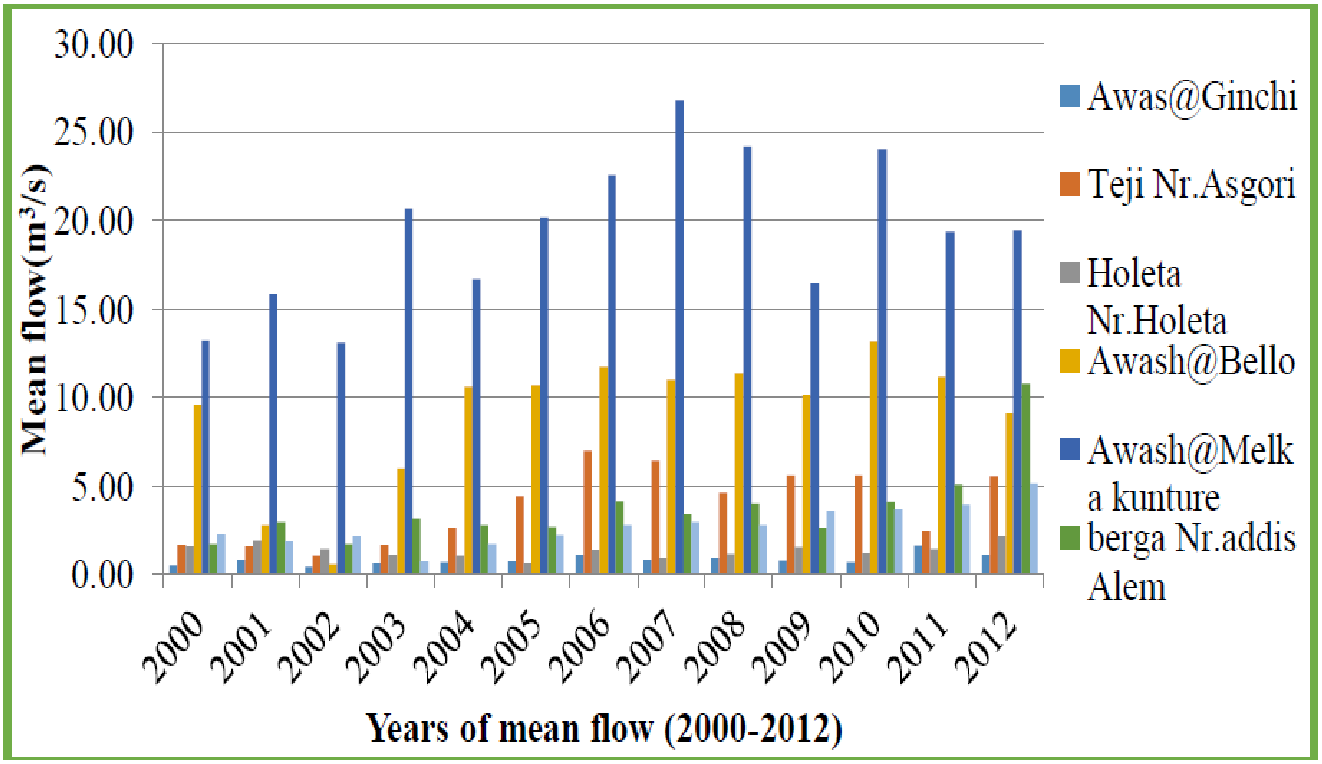


Figure 3.4: Mean annual flow characteristics of main river gaging station in Melka Kunture watershed

3.3 Materials

3.3.1 Data and Data Source

SWAT has different components. Hydrologic components of the model work on the water balance equation, which is based on surface runoff, precipitation, percolation, evapotranspiration, and return flow data and the sediment component of swat model use revised universal soil loss equation to model the sediment yield in the study area. Weather is one of the model component that needs data on precipitation, air temperature, solar radiation, wind speed, and relative humidity data. The data required for the SWAT model setup were DEM, soil data, land use data, precipitation and other weather data used for preparation of weather generator file. For calibration and validation purposes, river discharge and sediment yield data were required at the outlet of the watershed. Table 3.3 showed the data and data source of geographical data used in SWAT model simulation.

Table 3.3: Data and data Source

St No	Data type	Year of production	Scale	Source	Purpose of Data Acquisition
1	Landsat image (TM)	1986	30m	USGS	For generation of LULC
2	Landsat image (ETM)	2000	30m	USGS	For generation of LULC
3	Landsat image (ETM)	2010	30m	USGS	For generation LULC
4	SOIL	2006	1:250000	MoWE	For generation of HRU of Study Area
5	DEM	2019	30m	MoWE	Used for Delineation of the Watershed and To produce sub basin Parameters such as Slope and Stream Network.

Weather Data

The meteorological data elements such as daily precipitation, maximum and minimum temperature, daily wind speed, daily solar radiation, and daily relative humidity are climatic elements to set up the SWAT model. The data for the weather elements should be provided on a daily basis. Six meteorological data stations (Addis Ababa, Ginchi, Dertu Liben, Guranda Meta Teji and Boneya) are available within and nearby the study area. The stations record daily precipitation data for 25 years between 1986 and 2010.

Stream flow Data

SWAT simulates stream flow and sediment yield transport at catchment scale, on a continuous, daily time step (Neitsch, 2011). SWAT CUP uses this data values for comparing the observed values and simulated flow data. The observed flow data was prepared based on the requirement of the SWAT model and used for model calibration and validation. Daily stream flow data was obtained from Ethiopian Ministry of water and Energy form the year 2000 up to 2008.

Sediment Data

SWAT_CUP also uses this data values for comparing the observed values with simulated sediment data. The observed sediment data was prepared based on the requirement of the SWAT model and used for model calibration and validation. The sediment data was collected from MOW E which was recorded between the years of 2001 and 2005 at river gaging station and used to compare with the sediment data that generated by the model.

3.4 Methods of Data Analysis

3.4.1 Land Use Land Cover Mapping

Land-use and land-cover (LULC) maps are used as powerful tools for tackling environmental problems, facilitating planning activities, and managing natural resources such as water resources. The initial step, for preparation of LULC map of the study area was done using the layer stacking of separate bands of the datasets and sub setting the images based on the polygon of the study area. After the area was clipped using the boundary of the study area, different color composite images were prepared, in order to select the best band combination, that enhance the raw satellite images for identifying the different land cover classes in the study area. For the present study, bands 4-3-

2 (R-G-B) were found to be best for the identification of major land cover classes for both Landsat ETM and Landsat TM.

The preprocessing also aims to correct distorted data in order to create more realistic representation of the original scene. This typically involves the initial processing of raw image data to correct for geometric distortions, to calibrate the data radiometrically, and to eliminate noise present in the data. Geometric corrections include correcting for geometric distortions due to sensor-Earth geometry variations, and conversion of the data to real world coordinates (e.g. latitude and longitude) on the Earth's surface. The objective of radiometric correction is the elimination of atmospheric and terrain effects to retrieve physical parameters of the earth's surface, including surface reflectance and ground visibility.

Following the image preprocessing, the satellite images were classified by using a supervised classification using maximum likelihood classifier (MLC) algorithm. Supervised classification can be used to cluster pixels in a datasets in to classes corresponding to user defined training classes or the process of using samples of known identity (i.e., pixels already assigned to informational classes) to classify pixels of unknown identity. This classification assumes that the statistics from each class in each band is normally distributed and calculates the probability that a given pixel belongs to the specific classes. The basic procedures followed on supervised classification was;

Defining of Training Sites: This is usually done by using the on-screen digitized features. The created features are called Area of Interest (AOI).The selection of training sites was based on the representative tonal/color category of the image.

Extraction of Signatures: After the training site (AOI) being digitized, the next step was to create statistical characterizations of each information. These are called Signatures editors in ERDAS Imagine 2014. In this step, the goal was to create a signal (SIG) file for every informational class.

Classification of the Image (Supervised classification): The supervised classification has been applied after defining the training classes. During supervised classification process, the entire Signature editor was selected for classification purpose.

Following the step-by-step detection and quantification procedures on the satellite image, three land use and land cover maps of 1986, 2000 and 2010 were produced. Generally, Agriculture, barren land, Forest, urban and water bodies were the Land use Land cover classes identified in the Melka Kunture Watershed.

Accuracy assessment was performed to verify the quality of the obtained results for the classified maps. Google earth imagery was used as reference datasets to evaluate LULC classification accuracy assessments. A minimum of 20 reference samples per LULC category was used for the computation of the error matrices in order to assess the accuracy of the classification. The derived LULC classifications from remotely sensed datasets fulfilled the minimum 80% overall accuracy and kappa coefficient for map quality and accuracy standard (Congalton & Green, 2009). The result of accuracy assessment was depicted on Appendix A12.

3.4.2 Land Use Land Cover Change Detection

LULC detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Essentially, LULC detection involves the ability to quantify temporal effects using multi-temporal data sets. In this study two periods of change detection have been made first period between 1986 and 2000 and second period between 2000 and 20010 which is moderately enough in showing the long history of land use and land cover. These time periods were chosen based on the availability of satellite image, climate and hydrological data. The generic approach of the LULC Change detection is based on post-classification, comparison method, using ArcGIS 10.3 software which is commonly employed in land cover change detection studies. This method was found to be the most suitable for detecting LULC change detection analysis (Larsson 2002; Liu and Zhou 2004). Thus, this study is based on post classification, comparison of independently developed and classified Land Use Land Cover Maps of 1986, 2000 and 2010.

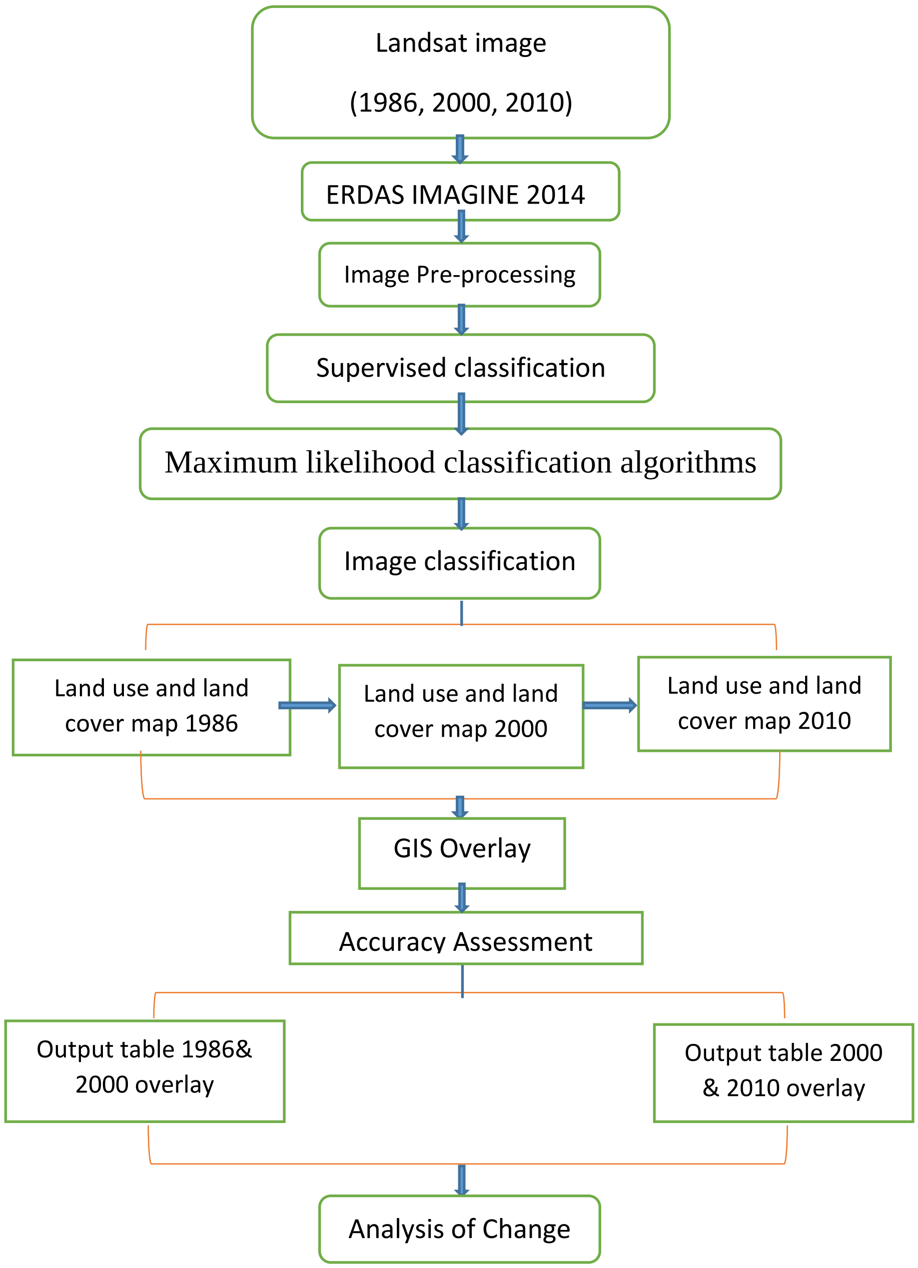


Figure 3.5: Flow chart of LULC change detection analysis

3.4.3 Modeling Stream Flow and Sediment Yield

3.4.3.1 Introduction

Reasonable prediction of stream flow and sediment transport is essential for developing watershed management. The ArcSWAT Model integrated with Geographic Information System (GIS) techniques was used to simulate stream flow and sediment yield in this study. Digital Elevation Model (DEM), polygon coverage of soil and land use land cover and point coverage of weather stations were used as basic input to the model. For modeling stream flow and sediment yield soil conservation curve number method (SCS, 1972) and the modified universal soil loss equation were used, respectively. In order to identify the most important or sensitive model parameters before calibration, model sensitivity analysis was carried out using SWAT_CUP Software. The efficiency of the model in modelling stream flow and sediment yield also examined. The first task in SWAT model simulation was to check the quality and consistency of the metrological data.

3.4.3.2 Data Quality Control

The raw data must be checked for qualities, which mean that its continuity and consistency before it is used for further analysis. The quality control can be done by visual inspection, filling of missing data if there is any. This will help to identify if there are any gaps or unphysical peaks in data series and correct them before the data is used or input to the model. Otherwise, using the erroneous data as input to the model will give erroneous output from the model.

A. Visual Inspection

The precipitation data must be checked for continuity and consistency before it is used for further analysis. After the rainfall, data were obtained from NMAE it must be checked for its quality. The first step in data quality control is by visual inspection. This can be done by checking if date and time record is complete, unphysical values (negatives), flat regions (sensor or transfer system fall out) and unphysical variation patterns (sensor malfunctioning).

B. Filling of Missing Data

Some precipitation stations may have short breaks in the records because of absence of the observer or because of instrumental failures. It is often necessary to estimate or fill in this missing record. The missing precipitation of a station will be estimated from the observations of precipitation at some other stations as close to and as evenly spaced around the station with the missing record as possible. Here, the station whose data is missing is called interpolation station and gauging stations whose data are used to calculate the missing station data are called index stations. There are methods to fill in missing data. These are the arithmetic mean method, normal ratio method and inverse distance weighing method. Inverse distance weighting method was used in this study to fill in the missing data.

Inverse distance weighing method

$$D = \sum_{i=1}^{i=n} d_i{}^{-b} \quad \ldots\ldots (2)$$

$$P_x = \frac{1}{D}\sum_{i=1}^{i=n} d_i{}^{-b} * p_i \ldots\ldots (3)$$

Where, P_x is the missing precipitation for any storm at the interpolation station $_x$, P_i is the Precipitation for the same period for the same storm at the i_h station, d_i is the normal annual Precipitation value for the i_{th} station, D is distance from gauge i to missing data poin

C. Statistical Parameters Calculation

A1. Precipitation Data

After the precipitation, data was checked for quality and the appropriate station was selected the statistical parameters of precipitation data must be calculated before model set up. The statistical parameters for precipitation was calculated using the programme called **pcpSTAT.exe:** This programme calculates the statistical parameters of daily precipitation data used by the weather generator of the SWAT model (Liersch, 2003).

B1. Temperature Data

The other program used for calculating dew point temperature using minimum and maximum temperature and average daily humidity is called **Dew02.exe.** . The data must be an ASCII text file format with three columns. The first column stores the maximum daily temperature data the second column the minimum daily temperature data and the third column the average daily humidity data. **Dew02.exe:** is used to calculate the dew point temperature using minimum and maximum daily temperature and the average daily humidity data.

3.4.3.3 SWAT Model Setup

A. Watershed Delineation

SWAT allows the user to delineate the watershed and sub basins using the Digital Elevation Model (DEM). This tool uses and expands ArcGIS and Spatial Analyst extension functions to perform watershed delineation (Neitsch, 2002). The DEM of the area was loaded into an ESRI (Environmental System Research Institute) grid format. Stream network was defined for the whole DEM by SWAT using the concept of flow direction and flow accumulation before defining the stream network, the model processes the DEM map grid to remove all the non-draining zones (sinks). To define the origin of streams a threshold area was defined. The threshold area defines the minimum drainage area required to form the origin of a stream. The size and number of sub basins and details of stream network depend on this threshold area (Winchell, 2007). The watershed outlet was manually added and selected for finalizing the watershed delineation. With this information the model automatically delineates a watershed area 4340km^2 with 7 sub- basins.

B. HRU Definition

Land use land cover map of 2000 was used for simulation of stream flow and sediment yield.

The LULC map was chosen based upon the metrological and hydrological data present on the study area. The land use and the soil data in a projected Raster format were loaded into the SWAT interface to determine the area and hydrologic parameters of each land-soil category simulated within each sub-watershed. The LULC classes were defined using the lookup table. A look-up table that identifies the 4-letter SWAT code for the different categories of land cover/land use was prepared so as to relate the grid values to SWAT land cover/land use classes. After the land use SWAT code is assigned to all map categories, calculation of the area covered by each land use and reclassification was done.

As for the land use, the soil layer in the map was linked to the user soil database information by loading the soil look-up table and reclassification applied. The DEM data used during the watershed delineation was also used for slope classification. After the reclassification of the land use, soil overlay operation was performed.

The second step in the HRU analysis was the HRU definition. The HRU distribution in this study was determined by assigning multiple HRU to each sub-watershed. In multiple HRU definition, a threshold level was used to eliminate minor land uses, soils or slope classes in each sub-basin.

Land uses, or soils which cover less than the threshold level are eliminated. After the elimination process, the area of the remaining land use, or soil was reapportioned so that 100% of the land area of the sub-basin was modeled.

The third step in HRU definition is a selection of slope classification option (single or multiple) and if multiple slope option is selected that defines the range of the slope. For this study multiple slope option (an option for considering different slope classes for HRU definition) was selected and the slope class was classified into five and the range was 0-10%, 10-15%, 15-25%, 25-35%, and above 35%.

Finally, after defining the HRUs within a sub-basin is completed the HRU will be set. For this study the option of multiple HRU was selected and 20%, 10% and 10% were the threshold area of land use, soil and slope in each HRU from the sub-basin values respectively.

The reason for taking these threshold values was in order to keep the HRUs to a reasonable and manageable number and also considering computer processing time required. Even though, the application of these thresholds eliminates the land uses and soils that covered relatively small areas in the sub-basins, it creates a total of 40 HRUs of 7 sub-basins.

C. Weather Data Definition

The WXGEN (*SWAT Software Specific File Coding Scheme for Weather Generator File*) weather generator model included in SWAT was used to fill in gaps in measured records. The meteorological stations used for daily precipitation data were Addis Ababa, Guranda Meta, Ginchi, Dertu Liben, Teji, and Boneya stations were included and the Addis Ababa Station was selected to be a principal station for the weather generator. The WXGEN weather generator was provided with all the necessary statistical information from the meteorological records of the watershed. These statistical values were calculated from the meteorological data available in the study area watershed. The number of years for calculating the statistical values depends on the availability of data in the stations. Other meteorological data (daily precipitation, daily minimum and maximum air temperature, daily relative humidity, daily solar radiation and daily wind speed) including the corresponding location table were prepared according to the SWAT format and integrated into the model using the weather data input wizard, see Appendix A11.

D. Model Simulation

After the model was set up the next step was to run the model and the result from the simulation cannot be directly used for further analysis. Instead, the ability of the model to sufficiently predict the stream flow and sediment yield; the simulation results should be evaluated through sensitivity analysis, model calibration and model validation (Chaubey, 2005).

3.4.3.4 Sensitivity Analysis

The first step in the calibration and validation process in SWAT is the determination of the most sensitive parameters for a given watershed or sub watershed (Abbaspour., 2013). Therefore, methods to reduce the number of parameters via sensitivity analysis are important for the efficient use of these models (Griensven, 2005). Sensitivity analysis is a process of testing and identifying model parameters that affect mostly the output from the model when parameter are changed.

In other words, sensitivity analysis is the process of determining the rate of change in model output with respect to changes in model inputs (parameters) (Abbaspour, 2013). Therefore, a parameter is considered sensitive when the change in that parameter causes a large change in model output.

The current version of SWAT model, SWAT2012, provides the algorithmic techniques for sensitivity analysis. Two types of sensitivity analysis are allowed when using SUFI2 (Sequential Uncertainty Fitting version 2).

Global Sensitivity and One-at-a-time sensitivity analysis. Sensitivity of one parameter often depends on the value of other related parameters; hence, the problem with one-at-a-time analysis is that the correct values of other parameters that are fixed are never known. The disadvantage of the global sensitivity analysis is that it needs a large number of simulations. Both procedures, however, provide insight into the sensitivity of the parameters and are necessary steps in model calibration. For the present study global sensitivity analysis was used to conduct the sensitivity analysis.

3.4.3.5 Calibration and Validation

Theoretically Calibration is an effort to better parameterize a model to a given set of local conditions, thereby reducing the prediction uncertainty. Model calibration is performed by carefully selecting values for model input parameters (within their respective uncertainty ranges) by comparing model predictions (output) for a given set of assumed conditions with observed data for the same conditions. The final step is validation of the component of interest (streamflow, sediment yields, etc.). Model validation is the process of demonstrating that a given site-specific model is capable of making sufficiently accurate simulations, although "sufficiently accurate" can vary based on project goals. Validation involves running a model using parameters that were determined during the calibration process, and comparing the predictions to observed data not used in the calibration.

During the calibration process to maximize the model efficiency hydrological parameters selected during sensitivity analysis using a SUFI-2 algorithm were considered. The calibration was performed using monthly observed flow and sediment data from the year 2000 to 2005. The Calibrated model was validated using data from 2005 to 2008 on a monthly time step.

3.4.3.6 Model Efficiency

The performance of a model must be evaluated on the extent of its accuracy, consistency, and adaptability. The performance of the model in simulating stream flow and sediment yield is evaluated using SWAT-CUP. Three methods were used to evaluate the model efficiency during the calibration and validation periods, these are coefficient of regression (R2), Nash Sutcliffe simulation efficiency (NSE) and Percent Bias (PBIAS). The values of R 2 range from 0.0 to 1.0 with higher values indicating better agreement and the value of NSE ranges from minus infinity to 1.0, with the higher values indicating better agreement (Moriasi, 2006)A value of 0.0 for R2 indicates that none of the variance in the measured data is simulated by the model predictions. In other ways, a value of 1.0 indicates that all of the variance in the measured data is replicated by the model predictions. Percent Bias measures the average tendency of the simulated data to larger or smaller than the observations. The optimum value is zero, where low magnitude values indicate better simulations. Positive values indicate model underestimation and negative values indicate model over estimation.

Coefficient of determination (R^2): Is the index of correlation of measured and simulated values. The value of R2 ranges from 0 to 1. The more the value of R2 approaches 1, the better is the performance of the model and the values of R2 less than 0.5 indicate a poor performance of the model. R2 is calculated by the following equation:

$$R^2 = \frac{[\sum(Qmj-Qm)(Qsj-Qs)]^2}{\sum((Qmj-Qm)^2(Qsj-Qs)]^2} \quad \text{..........} \quad (4)$$

Coefficient of determination R2 where Q is a variable (e.g, discharge), and m and s stands for measured and simulated, i is the ith measured or simulated data and Q s the mean of the simulated value, Q m is the mean of the observed value.

Nash-Sutcliffe Efficiency (NSE): NSE is the normalized statistics which measures the relative magnitude of the residual variance as compared to measured data variance. Similar to R2, the more the NSE approaches 1, the better will be the model performance and vice versa.

$$NSE = 1 - \frac{\Sigma\ ((\mathrm{Qm} - \mathrm{Qs})^2)^2\mathrm{i}}{\Sigma\ (\mathrm{Qmj} - \bar{\mathrm{Q}}\mathrm{m})^2} \quad (5)$$

Nash-sutcliffe, where Q is a variable (e.g, discharge), m and s stand for measured and simulated, respectively, and the bar stands for average.

Root mean square error observation standard deviation ratio (RSR): It is an error index indicator. RSR ranges from 0 to 1, with the lower value closer to zero indicating higher accuracy of the model performance. Values approaching 1 indicate a poor model performance.

$$RSR = \frac{\mathrm{RMSE}}{\mathrm{STDEVobs}} = \frac{\left[\sqrt{\sum_{i=1}^{n}(\mathrm{Oi} - \bar{\mathrm{S}}\mathrm{i}\,)^2}\right]}{\left[\sqrt{\sum_{i=1}^{n}(\mathrm{Oi} - \bar{\mathrm{S}}\,)^2}\right]} \quad (6)$$

Percent Bias (PBIAS): Percent Bias measures the average tendency of the simulated data to large or smaller than the observations. The optimum value is zero, where low magnitude values indicate better simulations. Positive values indicate model underestimation and negative values indicate model over estimation (Gupta et., 1999). Percent Bias (PBIAS) is calculated by the following equation:

$$P\mathrm{bias}\ 100 * \frac{\sum_{i=1}^{n}(\mathrm{Qm} - \mathrm{Qs}\,)\mathrm{i}}{\sum_{i=1}^{n}(\mathrm{Qmj})} \quad (7)$$

Where Q is a variable (e.g, discharge), and m and s stands for measured and simulated, respectively

3.4.3.7 Impact of Land Use Land Cover on Stream Flow and Sediment Yield

Understanding of the effects historic land use changes on Sediment and river flow is required to understand the future effects of land use and land cover, and climate change on hydrological regimes at a watershed level. Some studies indicate that the trends and direction in hydrologic response can be correctly inferred from the corresponding trends and direction in LULC Change, predicated upon the use of comparable rainfall data in conjunction with differing land cover (Hernandez et al., 2000). Land use and land cover can also affect the direct interchange of water between streams and groundwater. The present study was used the land use land cover map of 1986, 200, 2010 to show the effect of LULC change on streamflow and sediment yield. The procedure was conducted by changing the land use land cover map of respective years without further adjustment of the parameters used by the SWAT model.

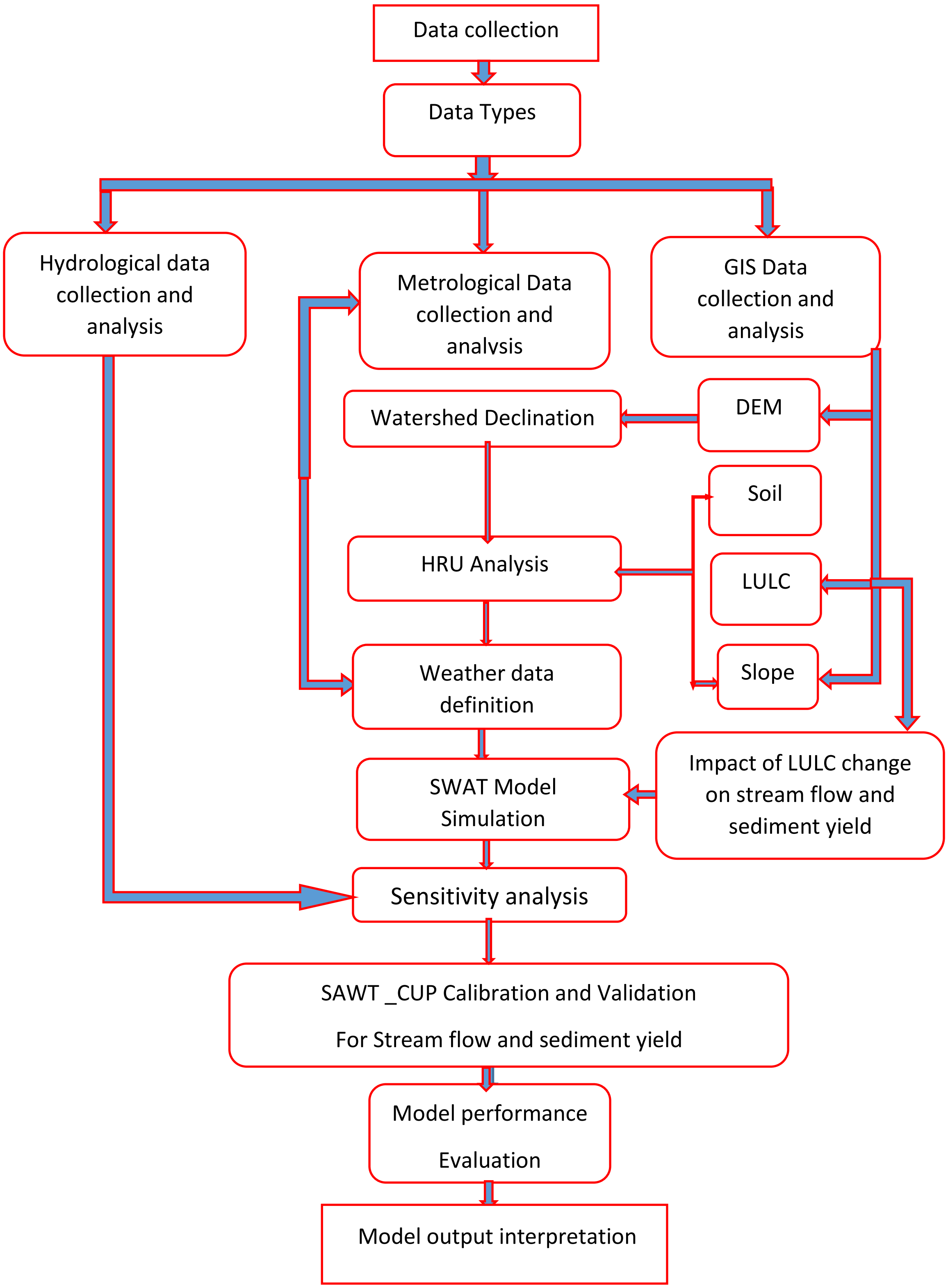


Figure 3.6: Flow chart of methods of data analysis for stream flow and sediment yield simulation.

4. RESULTS AND DESCUSSOIN

4.1. Introduction

This chapter discuss about land use land cover mapping and change detection for Melka Kunture Watershed using GIS and remote sensing technique. Following LULC mapping and change detection, Stream flow and sediment yield estimation using SWAT model were described. Sensitivity analysis, model calibration and Validation also computed to identify the most sensitive parameters and to evaluate the performance of the SWAT model in predicting stream flow and sediment yield of the study area. The method to evaluate the impacts of land use and land cover changes on hydrological regimes can be achieved through integrating GIS, remote sensing, and hydrological models. Finally the obtained results were discussed according to other related findings.

4.2 Land Use Land Cover Mapping

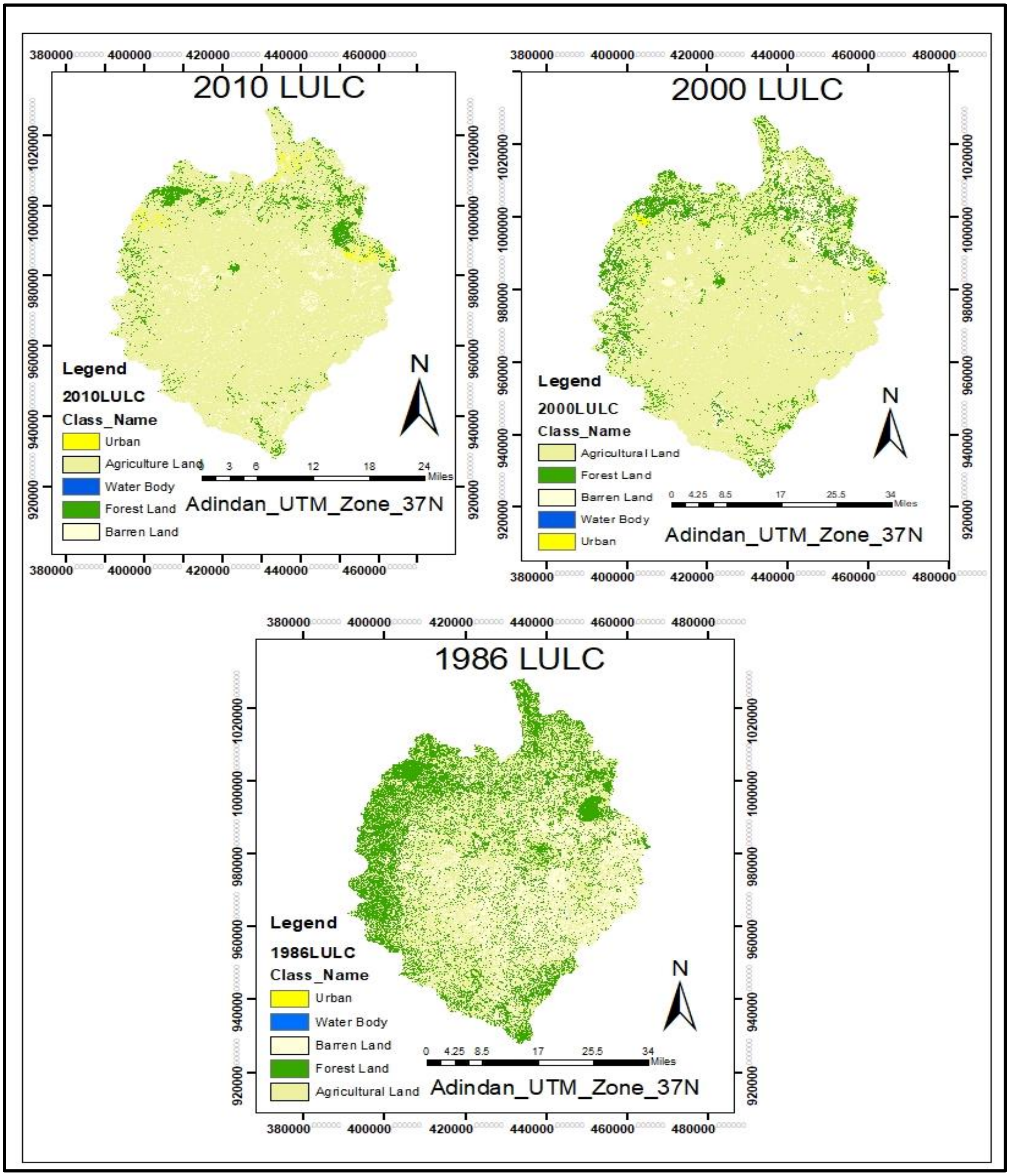


Figure 4.1: LULC Map of 1986, 200 and 2010.

It can be depicted from Figure 4.1 that in 1986 LULC map, agricultural land was the major land use followed by forest land, barren land, urban and water body. Both 2000 and 2010 LULC maps has identical trend with 1986 LULC map except that in both period barren land was increased due to the decrement of forest land .These land use types have common physical and geographical inter-connections, as an area increase in one type of land use category will be associated with an area decrease in another land use category. The changes happened in the areas with less steep slopes, and close to settlements.

4.3 Land Use Land Cover Change Detection

Table 4.1: LULC change detection analysis.

	Land use Land cover						**Land use Land cover Change**			
	1986		2000		2010		(1986-2000)		(2000-2010)	
LULC Type	Area		Area		Area		(%)	Rate (ha/yr)	(%)	Rate (ha/yr)
	(ha)	(%)	(ha)	(%)	(ha)	(%)				
URBN	602.4748	0.14	998.6631	0.23	4492.3028	1.03	39.1	28.299	77.6	349.36
WATR	77.4543	0.12	268.163	0.17	507.5137	0.19	29.4	13.62	10.5	23.93
BARR	128678.9	29.6	51140.5	11.7	40369.348	9.3	-60.2	-769.3	-21.1	-1077.1
FRSE	138276.3	31.8	50839.9	11.7	27666.6125	6.37	-20.1	-6245	-45.6	-2317.32
AGRL	166461.3	38.2	330849.3	76.1	361060.818	83.18	63.2	11742	8.44	3021.14
TOTAL	434096.5	100	434096.5	100	434096.5	100				

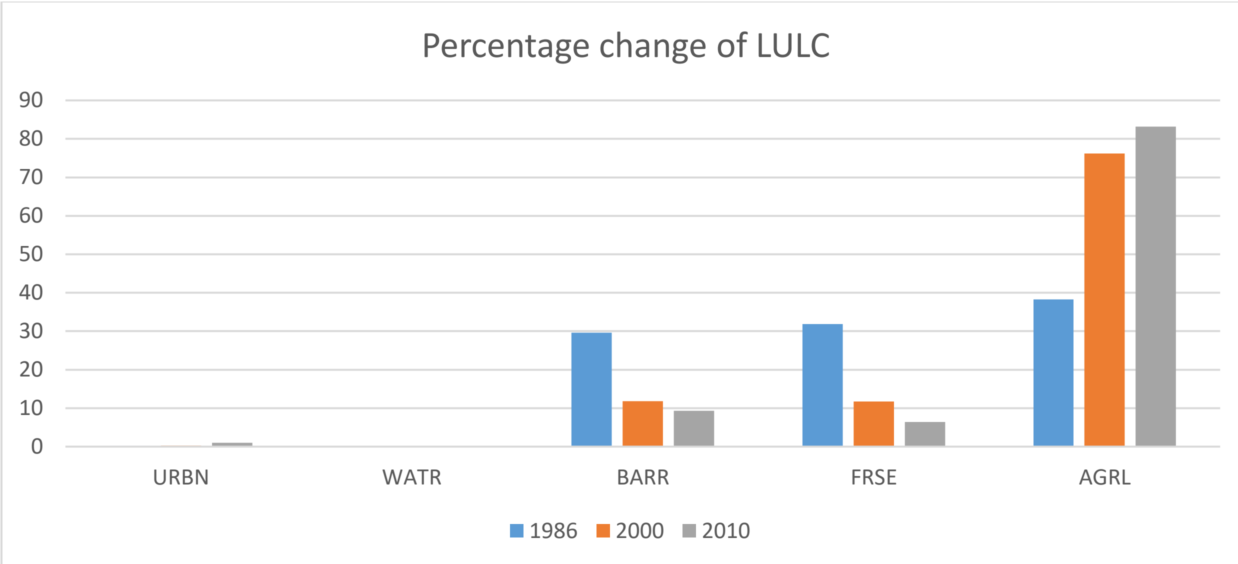


Figure 4.2: Percentage change of LULC analysis

It can be observed from table 4.1 and figure 4.2 that forest land was changed to agriculture and barren land and, some forests were altered to urban in both the first and second periods. Moreover, it is more remarkable that the rate of change to a barren and agriculture land was very high in the first period (- 60.37%), (63.2%) than that the second period (-21.1 %), (8.44%) respectively. However, the amount of Forest land was reduced in the second period (2000- 2010), than the first period (1986-2000). The rate of change of Barren land was decreased in the first period (-769.3) than the second period (-1077.1). The percentage increase of urban land was higher in the second period (77.6%) than the first period (39.1%) which shows urbanization was increased during the past three decades.

4.4 Modeling Stream Flow and Sediment Yield

4.4.1 Sensitivity Analysis for Stream Flow Simulation

Global sensitivity analysis was done for the 15 parameters shown in Appendix A14. According to the result from the global sensitivity analysis, the curve number (CN2) was found to be the most sensitive parameter followed by a Groundwater delay (GW_DELAY), Manning's "n" value for overland flow (OV_N), the Available water content of soil (SOL_AWC), base flow alpha-factor (ALPHA_BF) and Plant uptake compensation factor (EPCO) (Table 4.2). The sensitivity for each parameter was assigned depending on P-value and t-stat. Here, t-stat provides a measure of sensitivity and hence larger in absolute values are more sensitive. On the other hand, P-value indicates the significance of the sensitivity and hence a value close to zero has more significance. Therefore, ranking in both cases (t-stat or P-value) gives the same result i.e. a parameter will have the same rank whether it is ranked based on the t-stat or P-value.

Table 4.2: Result of sensitivity analysis for flow calibration.

parameter name	**t-Stat**	**P-Value**	**Rank**	**Category of sensitivity**
CN2.mgt	-8.91759163	0	1	Very high
GW_DELAY.gw	-4.72638394	0.00003109	2	Very high
OV_N.hru	1.931107987	0.060954617	3	High
SOL_AWC	1.12238183	0.268742048	4	High
ALPHA_BF	0.752544478	0.456360426	5	High
EPCO.bsn	0.488276928	0.628159565	6	Medium
GW_REVAP.gw	-0.33580191	0.738867345	7	Medium
CH_N2.rte	0.28627154	0.776225116	8	Medium
CH_K2.rte	-0.17424881	0.862594951	9	Medium
ESCO.bsn	0.137787435	0.891135953	10	Small
SOL_Z	-0.08359818	2 0.93381476	11	Small

4.4.2 Sensitivity Analysis for Sediment Simulation

The most sensitive parameters for sediment simulations were: USLE soil erodibility factor (USLE_K), Peak rate adjustment factor for sediment rout (ADJ_PKR), Linear parameter calculating the (max) sediment (SPCON), Exponent parameter for calculating sediment (SPEXP) and SCS runoff curve number (CN2) (Table 4.3).

Table 4.3: Result of sensitivity analysis for sediment calibration.

Parameter Name	t-Stat	P-Value	Rank	Category of sensitivity
USLE_K.sol	13.62692479	0.00000000	1	Very High
ADJ_PKR.bsn	8.031671065	0.00000000	2	Very High
SPCON.bsn	-2.39342472	0.02006802	3	High
SPEXP.bsn	1.217177721	0.2286412	4	High
CN2.mgt	-1.1650561	0.248935163	5	High
USLE_P.mgt	1.127658318	0.264272688	6	Medium
CH_COV2.rte	-1.08592788	0.282163412	7	Medium
ALPHA_BF.gw	0.578150574	0.565480276	8	Medium
LAT_SED.hru	0.559602307	0.57798224	9	Small
CH_EQN.rte	-0.46956536	0.64048887	10	Small

4.4.3 Stream Flow: Calibration and Validation

As SWAT model considers many parameters, it is mandatory to identify which of the basin parameters are most important to govern stream flow. For calibration of stream flow, governing parameters should be prioritized according to their order of influence. Prioritization of the parameters has been done using the robust Latin Hypercube Global sensitivity analysis method. The entire study area has been divided into 7 sub basins and 40 HRUs. For each Sub basin, the parameters have been ranked according to their order of influence. The computed result of the sensitivity analysis of stream flow is indicated in Table 4.

A. Model Calibration

The calibration of the SWAT model for stream flow was done by using the Daily and monthly observed stream flow data at the Melka Kunture Gauging station for the years 2001 and 2005. During the calibration period from 2001- 2005, the simulated monthly flow matched well with the measured monthly flow (with R^2 = 0.85, ENS = 0.76 and P_{bias} = -4.6). Figure 4.4 shows the comparison of the simulated versus observed Daily flow. The adequacy of the model is further indicated by its clear response to extreme rainfall events resulting in high runoff volume (Example in August). It can be clearly seen on the scatter plot of the simulated versus observed monthly flow that was agreed well by the model.

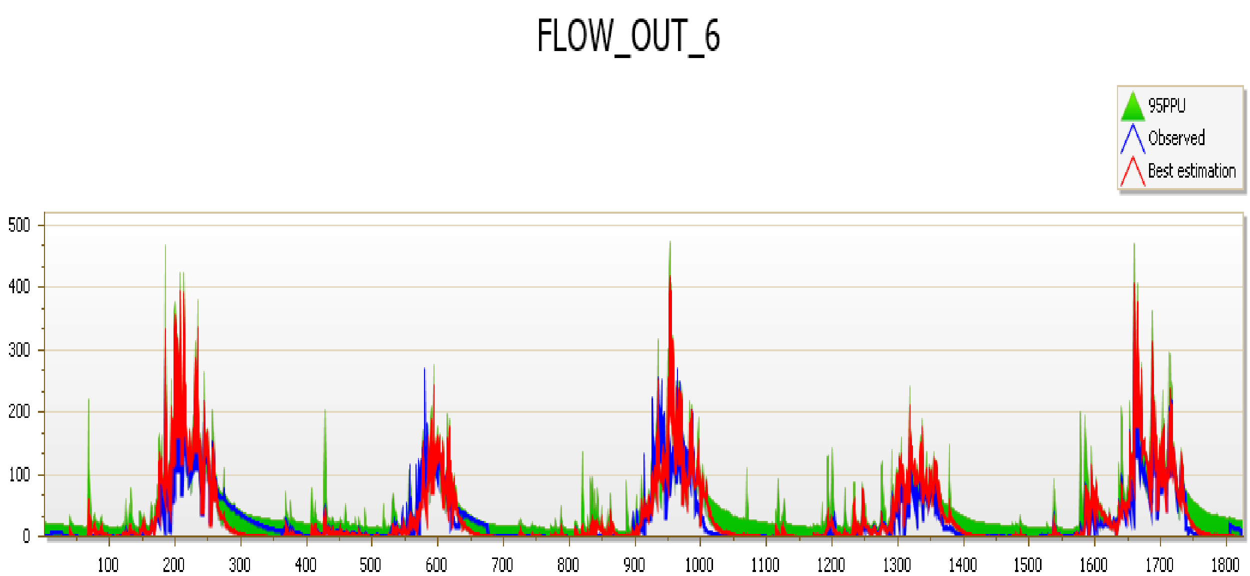


Figure 4.3: Simulated and observed daily flows generated from SWAT CUP during calibration.

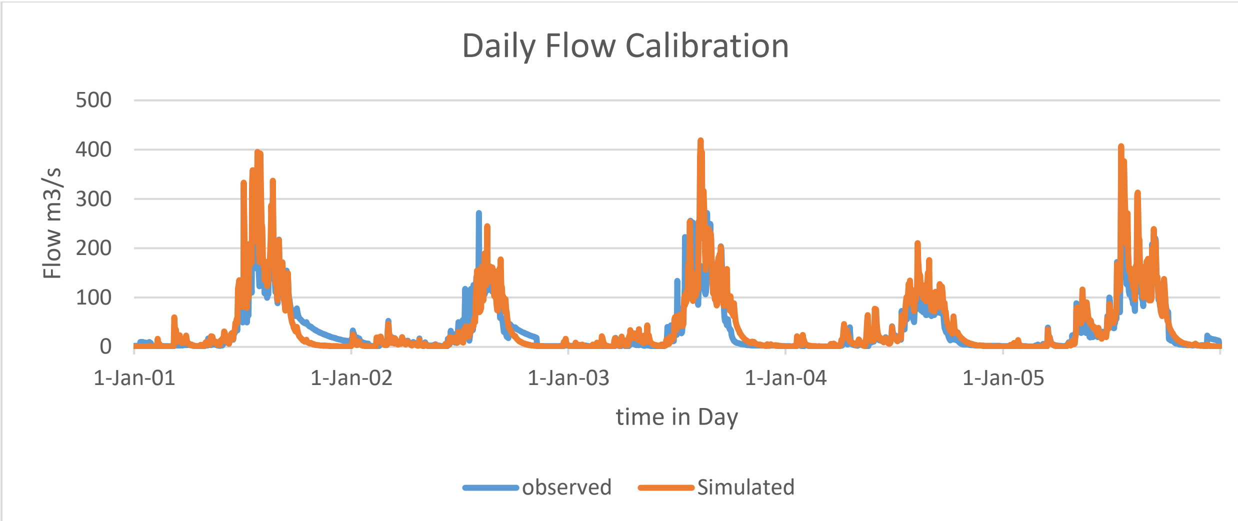


Figure 4.4: Simulated and observed daily flows by excel during calibration.

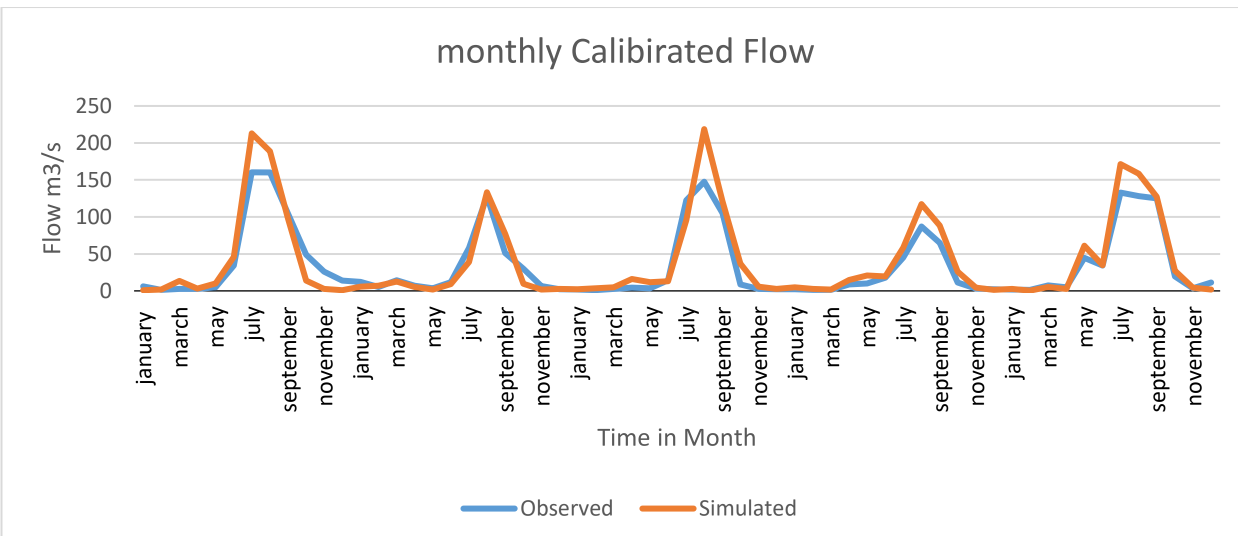


Figure 4.5: Simulated and observed average monthly flows by excel during calibration

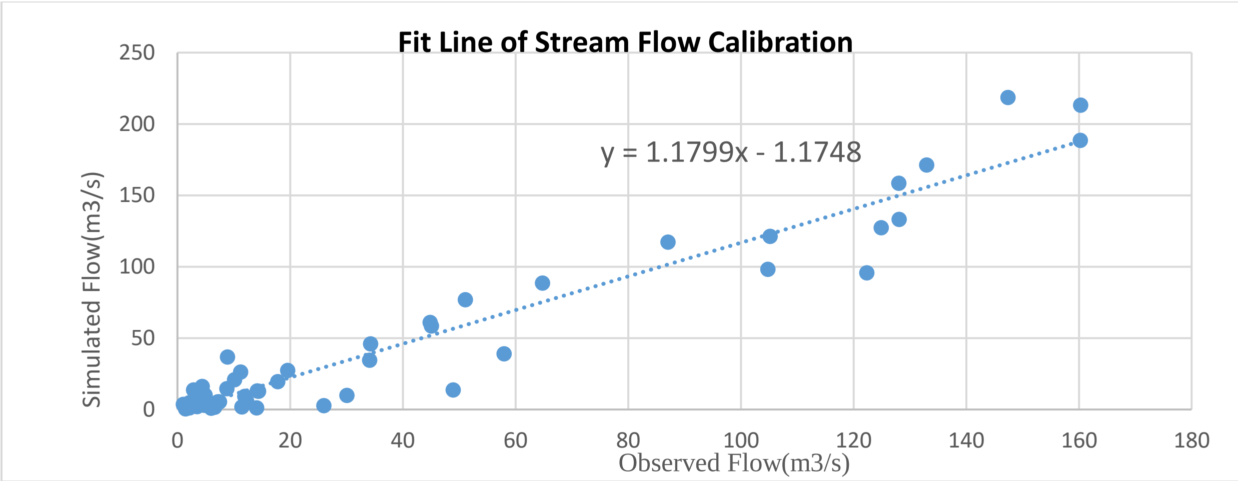


Figure 4.6: Simulated and observed monthly scatter plot for flow calibration

B. Model Validation

The model with calibrated parameters was validated by using an independent set of measured flow data which were not used during model calibration. The model performance in validation was carried out from 2006 to 2008, without further adjustment of the parameters selected for model calibration. Accordingly, a good match between daily and monthly measured and simulated flows in the validation period were demonstrated by the correlation coefficient (R^2) of 0.76, Nash-Sutcliffe simulation efficiency (ENS) of 0.74 and percentage of bias (P_{bias}) of 5.1.

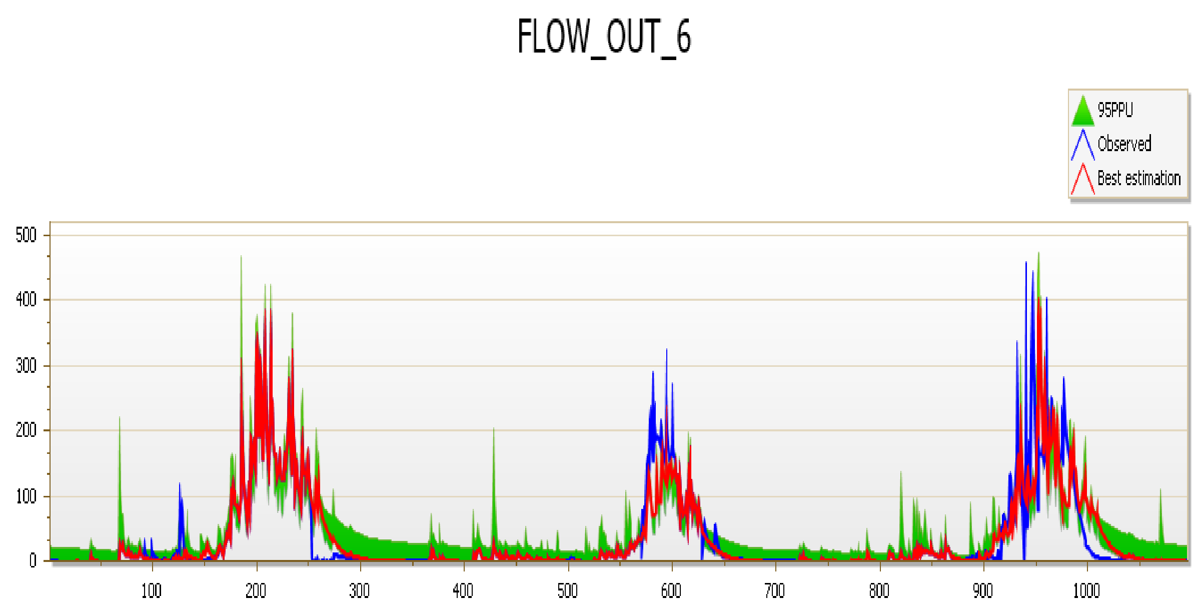


Figure 4.7: Simulated and observed daily flows generated from SWAT CUP during validation.

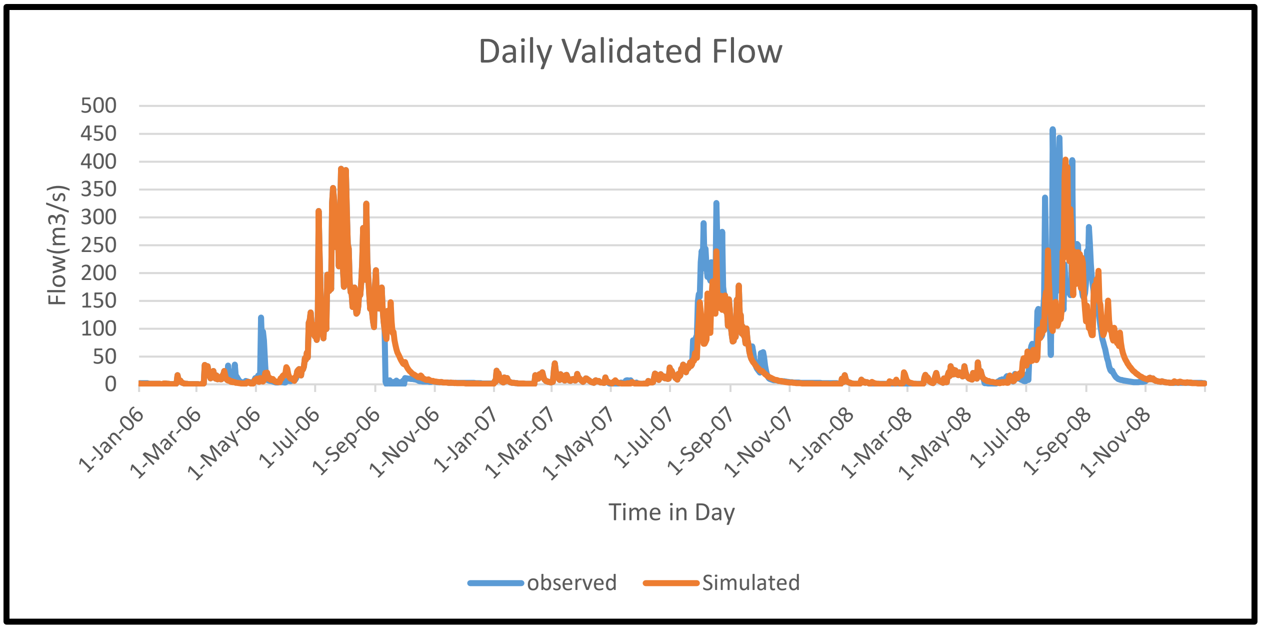


Figure 4.8: Simulated and observed daily flows by excel during validation.

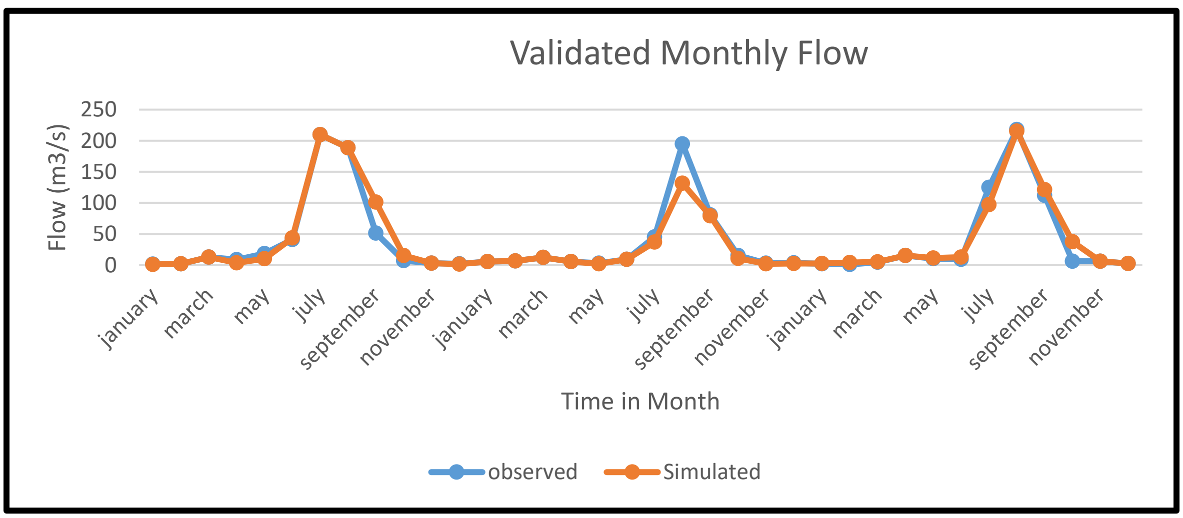


Figure 4.9: Simulated and observed monthly flows by excel during validation.

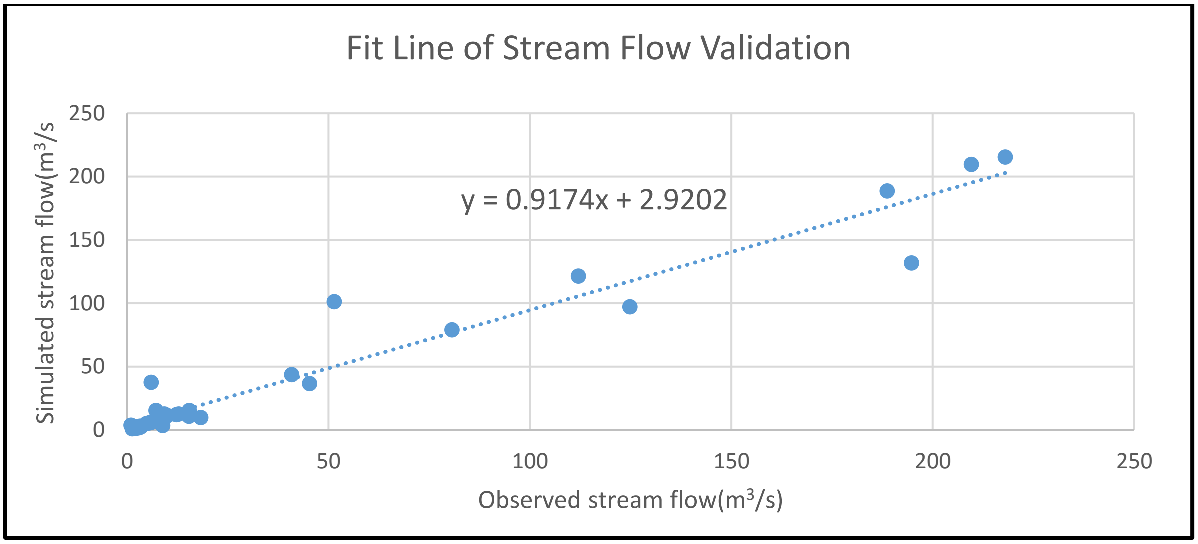


Figure 4.10: Simulated and observed monthly scatter plot for flow validation

4.4.4 Sediment Yield: Calibration and Validation

A. Model Calibration

The model also showed adequacy in predicting the monthly sediment yields in the study area with R2, ENS and P_{bias} values of 0.72, 0.78 and -13.5, respectively during calibration Table 4.5. The scatter plot and graph of the simulated versus observed monthly sediment yields shown on Figure 4.13 clearly indicated that the model over-predicted the sediment yield values during wet season from 2001 and 2003 such behavior of the simulated sediment yields indicated the high deposition of sediments as they travel along the channel.

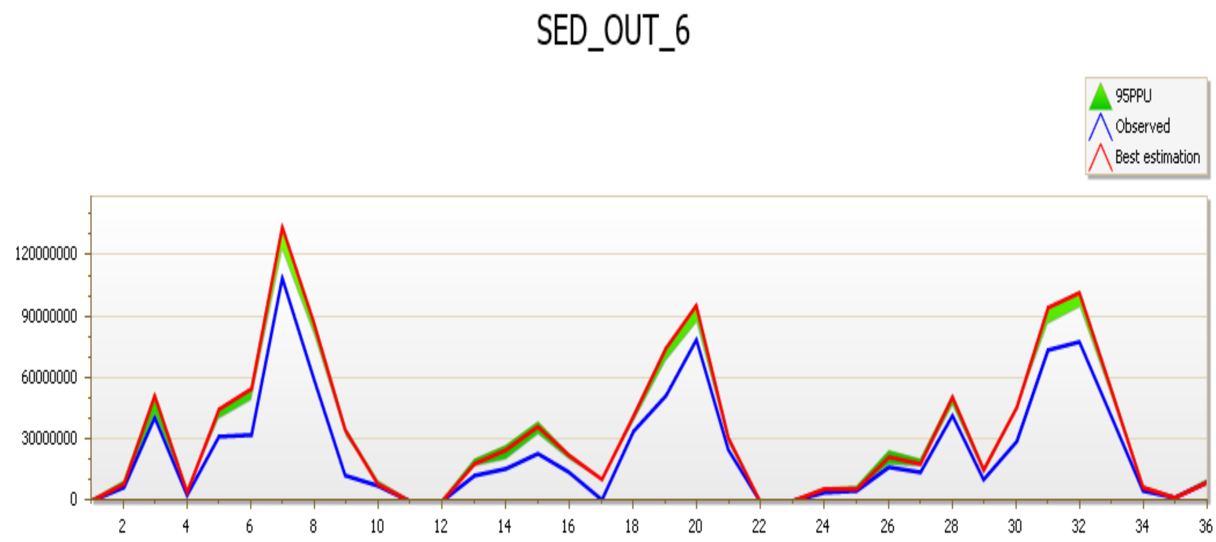


Figure 4.11: Simulated and observed monthly sediment generated from SWAT CUP during calibration.

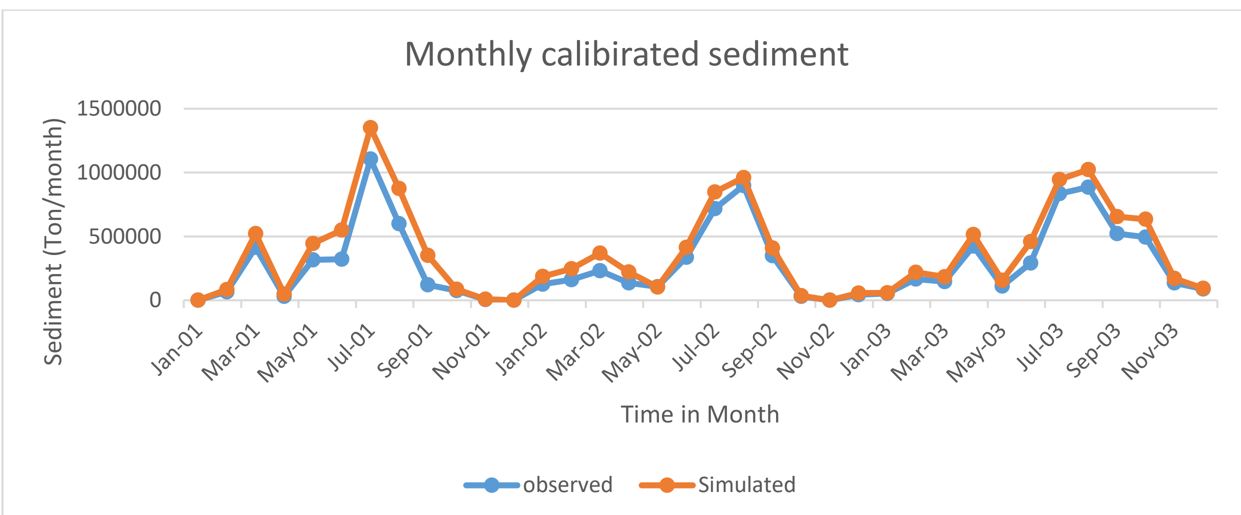


Figure 4.12: Simulated and observed monthly sediment by excel during calibration.

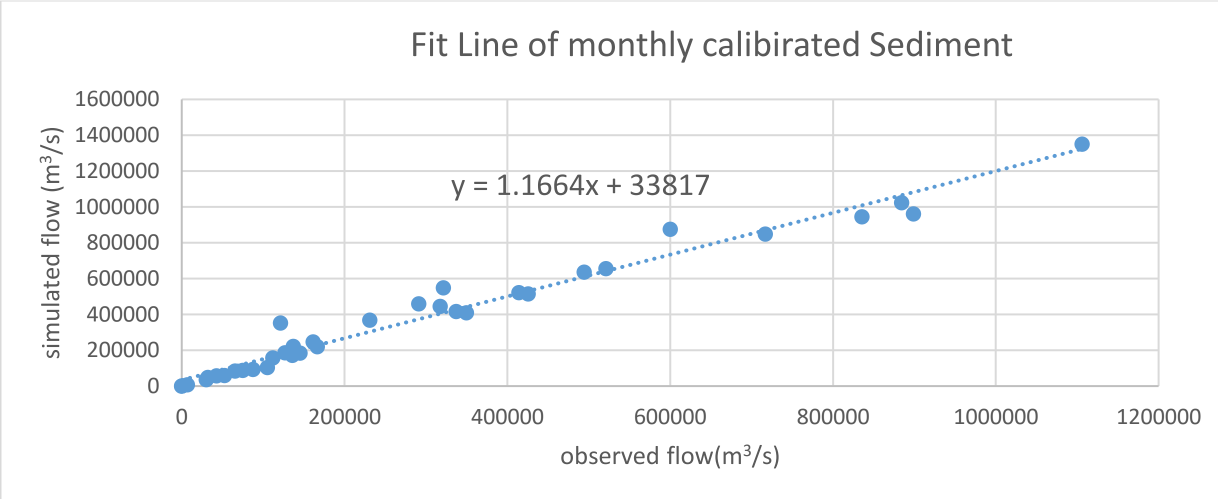


Figure 4.13: Simulated and observed monthly scatter plot for sediment calibration

B. Model Validation

After calibration, SWAT model was validated to sediment for the period 2004 to 2005 using the same parameters, which were adjusted during calibration processes. Monthly model simulated sediment load against monthly measured sediment load were compared graphically and statistically. The overall time series trend of the measured sediment load is well explained by the simulated sediment in both calibration and validation periods. The statistical values in the monthly basis of sediment yield estimation in the validation period results the R^2, ENS and P_{bias} of 0.71, 0.69 and -14.5 % respectively (Table 4.5). The observed and simulated sediment yield in monthly time step of the validation period shows that model slightly over estimate the sediment yields of highly flow time periods, and in low and medium flow periods. However, there was a good agreement between simulated and observed sediment yield in both calibration and validation periods.

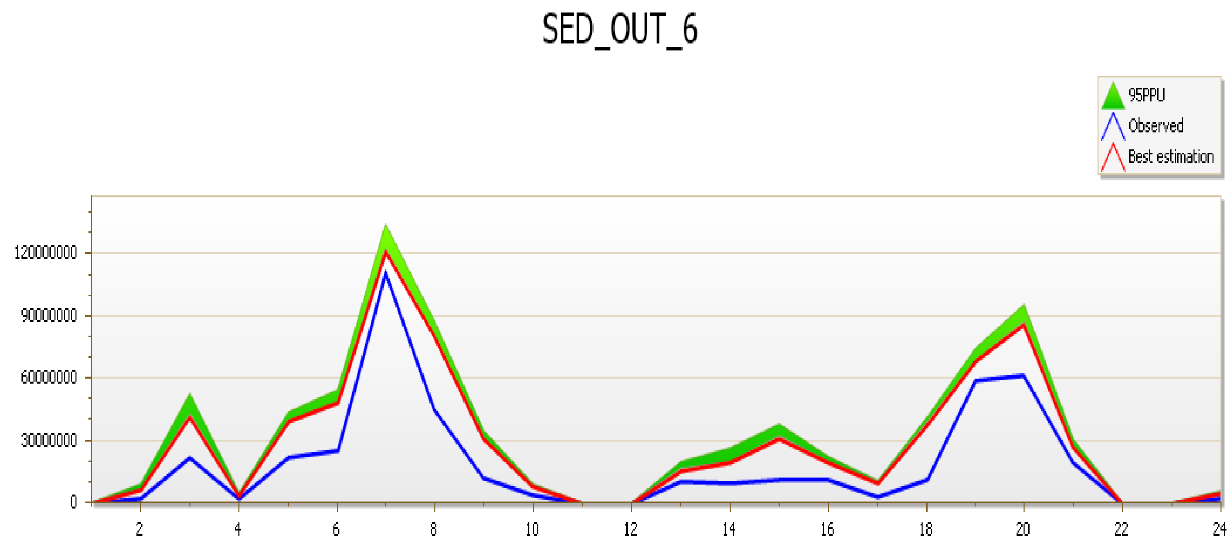


Figure 4.14: Simulated and observed monthly sediment generated from SWAT CUP during validation.

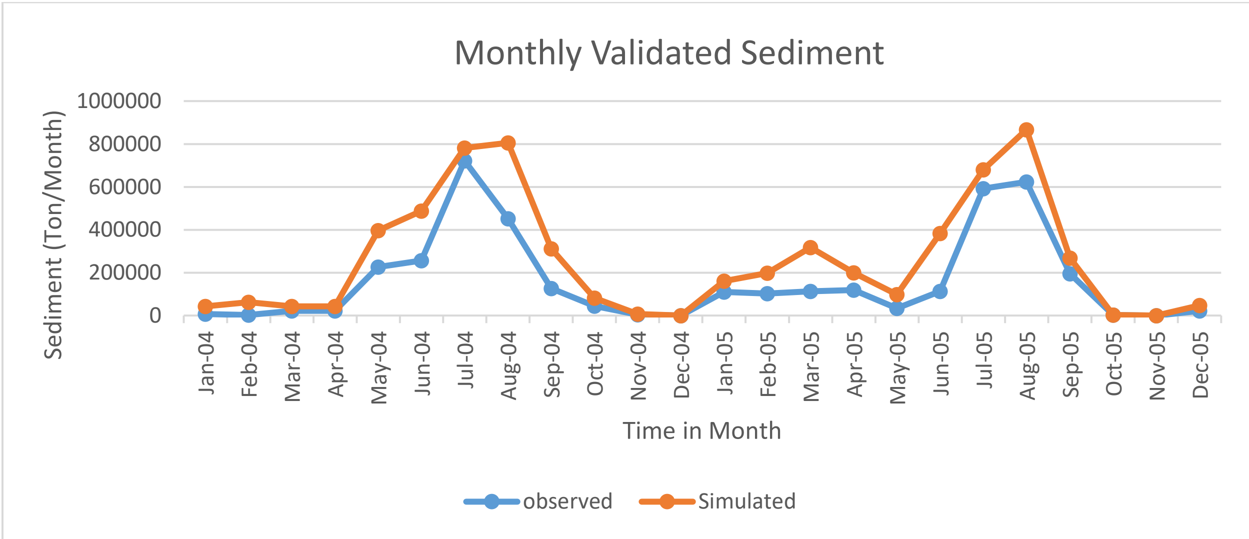


Figure 4.15: Simulated and observed monthly sediment yield

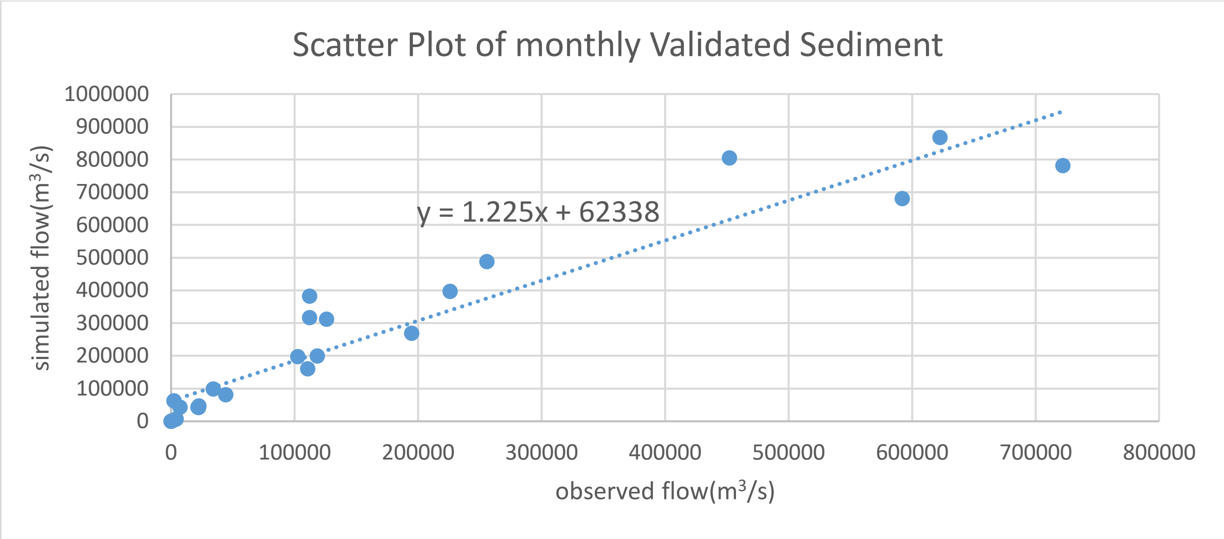


Figure 4.16: Simulated and observed monthly scatter plot for sediment validation

The sediment yield is directly related to the amount of discharge observed at each month. As depicted in Figure 4.15 the sediment load is high in rainy season July, August and September, this is directly related to rainy season where surface runoff is high.

4.4.5 Model Performance Evaluation for Stream flow Calibration and Validation

The performance of the model to simulate the stream flow during the calibration and the validation periods has been evaluated based on the computed results of the indicators and the suggested model performance rating standards. The computed statistical indicators from 0.85 for R^2, 0.76 for NSE, and -4.9 % for P_{bias}. The values of all statistical indicators fall in the range of good and Very good model performance in accordance with Moriasi, (2007) recommendations. Likewise, the model was evaluated for the performance of the validation period. The computed statistical indicators range from 0.76 for R^2, 0.76 for NSE and 5.1 for P_{bias}. Similar to the calibration period, the model performance rating was evaluated in terms of Moriasi, (2007) model performance evaluation criteria and was found to be a good and very good.

Table 4.4: Model performance evaluation for stream flow calibration and validation

Flow calibration and Validation	**R2**	**NS**	P_{bias}
Calibration	0.85	0.76	-4.6
Validation	0.76	0.74	5.1

4.4.6 Model Performance Evaluation of Sediment Yield Calibration and Validation

The method for goodness-of-fit measures of model predictions were used during the calibration and validation periods of sediment yield simulation. The computed statistical indicators range from 0.72 for R^2, 0.78 for NSE and -13.5 for P_{bias}. The indicators have been found to be within the range of a good and very good performance level. Similarly, for the validation period, the computed statistical indicators have been computed as 0.71 for R^2, 0.69 for NSE, and -14.1 for P_{bias}. Similarly the computed statistics for validation were evaluated as good and very good performance range. Generally the performance efficiency values in both the calibration and validation phases prove that SWAT2012 predicted measured streamflow and Sediment quite satisfactorily for daily time step for flow and monthly time step for Sediment.

Table 4.5: Model performance evaluation for sediment calibration and validation

Sediment calibration and Validation	**R2**	**NS**	$\mathbf{P_{bias}}$
Calibration	0.72	0.78	-13.5
Validation	0.71	0.69	-14.1

4.4.7 Impact of Land use Land cover Change on Stream Flow

One of the most significant parts of the study was to evaluate the hydrological response of Melka Kunture watershed to Land use Land Cover Change. LULC Change has a great influence on the rainfall-runoff process, particularly for a complex terrain, as for instance the study area Melka Kunture Watershed. SWAT2012 model was executed using the 1986, 2000 and 2010 land use and land cover maps, while setting all the other set of input variables similar for all simulations in order to quantify the variability of streamflow due to the land use and land cover changes.

Table 4.6: Impact of LULC on stream flow

LULC	**Stream Flow(m3/s)**	**difference**	**Change in (%)**
LULC 1986	24.06	_	_
LULC 2000	26.67	2.61	7.78
LULC 2010	28.026	1.356	4.84

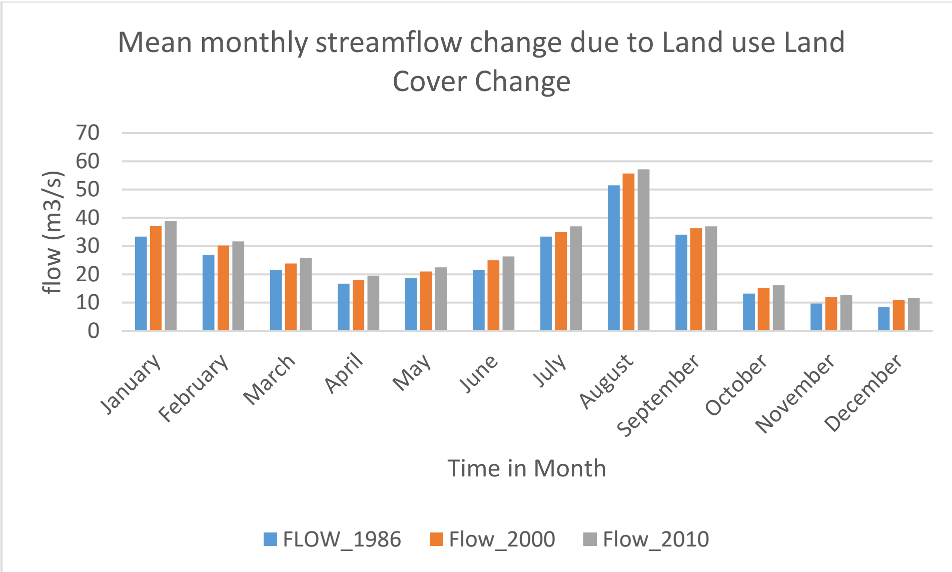


Figure 4.17: Mean monthly stream flow change due to LULC change.

The LULC Change Detection Analysis indicated that there is an immediate response to rainfall due to the decrease in forest land cover from 1986 to 2010. This is due to the reason that forest litter has a great influence on overland runoff by absorbing rainfall and decreasing overland runoff that increase soil water storage. Generally, the result of the analysis indicated that change of land use and land cover pattern has altered the rainfall-runoff relationship and contributed to an increase in runoff. As explained in section 4.4.7, all input parameters (including climatic, soil, etc) were kept unchanged during the simulations so that only the impacts of LUCC are recognized. It also identified that one of the most important concerns regarding forest to Agriculture land use change relates to water availability during the dry season that reduced the contribution of ground water flow. Further analysis streamflow data revealed that simulated Average monthly streamflow has increased at a rate of 7.78% from the year 1986 to 2000 and 4.84% from the 2000 to 2010.

4.4.8 Impact of land use Land Cover on Sediment yield

Sediment yield is the amount of overland soil loss due to erosion in the watershed. It reflects the integrated response of sediment generation processes and stream processes at watershed scale. The simulated sediment yields under different land use land cover change were presented below. Simulation results indicated that the sediment yields increased by 0.034 t/ha (58.62 %), and 0.004 t/ha (4.34%), respectively. This change was occurred due to high decrement of forest land and high increment of Agricultural land from the year 1986 to 200 and 2000 to 2010. Figure 4.15 showed that there was a clear response to stream flow and sediment yield due to the change in LULC spatially in rainy seasons, July, August, and September.

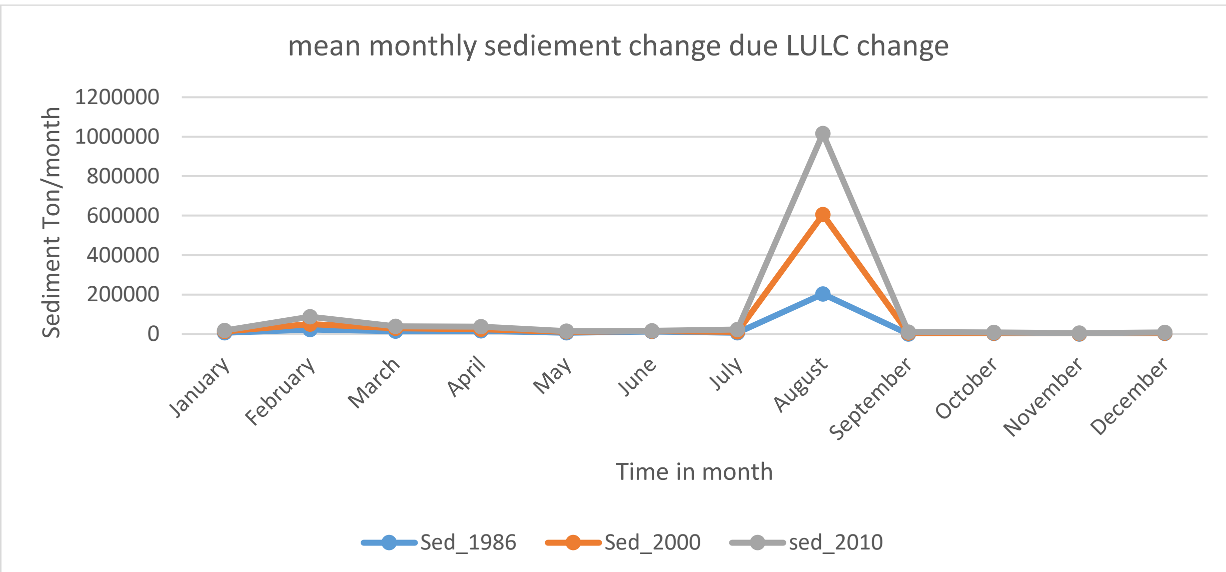


Figure 4.18: Average monthly sediment change due to LULC change.

Table 4.7: Impact of LULC on sediment yield

LULC	**Average Annual Sediment**	**Sediment (Ton/month)**	**difference**	**(Ton/ha/year)**	**difference**	**Change in (%)**
1986 LULC	301328.1298	25110.675	_	21.17	_	
2000 LULC	479153.0211	39927.92	14817.245	33.58	0.034	58.62
2010 LULC	502899.9086	41908.325	1980.408	35.04	0.004	4.34

4.3 DISCUSSION

4.3.1 Parameter Sensitivity for Stream flow and Sediment Yield Simulation

Model sensitivity evaluation was carried out to identify the most sensitive parameters for simulation of stream flow and sediment yield at Melka Kunture watershed. The sensitive parameters selected for the study area were showed similarity with watersheds which have similar topography and watershed condition. A study conducted by Berhan Gessesse (2015) at Mojo watershed demonstrated the most sensitive parameters for flow calibration were SCS_CN, ESCO, ALPHA_BF, and SOL_AWC most of the selected parameters were similar with selected parameters at Melka Kunture watershed. A study conducted on Upper Awash River Basin by Lemma,(2018) was depicted SCS_CN, USLE_K, SPEXP, and LAT-SED, were found to be the most sensitive parameters for sediment yield calibration. The results of previous studies conducted on areas which have similar watershed condition with Melka Kunture watershed revealed that, parameter sensitivity was dependent on hydrological and topographic condition presented on the area. Therefore, most of the simulated parameters on such watershed were found to be similar.

4.3.2 Melka Kunture sub watershed Stream flow and Sediment Yield status

Previous study findings and the output of the present study revealed that the ArcSWAT model fits well to simulate various hydrological components to tropical watersheds, although it was initially developed for temperate regions of the USA Neitsch (2011). For example, R^2 values of 0·7 and an NSE of 0·7 for daily and monthly time steps, respectively, were achieved when simulating sediment yield for the Hombole watershed in central Ethiopia, Alamirew (2006).On the other hand, a case study was provided by Setegn (2010) in the Anjeni watershed, northwestern Ethiopia, which assessed soil loss rate using an ArcSWAT hydrological model.

An R^2 value of 0·9 and an NSE of 0·9 for both monthly and daily time step sediment simulation model performances were achieved. Therefore, studies carried out to test the applicability of the SWAT model in tropical regions including the present finding reported reasonable accuracy.

A study conducted at Upper Awash River Basin by Dilnesaw (2007) reported that the average annual sediment yield of the area was estimated as 21.5 t/ha/y. Average annual sediment Yield of Melka Kunture watershed was estimated as 21.17 t/ha/y, 33.58 t/ha/y and 35.04 t/ha/y using LULC map of 1986, 2000, and 2010 respectively. The actual annual sediment yield in the study area exceeds the average sediment yield of the Upper Awash sub-Basin. This fact shows how far sedimentation is a serious threat to the study area as compared to the general sediment yield status of the Upper Awash Sub-Basin.

4.3.3 Impact of LULC change on Stream flow and Sediment Yield in Melka Kunture Watershed

The result of the effect of LULC change on stream flow and sediment yield showed that With the Increment of Agricultural land and Decrement of forest land both Stream Flow and Sediment yield were increased. Study conducted by Melka Lemma (2018) on upper awash basin Ethiopia showed that when 10% of agricultural lands are converted to forestland, runoff and sediment yields decreased by 0.5% and 2.47%. Study conducted by Nathaniel (2009) in the selected Manipuai River sub watersheds with an aggregate area of 200 ha to simulate the effects of land use on runoff volumes, sediment yield, and stream flows showed that ArcSWAT adequately predicted peak flows and temporal variation of runoff volumes and sediment yields. They reported that both runoff volumes and sediment yields were increased when 50% of the pasture area and grasslands are converted to agricultural lands. Generally the volumes of runoff and sediment yield that would be generated in any catchment increase with the reduction in the cover area and with increasing the cover area of the catchment reduce the volume of runoff and sediment yield.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The first step in effective watershed management planning is an attempt to obtain a scientific understanding of the hydrological characteristics of the watershed as well as defining adequate tools for long term predictions of the watershed characteristics. Thus, the general objective of this study was to examine the applicability of SWAT model in estimating the sediment and stream flow in Melka Kunture watershed, Ethiopia, and subsequently assessing the effect of LULC change on stream flow and sediment yield. The hydrological model SWAT was tested and applied for the assessment of the hydrology and sediment yield in the Melka Kunture Sub watershed, Awash Basin Ethiopia. The ability of SWAT to adequately predict stream flow and sediment yield was evaluated through sensitivity analysis, model calibration, and model validation. The model was successfully calibrated and validated for the Melka Kunture gauged watershed using SWATCUP, SUFI-2 algorithms. In the process of model calibration the identified sensitive parameters helps to reduce the number of model parameters to eleven for flow and ten for sediment. The selected parameters gave good results in minimizing the differences between observed and simulated stream flow and sediment yield. The model evaluation statistics for prediction of stream flow and sediment yield gave Good to very Good results that were verified by NSE, R^2 and P_{bias}. Generally, the following conclusions are drawn from the study:

- The current study confirmed that SWAT Model has a strong predictive capacity from the watershed in both case, for Stream Flow and sediment yield simulation. Therefore, the model can be used for simulating stream flow and sediment from ungauged watershed that is having similar physiographic and climatic condition with Melka Kunture Watershed.
- Out of 13 parameters considered for sensitivity analysis in stream flow only parameters CN2, GW_DELAY, OV_N, SOL_AWC, ALPHA_BF were Found to be Very Sensitive based on the highest absolute value of t-stat and low p-value. In the same way for sediment yield out of 13 parameters considered for sensitivity analysis USLE_K, ADJ_PKR, SPCON, SPEXP, CN2 were Very Sensitive.

- The watershed had experienced a significant change in land use and land cover over the past three decades from the year 1986 to 2010. It can be presumed that deforestation and increase i-n agricultural land has altered the whole Melka Kunture watershed. It was identified that land use and land cover changes has an identical trend during the two periods (1986-2000 and 2000-2010).
- Impact of land use land cover Change on Stream Flow and Sediment yield indicated that the average monthly Stream Flow and sediment yields were increased from the year 1986 to 2010 due to reduction of Forest land on the expense of Agricultural land. The predominant change in land use and land cover during the whole period was, the increase in agricultural Land and urban areas and reduction of Forest land particularly in the Middle and upper part of the watershed.

5.2 Recommendation

- Sedimentation is a serious threat to the study area as compared to the general soil erosion status of Upper Awash Basin. Therefore, Stakeholders must provide efficient soil and water conservation program.
- The SWAT Model prediction output depends on the quality of input data. One of the constraints in conducting this research work was lack of enough continuous measured suspended sediment data. The sediment data used for this study were only five year monthly Sediment for both calibration and Validation. There is therefore, possible discrepancy while predicting Long term Sediment yield over the Study area. Hence, responsible bodies should give due attention to the time and frequency of sampling, method of sampling and recording of reliable sediment data together with flow measurement.
- Short period of sediment yield and flow record of observation data was used in this study. Using longer period of stream flow and sediment data will improve the calibration result.
- It is recommended that the calibrated model can also be used for further analysis of the effect of climate on water resource as well as to investigate the effect of different management scenarios on stream-flows and sediment yields in the watershed.
- It is recommended to install more hydro-meteorological gauging stations in the catchment in respective with accurate measurement, so responsible bodies should have expose their contribution in additional installation and measurement accuracy.

REFERENCES

Abbaspour, K. C. (2007). Modelling hydrology and water quality in the prealpine alpine Thur watershed using SWAT.

Abbaspour, K. C. (2013). SWAT-CUP 2012: SWAT calibration and uncertainty programs user manual. Swiss: Eawag and Swiss Federal Institute of Aquatic Science and Technology.

Alamirew D. (2006). Modeling of hydrology and soil erosion of upper Awash River basin. PhD thesis. University of Bonn.

Arnold, J. S. (1998). Large area hydrologic modeling and assessment part I: model development. J. Am. Water Resour. Assoc., 34 (1), 7389.

AWBA. (2018). Report of Awash Basin Authority.

Awulachew, S. B. (2008). Impact of watershed interventions on runoff and sedimentation in Gumera watershed. Arba Minch University, Ethiopia Research Service and Texas A.

Berhan Gessesse, w. b. (2015). model-based characterization and monitoring of runoff and soil erosion in response to land use/land cover changes in the modjo watershed, ethiopia. land degradation & development, 711–724.

Bewket W, &. S. (2005). Dynamics in land cover and its effect on stream flow in the Chemoga watershed, Blue Nile basin of Ethiopia. Hydrological Processes, 445–458.

Bewket W, S. G. (2003). Assessment of soil erosion in cultivated fields using a survey methodology for rills in the Chemoga watershed, Ethiopia. Agriculture, Ecosystems & Environment, 81-93.

Bewket W, S. G. (2005). Dynamics in land cover and its effect on stream flow in the Chemoga watershed, Blue Nile basin. Ethiopia,. Hydrology Process, DOI.

Bouraoui F, D. T. (2001). ANSWERS-2000: runoff and sediment transport model. Journal of Environmental Engineering, 122(6):493–501.

Decoursey, D. G. (1988). Mathematical models for point sources water. Journal of Soil and Water Conservation., 568-576.

Decoursey, D. G. and E. H. Selly,. (1988). Journal of Soil and Water Conservation., 568-576.

Dilnesaw A., C. B. /(2007). Application of SWAT for assessment of spatial distribution of water resources and analyzing impact of different land management practices on soil erosion in Upper Awash River Basin watershed . Catchment and Lake Research.

Donigian AS, B. B. (1995). Hydrological simulation program—Fortran (HSPF), chap. 12. In Computer Models of Watershed Hydrology, Singh VP (ed). Water Resources Publications: Colorado, USA;, 395–442.

Easton, Z. M. (2010). A Multi basin SWAT Model Analysis of Runoff and Sedimentation Blue Nile, Ethiopia . Hydrol. Earth Syst., 1827-1841.

Ero˘glu, H. Ç. (2010). Using High resolution image and and elevation data classifiy erosion risk of bare soil areas in the hatila Vally natural protected area . turkey stich Env reasearch risk , 111-126.

FAO. (1998a). Soil and Terrain Database for north-eastern Africa (The Crop Production System Zones of the IGAD sub-region (CD ROM)).

Gassman, P. M. (2007). The Soil and Water Assessment Tool historical development, applications, and the future research directions.

Gessese, A. (2008). Prediction of sediment inflow for Legedadi reservoir using SWAT watershed and CCHE1D sediment transport models. . Faculty of Technology, Addis Ababa University.

Getnet Dubale Betrie. (2008). Integrated Sediment Transport Modelling Using OpenMI (SWAT and SOBEK-RE) for the Blue Nile River Basin". MSc thesis , UNESCO-IHE Institute for Water Education, Delft, the Netherlands.

Gobena, S. (2010). daily rainfall-runoff modelling of upper awash sub basin using conceptual rainfall runoff models.

Haregeweyn N, P. J. (2013). Assessing the performance of a spatially distributed soil erosion and sediment delivery model (WATEM/SEDEM) in northern Ethiopia. Land Degradation & Development, 188–204.

Herweg, K. S. (1999). The Variability of Soil Erosion in the Highlands of Ethiopia and Eritrea. Soil Conservation Research Program (SCRP), Centre for Development and Environment, University of Berne., Research Report 42.

Hibbert, A. (1967). Forest treatment effects on water yield. In: W.E. Sopper and H.W. Lull (Ed), Int. Syrup. Forest Hydrology.

Hietel, E. W. (2004). Analysing land-cover changes in relation to environmental variables in Hesse, Germany. 473–489.

Hollis G.E. (1975). The effect of urbanization on flood of different recurrence interval. Water Resourc. Res.

Hurni, H. (1983). Land degradation, famines and resource scenarios in Ethiopia, In World Soil Erosion and Conservation, . Cambridge University Press.

IGBP-IHDP. (1999). Land-use and land-cover change, implementation strategy. Prepared by Scientific Steering Committee and International Project Office of LUCC. Stockholm and Bonn, (p. IGBP Report 46/IHDP Repot 10).

Julien, P. Y. (1998). “Erosion and sedimentation”. Cambridge University Press.

Kumar, R. a. (2004). Geographic Resources Decision Support System for land use, land cover dynamics analysis. FOSS/GRASS International Users conference Bangkok, Thailand.

Lambin, E. G. (200).

Lambin, E. G. (2003). Dynamics of land use and land cover change in tropical regions. Annu. Rev. Environ. Resour., 205–41.

Langford, K. (1976). Change in yield of water following a bush fire in a forest of Eucalyptus egnans.

Legesse D, V.-C. C. (2003). Hydrological response of a catchment to climate and land use change in tropical Africa: case study south central Ethiopia. Journal of Hydrology, 67-85.

Leh M, B. S. (2011). Impact of land use change on erosion risk: an integrated remote sensing, geographic information system and modeling methodology. . Land Degradation & Development.

Lemma, M. (2018). sediment yield modeling using swat, case study of upper awash basin ethiopia. masters thesis, addis ababa university.

M.Winchell, R. S. (2013). ARCSWAT interface for SWAT2012 user's guide". Grassland, soil and water research laboratory USDA agricultural research service ,.

Meyer, L. D. (1969). Mathematical simulation of the processes of soil erosion by water. Trans. Am. Soc. Agric. Eng.,, 12, 754–758.

Moriasi, D. J. (2006). Model evaluation guidelines for systematic quantification of accuracy in watershed simulations.

Morris, G. L. (2009). Reservoir Sedimentation Handbook, Design and management of dams, reservoirs and watersheds for sustainable use,. McGraw-Hill, New York.

Nathaniel, R. V. (2009). Predicting the effects of land use on runoff and sediment yield in selected sub watershed of the Manupali River using ArcSWAT.

Neitsch SL, A. J. (2005). Soil and Water Assessment Tool, Theoretical Documentation:. Agricultural Research Service and Texas A&M Blackland Research Center.

Neitsch SL, A. J. (2011). Soil and water assessment tool, theoretical documentation: Version 2009. USDA Agricultural Research Service and Texas A&M Blackland Research Center,Temple: Texas.

PDRE., P. D. (1989). Master plan for the Development of Surface Water Resources in the Awash Basi n. Ethiopian Valleys Development Studies Authority. Final Report. Halcrow.

Saleh, A. J. (2000). Application of SWAT for the upper north Bosque Watershed.

Schreier, H. B. (2003). Gaining forests but losing ground: a GIS evaluation in a Himalayan watershed. Environmental Management, 18, 139-150.

SCS. (1972). USDA soil conservation service (SCS). In National engineering handbook.

Setegn SG, D. B. (2010). Modeling of sediment yield from Anjeni-gauged watershed, Ethiopia using SWAT model. Journal of the American Water Resources Association 46: , 514–526.

Setegn, S. S. (2008). Hydrological modelling in the Lake Tana Basin, Ethiopia using SWAT model. The Open Hydrology Journal, 2(2008), 49-62.

Sileshi Gobena. (2010). daily rainfall-runoff modelling of upper awash sub basin using conceptual rainfall runoff models. addis ababa university.

Singh. (2012). Rain runoff and sediment transport from a forested lesser himalayan watershed in Himachal Pradesh.

Siyam AM, E. S.-s. (2005). Assessment of the current state of the Nile basin reservoir sedimentation problems. Nile Basin Capacity Building Network River Morphology Research Cluster (Unpublished).

Slaymaker, O. (2003). The sediment budget as conceptual framework and management Tool. Hydrobiologia.

Srinivasan, R. T. (1998). Large Area hydrologic modeling and assessment.

Tadele K. (2009). Watershed hydrological responses to changes in land use and land cover and management practices at Hare watershed, Ethiopia. PhD thesis. University of Siegen: Siegen.

Thomas, M. (2001). Landscape sensitivity in time and space- an introduction, 42, 83-98.

Tripathi, M. P. (2005). Development of effective management plan for critical watersheds using SWAT model. Hydrol. Process. ., 19 (3), 809-826.

USAID. (200). Amhara National Regional State food security research assessment.

van Griensven, A. a. (2003,2005). Application and evaluation of ESWAT on the Dender Basin and Wister Lake Basin.

Vanoni, V. A. (2006). Sedimentation Engineering. American Society of Civil Engineers, .

Victor D.G., a. A. (2000). Restoring the forests. 127–144.

Walling, D. a. (2003). Recent trends in the susbpended sediment loads of the worlds rivers . global planet change , 111-126.

Walling, D. E. (1987). Rainfall, runoff and erosion of the land: a global view,. Wiley,Chichester, UK., 89-117. .

Watson, B. M. (2005). Evaluation of three daily rainfall generation models for SWAT,. Trans. ASABE, 1667-1711.

Williams, J. (1995). The EPIC model. In Singh VP. (ED). Computer models of watershed hydrology.

Wischmeier, W. a. (1978.). Predicting rainfall erosion losses. A guide to conservation planning. Agriculture handbook.

Xiuwan, C. (2002). Using Remote Sensing and GIS to analyze land cover change and its impacts on regional sustainable development. Internation Journal of Remote Sensing. 107-124.

Xue-song, Z. H.-b.-g.-f. (2003). Application of SWAT model in the upstream watershed of the Luohe River.

Young RA, O. C. (1989). AGNPS: a nonpoint-source pollution model for evaluating agricultural watersheds. Journal of Soil and Water Conservation, 44(2): 168–173.

APPENDIX

Appendix A1 Simulated Average Monthly Sediment Yield (Ton/month) for LULC 1986

year	Jan	Feb	March	April	May	June	July	August	Sep	Oct	Nov	Dec
1988	7487.53	64228.68	27517.58	7694.66	4244.5	3172.28	62832.86	81749.8	65.87	52.47	49.43	45.94
1989	75706.45	13282.19	21635.66	59.69	56.6	44.08	13416.83	28577.25	55.94	37.93	48.7	28.8
1990	26.58	5317.59	31268.31	97488.48	14254.05	28.6	25.15	143211.3	21.54	22.5	17.18	19.03
1991	73.98	2221.54	16781.73	232.12	21151.22	2215.72	96.55	123456.2	74.11	70.61	57.48	59.41
1992	29.31	10660.15	48.03	251.03	11952.67	2115.62	37.25	112611.2	29.15	20.7	17.95	15.65
1993	344.084	12161.11	80779.85	24434.19	114.84	1696.96	85.23	59793.12	1527.76	779.99	66.43	49.66
1994	37.74	82030.9	62.57	53.07	48.54	43.41	38.04	96423.76	31.92	39.42	26.29	25.91
1995	17.271	338.37	30.44	28.17	22.32	21.28	13312.26	28276.72	805.85	15.34	12.33	11.96
1996	81.46	18142.12	957.5	2182.68	7978.47	110.15	87.1	132185.8	82.29	62.7	57.38	53.11
1997	16121.21	2825.3	134.6	10.81	611.8	7.82	1215.21	541.67	1384.9	4642.1	11.28	7.48
1998	3447.42	59178.16	10957.48	8818.87	12123.16	40612.83	4439.7	52942.1	46.47	44.31	34.86	34.75
1999	27268.73	18942.26	15681.95	1784.95	12451.25	42542.75	18125.36	41317.23	45.4	37.74	34	35.21
2000	365.45	42063.56	15681.28	77351.51	3907.72	41586.52	13886.79	113053.9	32.06	5614.02	25.95	51774.86

2001	32.67	11416.49	1810.73	52445.83	45.1	32.61	249.11	5630.26	3168.38	19.86	18.92	13.42
2002	18.27	1118.22	102.03	7621.1	98.09	20.05	17.58	14279.37	14.36	14.75	11.14	9.53
2003	24.83	253214.22	44702.89	18746.52	27079.28	32.95	30.21	30466.43	23.94	22.33	19.31	7532.11
2004	32.43	31748.09	1687.46	12332.5	12153.36	55582.8	9806.43	25130.89	30.56	24.15	22.95	21.26
2005	48.15	4539.55	11100.72	259.65	5494.7	63.2	45.42	31879.78	36.53	35.89	34.24	26.27
2006	107.1	21822.66	1512.67	25596.02	16522.14	124.27	116.24	91160.67	1400.34	16955.18	83.43	134.2
2007	14253.23	78743.55	63546.18	18562.25	3040.15	71.39	5305.29	36757.64	2771.48	3682.04	51.36	45.29
2008	49.93	91979.06	200.45	10999.07	2498.83	82522.9	61.6	125157.7	1201.64	57769.76	12521.	35282.25
2009	14133.96	50194.87	3805.92	12848.54	5802.51	36757.55	92.49	13742.96	28.99	26.59	1318.46	19.77
2010	48.19	10243.72	10189.58	8633.49	8576.37	54.65	52.86	21489.23	38.48	34.19	33.15	24.17
Average	6945.912	22520.5943	15660.68	16888.49	7401.203	13454.8	6233.72	202971.2	561.6504	3914.1117	633.62	4142.17

Appendix A2 Simulated Average monthly Sediment Yield (Ton/month) for LULC 2000

Year	Jan	Feb	March	Apr	may	June	July	Aug	Sep	Oct	Nov	Dec
1988	1872.41	26061.17	18688.24	8633.72	1127.15	588.93	42355.73	44094.3	76.6	60.78	56.7	54.98
1989	33868.39	4750.9	9301.39	52.74	45.98	37.86	44496.48	10037.02	133.08	39.65	1188.8	30.91
1990	35.29	2758.5	12335.33	45423.94	5419.58	29.22	27.43	66627.99	31.72	37.83	33.01	46.95
1991	101.54	34453.16	18118.26	226.87	2642.12	3924.82	218.86	8575114	101.25	102.57	79.93	87.24
1992	38.17	3990.96	50.45	5249.91	8155.357	4796.45	60.09	49588.3	39.75	29.46	28.28	28.84
1993	184.82	62811.93	74233.72	8044.26	192.53	205.72	144.65	38352.75	15645.57	158.95	127.4	96.71
1994	50.65	33046	57.1	47.15	46.38	46.56	46.04	82168.55	47.13	852.03	42.98	68.87
1995	14.61	4057.46	18.39	14.64	11.88	12.59	2949.35	9898.18	1532.93	18.4	15.86	18.3
1996	110.14	51623.57	334.41	5215.78	2502.82	139.47	111.2	67886.23	118.96	93.8	92.19	90.45
1997	25451.26	18.54	1521.23	12.91	11.94	8.97	16841.26	3611.66	158	542.7	12.78	8.96
1998	3214.18	39388.96	6598.48	11363.89	32251.31	7647.53	1501.72	18138.75	60.18	57.08	44.62	44.53
1999	14967.42	9830.56	9819.27	2552.409	5100.342	5121.33	22451.45	15117	52.05	40	37.97	48.38
2000	55.25	10810.04	60659.25	30489.93	1008.561	4691.88	4402.49	57099.59	62.24	4234.84	54.93	18782.69
2001	47.39	1524.83	2870.49	15409.42	56.46	41.24	330.15	13363.25	194.65	31.98	32.37	22.6
2002	35.66	216.51	21.55	1785.72	30.62	28.69	29.7	4998.07	29.48	32.85	25.79	23.54
2003	57.09	39763.25	16096.02	6524.141	3171.2	60.9	68.06	23415.1	59.93	64.54	51.73	1924.71

2004	48.89	19978.24	369.23	3827.88	4527.902	914.06	2807.6	28601.42	57.89	48.58	51.13	53.8
2005	50.75	16550.72	30392.64	1222.61	1495.99	78.17	45.15	5901.29	41.38	40.6	43.13	33.88
2006	184.58	7658.11	6553.02	12302.79	9840.5	196.35	184	35597.61	207.52	2313.03	161.09	113.69
2007	53471.25	30340.3	25944.18	23451.98	8899.07	334.18	887.49	37802.55	70616.97	2107.02	157.43	103.01
2008	111.64	35620.54	1089.86	4380.42	653.683	9208.78	132.72	56005.17	123.61	34244.74	45583.17	18555.12
2009	5388.84	45813.02	824.98	4211.25	590.551	1170.57	69.8	3317.74	64.48	61.92	183.41	51.12
2010	95.12	36906.4	4761.35	5340.23	3096.61	94.34	91.4	7933.77	77.48	70.89	74.51	54.28
Average	6063.276	22520.59	13072.12	8512.373	3951.241	1712.113	6097.949	402377	3892.733	1968.88	2094.748	1754.068

Appendix A3 Simulated Average Monthly Sediment Yield (Ton/month) for LULC 2010

Year	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1988	54840.05	57566.89	20905.86	9677.12	1101.34	566.87	70075.41	1836.14	66.33	54.42	51.16	49.53
1989	9096.03	10255.6	12650.29	41.77	36.14	30.98	24983.63	28897.52	140.45	34.69	1042.35	27.68
1990	126277.49	2910.71	14405.56	49626.89	5338.45	18.14	18.99	25.57	23.79	29.55	26.76	41.09
1991	8490310	34221.62	18113.97	216.81	1521.21	3924.42	207.88	94.41	92.92	95.69	74.95	80.93
1992	103675.19	3891.4	41.94	4346.651	2445.52	2221.15	52.85	30.12	32.08	23.31	22.46	23.03
1993	44061.26	22161.25	68087.68	17480.88	163.46	339.23	128.98	171.15	41784.46	151.62	118.79	91.45
1994	73926.71	67681.77	43.84	35.49	37.53	39.02	40.4	43.88	42.32	752.61	40.37	70.78
1995	23256.84	3677.98	12.1	8.97	7.01	8.39	2898.48	10.37	1505.78	14.98	13.16	15.19
1996	68905.64	90480.14	309.76	4180.05	2460.31	127.51	103.64	102.98	114.37	91.53	89.88	88.8
1997	3121.19	9.8	1380.86	6.43	5.74	4.21	15103.58	11251.12	218.53	562.21	8.39	6.1
1998	38866.25	35037.51	10291.47	8575.02	11212.12	1712.24	3901.99	4481.84	52.78	50.13	40	40.86
1999	29128.55	10160.2	9617.72	2487.398	6071.002	6159.17	95136.63	14947.04	44.29	28.51	29.33	38.67
2000	118783.73	10711.19	13211.32	57828.85	1007.651	4468.48	4583.93	59.18	50.86	6566.16	48.04	26807.75
2001	8732.66	1502.95	2998.44	15189.53	51.88	38.83	336.9	42.62	255.08	29.93	31.53	22.1
2002	6108.2	504.77	14.2	5979.31	23.33	20.97	22.36	27.86	23.25	26.25	20.54	19.42

2003	22717.46	76342.36	15791.44	16235.25	218.46	50.1	57.4	48.25	51.82	55.74	44.74	5461.53
2004	29666.02	30511.95	904.69	3762.27	9698.212	580.25	8537.2	40.23	49.26	40.64	43.95	48.39
2005	8988.81	11658.71	29663.15	1245.19	1466.12	70.12	38.37	44.92	36.61	37.03	41.25	31.85
2006	59736.01	8922.31	5832.79	26941.38	7476.63	185.12	172.21	175.26	199.57	2284.8	154.48	110.19
2007	35733.34	30052.63	24529.74	21253.31	8894.47	319.65	882.07	52161.25	70815.79	2098.58	155.73	100.31
2008	67267.48	48408.67	1093.3	10296.29	1834.769	853.37	119.24	102.44	114.26	28715.21	44370.29	18730.25
2009	9649.67	42833.14	847.56	12325.33	571.491	1057	62.32	14225.87	56.61	56.51	603.19	47.1
2010	8928.87	36597.05	4749.55	9439.31	7971.66	89.47	87.59	91.99	75.94	68.94	72.83	54.74
Average	5604.87	38539.6678	11108.58	12051.28	3026.718	994.9865	9893.567	410512.1	5036.832609	1820.393	2049.746522	2261.206087

Appendix A4 Simulated Average Monthly Stream Flow (m3/s/month) for 1986 LULC

Year	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1988	58.47	39.7	34.83	21.28	17.33	15.15	34.17	16.06	12.68	11.44	10.85	10.16
1989	30.34	18.04	24.3	12.31	11.88	10.21	20.48	55.75	11.94	8.98	9.51	7.54
1990	57.68	18.99	18.92	59.58	13.22	7.46	6.84	6.9	6.01	6.1	5.3	5.5
1991	4.454	2.727	2.312	4.714	7.946	16.461	112.66	310.10	172.309	57.488	9.804	6.698
1992	35.57	14.67	10.27	10.72	12.91	41.77	8.87	7.47	7.07	5.78	5.43	4.74
1993	47.76	44.75	64.16	25.97	19.21	16.6	15.5	15.53	19.81	14.08	12.71	10.83
1994	76.64	40.34	12.86	11.09	10.41	9.98	8.95	8.76	7.81	8.9	7.04	6.63
1995	15.59	11.97	7.57	7.22	6.35	5.98	9.85	5.26	7.3	4.71	4.09	3.94
1996	73.58	75.85	24.14	23.03	20.88	18.39	16.09	15.21	14.78	12.74	12.05	11.17
1997	8.68	5.02	5.46	3.68	3.75	3.07	27.11	48.44	12.92	6.37	3.63	2.94
1998	26.8	44.52	18.58	19.06	75.66	36.62	13.42	12.66	10.28	9.95	8.63	8.38
1999	20.39	15.73	15.56	10.31	81.96	42.26	99.58	37.66	9.94	8.77	8.16	8.21
2000	41.08	24.75	61.65	22.29	10.67	22.63	13.26	8.16	7.84	9.12	7.12	17.95
2001	19.93	14.7	11.39	21.5	10.13	8.33	8.55	8.07	7.43	5.83	5.37	4.4
2002	15.91	7.83	6.73	7.27	6.78	5.84	5.51	5.31	4.56	4.7	3.91	3.4
2003	27.84	39.24	22.63	15.34	13.65	7.99	7.63	6.67	6.54	6.15	5.4	7.81
2004	36.89	24.71	14.24	13.89	14.18	26.34	10.04	7.92	7.65	6.7	6.2	5.88
2005	25.85	18.71	51	16.83	15.38	12.11	10.22	10.28	8.9	8.33	8.15	7.04
2006	55.07	34.65	32.3	29.17	27.36	20.73	18.83	17.77	17.01	18.38	14.59	12.5
2007	3.912	4.777	4.136	6.966	10.955	102.38	289.99	550.09	404.599	41.037	7.551	5.32
2008	50.52	43.31	17.81	15.95	11.51	29.46	11.9	10.31	10.72	34.43	53.02	30.74
2009	10.98	30.27	11.74	10.28	10.09	22.47	7.91	11.09	7.16	6.46	6.49	5.45
2010	22.22	42.58	23.71	14.38	15.24	11.24	10.26	9.77	8.57	7.64	7.49	6.06
Average	33.31	26.8623	21.57	16.64	18.584	21.455	33.375	51.532	34.07947	13.2210	9.6736956	8.4038260

Appendix A5 Simulated Average Monthly Stream Flow (m3/s/month) For 2000 LULC.

Year	**Jan**	**Feb**	**March**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1988	74.76	47.9	41.11	24.92	17.98	14.29	47.59	17.05	12.81	11.69	11.32	10.71
1989	28.5	15.52	25.58	8.98	8.69	7.96	23.26	81.36	16.88	8.58	10.66	7.37
1990	69.01	21.24	17.65	61.71	13.12	5	5.21	5.99	5.74	6.67	6.13	6.44
1991	4.454	2.727	2.312	4.714	7.946	16.461	112.66	310.109	172.309	57.488	9.804	6.698
1992	41.24	15.37	8.46	13.36	16.23	65.96	9.79	6.82	6.79	5.38	5.53	5.3
1993	55.98	49.57	74.76	33.03	22.77	19.95	19.65	20.57	26.89	18.64	18.28	15.72
1994	76.42	52.99	9.83	8.3	8.5	9.15	8.97	9.59	9.16	11.87	9.08	8.67
1995	13.82	13.6	3.8	3.21	2.73	2.93	7.52	3.25	5.6	4.19	3.85	4.28
1996	77.12	91.07	24.2	24.91	20.83	19.04	17.25	16.84	17.59	15.41	15.3	14.9
1997	10.66	3.44	5.52	2.55	2.32	1.93	20.58	64.24	26.83	5.28	2.98	2.51
1998	29.89	54.62	21.56	21.12	88.61	53.11	17.68	15.28	11.16	10.75	9.58	9.3
1999	25.29	20.48	18.06	10.6	112.1	66.13	100.81	61.28	8.68	6.53	6.58	7.93
2000	46.55	25.91	69.77	27.32	10.2	25.27	14.08	8.64	9.25	13.65	9.39	24.87
2001	22.91	11.59	10.12	25.1	9.87	8.16	8.65	8.64	7.55	6.74	6.78	5.27
2002	16.22	5.1	4.16	5.72	5.72	5.16	5.53	5.93	5.24	5.88	4.95	4.54
2003	33.35	45.76	22.71	19.33	16.07	8.84	9.74	8.3	8.98	9.36	7.98	11.69
2004	46.21	26.16	12.24	9.94	12.32	28.91	10.73	8.32	9.41	8.63	8.78	9.27
2005	19.26	17.74	64.39	15.09	12.72	9.9	7.92	8.88	8.03	7.89	8.33	7.32
2006	60.81	37.81	39.82	35.29	35.44	25.91	23.71	23.64	22	23.4	20.72	17.3
2007	3.912	4.777	4.136	6.966	10.955	102.386	289.99	550.094	404.599	41.037	7.551	5.32
2008	58.17	50.33	23.25	20.97	14.93	39.34	17.47	15.7	16.89	47.35	69.02	47.24
2009	12.53	40.5	15.1	11.79	10.82	24.74	10.15	16.68	10.34	9.79	10.57	9.03
2010	26.04	39.57	30.41	18.59	20.96	14.61	13.9	14.3	12.59	11.69	12.08	9.82
Average	37.091	30.1640	23.86	17.97	20.949	25.005	34.90	55.717	36.318173	15.125	11.9671	10.934695

Appendix A6 Simulated Average Monthly Stream Flow (m3/s/month) for 2010 LULC

Year	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1988	70.91	49.08	45.03	28.24	19.59	16.43	50.07	18.55	14.21	12.75	12.3	11.51
1989	30.2	17.24	28.13	10.87	10.38	9.11	30.24	85.78	16.86	9.5	11.56	7.93
1990	70.55	22.84	19.75	63.83	15.47	7.09	7.05	7.73	7.17	8.07	7.27	7.65
1991	4.454	2.727	2.312	4.714	7.946	16.461	112.66	310.10	172.309	57.488	9.804	6.698
1992	41.22	16.78	9.82	15.82	16.93	67.31	11.09	8.25	8.14	6.59	6.73	6.42
1993	60.89	51.23	81.77	33.93	25.95	22.26	21.53	22.33	27.54	19.98	19.27	16.36
1994	87.04	49.28	11.94	10.19	10.06	10.38	9.93	10.39	9.76	12.65	9.48	9.05
1995	14.83	15.49	5.19	4.57	3.88	4.03	8.63	4.24	6.5	4.97	4.53	4.96
1996	80.38	91.36	27.16	26.84	22.51	20.61	18.23	17.64	18.21	15.77	15.63	15.1
1997	12.9	5.45	7.35	4.14	3.93	3.33	22.93	78.74	21.33	6.06	3.97	3.35
1998	31.66	58.5	23.74	24.65	88.55	56.69	19.44	16.91	12.26	11.9	10.37	9.91
1999	25.69	22.24	19.4	12.32	115.47	66.46	113.4	54.78	10.14	8.38	8.15	9.44
2000	45.47	27.3	69.8	28.65	12.25	27.49	15.91	10.35	10.85	14.8	10.48	25.72
2001	25.52	12.6	11.09	25.89	10.58	8.69	9.31	9.32	8.01	7.11	6.96	5.41
2002	18.27	6.9	5.82	7.07	7.35	6.65	6.92	7.27	6.43	7.13	5.99	5.44
2003	35.82	46.32	24.67	20.38	17.42	10.51	11.35	9.75	10.4	10.72	9.2	12.38
2004	47.43	27.26	14.29	12.47	14.29	30.8	12.15	9.72	10.71	9.67	9.69	10.13
2005	20.45	21.71	68.6	15.83	14.19	11.39	9.12	9.91	8.77	8.45	8.85	7.64
2006	63.21	41.26	43.28	36.01	37.85	27.2	24.96	24.83	22.9	24.27	21.41	17.78
2007	3.912	4.777	4.136	6.966	10.955	102.38	289.99	550.09	404.599	41.037	7.551	5.32
2008	60.25	52.43	25.38	22.53	16.62	39.61	19.05	16.82	18.12	50.11	70.5	49.69
2009	14.15	45	15.96	13.26	12.52	26.28	11.46	17.24	11.39	10.67	11.34	9.62
2010	28.24	40.78	31.68	19.63	21.66	15.23	14.35	14.74	12.87	11.92	12.26	9.82
Average	38.845	31.676	25.926	19.513	22.450	26.365	36.947	57.195	36.933826	16.0867	12.751956	11.622956

Appendix A7 Soil parameters Used for Model Simulation

OBJECTID	MUID	SEQN	SNAM	S5ID	CMPPCT	NLAYERS	HYDGRP	SOL_ZMX	ANION_EXCL	SOL_CRK	TEXTURE	SOL_Z1	SOL_BD1	SOL_AWC1	SOL_K1
218	VT023	11	Eutric fluvisols	NY0006	3	3	D	1800	0.5	0.5	CL-CL	600	1.13	0.22	6.6
219	VT023	13	Eutric nitisols	ME0017	3	1	B	1500	0	0	C-CL	1816	1.35	0.1	65.9
220	VT023	16	Leptosols	VT0008	1	1	A	500	0	0	SCL	500	1.44	0.19	287
221	VT025	8	Pellic vertisols	CT0014	3	3	D	1800	0.5	0.5	CL-SCL	600	1.35	0.2	7.9
222	VT025	11	Vertic cambisols	NY0025	3	1	B	1320	0.01	0	C	1320	1.12	0.14	0.39
223	VT021	16	Chromic vertisols	NY0096	3	3	C	1800	0.5	0.5	CL-SCL	600	1.25	0.16	37

SOL_CBN1	CLAY1	SILT1	SAND1	ROCK1	SOL_ALB1	USLE_K1	SOL_EC1	SOL_Z2	SOL_BD2	SOL_AWC2	SOL_K2	SOL_CBN2	CLAY2	SILT2	SAND2
3.49	13	42	25.8	0.2	0.01	0.32	0	1200	1.45	0.22	0.65	1.02	30	39	31
1.9	50	23	27	0	0.14	0.25	0	0	0	0	0	0	0	0	0
1.8	35	38	27	0	0.13	0.21	0	0	0	0	0	0	0	0	0
5.81	76	8	16	0	0.01	0.49	0	1200	1.35	0.15	0.23	1.94	70	11	19
2.2	42	30	28	0	0.1	0.38	0	0	0	0	0	0	0	0	0
2.33	46	21	33	0	0.01	0.28	0	1200	1.35	0.14	5.5	0.78	75	17.58	7.42

ROCK2	SOL_ALB2	USLE_K2	SOL_EC2	SOL_Z3	SOL_BD3	SOL_AWC3	SOL_K3	SOL_CBN3	CLAY3	SILT3	SAND3	ROCK3	SOL_ALB3	USLE_K3
1	0.03	0.49	0	1800	1.6	0.16	0.33	0.15	41	24	35	2	0.17	0.49
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0.01	0.49	0	1800	1.35	0.13	0.12	0.65	79	7	14	0	0.07	0.49
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0.05	0.28	0	1800	1.35	0.08	33	0.26	75	17.58	7.42	0	0.14	0.28

SOL_EC3	SOL_Z4	SOL_BD4	SOL_AWC4	SOL_K4	SOL_CBN4	CLAY4	SILT4	SAND4	ROCK4	SOL_ALB4
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	787.4	2.5	0.01	400	0.09	5	25	70	0	0.2

Appendix A8 Measured Average Monthly Sediment Used for Model Calibration and Validation

year	Jan	Feb	March	April	May	June	July	August	Sep	Oct	Nov	Dec
2001	13.03	6.94	150.4	12.1	36.67	200.16	4706.7	2011046	54538.1	771.42	183.86	48.02
2002	17.88	8.25	12.55	11.29	8.48	227.22	1333.7	26573.1	949.23	131.52	32.13	9.8
2003	5.77	5.75	16.4	3442.43	48.4	270.16	38376	2016467	45165.5	920.31	190.81	66.69
2004	31.07	12.76	27.31	92.92	18.29	85.75	668322 .	337840	6378.74	470.53	90.46	28.78
2005	19.41	8.96	73.05	480.89	3627.3	1116.9	109416	118048.	16526.32	571.54	154.12	34.09

Appendix A9 Measured Average Monthly Stream Flow Used for Model Calibration and Validation

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2001	5.99	1.54	2.84	2.64	4.92	34.29	160.28	160.25	104.81	48.96	26.01	14.08
2002	12.27	5.08	14.39	7.2	3.47	11.95	57.95	128.12	51.1	30.08	6.62	2.05
2003	1.89	1.06	2.82	4.41	3.48	14.17	122.38	147.39	105.21	8.87	2.85	2.26
2004	2.14	1.44	1.38	8.79	10.16	17.81	45.09	87.08	64.77	11.24	3.23	2.1
2005	1.92	1.45	7.47	4.8	44.85	34.14	132.97	128.03	124.93	19.55	3.39	11.46
2006	1.71	1.29	5.53	9.6	18.28	19.56	135.76	4.28	3.4	7.16	3.13	2.1
2007	1.46	1.97	1.54	2.69	4.09	39.5	108.27	205.38	156.1	15.32	2.91	1.99
2008	1.38	0.98	0.67	1.11	1.97	9.18	124.8	218.01	112.06	5.96	8.14	2.67

Appendix A10 Average Annual Precipitation.

year	Ginchi	Boneya	Teji	Addis Ababa	Dertu Liben	Gurada Meta
1986	1444.9	856.09	998.6	1236.7	1022.3	718.4
1987	1292.2	1106	821.32	1317.9	754.8	911.9
1988	1417.4	918.34	1152.8	1202.6	1012.3	941.5
1989	1486.4	955.9	898.2	1321.3	800.5	667.1
1990	1125.6	1127.57	990.8	1124.6	1008.4	1113.4
1991	893.4	1096.7	961	1167	709.7	709.7
1992	1023.6	858.7	962	1101.4	703.4	879.2
1993	1463	881.3	1093.6	1567.9	797	1308.382
1994	1173.5	811.2	866.1	1042.5	643.5	871.3
1995	991.8	706.2	786.8	1148.1	781.4	850.6
1996	1249.8	1146.5	946.1	1548.5	1198.1	1377.5
1997	1029.2	497.3	794.7	952.4	824	565.6
1998	1226.5	718.9	1135.7	1337.7	1072.2	1088.7
1999	1135.5	679.9	833.8	943	869.6	848.9
2000	993.2	583.9	866.1	1191.1	726.8	1093.4
2001	1102.6	632.4	872.5	1452	846.3	1130.5
2002	1047.4	489.4	811.1	1176.4	571.4	971.4
2003	1082.8	575.6	1082	1210.3	998.2	1286.5
2004	1133.3	389.8	941.9	1192	536.9	998.6
2005	1148.3	557.31	1112.6	1128.6	853.5	1258
2006	2152.6	1061.67	1170.9	1190.4	974.4	1411
2007	1090.7	1024.69	969.3	1236.7	898.8	1483.1
2008	1024.1	790.8	806.5	1284	646.9	1399.1
2009	940.4	808.82	809.6	1038.5	443.8	1240.52
2010	1211.4	1003.69	1225.7	1137.1	534.8	1639.6

Appendix A11 hydrological parameter used for preparing weather generator file

Month	**Jan**	**fab**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
TMPMX	23.86	24.76	24.95	24.34	24.89	23.17	21.1	20.94	21.73	22.68	23.13	23.23
TMPMN	8.84	10.19	11.69	12.11	12.29	11.4	11.28	11.32	11.07	10.07	8.75	8.32
TMPSTDMX	1.3878	1.8135	1.9705	2.1357	1.9032	2.0506	1.6495	1.4932	1.3655	1.1982	1.0799	1.1944
TMPSTDMN	1.9501	1.8911	1.3812	1.1006	1.1097	1.0234	0.8852	0.9185	1.0738	1.493	1.6697	1.7536
PCPMM	10.8	38.91	72.04	94.84	98.82	146.52	258.1	274.34	162.9	39.46	6.38	6.84
PCPSTD	2.2505	4.8946	7.1194	7.8897	7.4567	6.9979	8.7964	9.4592	8.7079	5.2013	1.5858	2.2612
PCPSKW	9.1029	5.6531	6.0898	5.0013	3.2227	2.4073	1.7162	2.0455	2.4818	7.8768	10.354	16.135
PR_W1	0.0399	0.1163	0.2029	0.2956	0.249	0.473	0.8507	0.7846	0.4375	0.1037	0.0334	0.031
PR_W2	0.3673	0.5442	0.4781	0.5584	0.57	0.7765	0.887	0.893	0.7287	0.4797	0.25	0.2813
PCPD	1.96	5.88	9.12	12.68	11.72	21.12	28.32	28.4	19.76	5.92	1.28	1.28
RAINHHMX	5.4	19.455	36.02	47.42	49.41	73.26	129.05	137.17	81.45	19.73	3.19	3.42
SOLARAV	28.3232	29.5768	30.374	29.06	29.2032	25.4224	23.2424	24.1736	26.3132	30.5628	29.656	28.490
DEWPT	9.96	11.61	11.89	12.46	10.86	12.95	13.75	13.82	13.18	9.81	8.65	9.15
WNDAV	0.678	0.728	0.7632	0.6972	0.6804	0.4408	0.354	0.3232	0.4244	0.7156	0.7296	0.6948

Appendix A12 Accuracy assessment of LULC mapping.

Class Name	1986		2000		2010	
	Pro.Acc (%)	Use.ACC (%)	Pro.Acc (%)	Use.ACC (%)	Pro.Acc (%)	Use.ACC (%)
Agriculture	98	80	100	100	100	100
Bare Land	75.47	81.25	78.95	89.75	72.43	81.89
Urban	86.61	100	100	100	100	100
Forest	87.79	80	97.14	89.47	94.44	85
Water	100	100	_	_	_	_
Overall Acc.	85%		88%		85.42%	
Kappa Stat.	0.8183		0.8756		0.8258	

Appendix A13 Selected Parameters for both sediment Calibration and validation

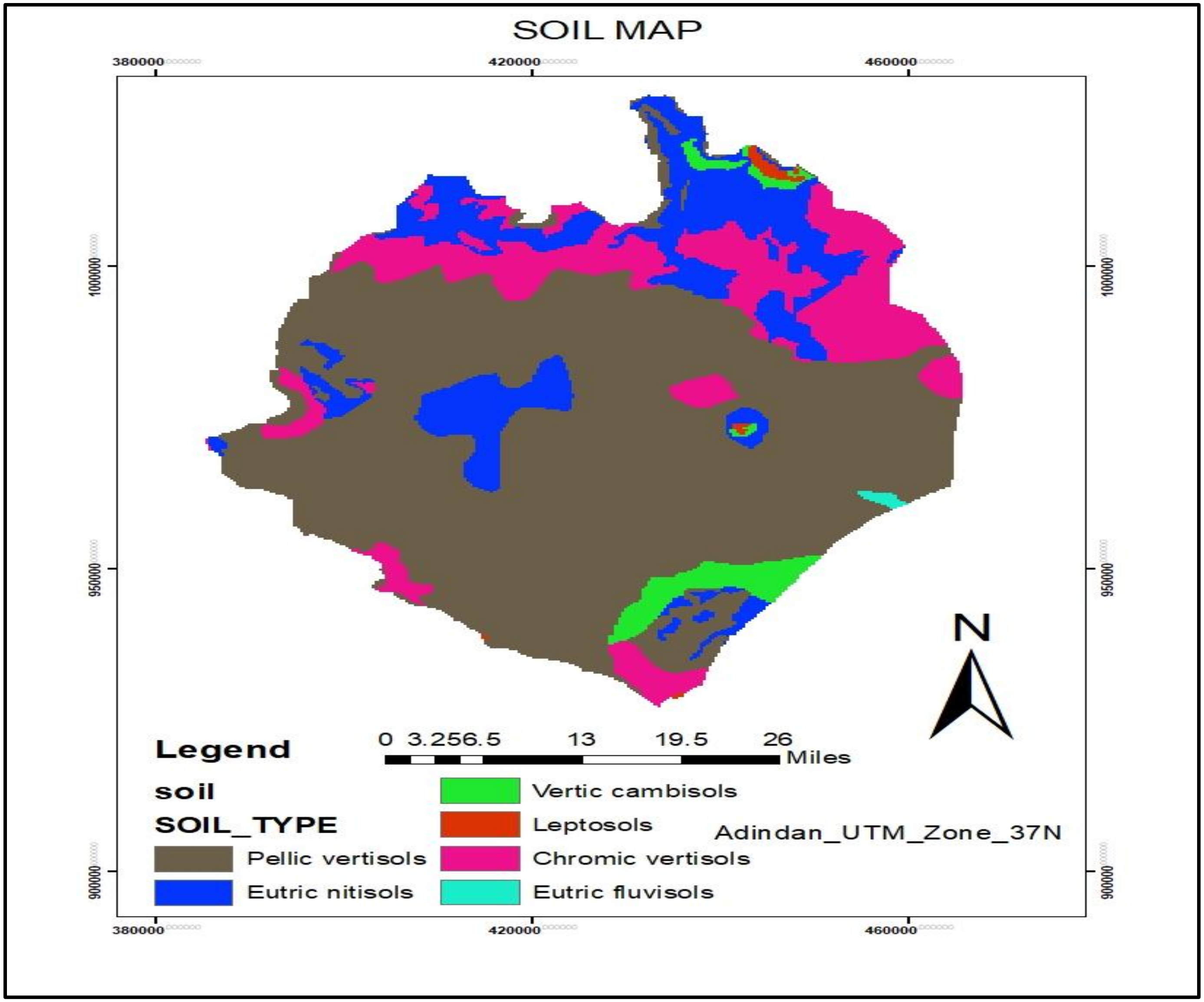
S/N	Parameter Name	Description of parameters	Range of Value
1	CN2.mgt	SCS runoff curve number	(35-98)
2	ALPHA_BF.gw	Base flow alpha factor	(0-1)
3	SPCON.bsn	Linear parameter calculating the (max) sediment	(0.0001-0.01)
4	USLE_K.sol	USLE equation soil erodibility (K) factor	(0-0.6)
5	USLE_P.mgt	USLE equation support practice factor	(0-1)
6	BIOMIX.mgt	Biological mixing efficiency	(0-1)
7	SPEXP.bsn	Exponent parameter for calculating sediment	(1-1.5)
8	CH_ERODMO.rte	Channel erodibility factor	(0-1)
9	CH_COV2.rte	Channel cover factor	(0.001-1)
10	LAT_SED.hru	Sediment concentration in lateral flow	(0-5000)
11	CH_EQN.rte	Sediment routing method	(0-4)
12	EROS_SPL.bsn	The splash erosion coefficient	(0.9-3.1)
13	ADJ_PKR.bsn	Peak rate adjustment factor for sediment rout	(0.5-1)

Appendix A14 Selected Parameters for both stream flow Calibration and validation

S/N	**Parameter**	**Description of Parameter**	**Ranger var**
1	CN2	SCS runoff curve number	35-98
2	ALPHA_BF	Base flow alpha factor	0-1
3	ESCO	Soil evaporation compensation factor	0-1
4	CH_N2	Manning? s "n"value for the main channel	-0.31
5	SULAGR	Surface runoff lag time	0.05-24
6	GW_DELAY	Ground water delay	0-500
7	GW_REVAP	Groundwater revap coefficient	0.02-0.2
8	SOL_Z	Soil depth (for each layer)	0-3500
9	SOL_AWC	Available water content of soil	0-1
10	SOL_K	Saturated hydraulic conductivity(mm/hr)	0-2000
11	CH_K2	Effective hydraulic conductivity in the main channel	0.025-250
12	BIOMIX	Biological mixing efficiency	0-1
13	EPCO	Plant uptake compensation factor	0-1
14	OV_N	Manning's "n" value for overland flow.	0.01-30
15	REVAPMN	Threshold depth of water in the shallow	0-500

Appendix A15 Soil map of Melka Kunture Watershed

Different soils have different soil erodibility factor, hydraulic conductivity, infiltration capacity etc that affects the water balance and sediment yield from the watershed. SWAT model requires different soil textural and physicochemical properties such as soil texture, available water content, hydraulic conductivity, bulk density and organic carbon content for different layers of each soil type. Basic physical and chemical properties of major soil types in watershed were collected from the Ministry of Water and Energy (MoWE).The soil map obtained from MoWE was projected to Adindan UTM Zone37N using the raster projection in ArcMap before it was imported to ArcSWAT. The physical properties of the soils in Study Area basin will have been extracted from FAO (1998) world soil database. Major soil types in the watershed are Chromic Luvisols, Eurotic Leptosols, Eurotic Vertisols and Haplic Nitisots. The value of different soil parameters (properties) for each soil are listed in Appendix A7. .



SOIL MAP
380000
420000
460000
1000000
950000
900000
0 3.256.5 13 19.5 26
Miles
N
Legend
soil
SOIL_TYPE
Pellic vertisols
Eutric nitisols
Vertic cambisols
Leptosols
Chromic vertisols
Eutric fluvisols
Adindan_UTM_Zone_37N