JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Impacts of land use/ land cover Change on sediment yield and stream flow to Reservoirs.
Case Study on Finchaa Hydropower Reservoir, Ethiopia.

A thesis submitted to the School of Graduate Studies of Jimma University in Partial fulfillment of the requirements for the Degree of Masters of Science in Hydraulic Engineering

By

Megersa Kebede Leta

November, 2015

Jimma, Ethiopia

JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Impacts of land use/ land cover Change on sediment yield and stream flow to Reservoirs.
Case Study on Finchaa Hydropower Reservoir, Ethiopia.

A thesis submitted to the School of Graduate Studies of Jimma University in Partial fulfillment of the requirements for the Degree of Masters of Science in Hydraulic Engineering

By

Megersa Kebede Leta

Advisor: Dr.-Ing. Tamene Adugna (PhD)

Co-Advisor: Sifan Abera (MSc)

November, 2015

Jimma, Ethiopia

Impacts of land use/ land cover Change on sediment yield and stream flow to Reservoirs.

Case Study on Finchaa Hydropower Reservoir, Ethiopia.

A thesis submitted to the School of Graduate Studies of Jimma University in Partial fulfillment of the requirements for the Degree of Masters of Science in Hydraulic Engineering

By

Megersa Kebede Leta

APPROVED BY BOARD OF EXAMINERS

Dr.-Ing. Tamene Adugna	---------------------	--------------------
(Advisor)	Signature	Date
Mr. Sifan Abera	----------------------	--------------------
(Co-Advisor)	Signature	Date
Prof. Dr.-Ing. Alemayehu Gebissa	--------------------	--------------------
(External Examiner)	Signature	Date
Mr. Mamuye Busier	----------------------	--------------------
(Internal Examiner)	Signature	Date
Mr. Dawud Temam	----------------------	--------------------
(Chairman)	Signature	Date

DECLARATION

I, the undersigned, declare that this thesis proposal entitled "**Impacts of land use/ land cover Change on sediment yield and stream flow to Reservoirs. (Case Study on Finchaa Hydropower Reservoir, Ethiopia.)"** Is my original work, and has not been presented by any other person for an award of a degree in this or any other University.

Megersa Kebede Leta

Signature: _______________ Date ________________

CERTIFICATION

I, the undersigned, certify that I read and hereby recommend for the acceptance by the Jimma University a dissertation entitled: "**Impacts of land use/ land cover Change on sediment yield and stream flow to Reservoirs. (Case Study on Finchaa Hydropower Reservoir, Ethiopia.)"** In partial fulfillment of a degree of Masters of Science in Hydraulic Engineering.

Dr.-Ing. Tamene Adugna	----------------------	-------------------
(Advisor)	Signature	Date
Sifan Abera	----------------------	-------------------
(Co-Advisor)	Signature	Date

DEDICATION

I dedicate this work to my family with love!!

ABSTRACT

Throughout the world, Land use/ land cover change impact on the reservoir is the main concern for sustainability of water management and water use activities. Changes in land use/ land cover is a fundamental variable that impacts on, and links many parts of the global environment. The effects of land use/ land cover changes and improper management systems have played a significant role in causing high soil erosion rates, sediment transport and affects life expectancy of the reservoir and have an impact on the water balance of the catchment by changing the magnitude and pattern of runoff, peak flow, sediment yield and ground water levels.

The Finchaa watershed has an area of about 2863km^2. For the analysis of land use/ land cover change in the Finchaa watershed the Geographic Information System (GIS) version based Soil and Water Assessment Tool (SWAT) has been used to evaluate sensitivities and patterns of land use/ land cover changes in the Finchaa sub-basin. The aim of this study is to evaluate the possible impacts of land use/ land cover Changes on sediment yield and stream flow to Finchaa hydropower reservoir, located in western Oromia Regional state, Ethiopia, Upper Blue Nile Basin.

The required input data for this study were Digital Elevation Model, Land use/ land cover map, soil map and data, stream flow data and weather data. After the data was collected, an analysis of all the collected data was made. Model calibration and uncertainty analysis were performed with sequential uncertainty fitting (SUFI-2) that is linked with SWAT in calibration Uncertainty program known as SWAT-CUP. The calibration process was used to calibrate the model parameters using time series data from 1990 to 2002 and data from 2003 to 2011 were used to validate the model using the input parameters.

Twelve flow parameters were the most sensitive parameters for the stream flow of the study area and used for the model calibration and validation. Calibration and validation of the SWAT against streamflow in the Finchaa reservoir attained a coefficient of determination (R^2) and Nash- Sutcliffe (NS) were used to evaluate the performance of the model monthly. Flow calibration gives coefficient of determination and Nash-Sutcliffe simulation efficiency 0.83 & 0.74 respectively. Flow validation gives 0.86 & 0.83 for coefficient of *determination and Nash-Sutcliffe values respectively. This result indicates that the observed values show good agreement with simulated value for stream flow.*

Land use change scenarios were generated for four scenarios based on socio-economic data and physical factors influencing the land use. The results of the Evaluation of land use/land cover changes in Finchaa watershed show that land use changes can have significant impacts on the Finchaa reservoir. From scenario simulation it was observed that extreme deforestation (0% forest cover) likely due to growth in urbanization, agriculture etc. exhibited an increase of about 0.210% in the water yield and 57.361% in the sediment yield from base conditions. In case of afforestation (100% forest cover) scenario the sediment yield decreased by about 16.207% and 0.160 % water yield.

Therefore, various land use mitigation measures were further evaluated based on economic analysis as adaptation options to mitigate the land use/ land cover change impacts and appropriate soil conservation measures based on suitable afforestation techniques can prove influential in mitigating the risk of soil erosion in this Finchaa watershed. Understanding how changes in individual land use types influence the dynamics of streamflow and sediment yield would greatly improve the predictability of the hydrological consequences of land use changes and could thus help stakeholders to make better decisions.
Keywords: Finchaa Watershed, Hydrological Modeling, Land Use/land cover Change, Sediment yield, SWAT.

ACKNOWLEDGMENT

First and above all I would like to thank the Almighty GOD for his guidance and grace upon me and for giving me the courage, wisdom and strength to walk unpaved way to reach this point in life during all my works and His provision to complete this work.

My sincere and special thanks go to my advisor Dr.-Ing Tamene Adugna for his supervision, encouragement, unreserved assistance, constructive and timely comments and all rounded support he has provided me at all stages of my work. I would also like to thank my Co-advisor Sifan Abera for making this work possible. I am very grateful for his guidance, support and for supplying me relevant materials to carry out the research.

My gratitude also goes to the Ethiopian Road Authority (ERA) for their Financing of this program and supporting all times with work in partnership course carried out as part of agreements signed between Ethiopian Road Authority and Jimma University.

My special and great thanks goes to my beloved families who have been providing me with their love, support and encouragement the Necessary help during my academic careers. Without their consistent help and advice this wouldn't be real I am very proud to be part of such beautiful family.

My special gratitude go to Ethiopian National Meteorological Service, Ministry of Water and Energy of Ethiopia for providing me the necessary input data during my study. Finally, my thanks and my warm feeling of appreciation to all my friends and relatives who have helped me in any form of support which are greatly needed for the advancement and completion of this work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

ARS	Agricultural Research Services
95PPU	95% Prediction Uncertainty
DEM	Digital Elevation Model
Dew02	Dew Point Temperature Calculator
DMC	Double mass curve
DWSM	Dynamic Watershed Simulation Model
EPIC	Erosion-Productivity Impact Calculator
ERA	Ethiopian Road Authority
ET	actual evapotranspiration
FAO	Food and Agriculture Organization
GCM	General circulation model
GIS	Geographical Information System
HRU	Hydrologic Response Unit
HSPF	Hydrologic Simulation Program-Fortran
IHDP	International Human Dimension Program
IPCC	Intergovernmental Panel on Climate Change
Km	Kilometer
kPa	Kilo Pascal
LULC	Land Use/ Land Cover
LULCC	Land Use/ Land Cover Change
m	Meter
masl	Meter above sea level
mm	Millimeter
MUSCLE	Modified Universal Soil Loss Equation
MW	Mega watt
NS	Nash-Sutcliffe Efficiency
OADB	Oromia Agriculture Development Bureau
PCP	Precipitation
PCP STAT	SWAT Precipitation input preprocessors

PET	Potential Evapotranspiration
R^2	Coefficient of Determination
RS	Remote sensing
SCRP	Soil conservation research program
SCS	Soil Conservation Service
SMDR	Soil Moisture Distribution and Routing
SUFI-2	Sequential Uncertainty Fittings 2
SWAT	Soil and Water Assessment Tool
SWAT-CUP	Soil and Water Assessment Tool- Calibration and Uncertainty Programs
USDA	United States Department of Agriculture
USDA-SCS	United State Department of Agriculture-Soil Conservation Service
WCD	World Commission on Dams
WGEN	Weather Generator

1. INTRODUCTION

1.1. Background

Land and water are the two most valuable and vital resources essentially required not only for sustenance of life but also for the economic and social progress of the country throughout the world and it is strongly affected by anthropogenic influences. Land use planning and management are closely related to the sustainability of water resources as changes of land use are linked with amount of water through relevant hydrological processes (Guo, et al., 2008). General statements about 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 (FAO, 2002).

Land use/ land cover change (LULCC) is a major issue of global environment change (Prakasam, 2010). Especially in fast changing developing countries, it is a scientific challenge to predict land use/ land cover changes and their effects on water availability, flood risk and erosion rates which have agriculture based economics and rapidly increasing populations. LULC changes some hydrological factors, such as interception by vegetation, soil water content and surface evapotranspiration; therefore, the hydrological regime and rainfall-runoff mechanisms are also changed (Li, et al., 2007). Land-use changes are known to impact the hydrology of the catchment area and have been singled out as the main contributing factors to sedimentation of reservoirs (Hundecha and Bardossy, 2004).

LULCC, Climate change and global warming is the most significant threat to the reservoir and living things in this planet. The changes of Land use/land cover has been responsible for fluctuating the hydrologic response of watersheds leading to impacting river flows and is one of the main drivers of hydrological change. The land use and land cover changes are caused by a number of natural and human driving forces (Meyer and Turner, 1994). Natural effects such as climate changes are only over a long period of time, high intensity of rainfall and steep relief (Lakew, et al., 2000) and soil types, whereas the human effects are immediate and often direct. Out of the human factors, population growth is the most important in Ethiopia (Tekle and Hedlund, 2000), as it is common in developing countries.

Today the land cover changed due to human induced factors is mainly agricultural expansion, burning activities or fuel wood consumption, deforestation, expansion of grazing land, some construction works and urbanization which cause land cover changes. Land use and land cover dynamics are widespread, accelerating, and significant processes driven by human actions but also producing changes that impact humans (Agarwal, et al., 2002). The increase in population growth, economic development and climate change have been proven (IPCC, 2007) to cause rise in water demand, necessity of improving flood protection system and drought (Water scarcity).

The poor land use practices, improper management systems and lack of appropriate soil conservation measures have been major causes of soil erosion and land degradation problems in the country. Because of the rugged terrain, the rates of soil erosion and land degradation in Ethiopia are high. For more than 34% of the land area of Ethiopia the soil depth is already less than 35 cm (Zemenfes, 1995)and (SCRP, 1996). Ethiopia loses about 1.3 billion metric tons of fertile soil every year and the degradation of land through soil erosion is increasing at a high rate (Hurni, 1989). These call for immediate measures to save the soil and water resources degradation of the country.

Africa is experiencing rapid and substantial social, economic, climatic and environmental change (IPCC, 2007). Ethiopia experiences persistent land, water and environmental degradation due to localized and global climatic variances. Land use dynamics is one of the major environmental problems in Ethiopia (Berhan, 2010). Land degradation includes all process that diminishes the capacity of land resources to perform essential functions and services in ecosystems (Hurni, et al., 2010) and results in high erosion problems. Soil erosion is a worldwide environmental problem that degrades soil productivity and water quality, causes sedimentation of reservoirs and increases the probability of floods (Oyung and Bartholic, 2001). Sediment may cause severe damages depending on the amount, character, and place of deposition.

Man- made reservoirs usually satisfy multiple objectives including flood control, irrigation, hydropower generation, water supply, boating, fishing and recreation. The reservoir sedimentation is a serious offsite consequence of soil erosion that threatens the sustainability of dams built for various purposes in many parts of the world as well as throughout Ethiopia with different climatic conditions. It depends on the river regime, flood frequencies, reservoir geometry and operation, sediment consolidation, density current, and possible land use change over the life expectancy of reservoir. The magnitude of changes on the streamflow due to land use changes varies with catchments and other factors such as climate change and human activities.

Streamflow is crucial for both ground and surface water resources and is the main hydrological factor which influences the hydrological characteristics in many ways. Streamflow generation at different spatial and temporal scales can be generally seen as a complex interaction of terrestrial factors such as watershed geomorphology, soil type, vegetation and land use, with atmospheric factors (precipitation, temperature, air humidity, wind, etc.), and the spatial and temporal variability of the aforementioned variables. Hence, assessing vulnerability to LULCC impacts and preparing adaptation options as a part of the entire program is very crucial for the country. Given that impacts of LULCCs on water resources are the result of complex interactions between diverse site- specific factors and offsite conditions, standardized types of responses will rarely be adequate (Tsegaye, 2006).

Blue Nile Basin is one of the largest basins in the country with high population pressure, degradation of land and highly dependent on agricultural economy (Tsegaye, 2006). The Blue Nile Basin is generally divided in to 16 Sub-basins (Finchaa, Lake Tana, N. Gojam, Beshil, Welaka, Jemma, S. Gojam, Muger, Guder, Didessa, Anger, Wenbera, Dabus, Beles, Dinder, Rehad) according to their configuration in topology, among them Finchaa Sub-basin is one of the primary sub-basin which experiences LULCC and the lack of advanced water infrastructure to use the full potential of available water resources. Therefore, the study of the various impacts of LULCC on reservoirs over the coming century has become a priority, for watershed management and development strategies.

Hydropower generation plays a significant role for the sustainable economic growth of Ethiopia. The major drivers of the erosion and sedimentation problems are the land-use changes that have been induced by Finchaa dam, coupled with population growth. On most steep parts of the basin as well as in Finchaa watershed, the soil has become shallow, which means that any further soil loss might lead to reduced soil productivity, threaten farmers' food security, and increase offsite reservoir sedimentation. The removal of vegetation cover on steep slopes will have reduced rainfall infiltration and probably also groundwater recharge.

The implementation of this reservoir generates power, irrigate land for sugarcane and minimize the food scarcity from the surrounding area. The major purpose of this study is to investigate the impacts of LULCCs on sediment yield and stream flow to hydropower reservoir of Finchaa. Models are generally used as efficacy in various areas of water resource development, in assessing the available resources, in studying the impact of human interference in an area such as LULCC, deforestation and change of watershed management.

1.2.Statement of the problem

Land use/ land cover change is the sever problem that the whole world facing today and the most crucial research agenda in worldwide level (Yang, et al., 2003). Throughout the world, LULCC impacts are the main concern for sustainability of water management and water use activities. This is because it is often induced by changes in population trends and economic environments, and can be intimately linked to other forms of change, including changes in climate and accelerated land degradation. It is now widely accepted that LULCC is already happening and further change is inevitable. The impacts of land use change on the reservoir and water resources are mainly reflected in changes in the water cycle, water quantity and water quality (Shi, et al., 2000).

It has been clearly seen that LULC has huge influence to impose on the water availability of the reservoirs by bringing a change in the magnitudes of the hydrologic components of the reservoirs. With respect to available water resources, any LULCC may affect the hydrological cycle and its water balance terms. For instance, changes in precipitation and temperature will have direct impact on the processes of runoff production. Deforestation, overgrazing, and poor land management accelerated the rate of erosion. Total land area affected by soil erosion all over the world is 1,094 Mha of which 43% suffer from deforestation and the removal of natural vegetation, 29% from overgrazing, 24% from improper management of the agricultural land and 4% from over-exploitation of natural vegetation (Walling and Fang, 2003).

Soil erosion is a serious problem in Ethiopian highland areas, threatening and agricultural sector and causing increased sedimentation of reservoirs and lakes. Soil erosion is a major watershed problem in many developing countries including Ethiopia (Awulachew, et al., 2008). Ethiopia has ample water resources, which can be appropriately utilized to enhance socio-economic development of its people. Due to under-development of this resource among others, the people of Ethiopia have been exposed to major problems such as impacts of drought and flood, land use change, shortage of clean water supply and inadequate energy supply (Hailemariam, 1999). Soil erosion is one of the most serious land degradation problems all over the world. At the global scale, soil erosion is the dominant agent of soil degradation (Lal, 2001) and (Morgan, 2005) accounting for between 70 and 90% of total soil degradation (Lal, 2001).

In Ethiopia the construction of dams has caused social, environmental and economic problems by increasing the relocation of communities against their will and inducing watershed land degradation (Bezuayehu, 2006). Many farmers in Ethiopian highlands cultivate Sloped or hilly land, causing topsoil to be washed away during the heavy rains of the rainy Season. The projected change in the mean rainfall will affect the streamflow. In addition, the projected increase in the intensity of rainfall has a significant impact on soil erosion rates (Nearing, et al., 2004). High intensity rain storms cause significant erosion and associated sedimentation, increasing the cost of operation & maintenance and shortening lifespan of water resources infrastructure (Tamene, et al., 2005). Land use/ land cover changes alter regional hydrologic conditions and results in a variety of impacts on water resource systems (Schilling, et al., 2008).

Although LULCC is expected to have adverse impacts on hydropower reservoir and socio economic development globally, the degree of the impact will vary across nations. It may have far reaching implications to Ethiopia for various reasons, mainly as its economy largely depends on agriculture (Hurni, 1990). Thus, changes in LULC have occurred at all times in the past, are presently ongoing, and are likely to continue in the future (Fu C, 2003). Many Reservoirs around the world are losing on average about one percent of their storage capacity annually causing serious problems for Hydropower, irrigation, water supply and flood control due to sedimentation (WCD, 2000). Hydropower projects would be affected by changes in LULC, particularly by regional LULCC.

The problem of land degradation is a threat and devastating challenge to the Finchaa hydropower reservoir and downstream areas due to generating high runoff discharges and imposing huge sediment yield, which may result in reducing water storage capacity of the dam reservoir, unless the upper watershed is treated with appropriate watershed management interventions and strategies. Finchaa hydropower reservoir is a highland area with a severe soil erosion problem that drains to the Blue Nile River and has inundated large areas with different land use types and driven people from their original places of settlement. The development of Finchaa dam and Finchaa Sugar Estate have caused land use changes and probably aggravated the rate of environmental degradation downstream of Finchaa watershed in general. The total amounts of runoff volume and sediment yields annually leaving the watershed are not easily quantified.

Therefore, to address the above situation, watershed management is one of the most important approaches, which helps to reduce land degradation, increase vegetation cover, and increases the productivity of the watershed area (EFAP, 1994). A proper investigation of the sediment and runoff yield of the catchment is essential for management of sedimentation and utilization of water resource. If these are not investigated the life of Finchaa hydropower reservoir is shortened by sedimentation. Therefore, assessing the possible impact of LULCC on the hydropower reservoir event is essential for future development as well as for managing the current reservoir development projects in adaptive way in Finchaa.

1.3. Objectives of the study

1.3.1. General Objective

The general objective of this study is to investigate the impacts of land use/ land cover Changes on sediment yield and stream flow to hydropower reservoir of Finchaa using Geographic Information System based version of the Soil and Water Assessment Tool.

1.3.2. Specific objectives

In order to achieve the main objective of the study, the following specific objectives are set for major indicators of the study.

- ❖ To calibrate and validate the hydrologic SWAT model based on a stream flow data.
- ❖ To evaluate the effects of land use/ land cover changes on sediment yield and stream flow to hydropower reservoir.
- ❖ To develop the adaptation options to mitigate the adverse impacts of the land use/ land cover changes on the reservoir.

1.4.Research Questions

In order to meet the research objectives of the study, the research questions of the study are:

1. How to calibrate and validate the hydrologic model of SWAT was based on stream flow data?
2. How to evaluate the effects of land use/ land cover changes on sediment yield and stream flow to hydropower reservoir?
3. What are the adaptation options to be taken to mitigate the adverse impacts of land use/ land cover change on the reservoir?

1.5.Significance of the study

The land use and land cover change has significantly impacts on natural resources, socio-economic and environmental systems. However, to assess the effects of land use and land cover change on stream flow and sediment yield, it is important to have an understanding of the land use and land cover patterns and the hydrological processes of the watershed. The major significant of this study is, it allows the planners, decision makers and any concerned persons to understand the consequences of LULCCs on hydrological variables and the impacts these have on hydropower reservoirs, water resource planning management and accordingly device decision and management support tools.

The thesis is also believed to have a special contribution in identifying the impacts of land use/ land cover types on the reservoir and to address. Furthermore; it helps to identify the land use/ land cover type used to mitigate the effects of land use/ land cover on stream flow and sediment yield. Therefore, evaluating the different approaches in achieving Land use/ Land cover sustainability and selecting those approaches will result in sustainable Land use/ Land cover services in order to forward these approaches to organizations that implement these services.

1.6.Scope of the study

The study attempts on the impact of LULCC on sediment yield and stream flow to hydropower reservoir. Since it is not possible to cover the whole aspects of the study area, it is advisable to limit the scope of the problem to a manageable objective. Hence, the scope of this study attempts to address the method how to minimize the land from the erosion which is produced or wearing away of the land surface by the action of water, wind, and gravity. The study indicates the way of evaluating the impact of LULCC on the storage capacity of reservoirs by using Soil and Water Assessment Tool (SWAT).

1.7.Organization of the Thesis

The thesis contains five chapters organized as: Chapter one was an introduction section where the background, statement of the problem, objectives of the study, research questions, significance and scope of the study were discussed. In Chapter two, review of related literatures where the definition and concepts of land use and land cover changes, land use and land cover changes in Ethiopia, hydrological models, an Introduction to SWAT model, application of SWAT model were reviewed. In the third Chapter. Data and methodology section in which Description of the study area, materials used and methods followed, Collection of input data and analysis, input data preparation, model setup, sensitivity analysis, model calibration and validation, model performance evaluation and land use/ land cover change scenarios were elaborated. The fourth Chapter describes with the result and discussions which were stream flow modeling and evaluation of stream flow due to land use/ land cover change scenario analysis. The stream flow modeling includes sensitivity analysis, calibration and validation of stream flow simulation, and the performance evaluation of the model. Finally, in Chapter five, conclusions and recommendations of the study were explained.

2. LITERATURE REVIEW

2.1. Land use/ land cover

The terms land use and land cover are often used interchangeably even though the distinction between the two is important. Land use refers to the actual economic activity for which the land is used whereas land cover (cropped land, woodland, water, grassland and bare land) refers to the cover of the earth's surface. Land cover is the physical or biological cover over the surface or layer of soil including natural vegetation, crops, and man-made infrastructure that cover the land surface, whereas land use is the purpose for which humans exploit the land cover. LULC describes the economic use of land and surface features, respectively (Campbell, 2007). In many cases, land cover and land use are directly related; for example, grass (land cover) may generally be used for livestock grazing (land use). However, such close relationships may not always be true. Land cover plays a key role in controlling the hydrologic response of watersheds in a number of important ways (Elfert and Bormann, 2010).

2.2.Land use/ land cover change

Land use change is defined as the alteration of land use due to human intervention for various purposes, such as for agriculture, settlement, transportation, infrastructure and manufacturing, park recreation uses, mining and fishery. Land use change is a very important issue considering global dynamics and their responses to environmental and socio-economic drivers. In contrast, land cover change refers to the conversion of land cover from one category of land cover to another and/ or the modifications of conditions within a category. Land use change is the main causes for soil degradation and could significantly change the streamflow availability (Tolba and El-Kholy, 1992).

Land cover change is a primary concern in watershed management as it may also lead to increased flooding, soil degradation and decreased recharge of aquifers. A change in land use and land cover is increasingly rapid, and can have adverse impacts and implications at local, regional, and global environments (Brandon, 1998). One of the most significant global challenges in this century relates to management of the transformation of the earth's surface occurring through changes in land use and land cover are complex and interrelated that is the expansion of one land use type is at the expense of others (Abate, 2011).

LULCC is commonly grouped in to two broad categories: conversion and modification (Meyer and Turner, 1994). Conversion refers to a change from one cover or use category to another (e.g. from forest to grassland). Modification, on the other hand, represents a maintenance of the broad cover or use type in the face of changes in its attributes (e.g. from rainfed cultivated area to irrigated cultivated area) due to changes in its physical or functional attributes. These changes in land use and land cover systems have important environmental consequences through their impacts on soil and water, biodiversity, and microclimate (Lambin, et al., 2003).

The Factors that influence land management decision of land use and land cover change are:
Multiple causes: A mix of driving forces that varies in time and space and acts on different levels. They are specific to human environmental conditions. They are biophysical and socio-economic factors which can be slow and/or fast in nature.

Natural variability: Natural environments interact with human causes of land use change. This could be in a synchronous or independent manner which leads to socio-economic unsustainability. Usually, climatic driven ecosystem conditions amplify the pressure due to demands on the resources.

Economic and technological factors: Land use/ land cover change is predominantly the result of society responding to the opportunities and constraints created by markets and policies which in turn are influenced by global factors.

Demographic factors: This also is another factor which has a great impact on land use/ land cover change over a longer time scale. It is a shift in rates of fertility and mortality, but it also means associated development of household’s life cycle.

Institutional factors: Local and national policies and institutions (political, legal, economic, and traditional) affect decision making as they usually constrain the access to land, labor, capital, technology, and information and thus determine the land managers capabilities to participate and define institutions. E.g. decision making systems (decentralization, inclusion of local communities in decision making) and institution control over distribution of resources.

Cultural factors: The individual land managers' beliefs, attitudes, motives, collective memories, knowledge, skills, individual perceptions, and personal histories influence land use decisions. Cultural factors can be linked to political and economic inequalities

Globalization: This is the process that underlies the other drivers and it amplifies or attenuates their impact by removing regional barriers, weakening national connections, and increasing the interdependency among people and between nations.

Though these are the general factors influencing land use change, (Lambin, et al., 2003) specifies the most frequent causes of land use change such as resource scarcity (which causes pressure on resources), market opportunities, outside policy interventions, loss of capacity and increased vulnerability, changes in social organization, changes in resource access, and changes in attitude. Therefore, LUCC research needs to deal with the identification, qualitative description and parameterization of factors which drive changes in land use and land cover.

2.3.Effects of land use/ land cover change

Land use/ land cover characteristics have many connections with hydrological cycle. The land use and land cover type can affect both the infiltration and runoff amount by following the falling of precipitation (Houghton, 1995). Both surface runoff and ground water flow are significantly affected by types of land cover (Abebe, 2005). Surface runoff and Ground water flow are the two components of the stream flow. Surface runoff is mostly contributed directly from rainfall, whereas ground water flow is contributed from infiltrated water. However, the source of stream flow is mostly from surface runoff during the wet months, whereas during the dry months the stream flows from the ground water.

LULCCs some hydrological factors, such as interception by vegetation, soil water content and surface evapotranspiration; therefore, the hydrological regime and rainfall-runoff mechanisms are also changed (Li, et al., 2007). LULCC will affect the evapotranspiration regime and subsequently, modify the runoff volume. The LULCC assessment is an important step in planning sustainable land management that can help to minimize agro-biodiversity losses and land degradation, especially in developing countries like Ethiopia (Hadgu, 2008).

Deforestation which has converse effects to afforestation, significantly affects the characteristics of stream flow (Calder, 1992). Though considered as a legends (McCulloh and Robinson, 1993) and (Calder, 1998) forests are thought to make rain, augment low flows, reduce floods, improve soil erosion, reduce amount of sediment in the reservoir and sterilize water. Deforestation also has its own impact on hydrological processes, leading to declines in rainfall, and more rapid runoff after precipitation (Legesse, et al., 2003). Therefore, such changes of land use and land cover may have impacts on the stream flow and also sediment yield to reservoirs during the wet and dry months, and on the components of stream flow.

2.4.Sedimentation and land use/ land cover

The impact of land-use and climate changes on the sediment transported from rivers to the oceans is largely dominated by forest conversion to cropland. The major sources of sediments may be from other human activities such as road construction, poorly constructed and maintained terraces, and runoff from cultivated land or bank erosion (Sidle, et al., 2006). Erosion is a consequence of complex interactions among climate (precipitation, temperature, wind speed and direction), geology (volcanic and tectonic activities), soils, topography (slope, catchment orientation, drainage basin area), and land use/land cover (White, 2005).

Soil erosion is largely determined by the absence of protective land cover, whereas sediment export to rivers is determined by on site sediment production and connectivity of sediment sources and rivers (Bakker, et al., 2008). also Soil erosion is controlled by many factors, including soil properties, land use, climatic characteristcs and topography. Although there is a significant relationship between land use and stream water quality (Tong and Chen, 2002) the relative impacts of different types of land use on the amount of surface water are yet to be ascertained and quantified.

2.5.Reservoirs and sedimentation

All reservoirs formed by dams on natural water courses are subject to some degree of sediment inflow and deposition. Sedimentation reduces reservoir storage worldwide (Palmeiri, et al., 2001). Reservoir sedimentation is a complex process that varies with watershed sediment production, rate of transportation and mode of deposition. The deposition of sediment which takes place progressively in time reduces the active capacity of the reservoir which in turn affects the regulating capability of the reservoir to provide the out flows through the passage of time. Sediment deposition in reservoirs for irrigation schemes, hydroelectric power supply and urban water supply reduces their capacity, shorten lifespan, reduce water quality and requires costly operations for removal and treatment.

In order to increase the life of the reservoir and to best achieve the purpose for which it has been constructed, reducing sediment inflow and removing sediment from the reservoir are substantial activities. The development of effective strategies to reduce sedimentation rates requires distinguishing between background erosion rates in undisturbed settings and human-accelerated erosion in disturbed settings (Palmeiri, et al., 2001). The rate of sediment varies dramatically as the differences of river basin and impoundment characteristics control the rate and pattern of the sedimentation deposition in the reservoir (Small, et al., 2003). The reservoirs of many countries are adversely affected by high rate of sedimentation. In Ethiopia accelerated sedimentation in reservoirs providing hydroelectric power and irrigation water has resulted in loss of these intended services.

The frequent power cuts and rationing based electric power distribution recently experienced in the country are also partially attributed to the loss of storage capacity of hydroelectric power reservoirs, a consequence of sedimentation (Tamene, et al., 2006). Reservoir sedimentation is a phenomenon that also has a positive impacts to water usage systems particularly to the downstream river. Reservoir sediment deposition is a reflection of watershed erosion and deposition processes which are controlled by terrain form, soil type, surface cover, drainage networks and rainfall- related environmental attributes (Tamene, et al., 2005). Sediment inflow can be reduced either by implementing land management methods, particularly integrated watershed management, that reduce sediment yield.

2.6.Sediment Yield

Sediment is fragmental material, primarily formed by the physical and chemical disintegration of rocks from the earth’s crust. Sediment yield refers to the amount of sediment exported by a basin over a period of time and also it is the amount of eroded sediment discharged by a stream at any given point; it is the total amount of fluvial sediment exported by the watershed tributary to a measurement point and is the parameter of primary concern in reservoir studies. They ranges in size also vary in specific gravity and mineral composition. Once the sediment particles are detached, they may either be transported by gravity, wind or/and water. Sediment is a critical pollutant in surface water that adversely affect water quality and contains other important contaminants (including nutrients, pesticides and heavy metals) (Amare, 2005). Sediment yield is dependent on factors of soil erosion (mainly rainfall, soil condition, land use, topography) and the capacity of transportation.

Sediment export is also a function of land use, since the sediment transport capacity is different for different types of land cover. The incoming sediment load is usually measured at gauging stations. Flow and sediment measurements define the sediment-rating curve. The sediment rating- curve is typically highly scattered and daily sediment discharge covers several orders of magnitude. It is important to realize that a single point on the upper part of the sediment-rating curve can correspond to a daily sediment load in excess of the daily sediment load at a low discharge. The rate at which sediment is carried by natural streams is much lower than the gross erosion on its upstream watershed. Sediment is deposited between the source and the stream cross section whenever the transport capacity of runoff water is insufficient to sustain transport.

2.7.Soil type

Soil is defined as the top layer of the earth's crust. It is formed by mineral particles, organic matter, water, air and living organisms. It is in fact an extremely complex, variable and living medium. The soil profile is sub-divided into multiple layers that support soil water processes including infiltration, evaporation, plant uptake, lateral flow, and percolation to lower layers. The soil percolation component of SWAT uses a water storage capacity technique to predict flow through each soil layer in the root zone.

Soil may be place in one of four groups according to hydrologic Group, A, B, C, and D. **Definitions of the classes**: **A.** (Low runoff potential). The soils have a high infiltration rate even when thoroughly wetted. They chiefly consist of depth, well drained to excessively drained sands or gravels. They have a high rate of water transmission.

B. The soils have a moderate infiltration rate when thought wetted. They chiefly are moderately depth to deep, moderately well-drained to well-drained soils that have moderately fine to moderately coarse textures. They have moderate rate of water transmission.

C. The soils have a slow infiltration rate when thoroughly wetted. They chiefly have a layer that impedes downward movement of water or have moderately fine texture. They have a slow rate of water transmission.

D. (High runoff potential). The soils have a very slow infiltration rate when thoroughly wetted. They chiefly are of clay soils that have high swelling potential, soils that have a permanent water table, and soils that have a clay pan or clay layer at or near the surface and shallow soils over nearly impervious material. They have a slow rate of water transmission.

2.8. Land use/ land cover change studies in Ethiopia

Most of land cover in east Africa is in a state of flux at a variety of spatial and temporal scale due to climatic variability and human activities (Kiage, et al., 2007). The researches that have been conducted in different parts of Ethiopia have shown that there were considerable LULCCs in the country. Studies relating to LULCCs in Ethiopia are rare, with most focusing on the northern highlands of Ethiopia (Tegene, 2002) and (IFPRI, et al., 2005). Most of these studies indicated that croplands have expanded at the expanse of natural vegetation including forests and shrub lands; for example (Belay, 2002); (Bewket, 2003); (Kidanu, 2004); (Abebe, 2005) in northern part of Ethiopia, (Zeleke and Hurni, 2001) in north western part of Ethiopia, (Kassa, 2003) in north eastern part of Ethiopia; and (Denboba, 2005) in south western part of Ethiopia.

Nevertheless there are common characteristics about all LULCC studies in Ethiopia, Such as the outspread of agriculture and the loss of natural vegetation, combined with a loss of biodiversity. As a consequence, considerable LULCCs have occurred in Ethiopia during the second half of the 20th century (Gete, 2000) and (Kebron and Hedlund, 2000). The result of these studies have identified deforestation and encroachment of cultivation into marginal areas as the main agents of LULC. However, the previous studies focused mainly on the changes of LULC impact and the implication of such changes on the reservoir. Evaluation of land use and land cover dynamics at this level is rare in Ethiopia in general and around the watershed of Finchaa in particular.

2.8.1. Previous studies around Finchaa Watershed

In 2007, (Bezuayehu and Geert, 2007). Carried out the analysis and impacts of Hydropower-Induced Land Use Change in Finchaa Watershed. They found out that; Land use changes in Finchaa watershed are mainly the result of construction of the hydropower dam, population pressure (induced by forced migration and normal growth), and annual rainfall fluctuations. Changes in land use in this watershed affect the livelihood of the community and will also affect the ability of the dam to deliver the planned economic benefits.

Land use changes induced by irrigation development in the Finchaa sugar estate, Blue Nile basin, Ethiopia. Researched by (Getahun, et al., 2013). In their study they reported clearing increasingly flat and steeper land for cultivation and built-up land, land degradation is becoming a serious problem. Land use and land cover changes that occurred from 1984 to 2009 in the Finchaa Sugar Estate, Blue Nile Basin of western Ethiopia, were monitored using a geographic information system (GIS) and a remote sensing approach with field verification.

Simulation of Sediment Yield using SWAT Model in Finchaa Watershed, Ethiopia. By: (Abdi, et al., 2012). This study showed that the SWAT model is capable of predicting sediment yields and hence can be used as a tool for water resources planning and management in the study watershed. They concluded that the SWAT model performed well in predicting both the flow and sediment yields from the study watershed and the results were acceptable. It is a capable tool for further analysis of the hydrological responses in the watershed.

2.9.Hydrological impacts of land use/ land cover changes

Hydrological characteristics vary between different land use types, which are not only related to land use characteristics, but also to the spatial distribution of land use in a watershed. The hydrological impact of LULCC is important to consider not just the impacts of the initial intervention but the impacts of the subsequent form of land use, as well as the type of management regime undertaken (Bruijnzeel, 1990). Land use and land cover play a crucial role in driving hydrological processes within watersheds (Gerten, et al., 2004).These include changes in water demands e.g. irrigation and urbanization, changes in water supply from altered hydrological processes of infiltration, groundwater recharge and runoff, and changes in water quality from agricultural runoff and suburban development.

These hydrological impacts may be loosely grouped according to whether they relate to water quality or water quantity, Erosion, sedimentation and nutrient outflow are grouped together under the heading of water quality impacts; and changes in water yield, seasonal flow, storm flow response, groundwater recharge and precipitation are considered as water quantity issues. Beginning with water quality and moving on to water quantity the hydrological impacts of changes in land use and conversion of tropical forests can be summarized by compiling the general nature of these impacts as extracted from a number of authoritative reviews on the subject (Bruijnzeel, 1990) and (Calder, 1992).

2.10. Modelling approach

The Soil and Water Assessment Tool (SWAT) is a physical based hydrological model developed by USDA Agricultural Research Services (ARS) (Arnold, et al., 1993) will be used to analyses the impact of land use change, climate change and reservoir construction on sediment yield in river basins. SWAT is a physically based catchment model which can predict the impact of land use change and management practices on water and sediment budgets in a catchment over a long period of time. SWAT has been tested in different tropical watersheds (Neitsch, et al., 2011). The SWAT model is a catchment-scale hydrological model based on the principles of the water balance. The studies indicated that the SWAT model is capable in simulating hydrological process and erosion/sediment yield from complex and data poor watersheds with reasonable model performance statistical values.

The soil and water assessment tool has recently been adapted to more effectively model hydrological processes in monsoonal climates such as Ethiopia (White, et al., 2008). Hydrologic models can be further divided into event-driven models, continuous process models, or models capable of simulating both short-term and continuous events. Event-driven models are designed to simulate individual precipitation-runoff events. Typically, event models have no provision for moisture recovery between storm events and, therefore, are not suited for the simulation of dry-weather flows. Continuous-process models simulate instead a longer period, predicting watershed response both during and between precipitation events. They are suited for simulation of daily, monthly or seasonal stream flow, usually for long-term runoff volume forecasting and for estimates of water yield (Cunderlik, 2003).

2.10.1. Hydrological component of SWAT

The land phase of the hydrologic component controls the water movement in the land and determines the water, sediment, nutrient and pesticide amount that is loaded into the main stream. Infiltration, redistribution, evapotranspiration, lateral sub-surface flow, surface runoff, ponds and tributary channel return flow are simulated in this hydrological component. The second component is the routing phase in which the water is routed in the channel network of the basin, carrying the sediment, nutrients and pesticides to the outlet.

SWAT is a model that can be used to simulate flow and sediment for large basins. It can predict non-point source pollution. Furthermore, it can be used for impact studies such as climate and land-use changes, and water quality loading. The model can be used in planning and decision making. It also simulates the major hydrologic components and their interactions simply and yet as realistically as possible (SWAT manual, 2012). The method to evaluate the hydrological impacts due to LULCCs and land use modifications can be achieved through integrating Geographical Information System based Soil and Water Assessment Tool model.

2.10.2. Application of SWAT model

SWAT has already been validated in the regions of the world for a variety of applications in hydrologic as well as water quality studies (Jha, et al., 2007). SWAT has been successfully applied in evaluating the best management practices in various parts of the world (Betrie, et al., 2011). The model has good reputation for best use in agricultural watersheds and its uses have been successfully calibrated and validated in many areas of the USA and other continents (Tripathi, et al., 2003). The SWAT model application was calibrated and validated in some parts of Ethiopia. (Tibebe and Bewket, 2010), argued that based on reasonable model results, SWAT turned out to be sensitive to land use changes and would be a good tool to assess soil erosion and the effects of best management practice in Ethiopia.

The SWAT model was tested for prediction of sediment yield in Anjeni gauged watershed by (Setegn, et al., 2008). A study conducted on modeling of the Lake Tana basin with SWAT model also showed that the SWAT model was successfully calibrated and validated. This study reported that the model can produce reliable estimates of stream flow and sediment yield from complex watersheds.

The SWAT model showed a good match between measured and simulated flow and sediment yield in Gumara watershed both in calibration and validation periods (Asres and Awulachew, 2010). Through modeling of Gumara watershed (in Lake Tana basin), (Awulachew, et al., 2008) indicated that stream flow and sediment yield simulated with SWAT were reasonable accurate. The SWAT model is capable of predicting sediment yields and hence can be used as a tool for water resources planning and management in the study watershed. Simulation of Sediment Yield using SWAT Model in Finchaa Watershed, Ethiopia. By: (Abdi, et al., 2012).

2.10.3. Comparisons of SWAT with other models

For this study the program SWAT was selected due to its continuous time scale, computational efficiency, its ability to simulate long-term impacts, its applicability to large-scale catchment, distributed spatial handling of parameters and integration of multiple processes such as climate, hydrology, nutrient and pesticide, erosion, land cover, management practices, channel processes, and processes in water bodies has an important tool for watershed scale studies.

The model was applied for LULCC impact assessment in different parts of the world and also in Ethiopia. It is also readily and freely available model.
(Borah and Bera., 2003), compared SWAT with several other watershed-scale models. In the study, they reported that the Dynamic Watershed Simulation Model (DWSM) (Borah, et al., 2004), Hydrologic Simulation Program-Fortran (HSPF) model (Bicknell, et al., 1997), SWAT and other models have hydrology, sediment and chemical routines applicable to watershed-scale catchments and concluded that SWAT is a promising model for continuous simulations in predominantly agricultural watersheds.

In the 2004 study, they found that SWAT and HSPF could predict yearly flow volumes and pollutant losses, were adequate for monthly predictions except for months having extreme storm events and hydrologic conditions and were poor in simulating daily extreme flow events. In Contrast, DWSM reasonably predicted distributed flow hydrographs and concentration or discharge graphs of sediment and chemicals at small time intervals. (Saleh and Du., 2004), found that the average daily flow, sediment loads, and nutrient loads simulated by SWAT were closer than HSPF to measured values collected at five sites during both the calibration and verification periods for the upper north Bosque River watersheds in Texas.

(Singh, et al., 2005) found that SWAT flow predictions were slightly better than corresponding HSPF estimates for the 5,568km^2 Iroquois River Watershed in eastern Illinious and western Indiana, primarily due to better simulation of low flows by SWAT, (El-Nasr, et al., 2005), found that both SWAT and the MIKE-SHE model simulated the hydrology of Belgium’s Jeker River basin in an acceptable way. However, MIKE-SHE

predicted the overall variation of river flows slightly better. (Srinivasan, et al., 2005), found that SWAT estimated flow more accurately than the Soil Moisture Distribution and Routing (SMDR) model (Cornell, 2003) that SWAT was also more accurate on a seasonal basis.
In the critical review of SWAT model applications, (Gassman, et al., 2005), reported the results of various researchers that compared the performance of SWAT model with other hydrologic models like Dynamic Watershed Simulation Model (DWSM), Hydrologic Simulation Fortran- Program (HSFP), MIKE-system Hydrologic European (MIKE-SHE).

The continuous simulation type for larger basin size of Hydrologic Response Unit (HRU) spatial distribution for overland flow of Excess rainfall and Up-ward saturation and for different erosion process having Output of Time-varying Sedigraph, Time integrated yield and erosion map of wide range of land use SWAT model used. The model objective of SWAT is predicting the impacts of land management practices on water and sediment where as other models objective mostly simulate the rainfall- run off process of watershed.

2.10.4. Benefits of SWAT Model Approach

- Watersheds with no monitoring data (e.g., stream gage or water quality data) can be modeled.
- The relative impact of alternative input data (e.g. changes in management practices, climate, vegetation, or land use) on water quality or another variable of interest can be quantified.
- The model uses readily available inputs. While SWAT can be used to study more specialized processes such as bacteria transport, the minimum data required to run the model are commonly available from government agencies.
- SWAT is computationally efficient. Simulation of very large basins or a variety of management strategies can be performed without excessive investment. The model enables users to study long-term impacts.
- SWAT explicitly incorporates elevation or orographic effects on precipitation and temperature.
- It is a continuous time or long term yield model able to simulate long term impacts of land use, land management practices and build-up of pollutants (Neitsch, et al., 2005).
- SWAT has a weather simulation model that generates daily data for rainfall, solar radiation, relative humidity, wind speed and temperature from the average monthly

variables for the data provides a useful tool to fill in gaps in daily data in the observed records.

- SWAT is designed to use either observed meteorological data or statistically generated meteorology, facilitating the development of long term analysis.
- SWAT was developed for and has been widely applied to simulation of watersheds in arid regions.
- SWAT explicitly incorporates routines for agricultural diversions and irrigation.
- The other advantage of the SWAT model is the ability to build different scenarios.
- SWAT includes routines designed to address the impacts on flow and pollutant loading of multiple small (or large) farm ponds within a basin.

2.10.5. SWAT-CUP

SWAT-CUP is an interface that was developed for SWAT. SWAT-CUP is designed to integrate various sensitivity analysis, calibration, validation and uncertainty programs for SWAT using different interface. The main function of an interface is to provide a link between the input/output of a calibration program and the model. Using this generic interface, any calibration, validation/uncertainty or sensitivity program can easily be linked to SWAT.

The recently developed SWAT-CUP interfaced program for calibration and uncertainty analysis procedures (Abbaspour, et al., 2007) also made the SWAT model more attractive for this study. SWAT-CUP is linked to five different algorithms such as: Sequential Uncertainty FItting (SUFI-2) (Abbaspour, et al., 2007)Generalized Likelihood Uncertainty Estimation (GLUE) (Beven and Binley, 1992), Parameter Solution (ParaSol) (Van Griensven & Meixner, 2006), Particle swarm optimization (PSO) (Eberhart and Kennedy, 1995) and Markov Chain Monte Carlo (MCMC) (Kuczera and Parent, 1998) procedures to SWAT.

- SUFI2 (Abbaspour, et al., 2007): Sequential Uncertainty Fitting Ver. 2, the parameter uncertainty in driving variables (e.g., rainfall), conceptual model, parameters, and measured data.
- GLUE (Beven and Binley, 1992): Generalized Likelihood Uncertainty Estimation is based on the estimation of the weights or probabilities associated with different parameter sets, based on the use of a subjective likelihood measure to derive a posterior

probability function, which is subsequently used to derive the predictive probability of the output variables.

- Parasol (Van Griensven and Meixner, 2006): Parameter Solution method aggregates objective functions into a global optimization criterion and then minimizes these objective functions or a global optimization criterion using the SCE-UA (Shuffled Complex Evolution, (Duan, et al., 1992) algorithm, which is a global search algorism for minimization of a single function, were utilized in the calibration process.
- MCMC: Markov Chain Monte Carlo generates samples from a random walk which adapts to the posterior distribution (Kuczera and Parent, 1998). This simple techniques from this class is the Metropolis Hasting algorithm (Gelman, et al., 1995).

Various SWAT parameters for estimation discharge were estimated using the SUFI-2 program (Abbaspour, et al., 2007). In SUFI-2, parameter uncertainty accounts for all sources of uncertainties such as uncertainty in driving variables (e.g., rainfall), conceptual model, parameters, and measured data. Uncertainty is defined as discrepancy between observed and simulated variables in SUFI-2 where it is counted by variation between them. SUFI-2 combines calibration and uncertainty analysis to find parameter uncertainties while calculating smallest possible prediction uncertainty band. It is automated model calibration requires that the uncertain model parameters are systematically changed, the model is run, and the required outputs (corresponding to measured data) are extracted from the model output files.

The SUFI-2 was the most suitable way to find the SWAT Uncertainty under the condition that the parameter range. The Goodness of fit in SUFI-2 is expressed by the 95PPU band, it cannot be compared with observation signals using the traditional indices such as R^2, Nash-Sutcliffe (NS). For this reason two measures referred to as the P-factor and the R-factor (Abbaspour, et al., 2004, 2007), the P-factor is the percentage of the measured data bracketed by the 95PPU. The R-factor, on the other hand, is a measure of the quality of calibration and indicates the thickness of the 95PPU. As all forms of uncertainties are reflected in the measurements (e.g., discharge), the parameter uncertainties generating the 95PPUaccount for all uncertainties.

2.11. Sensitivity analysis

Sensitivity analysis determines the sensitivity of the input parameters by comparing the output variance due to the input variability. This is useful not only for model development, but also for model validation and reduction of uncertainty (Hamby, 1994). The sensitivity analysis was carried out to identify the sensitive parameters of the SWAT model. The sensitivity analysis is done by varying parameters value and checking how the model reacts. If small change on a given parameter value results on a remarkable change on the model output, the parameter is said to be sensitive to the model.

2.12. Model calibration and validation

In hydrologic simulation there are two main exercises that must be successfully achieved before using a model. These are calibration and validation of the models.

2.12.1. Calibration

Calibration is an intensive exercise used to establish the most suitable parameter in modeling studies and an iterative process that compares simulated and observed data of interest (typically streamflow data) through parameter evaluation. The exercise is vital because reliable values for some parameters can only be found by calibration (Beven, 1989).The model parameters changed during calibration are broadly classified into physical and process parameters. Physical parameters represent measurable properties of the basin such as surface area and slope of the basin. On the other hand, the process parameters represent watershed characteristic that are not directly measurable e.g. deep percolation.

2.12.2. Validation

Model validation is the process of representing that a given site specific model is capable of making sufficiently accurate simulation. The degree of accuracy of parameter estimates was assessed by applying the model to different data set that was not used for calibration. The goal of validation is to assess whether the model is able to predict field observations for time periods different from the calibration period. This implies the application of the model without changing the parameter values that were set during calibration (Refsgaard and Storm, 1996).The model is validated if its accuracy and predictive capability in the validation period have been proven to lie within acceptable limits (Refsgaard and Storm, 1996).

2.13. Assessment of model performance

The performance of SWAT is evaluated using statistical measures to determine the quality and reliability of predictions when compared to observed values. During calibration and validation of a hydrological model it is necessary to assess the performance of the model. This is done by statistically comparing the model output and observed values using various statistical measures. These measures include the coefficient of determination (R^2) and Nash-Sutcliffe Efficiency (NS) (Loage and Green, 1990).

The range of values for R^2 is 1.0 (best) to 0.0(poor). The R^2 coefficient measures the fraction of the variation in the measured data that is replicated in the simulated model results. A value of 0.0 for R^2 means that none of the variance in the measured data is replicated by the model predictions. On the other hand, a value of 1.0 indicates that all of the variance in the measured data is replicated by the model predictions. Nash-Sutcliffe simulation efficiency (NS), indicates the degree of fitness of the observed and simulated plots with the 1:1 line. The statistical index of modelling Nash-Sutcliffe Efficiency (NS) values range from 1.0(best) to negative infinity. NS is a stricter test of performance than R^2 and is never larger than R^2.

3. METHODOLOGY

3.1. Introduction

This study concerns the Impacts of LULCC on sediment yield and stream flow to Hydropower Reservoirs with the application of a physically based watershed model SWAT version 2012. This chapter describes the study area, the input data, their source and the methodology adopted to evaluate the impacts of LULCCs on sediment yield and stream flow to hydropower reservoir of the Finchaa watershed. Finally the application of the model in scenario modelling of land use/ land cover has been discussed.

SWAT simulation run was carried out using a set of input variables, then a sensitivity analysis was performed to identify the most parameters that influence the streamflow and calibration and validation of SWAT to simulate streamflow in the basin. The efficiency of the model was assessed by comparing simulated and observed streamflow. The results from software works, visual identification results interpreted and report preparation follows.

3.2. Study Area

3.2.1. Location

Finchaa is located in Horro Guduru Wollega zone, East Wollega, Oromia regional state, western Ethiopia between 9°10'30" to 9°46'45" North latitude and 37°03'00" to 37°28'30" East longitude (Figure 3.1). Finchaa is located about 47 km from the zonal capital Shambu and 280km from capital town of Oromia and Ethiopia Addis Ababa. About 178,000 people live in the watershed area (Assefa, 1994). Finchaa sub-basin is a part of Blue-Nile river basin which contains three watersheds (Finchaa, Amerti and Neshe) watershed. The sub-basin has an area of 4089 km^2. It covers 6 weredas; Abay Chomen, Guduru, Ababo Guduru, Jimma Rare, Horro, and Jarte Jardega. Finchaa dam was constructed at the Finchaa River in 1973 as a strategy for fostering economic growth in Ethiopia through generation of hydroelectricity, irrigation, fishery, and tourism (HARZA Engineering Company, 1965). At the time the dam was the largest hydro-electric Projet in the country.

The Finchaa hydropower dam has a 340 m crest length and a height of 20 m above the lowest foundation level (HARZA Engineering Company, 1975). Finchaa sub-basin is normally endowed with land features that are characterized by large upstream water potential sites, intensive downstream irrigable lands and high head hydropower plant at the foot almost vertical canyons.

The Finchaa system was expanded in 1987 by diverting Amerti river flows into the Finchaa reservoir by constructing a 20m high earth and rock fill dam on Amerti River and a 1.57 km long diversion tunnel. As a result, the capacity was upgraded to 134MW by an additional turbine unit. Finchaa and Amerti dams and reservoirs are the earliest in the Blue Nile basin and Constructed in 1973 and 1987 respectively, whereas the construction of Neshe reservoir completed in 2011. The project comprises big irrigation for sugar factory and hydropower projects including the Community water supply.

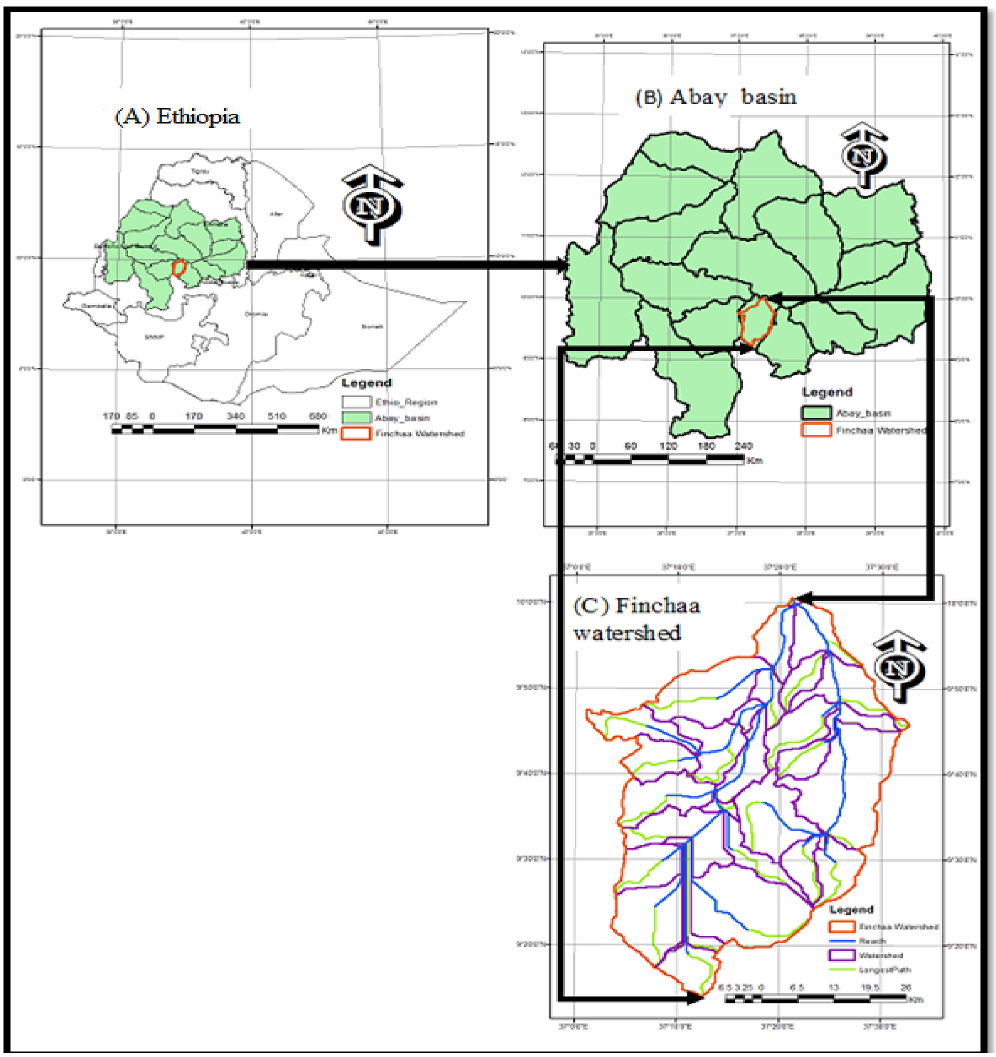


Figure 3.1. Location of the Study area.

3.2.2. Topography

Ethiopia is dominated by two plateaus, which were divided by the East Africa Rift Valley. About 50 percent of the country is above 1200 m and most of the terrain has slope in excess 16 percent, which exacerbates the risk of erosion. The topographic features of the Blue Nile basin vary between the highlands in the center and eastern part of the basin and the lowlands in the western part of the basin. The altitude in Finchaa sub-basin ranges approximately between 880 masl and 3200 masl. The highlands in the western and southern part of the sub basin are higher in altitude, greater than 2200 masl up to 3200 masl. The lowlands have lower altitude less than 1400 masl in the northern parts of the sub-basin.

3.2.3. Rainfall

The Ethiopian highlands having highest rainfall ranging from 1500mm to 2200mm whereas lowlands having rainfall less than 1500mm. The annual precipitation increases from northeast to southeast over the basin. The sub-basin is tropical Highland Monsoon with an annual rainfall ranging between 960 mm and 1835 mm. Lower annual rainfall less than 1100 mm in the northern lowlands of the sub-basin and higher rainfall greater than 1604 mm in the western and southern highlands is observed. Most of the rain falls during the months of June to September with peaks occurring during July and August and it is virtually dry from November to April. As the watershed is located in a high rainfall area, it receives frequent heavy and frequent flash floods during the rainy season.

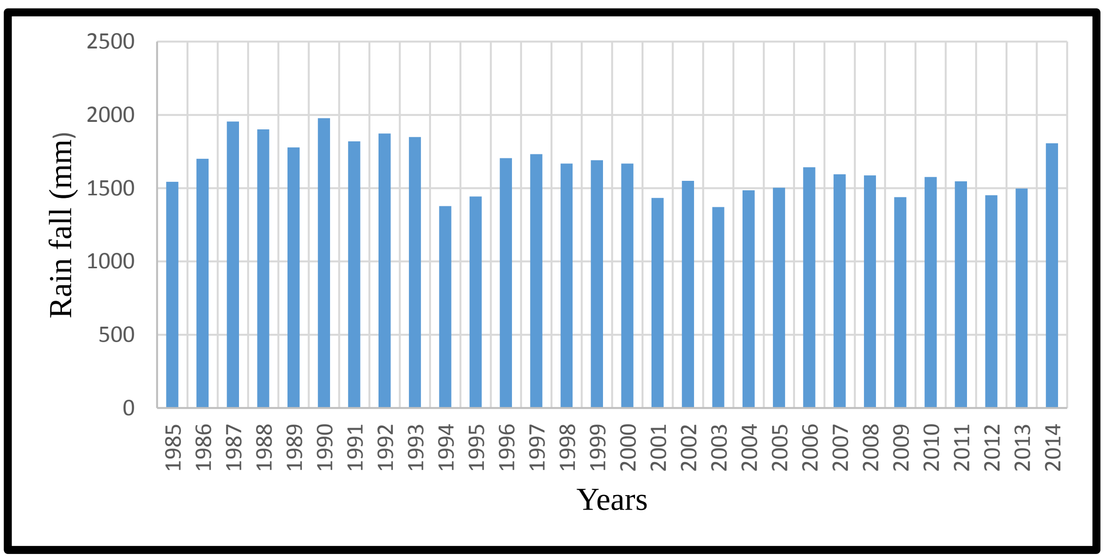


Figure 3.2. Average Annual rainfall of stations

3.2.4. Temperature

The highest temperature observed in the north western part of the basin and the lower temperature observed in the highlands of the central and eastern part of the basin. Finchaa Sub-basin is located in the moist humid climatic zone of the Blue Nile basin. The annual maximum and minimum temperature in the sub-basin varies between 19.5^{0}C – 31.5^{0}C and 6^{0}C - 16^{0}C respectively. Temperature is higher in the northern lowlands with a maximum of 29^{0}C – 31.5^{0}C and minimum of 14^{0}C - 16^{0}C. The mean monthly temperature of the area varies from 14.6^{0}C to 17.7^{0}C.

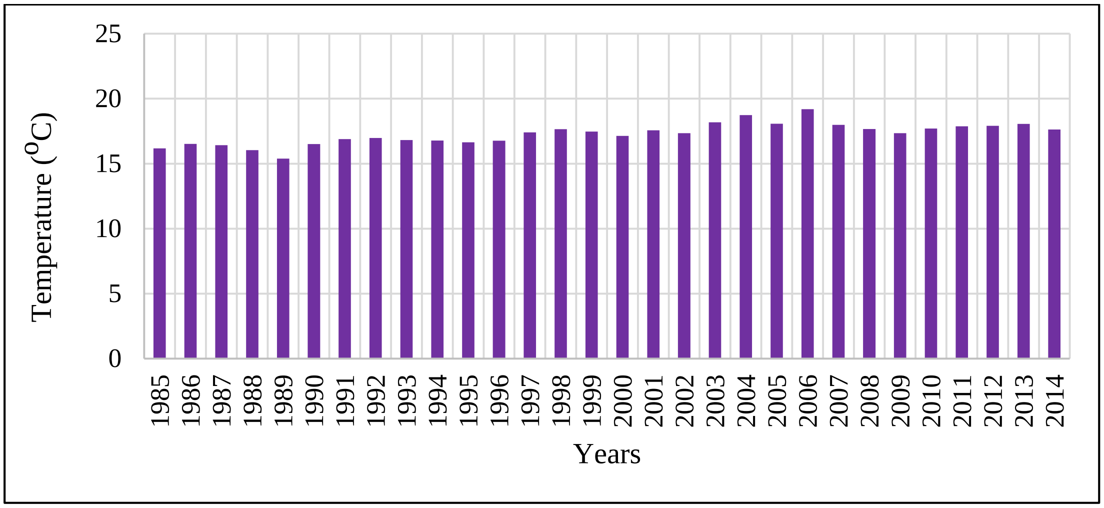


Figure 3.3. Average Annual temperature of stations.

3.2.5. Evaporation

Potential Evapotranspiration (PET) in the basin ranges between 1056 mm and 2232 mm per year. High PET is observed between 1800 mm and 2232 mm per year in North Western parts of the basin. The Eastern and Southern parts having lower PET ranging between 1200 and 1800mm per year and the lowest PET below 1200mm per year observed in the parts of the highlands. Potential Evapotranspiration (PET) in the sub-basin is generally between 1365 mm and 1970 mm per year. PET is higher than 1800 mm/yr., in the lowlands where high temperature is observed. The highlands in the western and eastern parts of the basin show lower PET, less than 1600 mm/yr.

3.2.6. Land use

The land use in Finchaa sub-basin is dominated by cultivation and irrigated agriculture. Pastoral land is also practiced in northern parts of the sub-basin. The major landform of the watershed includes flat to gently sloping, undulating plains, hills and mountains. The western part of the watershed is characterized by highly rugged, mountainous and rolled topography with steep slopes and the lower part is characterized by a valley floor with flat to gentle slopes. The major portion of the watershed is under intensive cultivation and teff, maize, barley and wheat are the major crops grown in the watershed. Shrub land, grazing land, forest, woodland and wetland/swamp are other land cover types in the watershed.

3.2.7. Soil

The catchment has a wide range of soil type mainly dominated by clay and loam soil (Bezuayehu, 2006). The largest portion of the watershed is characterized by red to reddish brown friable Luvisols and black heavy clay vertisols. Most of the soil of the irrigated land is Luvisols and the rest is vertisols. Vertisols is found mostly in the lower areas near the Finchaa River and at the upper ends of the interfluves commonly associated with swamps and temporary wetlands on the plains with good to moderate fertility. The dominant soils in the basin are Cambisols and Nitosols, with the occurrence of Arenosols, Luvisols, Vertisols and Regosols.

3.2.8. Geology

The geology of Ethiopia is the result of Cenozoic volcano- tectonic and sedimentation processes. The Geology of the Blue Nile basin having different formations such as Basalt, Alluvium, Lacustrine deposit, sand stone, granite and marbles (Aster and seleshi, 2009). The high elevations along the watershed boundary are formed from quaternary volcanics, which also occur as isolated outcrops in the middle of the watershed. A small part of the watershed in the northeast is on the Sandstone and Basalt formation. This formation is composed of alternating beds of sandstones and shales which have been deposited uncomfortably upon the eroded surfaces of the basement complex.

3.3.Reservoir area

Finchaa reservoir is one of the biggest man made body of water in Ethiopia, it is locally known as Chomen Lake. Finchaa reservoir has an area of 1318 km^2 where as its River originates from the Chomen and Finchaa swamps on the highlands. The hydropower reservoir covers approximately one-third of the watershed area. Many streams join Finchaa River, the main tributaries being Hagamsa, Korke, Fakare and Boye from the western side and Sargo-Gobana, Aware, Sombo, and Andode from the eastern side. The Reservoir initially stores 185 million cubic meters, after the water is diverted from Amerti River to the Finchaa reservoir through a tunnel the storage capacity of the Finchaa reservoir was raised from 185 to 460 million cubic meters of water and the capacity of hydroelectric power generation was raised from 100MW to 134MW. According to studies done by the Oromia Agricultural Development Bureau (OADB, 1996) and (Assefa, 1994) showed that Finchaa Reservoir has inundated large areas of different land use types and evicted several people from their original places.

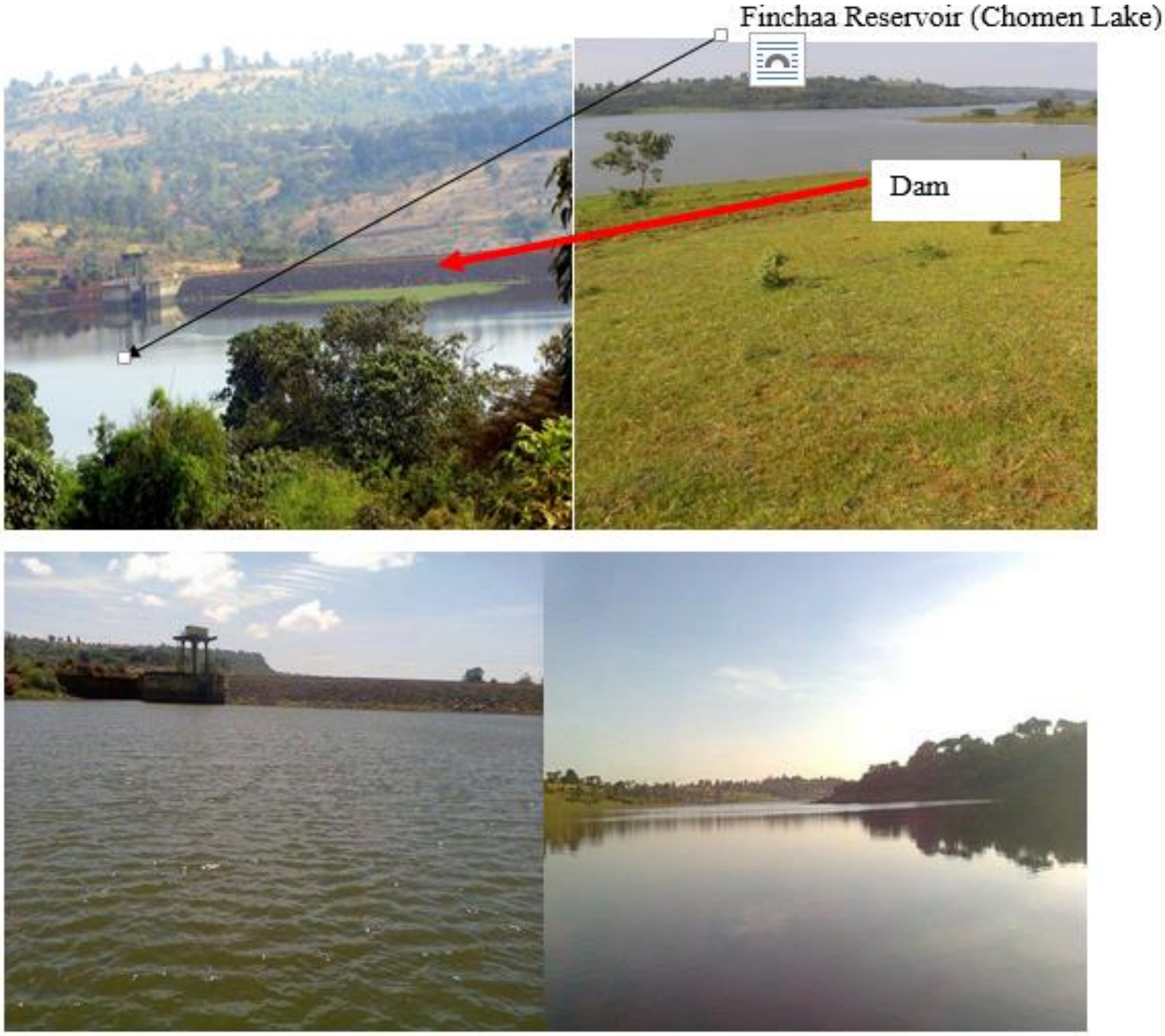


Figure 3.4.Reservoir area of Finchaa watershed (image taken during Field visit).

3.4. Materials and methods

The main tools (materials) used for input data preparation, analysis were:

- Arc SWAT
- SWAT-CUP
- PCP STAT

- Dew02.exe
- Microsoft Excel
- DEM, Meteorological, Hydrological map and data

The methods used for the application of the model involved Calibration, validation, sensitivity analysis and uncertainty analysis. For this purpose SUFI-2 calibration and Uncertainty analysis algorithms were used.

The methodology of this work has the following components.

1. Data collection
2. Data processing
3. Running model
4. Sensitivity Analysis
5. Calibration and validation of the model
6. Model result analysis.

The overall methodology was analyzed using the Geographical Information System (GIS) based version of soil and water Assessment Tool (SWAT). Finally, calibration, validation and evaluation by appropriate systems to check the performance of the model with observed data. The overall methodology of the study was presented in figure 3.5.

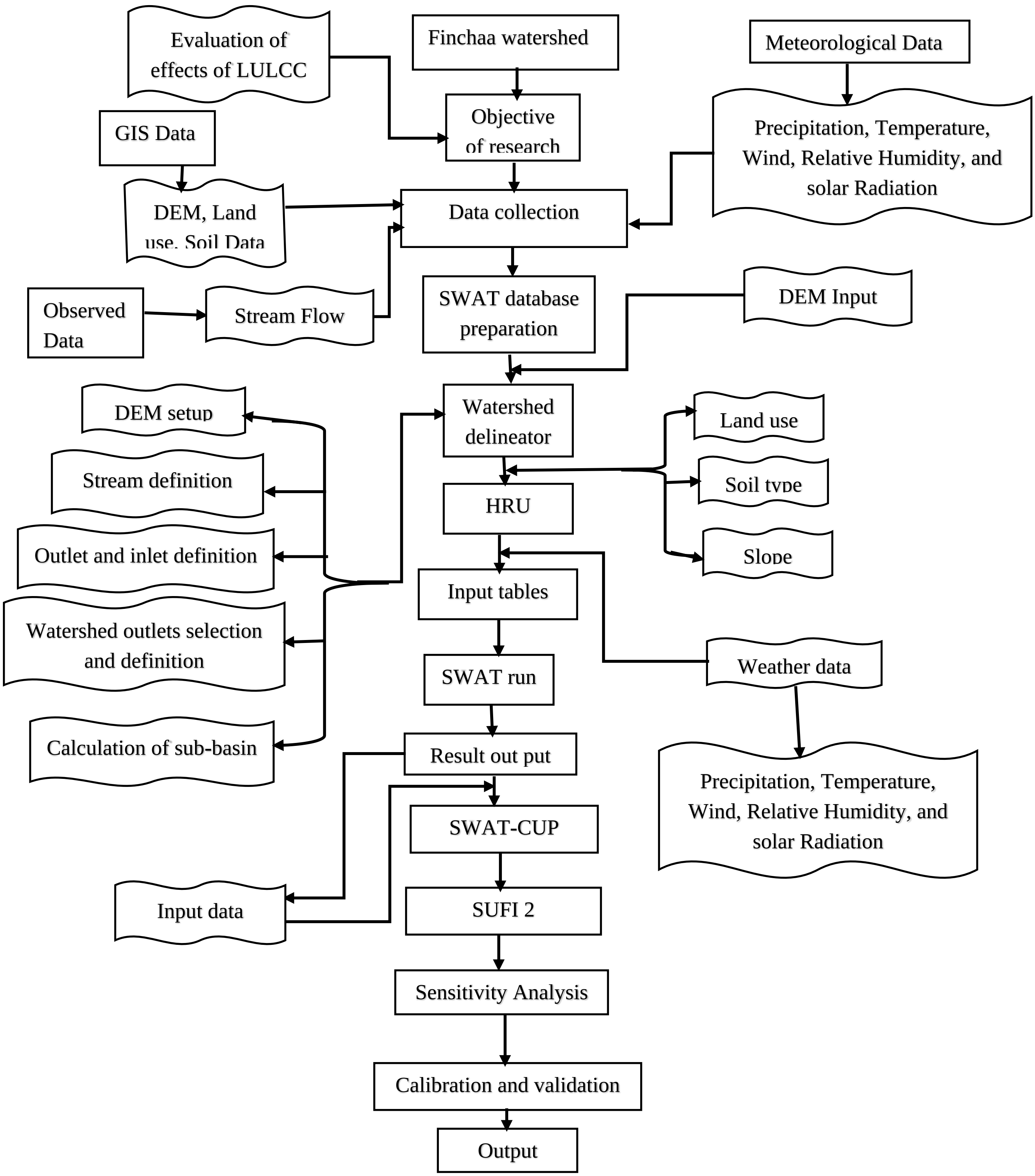


Figure 3.5.Flow chart of ArcSWAT Processing steps.

3.5.SWAT Model description

SWAT is a hydrological model that can be applied at the river basin, or watershed scale. It was developed for the purpose of simulation and to predict the impact of land management practices on water, sediment and agrochemical yields in large, complex watersheds with varying soils, land use and agricultural conditions over extended time periods (Neitsch, et al., 2005). A great number of SWAT applications have been used to study hydrology and sediment yield in small or large catchments in different regions of the world.

SWAT can be used to analyze small or large catchments by discretizing them into sub-basins, which are then further sub-divided for modelling purpose the catchment is divided into a number of sub-basins which will be divided into hydrological response units (HRUs) each having homogeneous land use, soil types, and management and slope characteristics. The SWAT system surrounded within GIS can integrate various spatial environmental data, including information about soil, land cover, climate and topographical features. The land phase of the hydrologic cycle is modelled in SWAT based on the water balance equation (Neitsch, et al., 2005).

$$SW_t = SW_o + \sum_{i=1}^{t} (R_{day} - Q_{Surf} - Ea - w_{seep} - Q_{gw}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

Where: SW_t: is the final soil water content (mm)

SW_o: is the initial water content (mm)

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

Q_{Surf}: is the amount of surface runoff on day i (mm)

Ea: is the amount of evapotranspiration on day i (mm)

w_{seep}: is the amount of water entering the vadose zone from the soil profile on day i (mm)

Q_{gw}: is the amount of return flow on day i (mm).

t: is the time (days)

A daily water balance in each HRU is calculated based on daily precipitation, runoff, evapotranspiration, percolation, and return flow from subsurface and groundwater flow (Nelson, et al., 2006). In the following section, different components of water balance in the SWAT model discussed.

3.5.1. Surface Runoff

Surface runoff or overland flow occurs whenever the rate of precipitation exceeds the rate of infiltration and occurs along a sloping surface. Surface runoff refers to the portion of rainwater that is not lost to interception, infiltration, and evapotranspiration (Solomon, 2005). Using daily or sub-daily rainfall amounts, SWAT simulates surface runoff volumes and peak runoff rates for each HRU.

SWAT uses two methods for calculating surface runoff namely; the modified SCS curve number method (USDA-SCS, 1972) and the Green & Ampt infiltration method (Green and Ampt, 1911). The SCS curve number, which was used in this study, is a function of the soil permeability, land use and the antecedent moisture condition. In the curve number method, the curve number varies non-linearly with the moisture content of the soil. The Green & Ampt method requires sub-daily precipitation data and calculates infiltration as a function of the wetting front metric potential and effective hydraulic conductivity. The SCS curve number equation which is calculated using the following equation:

$$Q_{surf} = \frac{\left(R_{day} - Ia\right)^2}{\left(R_{day} - Ia + s\right)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

Where: Q_{surf} : is the accumulated runoff or excess rainfall (mm H_2O),

R_{day}: is the rainfall depth for the day (mm H_2O)

Ia: is the initial abstractions which includes surface storage, interception and infiltration prior to runoff (mm H_2O), and

S: is the retention parameter (mm H_2O).

The retention parameter varies spatially due to changes in soils, land use, management and slope and temporally due to changes in soil water content. The retention parameter is defined as:

$$S = 25.4 * \left(\frac{100}{CN} - 10\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.3$$

Where: CN- is the curve number for the day. The initial abstractions, Ia, is commonly approximated as 0.2S. Then the above equation becomes:

$$Qsurf = \frac{\left(R_{day} - 0.2S\right)^2}{\left(R_{day} + 0.8S\right)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.4$$

Runoff will only occur when R_{day} > Ia. The peak runoff rate is the maximum runoff flow rate that occurs with a given rainfall event. The peak runoff rate is an indicator of the erosive power of a storm and is used to predict sediment loss. SWAT calculates the peak runoff rate with a modified rational method (Neitsch, et al., 2005). The rational formula is:

$$q_{peak} = \frac{C.i.A}{3.6} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 3.5$$

Where: q_{peak}: is the peak runoff rate (m^3/s),

C: is the runoff coefficient

i: is the rainfall intensity (mm/hr.)

A- is the sub-basin area (km^2) and 3.6 is a unit conversion factor.

3.5.2. Sediment Component

SWAT model calculates the surface erosion and sediment yield within each HRU with the Modified Universal Soil Loss Equation (MUSCLE) (Williams, 1975). The sediment routing in the channel consists of channel degradation using stream power and deposition in channel using fall velocity. MUSLE predicts sediment yield as a function of surface runoff volume, peak runoff rate, area, soil erodibility, land cover, land support practices, topography, and percent coarse fragments in top soil layer. The estimated sediment yield is a function of the surface runoff and peak rate of runoff. The sediment yield has direct relation with the rainfall and stream flow. Channel sediment routing in SWAT is based on the maximum amount of sediment that can be transported from a reach segment, which is a function of peak channel velocity (Neitsch, et al., 2011). The MUSCLE is:

$$Sed = 11.8\left(Q_{surf}.q_{peak}.A_{hru}\right)^{0.56}.K_{USLE}.C_{USLE}.P_{USLE}.LS_{USLE}.C_{FRG} \dots\dots\dots\dots\dots\dots 3.6$$

Where: sed: sediment yield on a given day (tons)

Q_{surf} : is the surface runoff volume (mm water/ha)

q_{peak}: is the peak runoff rate (m^3/s)

A_{hru}: is the area of the HRU (ha)

K_{USLE}: is the USLE soil erodibility factor (0.013 metric ton m^2hr/ (m^3.metric ton cm))

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

P_{USLE}: is the USLE support practice factor

LS_{USLE}: is the USLE topographic factor and

C_{FRG}: is the coarse fragment factor.

Sediment transport in the channel network is a function of two processes, deposition and degradation, operating simultaneously in the reach. Degradation occurs when sediment concentration is less than maximum amount of sediment that can be transported from a reach segment, whereas deposition occurs when sediment concentration is greater than the maximum amount. SWAT computes the maximum concentration of sediment in the reach at the beginning of the time step. Depending on the concentration of sediment in the reach and transport capacity of the channel deposition or degradation process will occur. The final amount of sediment in the reach is determined as:

$$sed_{ch} = sed_{ch,i} - sed_{dep} + sed_{deg} \dots\dots\dots\dots\dots\dots.\dots\dots 3.7$$

Where: sed_{ch} is the amount of suspended sediment in the reach (metric tons/day)

$sed_{ch,i}$: is the amount of suspended sediment in the reach at the beginning of the time period (metric tons/day)

sed_{dep}: is the amount of sediment deposited in the reach segment (metric tons/day) and

sed_{deg}: is the amount of sediment re-entrained in the reach segment (metric tons/day).

The amount of sediment transported out of the reach is calculated as:

$$sed_{out} = sed_{ch} * sed_{dep} \frac{V_{out}}{V_{ch}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..3.8$$

Where: sed_{out}: is the amount of sediment transported out of the reach (metric tons/day)

Sed_{ch}: is the amount of suspended sediment in the reach (metric tons/day)

V_{out}: is the volume of outflow during the time step (m^3/s), and

V_{ch}: is the volume of water in the reach segment (m^3).

3.5.3. Potential Evapotranspiration

Potential Evapotranspiration is a collective term that includes transpiration from the plant and evaporation from the water bodies and soil. Evaporation is the primary mechanism by which water is removed from a watershed. This process is responsible for the loss of water from the soil formation in the form of vapor. An accurate estimation of evapotranspiration is critical in the assessment of water resources and the impact of land use change on these resources. Data of evaporation and evapotranspiration is the main parameter provided for SWAT model simulation. It has two options, either loading measured evaporation data or choosing the methods for SWAT simulation.

There are three methods of Evaporation determination by SWAT model itself: Prestily-Taylor method (Priestly and Taylor, 1972), Penman-Monteith method (Monteith, 1965) and Hargreves methods (Hargreaves, et al., 1985). Penman-Monteith methods requires all climate data, Prestily method only depends on radiation data and Hargreves method uses maximum and minimum temperature data to determine potential evaporation (PET) and actual evapotranspiration (ET). Evapotranspiration is calculated using Penman-Monteith equation 3.9. For this study, the Penman-Monteith method was selected as the method is widely used and all climatic variables required by the model are available for the stations in and around the study area.

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad \ldots\ldots\ldots 3.9$$

Where: ETo - evapotranspiration $\left(\frac{mm}{day}\right)$

Rn – net radiation at the crop surface$\left(\frac{MJ}{m^2 day}\right)$

G- Soil heat flux density$\left(\frac{MJ}{m^2 day}\right)$

T-mean daily air temperature at 2m height $({}^0C)$

U_2 – wind speed at 2m height $\left(\frac{m}{s}\right)$

es – Saturation vapor pressure(KPa)

ea – actual vapor pressure (KPa)

es - ea - saturation vapor pressure deficit (KPa)

Δ - Slope vapor pressure curve $\left(\frac{KPa}{{}^0C}\right)$

γ – Psychometrics constant $\left(\frac{KPa}{{}^0C}\right)$

3.5.4. Groundwater

The groundwater system in SWAT consists of shallow and deep aquifers. Shallow aquifer water balance consists of recharge entering the aquifer, groundwater flow, or base flow into the main channel, the amount of water moving into the soil zone in response to water deficiencies, and the amount of water removed from the shallow aquifer due to pumping. The deep aquifer water balance consists of percolation from the shallow aquifer to the deep aquifer and the amount of water removed from the deep aquifer due to pumping.

The SWAT uses different empirical and analytical techniques to account for the above components of the ground water distribution (Neitsch, et al., 2005) The volume of water available in the shallow aquifer is governed by the recharge from the top soil profile (recharge), the flow into the main stream channels or reach (base flow), the movement into the overlaying unsaturated zone (revap), and the flow to the deep aquifer (deep percolation). Base flow occurs only when the amount of water stored in the shallow aquifer exceeds a threshold volume of water. Similarly, deep percolation happens only when the amount of water stored in the shallow aquifer exceeds a threshold value.

3.5.5. Soil- water interaction

Water that enters the soil may move along various pathways, including: removal from soil by plant uptake or evaporation, percolation past the soil profile to become aquifer recharge or lateral movement in the profile and contribute to stream flow. The movement of water through the soil can be along various pathways: removal from the soil by evaporation or plant uptake, percolation, or lateral movement in the profile. Water that infiltrates into the soil profile has several routes to leave the soil. The soil water process include: infiltration, evaporation, plant uptake, lateral flow, and percolation to lower layers.

The water content of a soil can range between wilting point to the soil porosity when the soil is saturated. Between these two states there are two points important for plant-soil interaction: field capacity and wilting point. Field capacity is the amount of water held in the soil after excess gravitational water has drained away and after the rate of downward movement has materially decreased. Permanent wilting point is defined as the water content at which the leaves of a growing plant reach a stage of wilting from which they do not recover.

The SWAT calculates field capacity by adding available water capacity which is an input by the user and the wilting point. Started flow occurs when the water content of a soil layer surpasses the field capacity for the layer. 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; weather is one of the model component that needs data on precipitation, air temperature, solar radiation, wind speed and relative humidity data; sedimentation is another component of the model that needs information on surface runoff, peak rate flow, soil erodibility, crop management, erosion practices, slope length, and steepness; soil temperature, crop growth, nutrient pesticides and agricultural management are also components of SWAT.

The SWAT model simulates eight major components: hydrology, weather, sedimentation, soil temperature, crop growth, nutrients, pesticides, and agricultural management (Neitsch, et al., 2005).

Hydrology: based on water balance equation, which relates interception, soil water, runoff, evapotranspiration, daily amount of precipitation, percolation and base flow or return flow.

Weather: weather variables for driving the hydrologic balance are precipitation, air temperature, solar radiation, wind speed and relative humidity, daily inputs can be entered directly or the weather generator can be used to simulate daily values for these variables from aggregated monthly values.

Sedimentation: sediment yield is computed from the MUSLE (Modified Universal Soil Loss Equation) equation.

Soil temperature: daily average simulated at the center of each soil layer for use in hydrology and residue decay.

Crop growth: crop growth model is a simplified of EPIC (Erosion-Productivity Impact Calculator) crop model with the concepts of phenological crop development based on daily accumulated energy units, harvest index for partitioning grain yield, Montheith's approach for potential biomass and water, nutrient and temperature stress adjustments.

Nutrients: amount of NO_3-N contained in runoff, lateral flow and percolation are estimated as the products of the volume of water and the average concentration. Estimating soluble P in surface runoff is based on the concept of partitioning of pesticides into the solution and sediment phase as P is mostly associated with the sediment phase.

Pesticides: GLEAMS (Groundwater Loading Effects on Agricultural Management Systems) technology for simulating pesticide transport by runoff, percolate, soil evaporation and sediment is used in the pesticide subcomponent.

Agricultural managements: provides sub models that simulate tillage systems, application of irrigation water, fertilizer, pesticides and grazing systems.

3.6.Input Data and Their Sources

SWAT is highly data intensive model that requires specific information about the watershed. The required input data for this study were Digital Elevation model (DEM), Land use/Land

Cover map, soil map and data, stream flow data, and weather data. These data were collected from different sources.

3.6.1. Digital Elevation Model (DEM)

The DEM was used to delineate the watershed and to analyze the drainage patterns of the land terrain. Topography is defined by a DEM that describes the elevation of any point in a given area at a specific spatial resolution. DEM was used to calculate Sub-basin parameters such as slope, slope length, and to define stream network characteristics such as a channel slope, length and width were all derived from DEM. A Digital Elevation Model of 30 m by 30m, in the Grid format and projected was used in this study and the original DEM in geographic coordinate system was obtained from Ethiopian Ministry of water, Irrigation and Energy bureau GIS Department.

3.6.2. Land Use/Land Cover Map

The land use/ land cover map gives the spatial extent and classification of the various land use/ land cover classes of the study area. The land use/land cover data combined with the soil cover data generates the hydrologic characteristics of the basin or the study area, which in turn determines the excess precipitation, recharge to the ground water system and the storage in the soil layers. LULC is one of the most important factors affecting different processes in the watershed, such as surface runoff, erosion, recharge and evapotranspiration. The LULC data for this study area was obtained from Ethiopian Ministry of water, Irrigation and Energy bureau GIS Department.

3.6.3. Soil Map and data

SWAT requires soil properties and land cover information to simulate loads in the hydrological components. The importance of soil properties stems from the important role they play in hydrological modeling (Kassa, 2009). Hydrological soil type classification considers the physical properties of soils including texture, infiltration capacity, and particle size and soil structure. The soil data as required by SWAT to predict the stream flow should include the relevant hydraulic conductivity properties: the soil bulk density, the saturated hydraulic conductivity and the soil available water capacity (SOL_AWC). The parameters of the soil such as the Soil Bulk Density (g/cc), Saturated Hydraulic Conductivity, Ks (mm/hr.), soil group and Soil map. They were obtained from Ethiopian Ministry of water, Irrigation and Energy bureau GIS Department.

3.6.4. Stream Flow data

SWAT simulates streamflow, sediment yield, nutrient and pesticide transport at catchment scale, on a continuous, daily time step (Neitsch, et al., 2011). SWAT does not use this data values in calculations but instead they are used for comparing observed and simulated values in calibration and validation periods. Stream flow in a main channel is determined by three sources: surface runoff, lateral flow and base flow from the shallow aquifers. Daily streamflow was obtained from Ethiopian Ministry of water, Irrigation and Energy bureau hydrology Department.

3.6.5. Sediment data

There was no measured sediment data for the Finchaa watershed, therefore it is necessary to construct the sediment rating curve to develop an equation between the relation of flow and sediment.

Sediment rating curve: a sediment rating curve describes the average relation between discharge and suspended sediment concentration for a certain location (Asselman, 2000). The sediment rating curve is usually expressed as a power function of discharge.

$$Q_s = aQ^b$$

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

Q is water discharge (m^3/s)

a and b are regression coefficient and exponent respectively

The sediment rating curve was constructed using the linear least squares fit of the Power. The figure below shows the sediment rating curve and the equation developed from the sediment rating curve described below.

$$Qs = 54.154Q^{0.219}$$

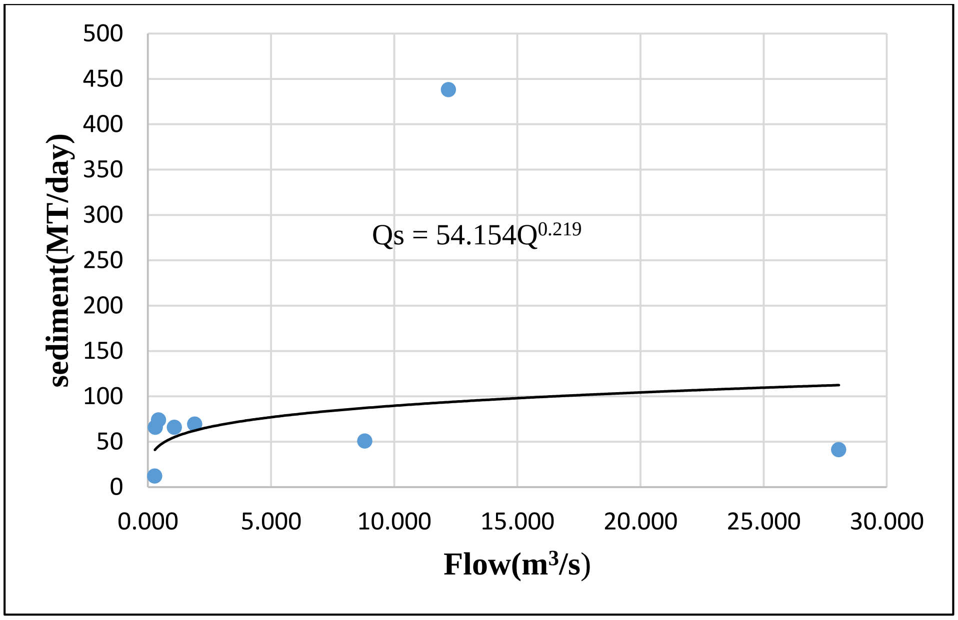


Figure 3.6. Suspended sediment concentration rating curve for Finchaa station.

3.6.6. Weather data

The SWAT model has a built-in weather generator to generate climate data for the whole basin using time series data of a single gauging station, which was used by (Schoul and Abbaspour, 2006). Weather data is needed by the SWAT model to simulate the hydrological process. The data required for this study was collected for four stations within and around the study area: Combolcha, Finchaa, Hareto and Shambu. SWAT requires daily precipitation, maximum and minimum temperature, solar radiation, wind speed, and relative humidity as inputs. The rainfall and temperature (maximum and minimum) data were available for all stations, but relative humidity, wind speed, solar radiation data were not available for all stations so they were downloaded from Global Weather data for SWAT for Shambu and Finchaa station. Hence, the downloaded data ranges from 1979 to 2014 but, for the study purpose thirty years data from 1985 to 2014 have been used for further analysis. The available weather data were obtained from Ethiopian National Meteorological Service Agency.

Table 3.1. Location of Meteorological Stations and the data year within and Around the Watershed.

S. No.	Station Name	Elevation(m)	Latitude	Longitude	Observation period					
					Pcp	Temp.	Rel.hum	Wind sp.	Solar rad.	Flow
1	Combolcha	2341	37.473	9.502	1985-2014	1985-2014	No data	No data	No data	no data
2	Finchaa	2248	37.370	9.570	1989-2014	1989-2014	1985-2014	1985-2014	1985-2014	1990-2011
3	Hareto	2260	37.120	9.350	1985-2014	1985-2014	No data	No data	No data	no data
4	Shambu	2460	37.121	9.571	1985-2014	1985-2014	1985-2014	1985-2014	1985-2014	no data

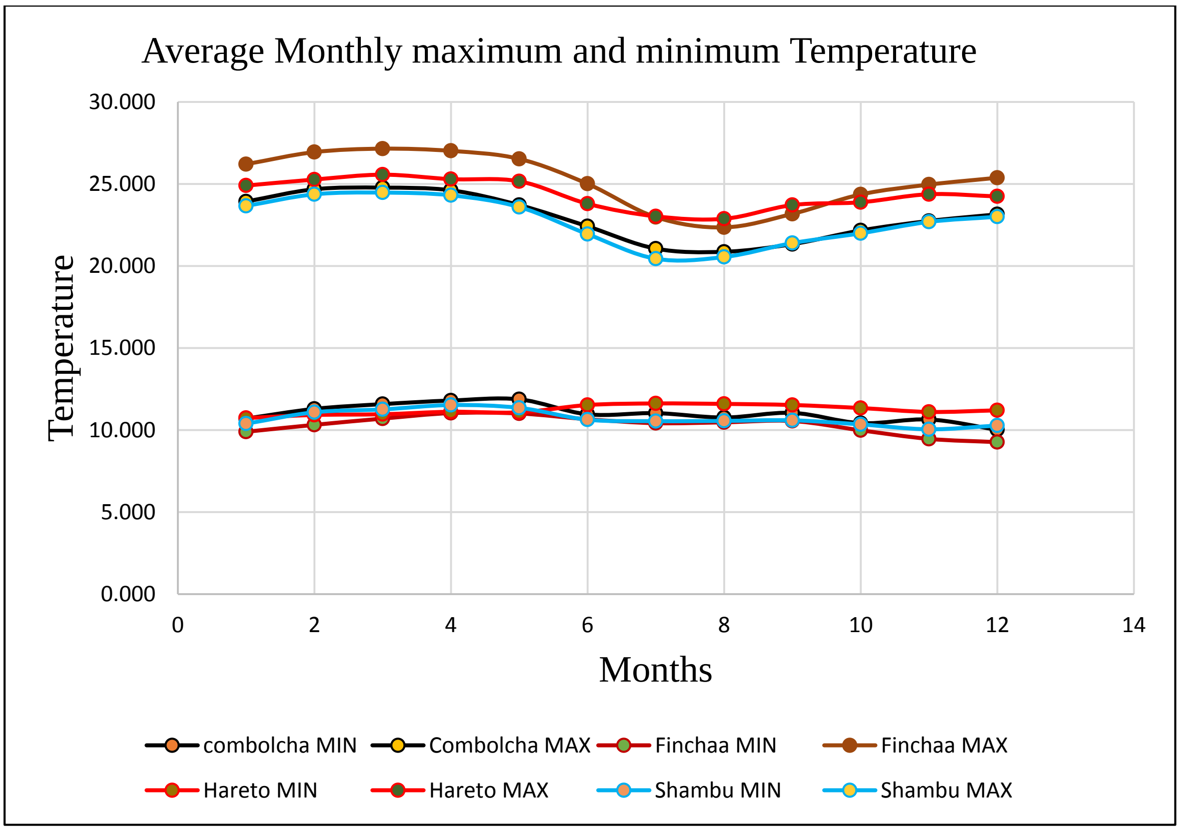


Figure 3.7. Average monthly minimum and maximum temperature patterns of different stations (1985-2014)

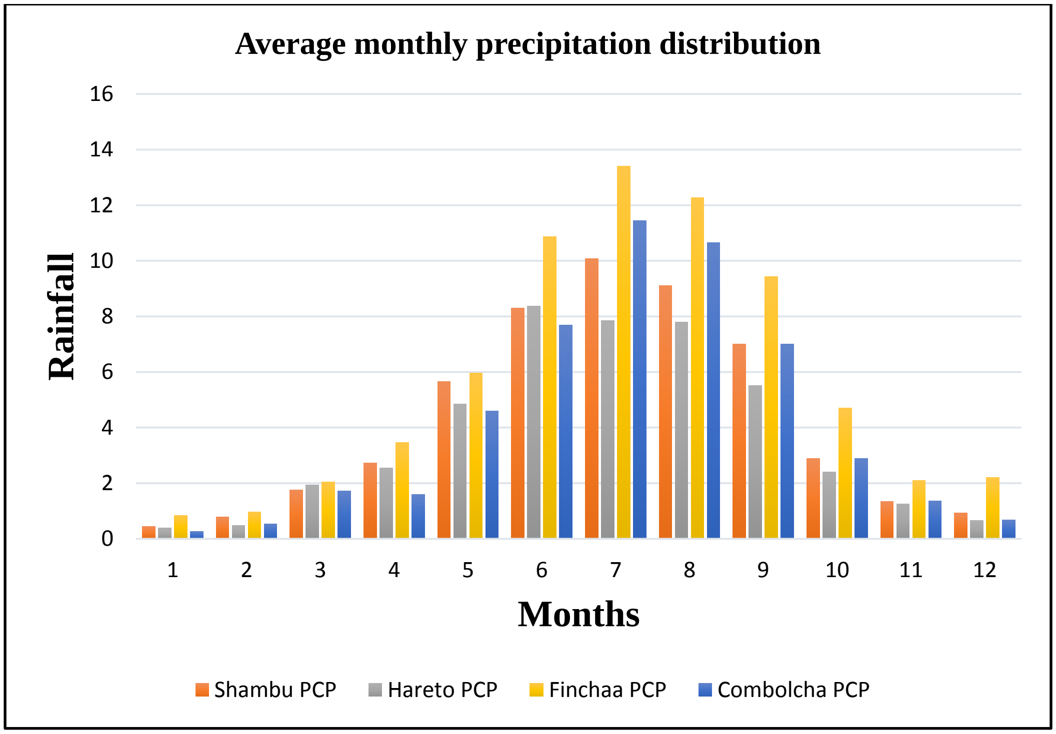


Figure 3.8. Average monthly rainfall distributions for different stations (1985-2014)

3.7.Input data preparation, processing and analysis

After the data was collected, an analysis of all the collected data was made. One of the problems in hydrology especially in developing countries is hydrological data both in quantity (length of record) and quality (standard of scientific approach). The output of any research depends highly on data input. The acquired data were checked for any outliers and missing values. The missing meteorological and stream flow data were filled using linear regression method. The Advances in scientific hydrology and in the practice of engineering hydrology are dependent on good, reliable and continuous measurements of the hydrological variables.

The data were then arranged into daily series and saved as Text files as an input into the SWAT model. For weather generator the necessary average Precipitation value, maximum and minimum temperature, relative humidity, dew point, average Solar radiation, average wind speed, maximum half hour, probability of wet and dry days, skewness coefficients were determined by using PCP STAT, Dew02.exe and pivot table. The weather generator is used to either generate daily weather data or fill in missing values in the input data. The generator generates daily weather data based on monthly averages.

3.7.1. Missing data completion

Missing data is a common problem in hydrology. To perform hydrological analysis and simulation using data of long time series, filling in missing data is very important. A number of methods have been proposed to estimate missing rainfall data (RichardHMcCuen, 1989). The missing data can be completed by using meteorological and hydrological stations located in the nearby stations, provided that the stations are located in the hydrologically homogenous region. The missing values were filled using the values from the nearby values of recording stations.

A regression analysis is the application of a statistical procedure for determining a relationship between variables (Haan, 2002). In this procedure one variable was expressed as a function of other variables. The variable to be determined is termed as the dependent variable while others are called the independent variables. Application of regression analysis made possible completing short and long period breaks in data series for given meteorological station.

3.7.2. Consistency of recording stations

The quality of the results for any study depends on the quality of the input data used in data analysis. Before using the recorded data of station, it is necessary to first check the data for consistency. If the conditions relevant to the recording of a rain gauge station have undergone a significant change during the period of record, inconsistency would arise in the rainfall data of that station. This inconsistency would be felt from the time the significant change took place. The checking for inconsistency of a record was done by double mass curve technique.

Double mass curve is a commonly used data analysis approach for investigating the behavior of records made of hydrological or meteorological data at a number of locations. Double mass analysis used for checking consistency of a hydrological or meteorological record and is considered to be an essential tool before taking it for analysis purpose. This technique is based on the principle that when each recorded data comes from the parent population, they are consistent. The accumulated totals of the gauge are compared with the corresponding totals for a representative group of nearby gauge. If a decided change in the regime of the curve is observed it should be corrected. It is used to determine whether there is a need for corrections to the data to account for changes in data collection procedures or other local conditions.

However, as all the selected stations in this study were consistent, there was no need of further correction. The graphs below shows all points set on or from almost the straight lines, which was plotted for checking of consistency of rainfall, all stations were consistence to each other. Therefore, the stations did not need further adjustment. The Double mass curve for each stations of rainfall and for temperature were illustrated under Appendix I and II respectively.

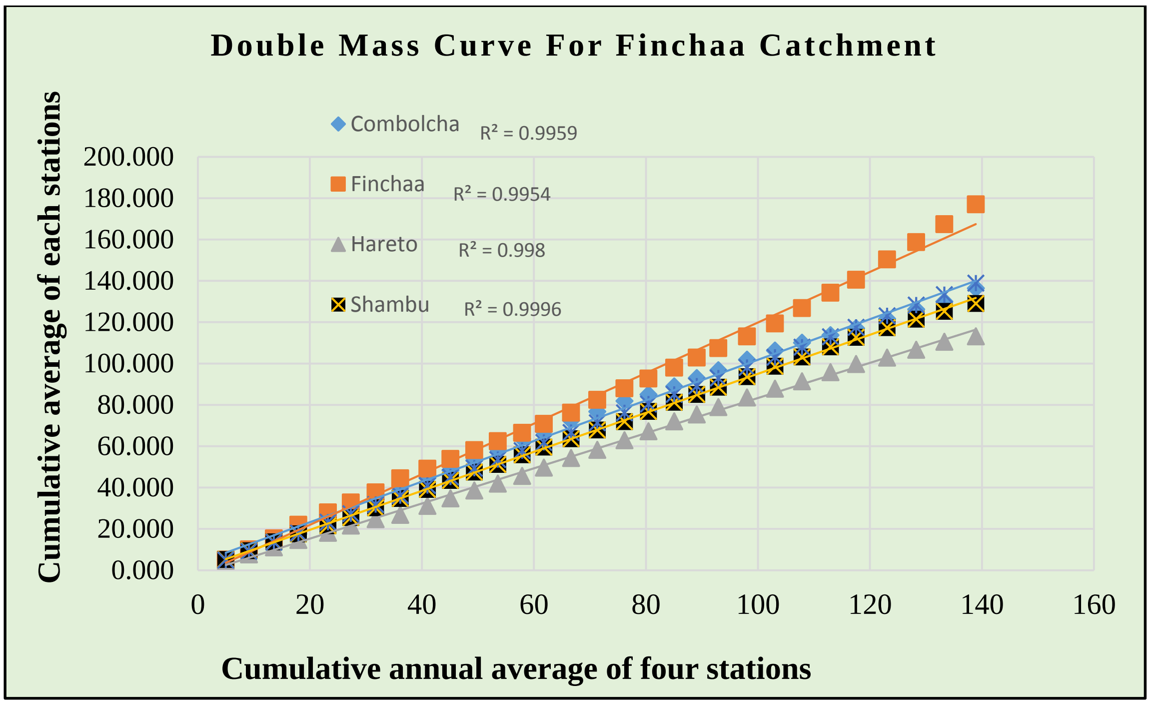


Figure 3.9. Consistency checking for the four Rainfall stations within and around the catchment.

3.8.Model Setup

3.8.1. Watershed delineation

At first, setup for new SWAT project has been created. The required spatial data sets were projected to the same projection called Adindan UTM Zone 37 N, which is the transverse Mercator projection parameters for Ethiopia, using ArcGIS 10.1. The geographic information system interface-ArcSWAT was used for the setup and parameterization of the model. A DEM had a Geographic coordinate system so it was converted into the projected coordinate system by using Arc tool box Data management tool. After sub-setting the DEM data, it has been imported in the SWAT project to start watershed delineation.

The procedures followed in the model setup were involved integrating the DEM, watershed delineation, land use/land cover map and soil characterization, weather data to create Sub-basins and hydrologic response Units and editing input information's. This was followed by the creation of the watersheds. The watershed delineation process consists of five major steps, DEM setup, stream definition, outlet and inlet definition, watershed outlets selection and definition and calculation of sub basin parameters.

3.8.1.1.DEM Setup

Digital Elevation Model data is required to calculate the flow accumulation, Stream networks and watershed delineation using SWAT watershed delineator. In the watershed delineation the DEM was loaded to the model interface. Its properties were the set to verify the projection and units of measurement. Finally, the DEM was pre-processed to remove all the non- draining zones (sinks).

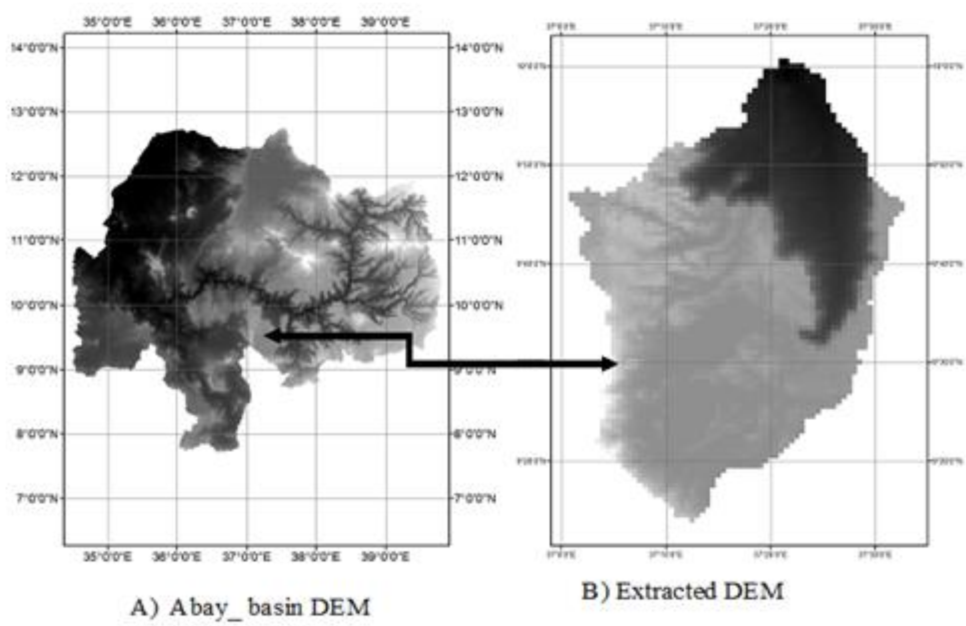


Figure 3.10. Digital Elevation Model (DEM) of the study area.

3.8.1.2.Stream definition

The stream definition and the size of sub-basins were carefully determined by selecting threshold area or minimum drainage area required to form the origin of the streams. In this section, initial stream network and sub-basin outlets were defined. This was achieved by specifying a threshold area or critical source area (Di Luzio, et al., 2002), which is the minimum drainage area required to form a source of stream. Since the number of sub-basins does not affect the simulated stream flow significantly (Jha, et al., 2007), the suggested threshold was used. It provides the option of defining streams based on DEM under which the flow direction and accumulation have been calculated or importing pre-defined watershed boundaries and streams watershed dataset and stream dataset have been determined. In this section, the method based threshold area was used. Stream definition defines both the stream network and sub-basin outlets. A minimum, maximum and suggested watershed area in hectares was shown in the drainage area box. The size of the sub-basin was changed within the specified range values. The threshold area defines the drainage area required to form the beginning of a stream. After that stream network Create streams and outlets.

3.8.1.3. Outlet and inlet definition

In this section by defining the outlet point of discharge for the sub-basin and inlet of draining watershed and the definition of point source input or by adding manually point source to each sub-basin. The outlets of the sub-basin can represent the monitoring data points and the reservoir where as the inlets of draining watershed represent point source discharge and watershed not modelled in SWAT. Drainage inlets and Sub-basin watershed outlets may be added, deleted or redefined. In this study the outlet and inlet definition was selected by using sub-basin outlet and manually adding the out let for the Finchaa reservoir particularly at the dam site.

3.8.1.4.Watershed outlet(s) selection and definition

Watershed delineation was more defined in this section by defining the outlet(s) point for the whole watershed. It is useful for comparison of measured and predicted flows and concentrations. It is convenient to select the most down-stream outlet of each target watershed to determine the whole basin. The area of the sub-basin was cut short from previous defined sub-basin area after defining the outlet and those are stored in the ‘‘Monitoring Points’’ layer. At the last delineation of watershed process has been run, and when completed a message indicating successful completion displayed.

3.8.1.5.Calculation of Sub-basin Parameter

Final step in the delineation of the watershed was calculation of Sub-basin parameters. The Calculation of Sub-basin Parameters section contains functions for calculating geomorphic characteristics of the sub-basins and reaches, as well as defining the locations of reservoirs within the watershed, number of outlets and number of sub-basins were determined.

Topographic report was created which contained the summary and distribution of discrete land surface elevations in the sub-basins. In addition, a new layer called longest path was added to the map which represents the longest flow path within each of the sub-basins. After the delineation was completed the reservoir along the main channel network was added by the reservoir symbol to the monitoring point's layer.

3.8.2. HRU Analysis

This step calculates the details of the Hydrological Response Units (HRUs) that are used by SWAT. This is basically dividing the basins into smaller pieces each of which has a particular soil/land use /slope range combination. SWAT predicts the land phases of the hydrologic cycle separately for each HRU and routes to obtain the total loadings of the catchment. HRUs enable the model to reflect differences in evapotranspiration and other hydrologic conditions for different land covers and soils. The total runoff depends on the actual hydrologic condition of each land cover/land use and soil present in the watershed. Land cover/land Use and soil are factors greatly influencing the hydrological properties of a watershed that are required by SWAT to describe a sub-basin or HRU.

The distribution of land use, soil and slope characteristics within each HRU have the greatest impact on the predicted stream flow. As the percentage of land use, slope and soil threshold increases, the actual evapotranspiration decreases due to eliminated land use class. Hence, the characteristics of HRUs are the key factors affecting the stream flow. The land use/ land cover and soil maps of the study area were also imported into the model and overlaid to obtain a unique combination of land use, soil and slope within the watershed to the modeled. After the overlay of the land-use, soil maps and slope, the distributions of the Hydrological Response Units within the watershed were determined.

The last step in the HRU analysis was the HRU definition. When defining a HRU, SWAT uses two options that is the dominant land use in the sub-basin and the corresponding soil type, or the generation of multiple HRUs within the sub-basin (Di Luzio, et al., 2002). The

HRU distribution in this study was determined by assigning multiple HRU to each sub-basin. Multiple HRUs create multiple HRUs within each sub-basin. In multiple HRU definition, a threshold level was used to eliminate minor land uses, soils and slope classes in each sub-basin. After the elimination process, the area of the remaining land use, or soil was reapportioned so that 100% of the land area in the sub-basin was modeled. The SWAT user's manual suggests that a 20 % land use threshold, 10 % soil threshold and 20 % slope threshold are adequate for most modeling application.

However, (Setegn, et al., 2008), suggested that HRU definition with multiple options that account for 10% land use, 20% soil and 10% slope threshold combination gives a better estimation of runoff and sediment components. For this study, 10% land use threshold, 10% soil and 10% for slope was used. After land use/ soils/slope definition and HRU definition was done a shape file called 'Full HRUs' were created. There is also the option of performing some additional land use refinements before applying the thresholds and creating the HRUs on the Land Use Refinement (optional) tab. The options under the Land Use Refinement (optional) tab are of either splitting or exempting land use classes depending on the aim of analysis.

The last Step was now reported as done and now available various reports concerning the sub-basin land use, soil and slope distribution, topographic and HRUs properties. To access the report using the HRU analysis reports under the HRU Analysis menu the Final HRU Distribution report was generated. As per the final report the watershed was divided into 27 sub-basins which were further divided into 339 hydrologic response units were created within the Finchaa watershed and sub-basin HRU report has been generated composed of homogeneous land use, soil type, and relevant hydrologic components.

3.8.2.1.Land use/ land cover

Land Use/ land cover is one of the highly influencing the hydrological properties of the watershed. The prepared land-use /land cover was given as input to the model data of the SWAT to describe the HRU of the watershed. Therefore, the impact of each type of LULC was considered in this model to calculate runoff and sediment load in the basin. The default LULC of the SWAT model was linked to LULC map through the look up table which was again linked to the LULC Database.

Look up tables (Di Luzio, et al., 2002), were used to link the LULC and soil data to the SWAT database and custom soil database respectively. The major land use of the study area are presented in Figure 3.11. Original land use/land cover types and redefined according to the SWAT code and their aerial coverage are shown in table 3.2.

Table 3.2. Original land use/land cover types and redefined according to the SWAT code and their aerial coverage.

Original land use	Redefined land use according to SWAT database	SWAT code	Area	
			Ha	% watershed
Swamps/wetland	Wetlands-Non-Frosted	WETN	47488	16.59
Afro-alpine Belt	Forest-Evergreen	FRSE	11752	4.11
Built up-land	Residential	URBN	56328	19.67
Degraded Savanna	Range-Grasses	RNGE	17608	6.15
Open wood land	Forest-mixed	FRST	23652	8.26
Shrub land	Range-Brush	RNGB	57664	20.14
Water body	Water	WATR	41544	14.51
Irrigated Farm	Corn	CORN	7192	2.51
Moderately cultivated	Agricultural Land -Row -Crops	AGRR	23072	8.06
Total			**286300**	**100**

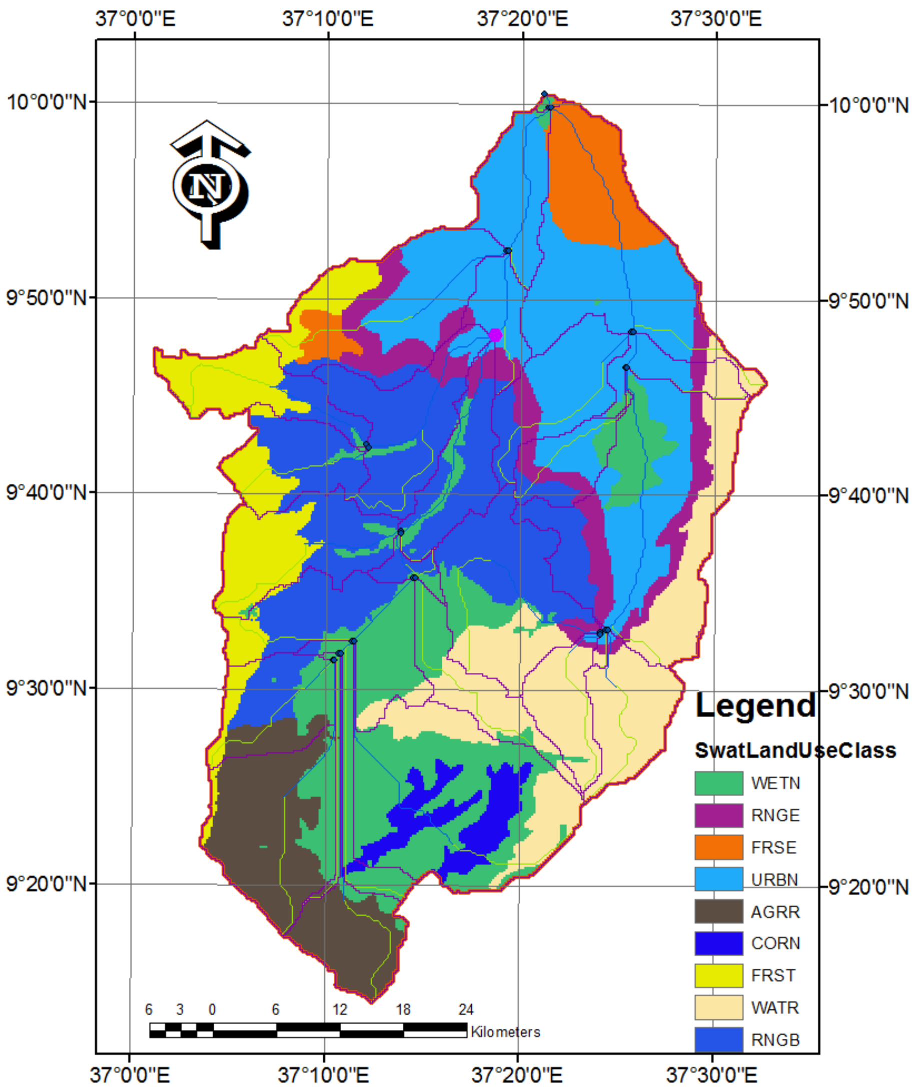


Figure 3.11. Map of the major land use/ land cover types of Finchaa watershed

Land Use classes and their description

Water body: Areas completely inundated by waters. Here are included lower level categories such as streams, rivers, canals, reservoirs, estuaries and the lake.

Swamp: Areas flat & swampy (locally called *raatuu)* during both wet & dry seasons; mainly covered with grass.

Wetlands: areas inundated or saturated by surface or groundwater in permanent or temporary basis to support a prevalence of vegetation adapted for life in saturated conditions, are those areas where the water table is at, near or above the land surface for a significant part of most years.

Shrub land: Is a plant community characterized by vegetation dominated by shrubs, often also including grasses, herbs and geophytes. Shrub land may either occur naturally or be the result of human activity. The dominant plant forms, i.e., the shrubs, constitute the non-herbaceous plants that branch out at the base of their stem and usually grow only to heights of less than 5 meters.

Grass land: Areas covered with grass used for grazing, as well as bare lands that have little grass or no grass cover. It also includes other small sized plant species. An area in which the natural vegetation consists largely of tall perennial grasses associated with savanna grasses, herbaceous and shrub vegetation with few and very sparse trees.

Built-up Land: This is an area of a permanent residential areas, service centers (as schools and health centers),offices, shops, warehouse, places of worship, barn/store, factory and refinery for processing of sugarcane, places for packing sugarcane, and infrastructures as transportation track ways and foot paths, educational centers, and medical centers.

Agricultural land: land used primarily for production of food. This land use type includes various lower level categories such as cropland and pasture, ornamental horticultural areas; confined feeding operations; and other agricultural land.

Forest land: Areas covered with natural and plantation trees and sometimes mixed with enrichment plantations, forming nearly closed canopies of 70-100% cover. It includes Evergreen forest land, mixed forest and deciduous forests.

- Evergreen forest: includes all forested areas in which the trees are predominantly those which remain green throughout the year.
- Mixed forest land: includes all forested areas where both evergreen and deciduous trees are growing.
- Deciduous forest: includes all forested areas having a predominance of trees that lose their leaves at the end of the frost-free season or at the beginning of a dry season.

Irrigated farm: Is the application of water to the land or soil. It is used to assist in the growing of agricultural crops, maintenance of landscapes and vegetation of distributed soils in dry areas and during periods of in adequate rainfall.

3.8.2.2.Soil Data

Soil data is also one of the major input data for the SWAT model with inclusive and chemical properties. Soil physical attributes were initially stored to the SWAT's soil database through an Edit database interlace and relevant information required for hydrological modeling and soil erosion modeling was provided to the model. To integrate the soil map with SWAT model, manually define was used. For this study the soil map was integrated or defined by double click in the land use SWAT column in the SWAT Land Use Classification. The soil types and areal coverage of the soil types are presented in Table 3.3. Major soil types in the sub-basin are shown in table 3.3 and Figure 3.12

Table 3.3. Soil type of the study area with their aerial coverage.

Soil types	Area	
	Ha	% in the watershed
Chromic Luvisols	10552	3.69
Eutric Cambisols,	42496	14.84
Eutric Regosols,	596	0.21
Humic Cambisols	1896	0.66
Eutric Nitosols	127036	44.37
Cambic Arenosols	24864	8.68
Haplic phaeozems	8720	3.05
Chromic Vertisols	23860	8.33
Dystric Cambisols	28348	9.90
Water	17932	6.26
Total	**286300**	**100**

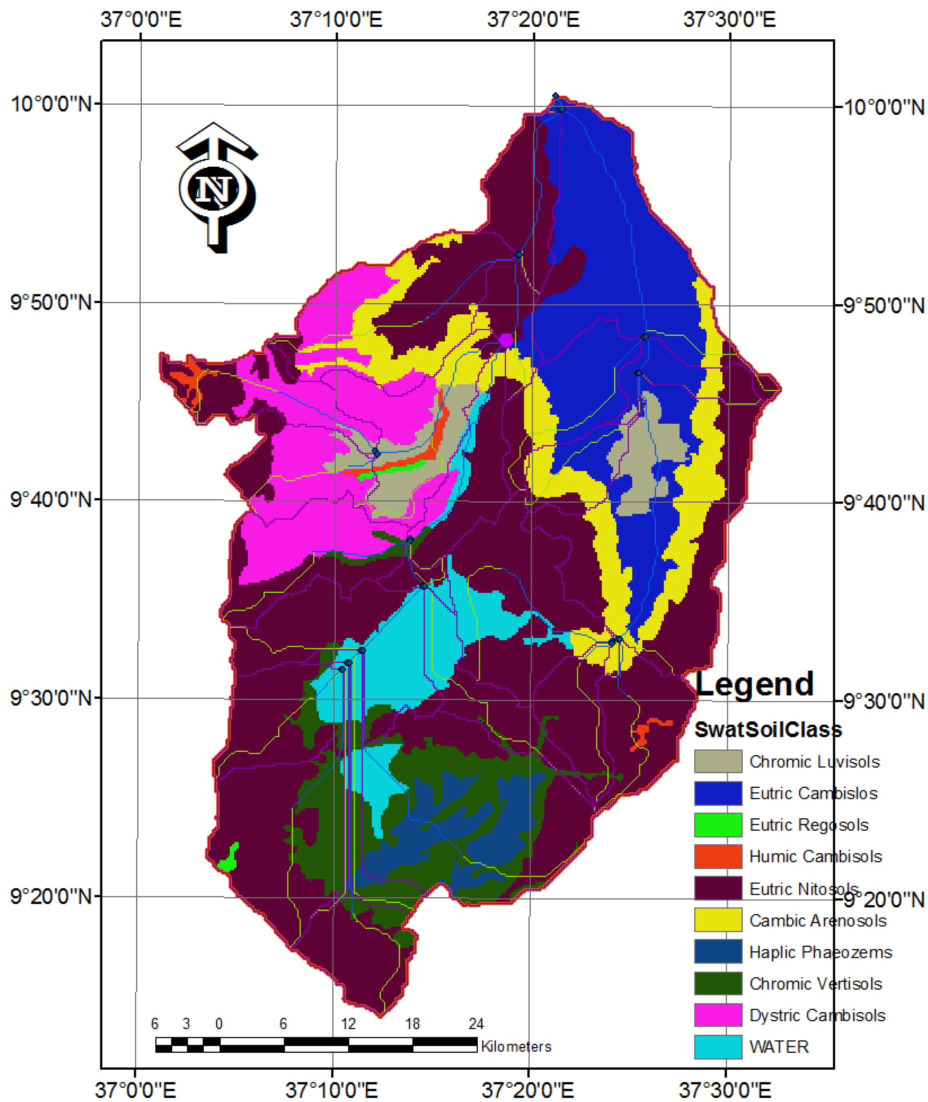


Figure 3.12. Map of the major soil types of Finchaa watershed.

3.8.2.3.Slope

Slope is derived from inputted DEM, so that the model uses this slope for the development of HRU in addition to LULC and soil input parameters. Arc SWAT allows the integration of land slope classes (up to five classes) when defining hydrologic response units. There are possibilities to choose simply a single slope class, or choose multiple classes. For this study multiple slope discretization has been selected.

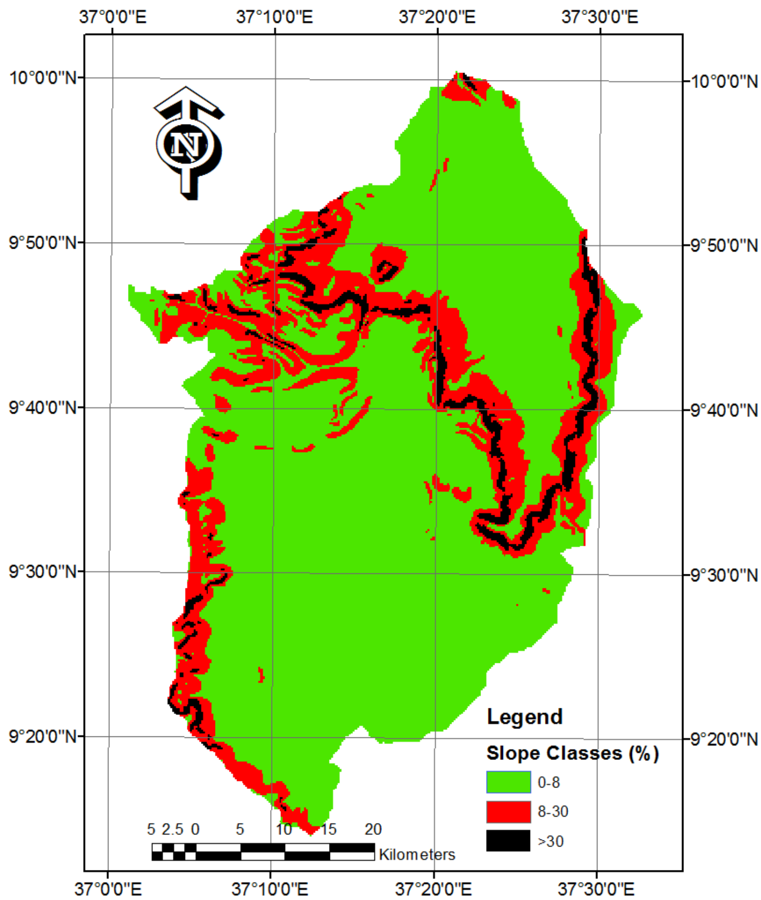


Figure 3.13. Map of Slope classes used in the SWAT of the Finchaa watershed.

Table 3.4. The slope classes of the Finchaa watershed

Classes	Slope range (%)	Land form	Area	
			ha	%
Class 1	0-8	Flat or almost Flat	218468	76.31
Class 2	8-30	Gentle Sloping, Undulating Plain	56396	19.70
Class 3	>30	Steep hills, Very steep slopes, ridges, and mountains	11436	3.99

3.8.3. Weather Generator and Writing input tables

Weather generators solve the problem of Lack of full and realistic long period climatic data by generating data having same statistical properties as the observed ones. SWAT built in weather generator called WGEN that is used to fill the gaps, for generating missing data.

But, for this study the missing data were filled by linear regression and the data used for weather generator were prepared using different software's discussed in section 3.4.

The Write Input tables menu contains items that allow building database files containing the information needed to generate default input for SWAT. Weather data to be used in a watershed simulation was imported once the HRU distribution has been defined. The weather data has been loaded using the weather stations command in the write input tables menu item. Using the file browser the locations of the weather generator stations prepared in the text format was selected. In this study all the weather stations or the weather data definitions (weather generator data, rainfall data, temperature data, solar radiation data, wind speed data and relative humidity data) locations were prepared in text format and loaded.

After the database set up was completed the weather gages selected was added to the monitoring point layer. The Write commands become enabled after weather data were successfully loaded. These commands were enabled in sequence and processed only once for a project. Before the SWAT run, the initial watershed input values were defined. These values were set automatically based on the watershed delineation and land use/soil/slope characterization. There are two ways to build the initial values: activate the Write All command or the individual Write commands on the Write Input Tables menu. The first option has been selected for this study.

3.8.4. Edit SWAT Input

The edit SWAT input menu allows to edit the SWAT model databases and the watershed databases files containing the current inputs for the SWAT model. To edit any parameters they should be added to the watershed configuration during the watershed discretization. The edits made to the parameters using the ArcSWAT interface are reflected only in the current SWAT project. If the parameters are not defined in the watershed a dialog box notifies the warning.

3.8.5. SWAT Simulation

The SWAT Simulation menu allows to finalize the setup of input for the SWAT model, to run the SWAT model and to read the SWAT output by importing files to database and saving to the place of interest or by opening the output.std. At the last Running SWAT check take

Place for output visualization. Finally, the other key aspects of the SWAT simulation performed for the watershed were:

- Output time step: Monthly.
- Simulation period: thirty years (1985–2014) totally but for calibration and validation separately.
- Rainfall distribution: skewed normal.

After this sensitivity analysis, calibration and validation has been carried out by using SWAT-CUP.

3.9.Base Flow Separation

Base flow is the ground water contribution to streamflow. Base flow is an important component of stream flow, which comes from ground water storage or other delayed sources (shallow subsurface storage, lakes, etc.). Base flow is a portion of stream flow that is not directly generated from the excess rainfall during storm event. Determination of the base flow component of stream flow is necessary to understand the hydrologic budgets of surface and ground water basins. The catchment size, soil type, geology, land scape, vegetation covers, climate etc., can be considered as the major catchment characteristics that influence the amount of the base flow contribution to the total stream flow. The automated base flow separation and recession analysis technique uses software called Base flow separator-program found from the SWAT website.

3.10. Conceptual Basis of the SUFI-2 Uncertainty Analysis

SWAT-CUP is a public domain program linking the SUFI-2 procedure to SWAT. SWAT-CUP provides a decision making frame work that incorporates a semi-distributed approach using both manual and automated calibration incorporating sensitivity and uncertainty analysis. The Sequential Uncertainty Fitting, version 2 (SUFI-2) is one of the uncertainty analysis programs that is incorporated in an independent program called SWAT calibration and Uncertainty Program (SWAT-CUP) (Abbaspour, 2007), that perform uncertainty analysis due to both parameter and model uncertainties. Its main function is to calibrate SWAT and perform validation, sensitivity and uncertainty analysis for a watershed model created by SWAT.

SUFI-2 is developed for a combined calibration and uncertainty analysis to find parameter uncertainties while calculating smallest possible prediction uncertainty band. In SUFI-2, parameter uncertainty accounts for all sources of uncertainties such as uncertainty in driving variables (e.g., rainfall), parameters, conceptual model, and measured data (e.g., observed flow, sediment) (Abbaspour, et al., 2007). Source of uncertainties in distributed models are due to inputs such as rain fall and temperature. Therefore, carrying out uncertainty analysis for the prediction of the hydrological model is crucial to decide the calibrated parameters to transfer to other homogenous catchments and also using for further predictions.

The sequential uncertainty fittings uncertainty of input parameters are depicted as uniform distributions, while model output uncertainty is quantified by a *P-factor* which is the percentage of measured data bracketed the 95% prediction uncertainty (95PPU) calculated at the 2.5% and 97.5% levels of the cumulative distribution of output variables obtained through Latin hypercube sampling (Abbaspour, et al.,2007). If measurements are of high quality, then 80-100% of the measured data should be bracketed by the 95PPU, while a low quality data may contain many outliers and it may be sufficient to account only 50% of the data in the 95PPU. The goodness-of-fit and the degree to which the calibrated model accounts for the uncertainties are assessed by the above two measures. Their fitted values are obtained through calibration using SUFI-2 (Abbaspour, et al., 2007).

3.11. Sensitivity Analysis

Sensitivity analysis is the process of determining the rate of change in model output with respect to changes in model inputs (parameters). Model parameters that have high sensitivity must be chosen with care because small variations in their values can cause large variations in model output, and therefore it is important to ensure that the parameter value is the best possible estimate. Model parameters that have low sensitivity do not require as much examination in their selection because small changes in their values do not cause large changes in model output. Sensitivity analysis is a method of minimizing the number of parameters to be used in the calibration step by making use of the most sensitive parameters largely controlling the behavior of the simulated process (Zeray, 2006). This appreciably eases the overall calibration and validation process as well as reduces the time required for it.

The theoretical background of the sensitivity analysis method that is implemented in SWAT is called the Latin Hypercube One-factor-At-a-Time (LH-OAT). LH-OAT design is very useful method for SWAT modelling as it is able to analyze the sensitivity of many parameters. The method in the ArcSWAT interface combines the Latin Hypercube (LH) and one –factor-at- a- time (OAT) sampling (Van Griensven, 2005). The LH-OAT merges the one-at- a time (OAT) plan and Latin hypercube sampling by using the Latin Hypercube example as primary points for an OAT design. This approach combines the advantages of global and local sensitivity analysis method and can efficiently provide a rank ordering of parameter importance (Sun and Ren, 2013).

Two types of sensitivity analysis were generally performed: local, by changing values one at a time, and global, by allowing all parameter values to change. The two analyses, however, may yield different results. The global sensitivities are determined by calculating the following multiple regression system, which regresses the Latin hypercube generated parameters against the objective function values in file goal.sif2. $g = \alpha + \sum_{i=1}^{n} \beta ibi$. The sensitivities given above are estimates of the average changes in the objective function resulting from changes in each parameter, while all other parameters are changing.

This gives relative sensitivities based on linear approximations and hence, only provides partial information about the sensitivity of the objective function to model parameters. The disadvantage of the global sensitivity analysis is that it needs a large number of simulations. 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.

3.12. Model calibration and Validation

The ability of a watershed model to accurately predict stream flow and sediment yield is evaluated through sensitivity analysis, model calibration, and model validation. The results from the simulation cannot be directly used for further analysis but instead the ability of the model to sufficiently predict the constituent stream flow and sediment yield should be evaluated through sensitivity analysis, model calibration and model validation (White and Chaubey, 2005). Calibration involved model testing with known input and output data in order to adjust some parameters, whereas validation involved comparison of the model results with an independent dataset from the one used in calibration process without any further adjustment of the calibration parameters.

The calibration and validation of the model was preceded by input data preparation, model set up, and parameter sensitivity analysis. Since it is impossible to replicate watersheds and river basins, common practice in hydrologic studies is to divide the measured data either temporally or spatially for calibration and validation (Engel, et al., 2007). One view suggests that both wet and dry periods be included in both calibration and validation periods (Gan, et al., 1997), ensuring that both periods reflect the range of conditions under which a model is expected to perform. This is often not visible due to limitations in the length of monitoring data available for calibration and validation.

In general, a good model calibration and validation should involve: (1) observed data that include wet, average, and dry years (Gan, et al., 1997); (2) multiple evaluation techniques (Legates and McCabe, 1999); (3) calibrating all constituents to be evaluated; and (4) verification that other important model outputs are reasonable. There are several calibration and uncertainty analysis techniques common among researchers (Setegn, et al., 2010).

3.12.1. Model calibration

Model Calibration is an effort to better parameterize a model to a given set of local conditions, thereby reducing the prediction uncertainty. Calibration can be accomplished manually or using auto calibration tools in SWAT (Van Liew, et al., 2005) or SWAT-CUP (Abbaspour, et al., 2007). (Refsgaard and Storm, 1996), distinguished three types of calibration methods: the manual trial and error method, automatic or numerical parameter optimization method, and a combination of both methods. According to the authors, the manual calibration is the most common and especially recommended in cases where a good graphical representation is strongly demanded for the application of more complicated models. However, it is very cumbersome, time consuming, and requires experience.

Automatic calibration makes use of a numerical algorithm in the optimization of numerical objective functions. The method undertakes a large number of iterations until it find the best parameters. The auto-calibration option in SWAT provides a powerful, labor saving tool that can be used to substantially reduce the frustration and uncertainty that often characterizes manual calibration (Van Liew, et al., 2005). The third method makes use of combination of the above two techniques regardless of which comes first. Visual and numerical methods were used to assess the goodness fit between the simulated and observed stream flow. The other calibration tools such as the 'Sequential Uncertainty Fitting Algorithm' (SUFI-2) program (Abbaspour, et al., 2004, 2007) were used. For this study, SWAT-CUP method was considered for calibration because in SUFI-2 both manual and automated calibration incorporates sensitivity and uncertainty analysis.

The study was done using historical records of Twenty Two years for Finchaa Watershed. However the calibration was run for 13 years (1990 – 2002) where the first one year (1990) used to "warm up" the model. Thus, only results for the period 1991 – 2002 were used in the evaluation of the calibration. Warm up is very important part of the simulation process that ensures the establishment of the basic flow conditions for the simulation to follow by bringing the hydrologic processes to an equilibrium condition. The warm-up period allows the model to cycle multiple times in an attempt to minimize the effect of the user's estimates of initial state variables such as soil water content and surface residue (Zhang, et al., 2007).

3.12.2. Model Validation

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 (Refsgaard, 1997). 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. Similarly, model validation is testing of calibrated model results with independent data set without any further adjustment at different spatial and temporal scales. The final step is validation for the component of interest (streamflow, sediment yields, etc.).

To perform validation in SUFI 2, once calibration is finished, the parameter ranges are used without further changes to simulate the validation period by editing the files observed_rch.txt, observed_hru.txt, observed_sub.txt, and observed.txt under objective function as necessary for the validation period. Also the extraction files and the file.cio to reflect the validation period. The measured data of stream flow of 9 years (2003 – 2011) were used for the model validation process. In general, graphical and statistical methods with some form of objective statistical criteria are used to determine when the model has been calibrated and validated.

3.13. Model Efficiency

The performance of a model must be evaluated on the extent of its accuracy, consistency, and adaptability (Goswami, et al., 2005). The performance of the model in simulating stream flow and sediment yield is evaluated using (SWAT-CUP). The performance of the model to simulate the stream flow during the calibration and validation periods has been evaluated based on the computed results of the indicators and the suggested model performance rating standards. Two methods for goodness-of-fit measures of model predictions were used during the calibration and validation periods, these numerical model performance measures the fraction of the variation in the measured data that is replicated in the simulated model results are coefficient of regression (R^2) and the Nash-Sutcliffe simulation efficiency (NS) (Nash and Sutcliffe, 1970).

The other parameters used to evaluate the performance of the model are Modified coefficient of determination % (bR^2) and percent bias PBIAS (%) which measure the average tendency of the simulated data to be larger or smaller than their observed counterparts. A positive value indicates a model bias toward underestimation, whereas a negative value indicates a bias toward overestimation (Gupta, et al., 1999). The BIAS $< \pm$ 25 is satisfactory (Liew, et al., 2007). R^2 ranges from 0.0 to 1.0 with higher values indicating better agreement (Legates and McCabe, 1999) and the value of NS ranges from minus infinity to 1.0, with higher values indicating better agreement (Legates and McCabe, 1999). A value of 0.0 for R^2 means that none of the variance in the measured data is replicated by the model predictions. On the other hand, a value of 1.0 indicates that all of the variance in the measured data is replicated by the model predictions.

NS is a more stringent test of performance than R^2 and is never larger than R^2. NS measures how well the simulated results predict the measured data relative to simply predicting the quantity of interest by using the average of the measured data over the period of comparison. A value of 0.0 for NS means that the model predictions are just as accurate as using the measured data average to predict the measured data. NS values less than 0.0 indicate the measured data average is a better predictor of the measured data than the model predictions. R^2 is calculated by the following equation:

$$\boldsymbol{R^2} = \frac{[\sum_{i=1}^{n}(qsi-\bar{q}s)(qoi-\bar{q}o)]^2}{\sum_{i=1}^{n}(qsi-\bar{q}s)^2\sum_{i=1}^{n}(qoi-\bar{q}o)^2}$$

Where: qsi is simulated streamflow in m^3/s

qoi is is observed streamflow in m^3/s

$\bar{q}s$ is the mean of the simulated value

$\bar{q}o$ is the mean of the observed value.

Nash-Sutcliffe simulation efficiency, NS, indicates the degree of fitness of the observed and simulated plots. It is calculated as follows with the same variables defined above:

$$\mathrm{NS} = 1 - \frac{\sum_{i=1}^{n}(qoi-qsi)^2}{\sum_{i=1}^{n}(qoi-\bar{q}o)^2}$$

3.14. Land Use/ Land cover change Scenarios

The Soil and Water Assessment Tool (SWAT), a semi-distributed physically based model, (Arnold, et al., 1998) has been used for simulation of different scenarios both land use impacts and climate change. Another advantage of the SWAT model is the ability to build different scenarios. SWAT validation and scenario applications have been reported worldwide for a wide variety of watershed scales and environmental conditions, including a number of studies which focused on the impacts of historical or hypothetical land use changes on hydrology and/ or pollutant loss (Gassman, et al., 2007). Land use suitability assessment and scenario analysis that integrates land use and water resources assessment in the basin by incorporating the biophysical as well as the socio-economic dynamics would be an essential addition for resource management and decision making efforts in the basin.

LULC scenarios enable the modelling of flow and sediment movement in relation to sets of developed scenarios. Attempts were made to ensure these were realistic scenarios in accordance to the ongoing trends of land use change within the study area. Land change models were firstly used to develop land use change scenarios and characterize LULC dynamics. Watershed models were then applied to evaluate the associated impacts on hydrology and water quality. The transition from one land use type to another type is summarized as:

- The forest area reduction is due to an increase in agriculture area.
- The increase in agriculture area is due to an increase in population size.
- The increase in urban area is affected by the number of industries and schools.

LULCC scenarios simulated were time-dependent hence were not meant to prediction future land use, but rather to aid spatial planning of future land use for sustainable management of land and water resources. The scenarios were developed using simplified consistent set of assumptions based on biophysical parameters and socio-economic factors driving land use change in the study area. In reality, land use transition from one type to another is much more complicated and involves detailed transition rules between land use types or even for one land use type itself, such as evergreen forest, mixed forest to close row grown crops and transition from one agriculture type to another agriculture type.

Land use conversion may not have a consistent criteria about land use conversion or a sequential order, but for the study area it has to follow the transition rule from a low state in the hierarchy to a higher state due to the socio-economic development. The ability to forecast LULCC and ultimately predict the consequences of hydrologic change will depend on our ability to understand the past, current and future drivers of LULCC. In this study, Forest was regarded as the lowest state in the land use change next to the irrigated farm. It is very likely that the forest can change to range land, agriculture, whereas the probability of changing range land to forest or agricultural field to forest is very low unless it is forced by outside human interventions such as legislations or regulation by the government.

The patterns of LULCC, and land management are shaped by the interaction of economic, environmental, social, political, and technological forces on local to global scales. The LULC in the upper part of the watershed is brought about by agriculture and by the town while that of the downstream of the watershed is brought about by the irrigation in the form of sugar cane for Finchaa Sugar Factory. The scenarios performed simulations under different scenario conditions in order to analyze the impacts on the reservoir of possible changes in LULC that may occur in the near future, or may have occurred in the past.

The scenario analysis were performed considering one variable at a time and keeping other values unchanged. These scenarios are based on the field experience and the actual existence of the land use type change that most of the agricultural land is occurring while the existing forest type is being transformed to agricultural land use type. This is employed by changing percentage of one LULC class in to another based on the pre-defined criteria. To explore the sensitivity of model output LULCCs, mainly on the reservoir of Finchaa, LULCC scenarios were developed and explored. The baseline scenario was selected on the basis of the results obtained from the analysis from the input data. The other scenarios were based on a hypothetical variation of LULC using certain/ total percentages so as to see the impacts of lad use changes on the streamflow and sediment yield. The land use change scenarios included:

Scenario 1. Partial deforestation, change to Agriculture: This scenario involved manipulation of the forest cover reducing it partially by converting the Mixed-forest type which is 8.26% to agricultural land row crops and keeping other land use conditions same as of the base land use.

Scenario 2. Complete deforestation, conversion to grassland: This scenario involved replacing all the existing forest (12.37%) cover with grassland to simulate a complete absence of forest cover in the watershed. In this scenario deforestation case under which forest cover has degraded into bushes and shrubs rather than converting to Agricultural land use type.

Scenario 3. Complete afforestation: Foresting the cultivated and Agricultural fields is impractical and impossible for many reasons. In this scenario the Agricultural land was assumed to be 100% converting to forests. In practical sense some degraded areas around the watershed have been converted and used for Eucalyptus planting. This shows that the area have been already changing the degraded agricultural fields on the upstream and some part of the downstream of the watershed. This scenario may not practical but to analyze the land use change on the reservoir it is necessary to convert the agricultural land use type to forest land use type. Thus, this scenario was established by replacing the Agricultural fields and non-forested wetlands to the Forest-Evergreen and Forest mixed of the entire Finchaa watershed.

Scenario 4. Complete deforestation, conversion to agriculture: During this study the area under forest cover was taken to be zero and the area under agricultural land to be increased. This scenario was carried out by replacing all the forest cover with agricultural field, the watershed consists of two types of forest with a mixture of Forest-Evergreen (FRSE) and Forest-mixed (FRST) for the adaptation simulation both forest types were combined. Replacement of forest land by agriculture have been a common trend within the study area and seen to be one of the major causes of random river flows and increased sediment load in the reservoir.

4. RESULTS AND DISCUSSIONS

4.1.Introduction

In this chapter the results of the study were presented and discussed. In the first section, results of the parameter sensitivity analysis, calibration and validation of the SWAT of the stream flow in the Finchaa watershed. In the second section, the results of land use/ land cover change identification in the watershed were presented and discussed followed by the results of scenario simulation to establish the impact of land use/ land cover change and its mitigation measures around the watershed.

4.2.Sensitivity analysis

Before applying SUFI-2 for calibration the most sensitive parameters were selected by running the sensitivity analysis. It is important to identify sensitive parameters for a model to avoid problems known as over parameterization (Van Griensven, et al., 2006). To find the sensitive parameters Latin hypercube simulation, the one at-a-time (LH-OAT) method was used (Van Griensven, et al., 2006). Twenty seven parameters were considered for the model parameterization sensitivity analysis, only twelve of them were effective for monthly flow simulation analysis. The twelve most sensitive parameters most responsible for the stream flow assessment for the Finchaa catchment have been considered for the model parameterization and calibration process used for the model were depicted in table 4.1 with their fitted value. The remaining parameters had no significant effect on stream-flow simulations and depicted under Appendix III.

It has been observed that these sensitive parameters were mostly responsible for the model calibration and parameter changes during model iteration processes. The result of the sensitivity analysis indicated that these twelve flow parameters were sensitive to the SWAT model. i.e., the hydrological process of the study area mainly depends on the action of these parameters.

Table 4.1. Result of the sensitivity analysis parameters of flow in Finchaa watershed (sensitivity parameters maximum, minimum and fitted values using SUFI-2).

Parameters			Fitted Value	Min value	Max value
NO.	**Name**	**Description**			
1	CN2	SCS runoff Curve number for moisture condition II	-0.18	-0.2	0.2
2	ALPHA_BF	Base flow alpha factor (days)	0.85	0	1
3	GW_DELAY	Ground water Delay (days)	51	30	450
4	GWQMN	Threshold depth of water in shallow aquifer required for return flow (mm)	0.3	0	2
5	GW_REVAP	Ground water ‘revap’ coefficient	0.11	0	0.2
6	ESCO	Soil evaporation compensation factor	0.93	0.8	1
7	CH_N2	Manning’s roughness coefficient for main channel	0.045	0	0.3
8	CH_K2	Effective hydraulic conductivity of the main channel	23.75	5	130
9	ALPHA_BNK	Base flow alpha factor for bank storage	0.45	0	1
10	SOL_AWC	Soil available water capacity	-0.17	-0.2	0.4
11	SOL_K	Saturated Hydraulic conductivity	0.24	-0.8	0.8
12	SOL_BD	Moist bulk density	0.105	-0.5	0.6

4.3.Stream Flow Calibration

The stream flow comparison has been done between the observed and simulated discharge values for 13 years’ time-steps during 1990 – 2002 on the monthly basis. Initially one year of flow data during 1990 was taken as the warming period and the rest of the period was used for the model calibration. The model was calibrated using twelve parameters which were recorded as the most sensitive parameters were used for the stream flow measurement.

The coefficient of determination R^2 and the Nash- Sutcliffe equation has been applied for model testing between simulated and observed flows and calculated on monthly basis was 0.83 and 0.74 respectively. The degree to which all uncertainties are accounted for is quantified by a measure referred to as the P-factor, which is the percentage of measured data bracketed by the 95% prediction uncertainty (95PPU) and have been calculated as 0.52. The strength of the model calibration and uncertainty procedure has been analyzed using the R factor. The R-factor shows the average thickness of 95PPU band divided by the standard deviation of the observed data and have been calculated as 0.69.

The comparison of the observed and simulated discharges for the station during the calibration period was presented in figure 4.1. The time series data of the observed and simulated flows on monthly basis were plotted for visual comparison to explore the similarity within the peak values resulting from the procedures of SUFI-2 and the scatter plot of monthly stream flow showing a well-fitting relationship of the observed and simulated values for calibration shown in figure 4.2.

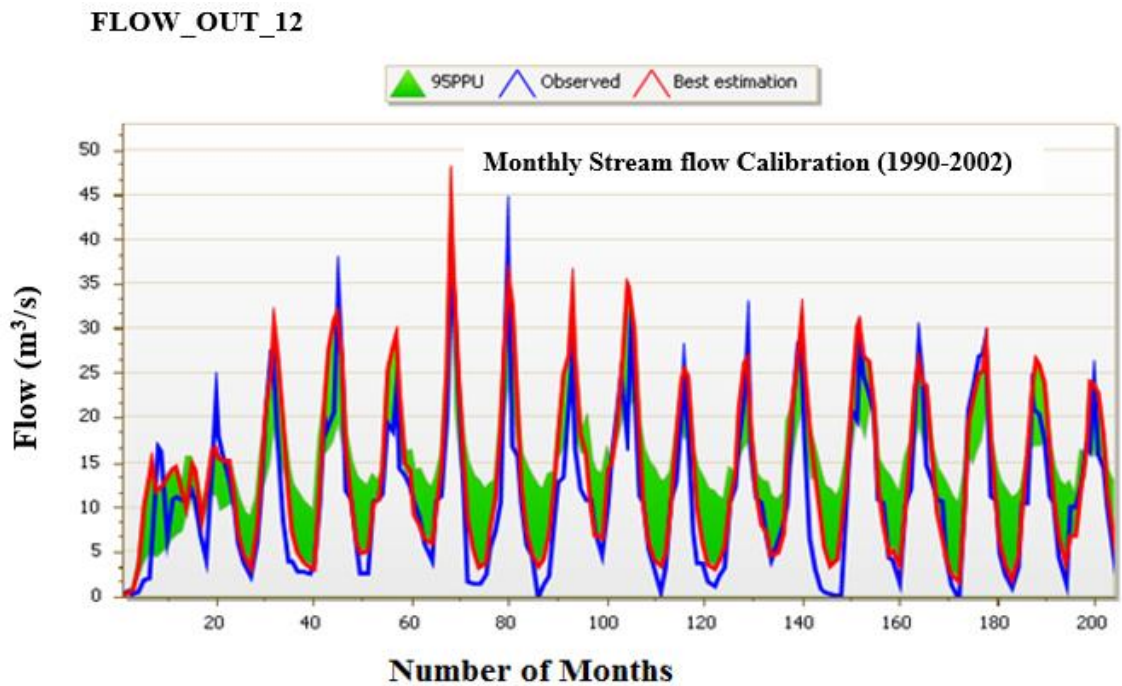


Figure 4.1.Calibration result of monthly observed and simulated flows of Finchaa watershed.

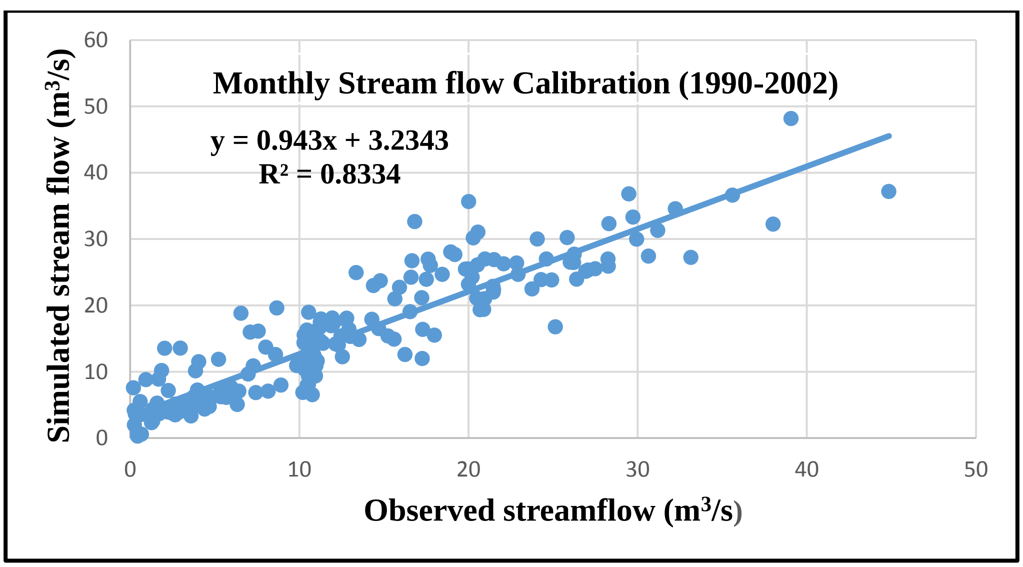


Figure 4.2. Scatter plot of observed and simulated stream flow for Finchaa watershed during calibration period.

4.4.Stream Flow Validation

Calibrated parameters were validated for the period of 9 years (2003 – 2011) from which one year was taken as warm up period. Validation proves the performance of the model for simulated flows in periods different from the calibration periods, but without any further adjustment in the calibrated parameters. Validation was performed for 9 years from January 1, 2003 to December 2011.

The correlation coefficient (R^2 = 0.86) and the Nash-Sutcliffe (NS=0.83) shows a good agreement between the observed and simulated values. The time series data of the observed and simulated flows on monthly basis were plotted for visual comparison to explore the similarity within the peak values resulting from the procedures of SUFI-2 (Figure 4.3) and the scatter plot showing the observed and simulated values for validation was shown in figure 4.4.

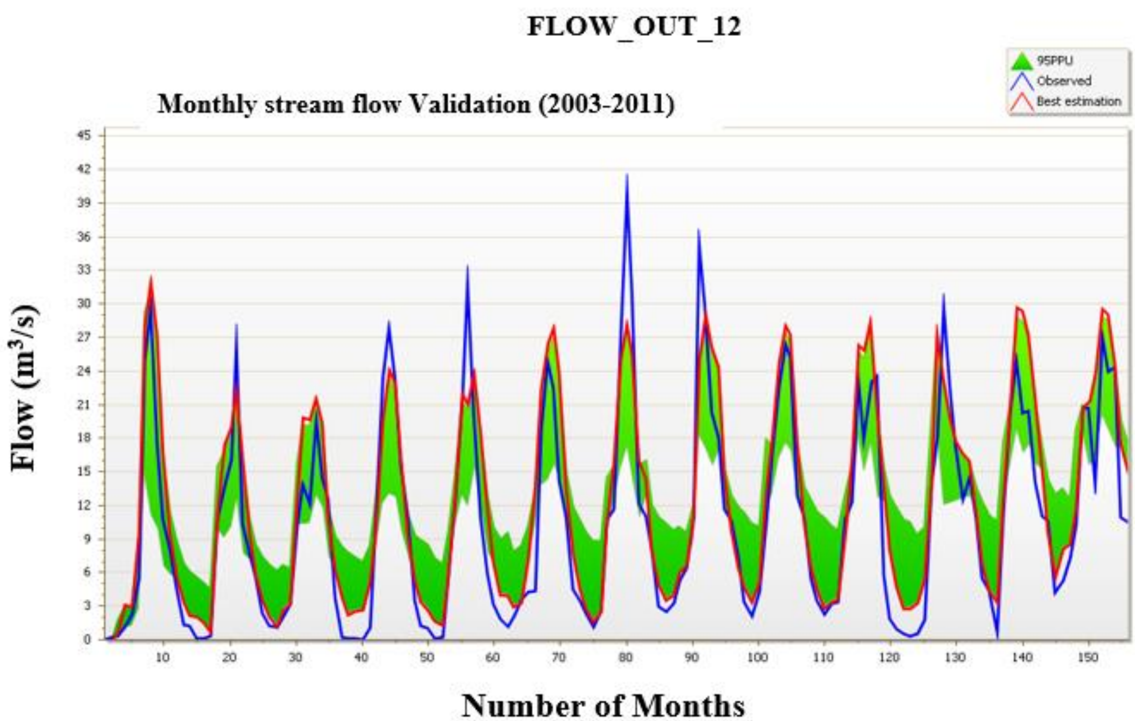


Figure 4.3.Validation result of monthly observed and simulated flows of Finchaa watershed.

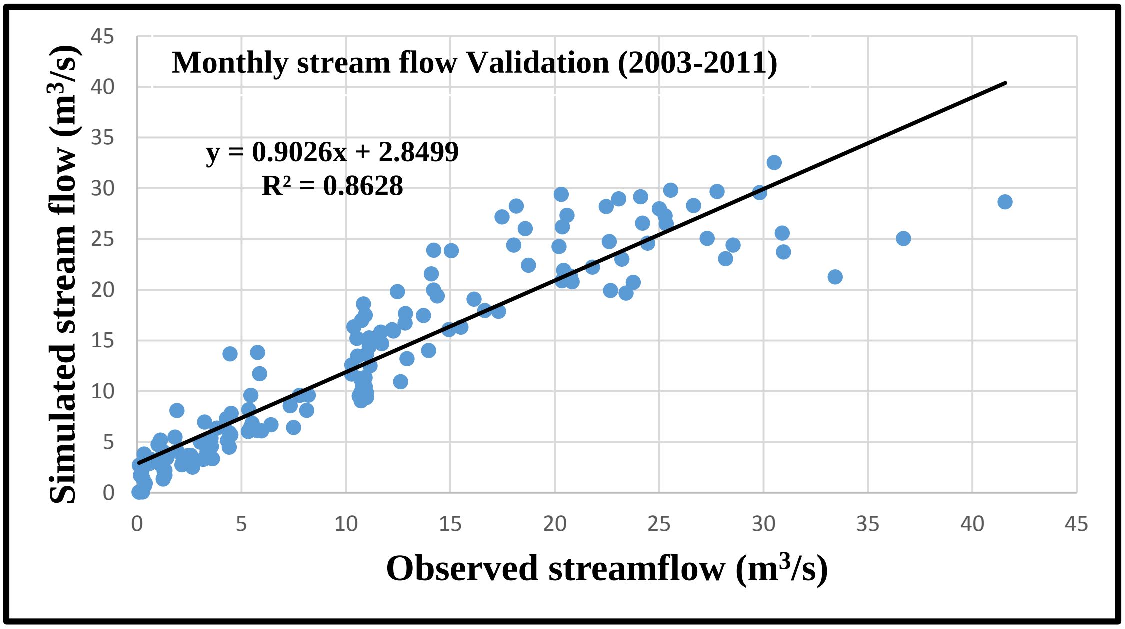


Figure 4.4. Scatter plot of observed and simulated stream flow for Finchaa watershed during Validation period.

Generally, the Stream flow calibration and validation results on monthly basis obtained from SWAT-CUP, SUFI-2 were shown in table 4.2.

Table 4.2.Stream flow calibration and validation results on monthly basis (Models evaluation performance results).

Variable		Calibration	Validation
p- Factor		0.52	0.52
r- Factor		0.69	0.64
R^2		0.83	0.86
NS		0.74	0.83
bR2		0.7859	0.7788
PBIAS		23.8	21.3
Average monthly flow (m^3/s)	Measured	12.43449	11.07667
	Simulated	14.96034	12.84731

4.5.Land Use/ Land Cover change Scenario analysis

It became evident from this study and the reality occurred around the area that the rate of sediment deposition will continue to increase in the future due to LULCCs. Therefore it is essential to assess the impacts of LULCC on the reservoir and to take adaptation options into account to reduce the vulnerability of sedimentation in order to maintain the constructed reservoir's life span. Surface runoff is increased in all land use change scenarios except in scenario 3 in complete afforestation of land use types. The baseline scenario is the only scenario with increasing lateral flow where the other scenario had a reduced lateral flow.

The largest impacts on water balance components in the watershed occurred in the completely conversion to Agriculture scenario, in which all the existing forest cover was converted to agricultural land uses in which the scenario with the increased surface flow and sediment yield. This scenario resulted in a 34.992% and 57.361% increase is Surface runoff and total sediment yield respectively, decreased by 7.899% in percolation and by 33.184% in lateral flow. Ground water discharge to shallow aquifer and deep aquifer was decreased by 7.960% and 7.972% respectively.

Generally, differences in annual surface runoff flows due to land use change scenarios gradually increased by 0.664% (Scenario 1), 2.773% (Scenario 2), and 34.992% (Scenario 4) and decreased by 15.979% (Scenario 3). The differences in sediment yield was increased by 0.949% (Scenario 1), 5.118% (scenario 2), 57.361% (Scenario 4) and decreased by 16.207% (Scenario 3). The table showing the percent changes in annual average water balance components for the Finchaa watershed land use/ land cover change scenarios is presented under table 4.4. The results of LULCC scenarios showed that different LULCs have different stream flow characteristics and sediment value. The peak, mean and frequency characteristics of the simulated stream flow varied depending on the LULC scenario.

The resulting land use change scenarios coverages area in hectare and percentage were shown in table 4.3 and figure 4.6. The figure and the table showing the different land use change scenarios on the sediment yield and Surface runoff was discussed under Appendix IV and V respectively. From the figure all the land use scenarios significantly shows that they produce high magnitude of Sediment and surface runoff during the rainy season and low during dry season. The result shows that during the rainy period the observed increase in flow rates results in a high rate of sediment transport to reservoir.

Table 4.3.The resulting land use/land cover change scenarios coverages area in hectare and in percentage.

Land use/ land cover	Original Land use/ land cover (base scenario)		Scenario 1. Partial deforestation, conversion to agriculture		Scenario 2. Complete deforestation, conversion to Grassland		Scenario 3. Complete Afforestation, conversion to Forest		Scenario 4. Complete deforestation, conversion to Agriculture	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Forest-Evergreen	11752	4.11	11752	4.11	0	0	82312	28.76	0	0
Forest-mixed	23652	8.26	0	0	0	0	30844	10.77	0	0
Agricultural Land Row-Crops	23072	8.06	46724	16.32	23072	8.06	0	0	181236	63.31
Corn	7192	2.51	7192	2.51	7192	2.51	0	0	7192	2.51
Rang-Grasses	17608	6.15	17608	6.15	29360	10.26	17608	6.15	0	0
Range-Brush	57664	20.14	57664	20.14	81316	28.4	57664	20.14	0	0
Wetlands-Non- forested	47488	16.59	47488	16.59	47488	16.59	0	0	0	0
Residential	56328	19.67	56328	19.67	56328	19.67	56328	19.67	56328	19.67
Water	41544	14.51	41544	14.51	41544	14.51	41544	14.51	41544	14.51
Total	286300	100	286300	100	286300	100	286300	100	286300	100

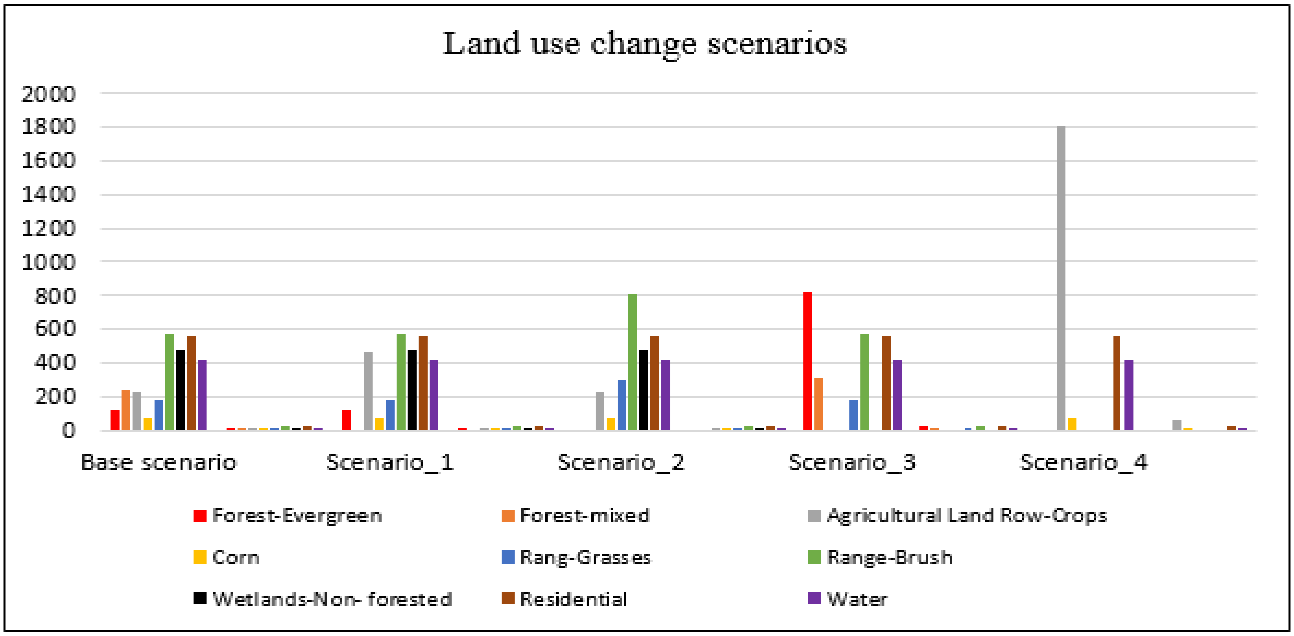


Figure 4.5.The resulting land use/land cover change scenarios coverages area (km^2) and percentage.

Scenario_1. Conversion to Agriculture Partially. This scenario considered that the Existing Mixed forest land use type would be converted to Agricultural Land – Row crops and remaining the other land use type as the base scenario Figure 4.7 (a). The model results that the annual sediment accumulation and the surface runoff is about 0.949% and 0.664% greater than the existing LULC type. Decreasing in forest and increasing in farm land would result in increasing runoff, therefore the amount of sediment has been increased.

Scenario_2. Conversion to Grassland. Under this scenario all the forest type is converted into range-grass land and range-brush land use type. The Agricultural and other land use types are remain as the base land use type. Then after completely deforesting or changing the forest type to grass land. i.e., Forest-Evergreen land use type which is 4.11% and Forest-mixed land use type which is 8.26% of the watershed converted to Range-Grasses and Range-Brush land class respectively Figure 4.7 (b). The Scenario has shown the increasing of sediment and surface runoff entering the reservoir is about 5.118% and 2.773% compared to the base land use types. The water yield decreased by % 0.019 while the lateral discharge decreased by 24.295%

Scenario_3. Complete afforestation. This scenario was changing the Agricultural land use class to the Forest land use type, Agricultural land row crops and wetlands non-forested to Forest Evergreen and Corn or irrigated farm to Forest mixed figure 4.7 (c). For this option the result indicated that the sediment yield and Surface runoff were decreased by 16.207% and 15.979% respectively. The scenario indicates a decrease in the total water yield by 0.16% besides a significant decrease in the sediment yield. This result supports that the principle of forests have the effect of reducing the runoff, and sediment yield. The results indicate that land use change may cause a great deal of sediment yield change.

Scenario_4. Conversion to Agriculture. This option was assessed by converting land use class to Agricultural land use type. i.e., Forest Evergreen, Forest mixed, Range Grasses, Range Brush, wetlands non-Forested to Agricultural Land-row crops Figure 4.7 (d). Agricultural land use type produces high sediment compared to Forest or Range grass or Rang Brush land use types. The mean annual sediment and surface runoff under this scenario is about 105.243 T/Ha and 366.14 mm respectively, which is about 57.361% and 34.992% greater than the baseline scenario respectively.

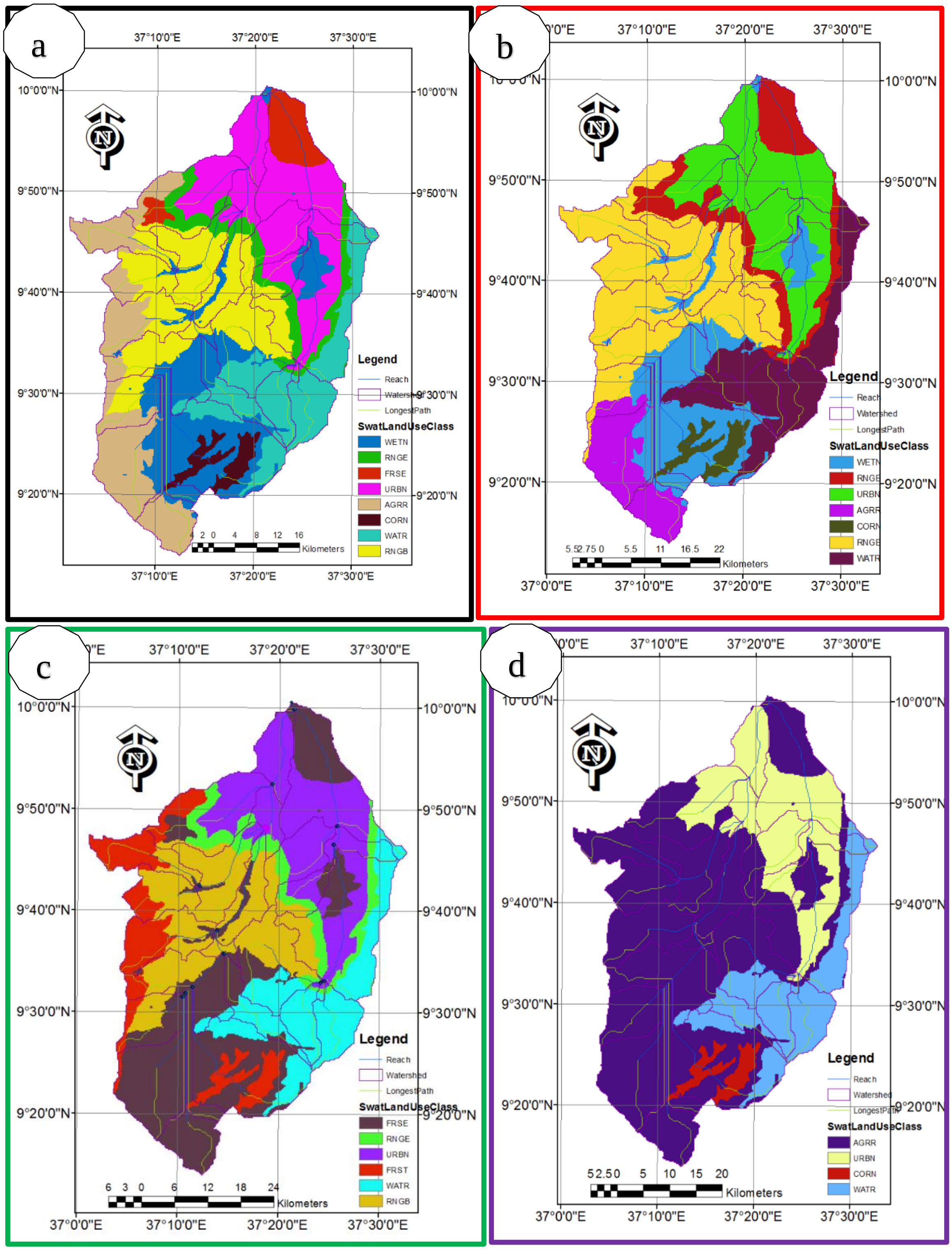


Figure 4.6. LULCC Scenarios.

a-Scenario-1. Conversion to Agriculture Partially. b- Scenario- 2. Conversion to Grassland. C- Scenario- 3. Complete afforestation. d- Scenario-4. Complete deforestation.

Evaluation of Stream flow and sediment yield due to land use/ land cover changes to hydropower reservoir

Evaluation of the impacts of LULCC on stream flow and sediment yield was one of the most significant parts of this study. The major land use changes that affect stream flow and sediment yield in this study catchments were changes to farmland, grassland and other Agriculture land use types. One of the most important things of the study was to evaluate the impacts of LULCCs on sediment yield and streamflow to hydropower reservoir. The method to evaluate the hydrological impacts due to LULCCs and land use modifications can be achieved through integrating Geographic Information System based Soil and Water Assessment Tool model. The evaluation was done in terms of the impacts of LULCCs on the variation of LULC types and the variations caused depending on the LULC types on the major components of stream flow and sediment yield including surface runoff and groundwater flow.

The study was carried out for different scenarios using generated LULC maps, soil, climate and stream flow data values were used to evaluate the impacts of LULCC on stream flow and sediment yield. To assess the changes in the contribution of the components of the stream flow due to the LULCC, analysis were made on the surface runoff and sediment yield, ground water flow. Generally, Table 4.4, presents Percent changes in annual average of the surface runoff and sediment yield, ground water flow including other water balance components for the Finchaa watershed LULCC scenarios of the stream simulated. The contribution of surface runoff, ground water flow and sediment yield has been changed due to LULCCs. The surface runoff and sediment yield has increased and the ground water flow has decreased during the expansion of agricultural land over the forest, the surface runoff and sediment yield decreased and the ground water flow has increased during the expansion of forests.

Scenario 4 (Conversion to Agriculture) has the largest impact on the yearly surface run off and sediment yield while scenario 3 (Complete Afforestation) has the smallest. The expansion of agricultural land use type results the increasing of sediment yield and reduction of water infiltrating in to the ground. Increase in surface runoff together with agricultural expansion can also lead to substantial redistribution of soil materials leading to erosion and sedimentation of water bodies. The SWAT model inputs under the complete afforestation scenario decrease in stream flow and sediment yield for all months. The increase in sediment due to LULCC will exacerbate reservoir sedimentation. The sedimentation might significantly reduce the life span of the reservoir and the hydroelectric power generation.

Generally, the Hydrological investigation with respect to the LULCCs within Finchaa watershed showed that the flow characteristics/ water balance components have changed through different Scenario of the study.

Table 4.4.Percent changes in annual average water balance components for the Finchaa watershed land use/ land cover change scenarios.

	Scenario_1	Scenario_2	Scenario_3	Scenario_4
Sur_Q (mm)	0.664	2.773	-15.979	34.992
Lat_Q (mm)	-26.265	-24.295	-25.369	-33.184
Gw (shal Aq)_Q (mm)	0.973	0.317	5.412	-7.960
Gw (Deep Aq)_Q (mm)	0.976	0.311	5.418	-7.972
Revap (mm)	0.000	0.000	0.000	0.000
Deep Aq Recharge (mm)	0.964	0.308	5.396	-7.961
Total Aq Recharge (mm)	0.974	0.319	5.412	-7.956
Total WYLD (mm)	-0.036	-0.019	-0.160	0.210
Perc (mm)	0.977	0.326	5.389	-7.899
Total SEDYLD (T/Ha)	0.949	5.118	-16.207	57.361

Adaptation options to mitigate the adverse impacts of the land use/ land cover changes on the reservoir

The adaptation of LULC patterns is an essential aspect of minimizing the expected impact of LULCCs at the regional and local scales. LULCC can play an important role in reducing the amount of sediment yield and stream flow to the reservoir through LULC and forestry activities that can occur through avoiding deforestation. Improved management of grassland over the agricultural land use type was also one type of mitigation measure to improve the LULCC.

The adaptation of watershed land use patterns used to mitigate the impact of LULCC on the region's hydrology. Adaptation strategies and decisions are more likely to focus on reducing the cumulative impacts of LULC change, and ensuring that the distributional impacts of adaptation are minimized. Land use is a key factor that must be considered when predicting potential future hydrological responses of a watershed and then can be adapted to minimize the impacts of LULCC on hydrological processes.

The LULCC scenario analysis were described under section 4.5. There was a base scenario of LULCC under the current land use policy; and scenario 1- 4 show the variation of the LULC patterns. In all scenarios the magnitude of sediment yield and stream flow increased but in scenario 3 (complete afforestation) the amount of sediment and surface runoff decreased. From the scenarios, scenario 3 is used for the mitigation measure of the LULCC. So one type of mitigation measures will be covering the surface of the earth by forests.

The third scenario incorporates LULC based mitigation measures to look at its effectiveness in mitigating the impacts of LULCC on stream flow and sediment yield to the reservoir. The LULC based mitigation measures include afforestation of the areas. The afforestation/ reforestation has a function to reduce over land flow and rainfall erosivity. Appropriate soil conservation measures based on suitable afforestation techniques can be highly influential in risk mitigation of soil erosion.

Therefore, the adaptation options to be taken to mitigate the adverse impacts of the LULCCs on reservoir would be, if possible to cover the land use type by forest or increase the forest type or grass land type of the watershed area in order to decrease the amount of sediment yield to the reservoir. The figure 4.8 and 4.9 shows the afforestation areas have reduced the intensity of soil loss rate in the Finchaa watershed by reducing the amount of sediment yield generated and the annual surface runoff to the reservoir.

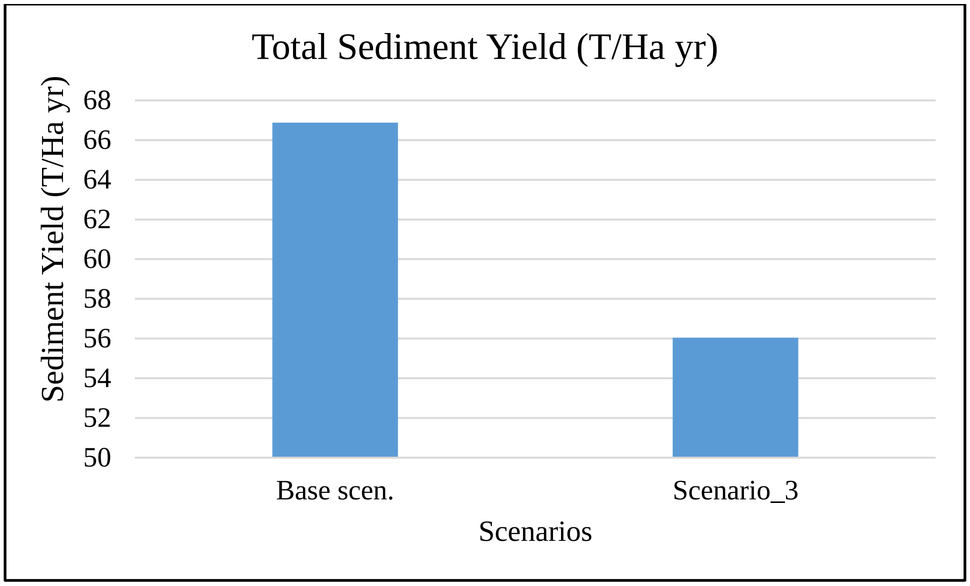


Figure 4.8.Sediment yield of the watershed before and after applying the mitigation measures.

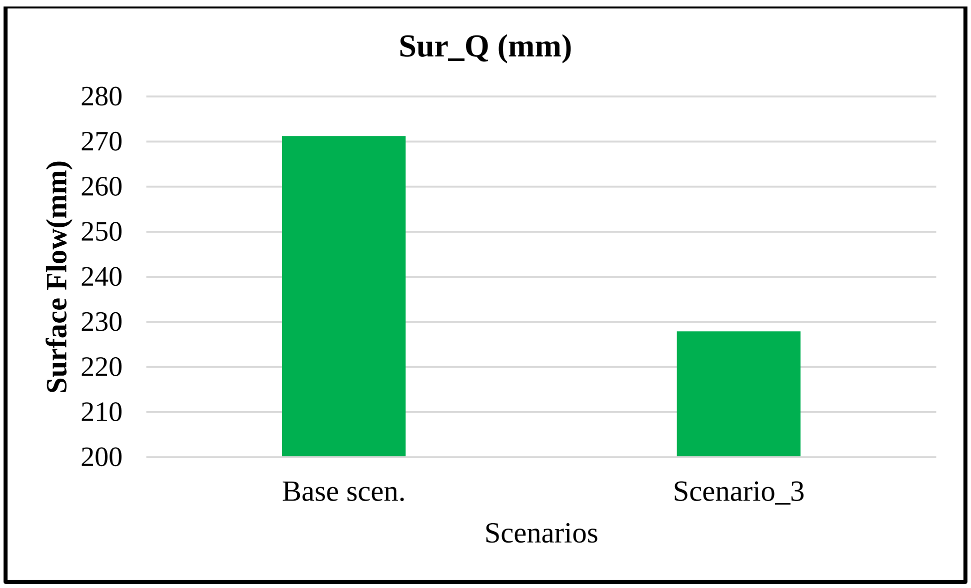


Figure 4.9.Surface flow of the watershed before and after applying the mitigation measures.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1.CONCLUSIONS

The physically based, spatially distributed and public domain Soil and Water Assessment Tool (SWAT) was successfully used to simulate the impact of LULCCs on sediment yield and stream flow on the hydropower reservoir. The impacts of the land use/land cover changes on stream flow and sediment yield was analyzed statistically using the hydrological model, SWAT then the model were tested for its performance at the Finchaa watershed in order to examine the hydrological response of the watershed.

The ability of SWAT to adequately simulate stream flows was evaluated through sensitivity analysis, model calibration and validation. The model was successfully calibrated and validated for the Finchaa watershed. Therefore, SWAT can be utilized very well for hydrological simulations in the selected catchments and it is a capable tool for further analysis of the hydrological responses in the watershed also, can be further extended to similar watersheds in the country, particularly in the Blue Nile Basin of Ethiopia.

In this study SUFI-2 was used for model calibration and validation, it could perform uncertainty analysis and calibrate the model for more number of parameters. SUFI-2 algorithm is an effective method but it requires additional iterations as well as it provides an effective graphical interface for visualization of outputs, including simulated data, observed data, best fit model results and 95PPU for all variables used in the model calibration. The sensitivity analysis parameters using SWAT-CUP SUFI-2 model has pointed out twelve most important parameters that control the streamflow of the studied watershed. The SWAT model was calibrated from 1990 to 2002 and validated from 2003 to 2011 including warm up period on a monthly basis to examine its applicability for simulating flows for the Finchaa watershed.

The average monthly simulated flows were compared with the average monthly observed values using graphical and statistical methods. As the measured data was not available on sediment yield, only the simulated data has been used to identify the impact of value on some measure of simulated sediment output. Performance of the model for both calibration and validation watershed were found to be reasonably good with coefficient of determination

(R^2) values of 0.83 and 0.86 and Nash-Sutcliffe values 0.74 and 0.83 for calibration and validation respectively. So, the coefficient of determination and Nash-Sutcliffe simulation efficiency values obtained proved the SWAT is good to simulate the hydrological process of the catchments. Hence, it can be concluded that SWAT is able to fairly explain the hydrological characteristics of the Finchaa catchment.

Land use/ land cover changes recognized to have major impacts on hydrological processes, such as runoff, sediment yield and ground water flow. The impacts of LULCC on the selected watershed of Upper Blue Nile Basin on water availability and reservoir using SWAT was carried out to address the problem and help to propose the adaptation mitigation measures. The study used LULCC scenario to assess the impacts of these changes on the water resource to be affected by LULCCs and determining the significance of impacts for the selected catchments. Systematic data preparation, sensitivity analysis, calibration, validation and uncertainty analysis were performed on the selected models before they were further used for scenario analysis.

To analyze the impacts of LULCC on sediment yield and stream flow to hydropower reservoir sedimentation four scenarios were developed. The scenarios were developed simply to show the potential change of stream flow and sediment yield from the corresponding land use/ land cover change to the hydropower reservoir. The LULCC scenarios developed shows in LULC variables are likely to have significant impacts on the flow volume into reservoirs and the hydrological components were changed. LULCC scenarios were also analyzed as adaptation options to reduce the sediment amount to the reservoir based on various LULCC practices.

The study result showed that the implementation of the four scenarios, among the scenarios afforestation (expansion of forest land use type) scenario reduce the soil erosion, run off and sediment yield at the sub-basin level. The average annual sediment yield and surface runoff were 56.041 T/Ha and 227.89 mm respectively. Therefore, this scenario can be taken as the adaptation options to mitigate the impacts of LULCC on the reservoir. Based on the scenarios developed the change of forest land use to agricultural land use type has great stream flow and sediment yield. The average annual sediment yield and surface runoff were

105.243 T/Ha and 366.14 mm respectively, where as the average annual sediment yield and surface runoff was 66.88 T/Ha and 271.23 mm respectively for base scenario.

The results of the model for all scenarios of LULC indicated that during the wet season, the mean monthly flow was increased while the mean monthly flow was decreased during the dry season. The model showed that the effects of LULCC on reservoir which is useful information for catchment and for the implementation of the watershed development by applying some mitigation measures to reduce the amount of sediment yield and stream flow to the reservoir. The findings suggest that LULCC has a great influence on the variability of stream flow and sediment yield in the sub-basin. Therefore, the issue of LULCC impact on stream flow and sediment yield on hydropower reservoir as part of the integrated adaptation mitigation measures program in order to achieve sustainable development is very relevant. The output of this study can help planners, decision makers and other different stake holders to plan and implement appropriate soil and water conservation strategies.

5.2.RECOMMENDATIONS

Changes of the land use and land cover is caused by the increased population growth and expansion of industry in the study area and the country in general. Nowadays, the current family size of the households in most part of the country will not be sustained by the existing farming practices. Therefore, family planning should be given widely and continuously through formal and informal education in school and some other social gathering area.

Availability of hydrological and weather data are very important while using any hydrological model. Most of weather observation stations concentrated in the western part of the basin; therefore, it is highly recommended that new weather observation stations should be established to eastern and south eastern part of the basin and should be improved both in quality and quantity in order to improve the performance of the model since the quality of output depends on the quality of input data.

Land use/ land cover change in Finchaa watershed should be controlled to reduce deforestation, which increases the frequencies and concentrations of sediment in the reservoir. Re- afforestation must be introduced within the catchment area of Finchaa watershed which tends to increase filtration of rainfall water and reduce surface runoff which subsequently reduces erosion within the catchment. In addition, solutions to the problems of LULCC should include improving the productivity of the agricultural sector through technical intervention. Hence, further development and environmental planning in the locality should take into account the direction and magnitude of land use and land cover change patterns.

The model simulations considered only LULCC scenarios assuming one variable at a time and keeping other values unchanged. But changes in climate scenarios, soil, management activities and other LULC variables will also contribute some impacts on water availability and reservoir. In order to obtain more reliable results on future changes in streamflow and sediment yield, studies should be carried out by considering all these variables.

The sedimentation might significantly reduce the storage capacity, life span of the reservoir and the hydroelectric power generation. Therefore, decision makers and all concerned stakeholders should plan and implement an integrated watershed development program in advance to alleviate the problem.

REFERENCES

Abate, S. (2011). Evaluating the Land use and land cover dynamics in Borena Worena of South Wollo highlands, Ethiopia. *Journal of sustainable Development in Africa, 13(1)*, 87 - 105.

Abbaspour. (2007). SWAT-CUP2: SWAT Calibration and Uncertainty Programs - A User Manual. Department of Systems Analysis, integrated assessment and modelling(SIAM), Eawag, Swiss Federal Institute of Aquatic Science and Technology, Duebendorf, Switzerland, 95pp .

Abbaspour, K., Johnson, A., and Genuchten.M.Th, V. (2004, 2007). Estimating Uncertain flow and transport parameters using a sequential uncertainty fitting procedure. *Vadose Zone Journal 3(4),* 1340 - 1352.

Abbaspour, K., M.Vejdani, and Haghighat, S. (2007). SWAT-CUP calibration and uncertainty programs for SWAT. In proc. Int. Congress on Modelling and Simulation (MODSIM'07). 1603 -1609.

Abdi, B. A., Desalegn, C. E., and Ekasit, K. (2012). Simulation of Sediment Yield using SWAT Model in Finchaa Watershed, Ethiopia. *J. (Nat. Sci.) 46*, 283 - 297.

Abebe, S. (2005). Land-Use and Land-Cover change in headstream of Abbay watershed, Blue Nile Basin, Ethiopia. Addis Ababa University.

Agarwal, C., Green, G. M., Grove, J. M., Evans, T. P., and Schweik, C. M. (2002). A Review and Assessment of Land - Use Change Models: Dynamics of Space, Time, and Human Choice. General Technical Report NE- 297. Newtown Square, Pennsylvania: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 61 pp.

Amare, A. (2005). Study of sediment yield from the watershed of Angereb reservoir. Master's Thesis, Department of Agricultural Engineering, Alemaya University, Ethiopia.

Arnold, J. G., Allen, P. M., and Bernhardt, G. (1993). A comprehensive surface - groundwater flow model. *Journal of Hydrology 142*, 47 - 69.

Arnold, J., Srinivasan, R., R.S.Muttiah, and Williams, J. (1998). Large area hydrologic modelling and assessment part I: model development. *J. American Water Resources Association 34(1)*, 73 - 89.

Asres, M., and Awulachew, S. B. (2010). SWAT based runoff and sediment yield modelling: a case study of the Gumera watershed in the Blue Nile basin. Ecohydrology & Hydrology, Ecohydrology for water ecosystems and socity in Ethiopia.

Assefa, K. (1994). Valuing Environmental Quality Changes in Horro-Guduru. Field Survey Report. Nekemte, Ethiopia: The Finish Forest Research Institute.

Asselman, N. (2000). Fitting and interpretation of sediment rating curves. *Journal of Hydrology 234,* 228 - 248.

Aster, D. Y., and seleshi, B. A. (2009). Characterization and Atlas of the Blue Nile Basin and its Sub basins. *International Water Management Institute*.

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

Awulachew, S., McCartney, M., Steenhuis, T., and Ahmed, A. (2008). A review of hydrology, sediment and water resource use in the Blue Nile Basin. International Water Management Institute, Colombo, Sri Lanka, pp: 87.

Bakker, M., Govers, G., Van Doorn, A., Quetier, F., Chouvardas, D., and Rounsevell, M. (2008). The response of soil erosion and sediment export to land-use change in four areas of a Europe: the importance of landscape pattern. Geomorphology 98. 213 - 226.

Belay, T. (2002). Land cover/ land use changes in the Derekolli catchment of the South Welo Zone of Amhara Region, Ethiopia. *Eastern Africa Social Science Research Review 18 (1),* 1-20.

Berhan, G. (2010). The role of Geo-information technology for predicting and mapping of forest cover Spatio-temporal variability: Dendi district case study, Ethiopia. *Journal of Sustainable Development in Africa, 12(6),* 9 - 15.

Betrie, G. D., Mohamed, Y. A., Van Griensveen, A., and Srinivasan, R. (2011). Sediment management modelling in the Blue Nile Basin Using SWAt model. Hydrology and Earth System Sciences, 15(15). 807 -818.

Beven, K. J. (1989). Changing ideas in Hydrology. The Case of Physically - Based Models. *Journal of Hydrology 105: 157 - 172. Catchments, Tanzania. Proceedings of the 3rd International SWAT conference, Zurich, 2005*.

Beven, K., and Binley, A. (1992). The Future of Distributed Model- Model Calibration and Uncertainty Prediction. *Hydrological Processes, 6(3),* 279 - 298.

Bewket, W. (2003). Towards integrated watershed management in highland Ethiopia: the Chemoga watershed case study, PhD thesis, Wageningen University and Research Centre, ISBN 90-5808-870-7.

Bezuayehu, T. (2006). people and Dams: Environmental and soci-economic impacts of Fincha'a hydropower dam, western Ethiopia. Tropical Res. Manag.Paper. No.75. Wageningen University and Research Center, Wageningen, The Netherlands.

Bezuayehu, T., and Geert, S. (2007). Hydropower-Induced Land Use Change in Fincha'a Watershed, Western Ethiopia: Analysis and Impacts.

Bicknell, B. R., Imhoff, J. C., Donigian, A. S., and Johanson., R. C. (1997). Hydrological simulation program - FORTRAN (HSPF): User's manual for release 11. EPA-600/R-97/080. Athens, Ga.: U.S. Environmental Protection Agency.

Borah, D. K., and Bera., M. (2003). Watershed-scale hydrologic and nonpoint-source pollution models: Review of mathematical bases. Trans. ASAE 46(6). 1553-1566.

Borah, D. K., M. Bera, M., and Xia., R. (2004). Storm event flow and sediment simulations in agricultural watersheds using DWSM. Trans. ASAE 47(5). 1539-1559.

Brandon, R. (1998). Mapping Ruaral Land Use and Land Cover Change in Carroll Country, Arkansas: Utilizing Multi- Tempora Landsat Thematic Mapper Satellite Imagery. UniversitynOf Arkansas.

Bruijnzeel, L. A. (1990). Hydrology of most tropical forests and effects of conversion: a state of knowledge rview. Amsterdam: UNESCO Humid Tropics Programme.

Calder, I. R. (1992). Hydrologic effects of land use change, Ed. in Chief D. R. Maidment. Handbook of Hydrology. 13.1-13.50.

Calder, I. R. (1998). Water- Resource and Land-use issues. SWIM paper 3. Colombo, Srilanka: International Water Management Institute.

Campbell, J. B. (2007). Introduction to Remote Sensing. New York: Guilford. 4th ed. 625.

Cornell. (2003). SMDR: The soil moisture distribution and routing model. Documentation version 2.0. Ithaca, N.Y.: Cornell University Department of Biological and Environmental Engineering, Soil and Water Laboratory.

Cunderlik, J. (2003). Hydrological model selection for CFCAS project, Assessment of water resource risk and vulnerability to change in climate condition, University of Western Ontario.

Denboba, M. A. (2005). Forest conversion - soil degradation - farmers' perception nexus: Implications for sustainable land use in the southwest of Ethiopia. Ecology and Development Series No. 26, 2005.

Di Luzio, M., Srinivasan, R., Arnold, J., and S.L.Neitsch. (2002). ArcView in terface for SWAT2000, user's guide. Blackland Research & Extension Center, Texas Agricultural Experimental Station Texas .

Duan, Q., Gupta, V., and sorooshian, S. (1992). Effective and efficient global optimization for conceptual rainfall-runoff models, water. Resourc. Res.28. 1015 - 1031.

Eberhart, R., and Kennedy, J. (1995). A new optimizer using particle swarm theory. Proceedings of the sixth International symposium on Micro Machine and Human Science, Nagoya, Japan, 39 - 43. Piscataway, NJ: IEEE Service Center.

EFAP. (1994). *The challenge for development, Transitional Government of Ethiopia, Ministry of Natural Resources Development and Environmental Protection,Ethiopia. Ethiopian Forestry Action Program, (EFAP), Vol. II. Final report.*

Elfert, S., and Bormann, H. (2010). Simulated impact of past andpossible future land use changes on the hydrological response of the Northern German lowland "Hunte" catchment,. J. Hydrol., 383. 245 - 255.

El-Nasr, Arnold, A. J., Feyen, J., and Berlamont., J. (2005). Modelling the hydrology of a catchment using a distributed and a semi-distributed model. *Hydrol. Process. 19(3)*, 573-587.

Engel, B., Storm, D., White, M., J.Arnold, and Arabi, M. (2007). A hydrologic/ water quality model application protocol. *J.American water Resour.Assoc. 43(5),* 1223 - 1236.

FAO. (2002). Food and Agriculture Organization of the United ations Viale delle Terme di Caracalla, 00100 Rome, Italy.

Fu C. (2003). Potential impacts of human-inducedland cover change on East Asian Monsoon. GlobaPlanet. Change 37. 219–229.

Gan, T., Dlamini, E., and G.F.Biftu. (1997). Effects of model complexity and structure, data quality and objective functions on hydrologic modelling. *J. Hydol. 192(1),* 81 - 103.

Gassman, P. W., Reyes, M. R., Green, C. H., & Arnold, J. G. (2005). THE SOIL AND WATER ASSESSMENT TOOL: HISTORICAL DEVELOPMENT, APPLICATIONS, AND FUTURE RESEARCH DIRECTIONS.

Gassman, P., Reyes, M., Green, C., and Arnold, J. (2007). The Soil and Water Assessment Tools: Historical Development, Applications and Future Research directions. Transactions of the ASABE. Vol. 50(4). 1211 - 1250.

Gelman, S., Carlin, J. B., Stren, H. S., and Rubin, D. B. (1995). Bayesian Data Analysis, Chapman and Hall, New York, USA.

Gerten, D., Schaaphoff, S., Haberlandt, W., Luht, W., and Sitch, S. (2004). Terrestrial vegetation and water balance-hydrological evaluation of a dynamic global vegetation model. *Journal of Hydrology. 286,* 249 - 270.

Getahun, K., Heluf, G., Tena, A., Megersa, O., and Hans, H. (2013). Land use changes induced by irrigation development in the Fincha'a sugar estate, Blue nile basin, Ethiopia. *Journal of Biodiversity and Environmental Sciences (JBES), III, No. 11*, 31 - 47.

Gete, Z. (2000). Landscape dynamics and soil erosion process modeling in the Northwestern Ethiopian highlands. PhD dissertation. Switzerland.

Goswami, M., K.M.O'Connor, Bhattari, K., and Shamseldin, A. (2005). Assessing the performance of eight real-time updating models and procedures for the Brosna River,Hydrology and the Earth system Sciences. 9(4). 394 - 411.

Green, W., and Ampt, G. (1911). Studies in Soil Physics,I: The Flow of Air and Water through Soils. *Journal of Agricultural Sciences 4*, 11 - 24.

Guo, H., Hu, Q., and Jiang, T. (2008). Annual and seasonal stream flow responses to cliamte and land cover changes in the poyang lake basin, China. *Journal of Hydrology, Vol. 355, 106 - 122*.

Gupta, H., Sorooshian, S., and Yapo, P. (1999). Status of automatic calibration for hydrologic models: Comparison with multilevel expert calibration. *J. Hydrol Eng.4,* 135 - 143.

Haan, C. (2002). Statistical Methods In Hydrology. 2nd Edition. Blackwell, pp. 496.

Hadgu, K. M. (2008). Temporal and spatial changes in land use patterns and biodiversity in relation to farm productivity at multiple scales in Tigray, Ethiopia. PhD Thesis Wageningen University, Wageningen, the Netherlands.

Hailemariam, K. (1999). Impact of Climate Change on the Water Resources of Awash River Basin Ethiopia. Climate Research.

Hamby, D. (1994). A review of techniques for parameter sensitivity analysis of environmental models Springer, PP. 135 - 154.

Hargreaves, G and J.P.Riley. (1985). Agricultural benefits for Senegal River Basin. J. Irrig. and Drain. Engr. 111(2). 113 - 124.

HARZA Engineering Company. (1965). Appraisal of Potential Agriculture Development. Finchaa Project, Ethiopia. Report prepared for Ministry of Public Works and Communications. Volume III, Appendices. Addis Abeba, Ethiopia: Imperial Government of Ethiopia.

HARZA Engineering Company. (1975). Finchaa Hydroelectric Project, Ethiopia. Civil Design Memorandum C-1. Washington, DC: HARZA Engineering Company.

Houghton, J. T. (1995). Climatic Change 1994: Radiative Forcing of Climatic Change and an Evaluation of IPCC IS92 Emission Scenarios. Intergovernmental panel on climate change. Cambridge University press, Cambridge, UK.

Hundecha, Y., and Bardossy, A. (2004). Modeling of the effect of land use changes on the runoff generation of a river basin through pa-rameter regionalization of a watershed model, J. Hydrol., 292,281–295.

Hurni, H. (1989). Soil for the Future. Environmental Research for Development Cooperation, Uni Press 62, University of Berne: Berne; 42 - 46.

Hurni, H. (1990). Degradation and Conservation of Soil Resources in the Ethiopian highlands. Mt. Res. Dev. 8(2-3). 123 - 130.

Hurni, H., Solomon, A., Amare, B., Berhanu, D., Ludi, E., Portner, B and Gete, Z. (2010). Land Degradation and sustainable land management in the hidhlands of Ethiopia.

IFPRI, WUR, and EEPFE. (2005). Poverty and Land Degradation in Ethiopia: How to Reservoir the Spiral? Concept note for the project Economic Sector Work on Poverty and Land Degradationin Ethiopia. Addis Ababa.

IPCC. (2007). Climate change 2007: Impacts, Adaptation, and Vulnerability- Contribution of Working Goup II to the Third Assessmsnt Report of the Intergovernmental Panel on Climate Change, edted by M. L. Parry et al Cambridge Univ. Press, Cambridge, U.K.

Jha, M. K., Gassman, P. W., and Arnold, J. G. (2007). Water quality modelling for the raccoon river watershed using SWAT. American Society of Agricultural and Biological Engineers, 50. 479 - 493.

Kassa, G. (2003). GIS based analysis of land use and land cover, land degradation and population changes: A study of Boru Metero area of south Wello, Amhara Region, MA Thesis, Department of Geography, Addis Ababa University. 110 pp.

Kassa, T. (2009). Watershed Hydrological Responses to Changes in Land use and Land Cover, and Management Practices at Hare Watershed, Ethiopia PHD thesis. University of Siegen, Germany.

Kebron, T., and Hedlund, L. (2000). Land cover change between 1958 and 1986 in kalu district, southern Wollo, Ethiopia. Mountain Research and development20. 42 - 51.

Kiage, L., Liu, K., walker, N., Lam, N., and Huh, O. (2007). Recent Land cover/use change associated with land degradation in the lake Baringo catchment, Kenya, East Africa: Evidence from Landsat TM and ETM+. *International Journal of Remote Sensing 28(19)*, 4285 - 4309.

Kidanu, S. (2004). Using Eucalyptus for soil and water conservation on the highland Vertisols of Ethiopia, PhD Thesis, Wageningen University, The Netherlands.

Kuczera, G., and Parent, E. (1998). Monte Carlo assessment of parameter uncertainty in conceptual catchment models: the Metropolis algorithm. *Journal of Hydrology 211(1-4)*, 69 - 85.

Lakew, D., Menale, K., Benin, S., and Pender, J. (2000). Land Degradation and Strategies for Sustainable Development in the Ethiopian Highlands: Amhara Region. Socio-Economics and Policy research Working paper 32, 122.

Lal, R. (2001). Soil Degradation by erosion. Land Degradation & Development, 12. 519 - 539.

Lambin, E. F., J, G. H., and E., L. (2003). Dynamics of land use and land cover change in tropical regions. Annu. Rev. Environ. Resour. 2003. 28. 205-41.

Legates, D., and McCabe, G. J. (1999). Evaluating the use of "goodness-of-fit" measures in hydrologic and hydroclimatic model validation. *Water Resour. Res. 35(1)*, 233 - 241.

Legesse, D., Vallet-Coulomb, C., and Gasse, F. (2003). Hydrological response of a catchment to climate and land use changes in Tropical Africa: case study South Central Ethiopia. Journal of Hydrology 275. 67-85.

Li, L., Jiang, D., Li, J., Liang, L., and Zhang, L. (2007). Advances in hydrological response to land use/land cover change. *J Nat Resour 22(2)*, 211-224.

Liew, M., Vieth, T., Bosch, D., and Arnold, J. (2007). Suitability of SWAT for the conservation effects assessment project: Comparison on USDA agricultural research service watersheds. *J. Hydrol. Eng.12(2)*, 173 - 189.

Loage, K., and Green, R. E. (1990). Statistical and graphical methods of evaluating solute transport models. Overview and Application. *Journal of Contaminant hydrology 7*, 51 - 73.

McCulloh, J., and Robinson, M. (1993). History of Forest Hydrology. *Journal of Hydrology*, 150: 189 - 216.

Meyer, W., and Turner, B. L. (1994). Changes in land use and land cover: A Global Perspective. Cambridge: Cambridge University Press. New York.

Monteith, J. (1965). Evaporation and the Environment. In The State and movement of water in living organisms. 19th Symposia of the Society for Experimental Biology. Cambridge Univ. Press, Llondon, U.K. 205 - 234.

Morgan, R. P. (2005). *Soil Erosion and Conservation* (3rd edition ed.). Blackwell: Malden.

Nash, J., and Sutcliffe, J. (1970). River flow forecasting through conceptual models: Part I. A discussion of principles. *J. hydrol. 10(3)*, 282 - 290.

Nearing, M., Pruski, F., and O'Neal, M. (2004). Expected climate change impacts on soil erosion rates, a review. *Journal of Soil and Water Coservation 59, Number 1*.

Neitsch, S. L., Arnold, J. G., Kiniry, J. R., and Williams, J. R. (2011). Soil and Water Assessment Tool - theoretical Documentation Version 2009. September 2011, Texas Water Resources Institute, Dallas, Texas, USA.

Neitsch, S., Arnold, J., Kiniry, J., and Williams, J. (2005). Soil and Water Assessment Tool, Theoretical documentation: Version 2005. Temple, TX. USDA Agricultural Research Service and Texas A & M Black land Research Centre.

Nelson, R. G., Ascough II, J. C., and Langemeier, M. R. (2006). Environmental and economic analysis of switchgrass production for water quality improvement in northeast Kansas. *J Environ Maname 79*, 336 - 347.

OADB. (1996). OADB(Oromiya Agriculture Development Bureau). Land resource and socioeconomic survey report of Coomman watershed, Ethiopia,. pp.107.

Oyung, D., and Bartholic, J. (2001). "Web- based Gis Application for Soil Erosion Prediction." Proceedings of An International Smposium, Soil Erosion Research for the 21st Century Honolulu, HI. Jan. Institute fo Water Research, Michigan State University. 3 - 5.

Palmeiri, A., Shah, F., and Dinar, A. (2001). Economic reservoir sedimentation and the sustainable management of dams. *Journal of Environmental Management, Vol. 61*, 149 - 163.

Prakasam, C. (2010). Land use and land cover change detection through remote sensing approach: A case study of Kodaikanal taluk, Tamil nadu. *International journal of Geomatics and Geosciences, 1(2),* 150-158.

Priestly, C., and Taylor, R. (1972). On the Assessment of Surface Heat Flux and Evaporation Using Larg- scale Parameters. Division of Atmspheric Physics, Commonwealth Scientific and Industrial Research Organization, Aspendale, Victoria, Australia.

Refsgaard, J. (1997). Parameterisation, calibration and validation of distributed hydrological models. *J.Hydol.198(1),* 69 - 97.

Refsgaard, K., and Storm, B. (1996). Construction, calibration and validation of hydrological models, Distributed Hydrological Modelling(eds. M. B. Abott and J. C. Refsgaard), Kluwer Academic Publishers.

RichardHMcCuen. (1989). Hydrologic analysis and Design Englewood Cliffs. New Jersey.

Saleh, A., and Du., B. (2004). Evaluation of SWAT and HSPF within BASINS program for the upper North Bosque River watershed in central Texas. Trans. ASAE 47(4). 1039-1049.

Schilling, K. E., Jha, M. K., Zhang, Y. K., Gassman, P. W., and Wolter, C. F. (2008). Impact of land use and land cover change on the water balance of a large agricultural watershed Historical effects and future direction, Water Resour. Res, 44, W00A09, 12 PP doi: 10. 1029/2007WR006644.

Schoul, J., and Abbaspour, K. (2006). Calibration and Uncertainty issues of a hydrological model (SWAT) applied to west Africa. Advances in Geosciences 9. 137 - 143.

SCRP. (1996). Database Report (1982 - 1993), series II: Gununo Research Unit:University Berne.

Setegn, S. G., Darfahi, B., Srinivasan, R., and Melesse, A. M. (2010). Modeling of sediment yield from Anjeni-gauged watershed, Ethiopia using SWAT model, J. Am. *Water Resour. Assoc., 46(5),* 514–526.

Setegn, S., Srinivasan, R., Dargahi, B., and Melesse, A. (2008). Spatial delineation of soil erosion vulnerability in the lake Tana Basin, Ethiopia. *Hydrological Processes, Hydrol. Process. (2009).*

Shi, P., Gong, P., Li, X., Chen, J., Qi, Y., and Pan, Y. (2000). Methodology and pactice of land use/land cover change. Science Press, Beijing.

Sidle, R. C., Ziegler, A. D., and Negishi, J. N. (2006). Erosion processes in steep terrain-truths, myths and uncertainties related to forest management in southeast Asia. Forest Ecology and Management 224(1-2). 199 - 225.

Singh, J., Knapp, H. V., Arnold, J. G., and Demissie., M. (2005). Hydrological modeling of the Iroquois River watershed using HSPF and SWAT. J. American Water Resour. Assoc. 41(2). 343-360.

Small, I., J, R., and R, D. (2003). Long-term sediment yield in crombie reservoir catchment, angus; and its regional significance within the midland valley of scotland. *Hydrological sciences Journal 48(4)*, 619-635.

Solomon, H. (2005). GIS-Based Surface Runoff Modelling and Analysis of Contributing Factors; a Case study of the Nam Chun watershed, Thailand. MSc Thesis, ITC, the Netherlands.

Srinivasan, M. S., Gerard-Marchant, P., Veith, T. L., Gburek, W. J., and Steenhuis., T. S. (2005). Watershed scale modeling of critical source areas of runoff generation and phosphorus transport. *J. Am. Water Resour. Assoc. 41*, 361-375.

Sun, C., and Ren, L. (2013). Assessment of surface water resources and evapotranspiration in the Haihe River basin of China using SWAT model. *Hydrol. Process. 27 (8)*, 1200–1222.

Tamene, L., Park, S., Dikau, R., and Vlek, P. (2005). Analysis of factors determining sediment yield variability in the highlands of Northern Ethiopia. Geomorphology, 76. 76-91.

Tamene, L., Park, S., Dikau, R., and Vlek, P. (2006). Reservoir siltation in the semi-arid highlands of northern Ethiopia: Sediment yield-catchment area relationship and a semi-quantitative approach for predicting sediment yield. Earth Surface Processes Landform,31. 1364 - 1383.

Tegene, B. (2002). Land-Cover/ Land- Use Changes in the Derekolli catchment of the South Wello Zone of Amhara Region, Ethiopia;EASSRR. *XVIII, no.1*.

Tekle, K., and Hedlund, L. (2000). Land Cover Changes between 1958 and 1986 in Kalu District, Southern Wello, Ethiopia. Mountain Research and Development, 20(1). 42 - 51.

Tibebe, D., and Bewket, W. (2010). Surface rRunoff and Soil Erosin Estimation Using the SWAT Model in the Keeta Watershed, Ethiopia. Land Degradation and Developement.

Tolba, M., and El-Kholy, O. (. (1992). The World Environment 1972 - 1992: Two Decades of Challeng, Chapman and Hall, London.

Tong, S. T., and Chen, W. (2002). Modeling the Relationship between land use and surface water quality. Journal of Environmental Management 66(4). 377- 393.

Tripathi, M. P., Panda, R. K., and S., R. N. (2003). Identification and prioritization of critical sub-watersheds for soil conservation management using SWAT model. *Bio systems Engineering, Vol.85*.

Tsegaye, E. (2006). Regionalization of potential Evapotranspiration prediction for Blue Nile (Abbay) river basin, Ethiopia.

USDA-SCS. (1972). US Department of Agriculture-Soil Conservation Service, National Engineering Handbook, Section IV, hydrology. 4 - 102.

Van Griensven, A. (2005). Sensitivity, auto-calibration, uncertainty and model evaluation in SWAT2005. UNESCO IHE. 48 p.

Van Griensven, A., and Meixner, T. (2006). Methods to quantify and identify the sources of uncertainty for river basin water quality models. *Water science and Technology, 53(1)*, 51 - 59.

Van Griensven, A., Meixner, T., Grunwald, S., T, B., Diluzio, M., and R, S. (2006). A global Sensitivity analysis tool for the parameters of multi-variable catchment models. *J Hydrol: 324 (1 -4)*, 10 - 23.

Van Liew, M., J.G.Arnold, and D.D.Bosch. (2005). Problems and potential of autocalibrating a hydrologic model. *Trans. ASAE 48(3)*, 1025 - 1040.

Walling, D., and Fang, D. (2003). Recent trends in the suspended sediment loads of the world's rivers. Global Plane Change, 39. 111 - 126.

WCD. (2000). WCD (World Commission on Dams). Dams and development: a new framework for decision-making. Earthscan: London.

White, E., Easton, Z., Fuka, D., Collick, E., E.Adgo, McCartney, M., and T.S.Steenhuis. (2008). Adapting the soil and water assessment tool(SWAT) for the Nile Basin (unofficial data describes that 70% of the cost of operation and maintenance in the Blue Nile part of the Sudan is spent on sediment related and canal maintenance).

White, K. L., and Chaubey, I. (2005). Sensitivity Analysis, Calibration and Validations for a Multisite and Multivariable SWAT model. Journal of the American Water Resources Association (JAWRA), 41(5). 1077 - 1089.

White, W. (2005). World Water: Resources,Usage, and the role of man-made reservoirs. Foundation for Water Resources. Allen House, The Liston Road, Marlow, Bucks SL7 IFD,U.K.

Williams, J. (1975). Sediment-yield Prediction with universal equation using runoff energy factor.p.244-252. In Present and prospective technology for predicting sediment yield sources: Proceedings of the sediment-yield workshop,USDA Sedimentation Lab.,Oxford.MS,1972.ARS-S-40.

Yang, D., Kanae, S., Oki, T., Koike, T., and Musiake, K. (2003). Global potential soil erosion with reference to land use and climate changes. *Hydrol process 17*, 2913 - 2928.

Zeleke, G., and Hurni, H. (2001). Implications of Land use and land cover dynamics for mountain resource degradation in the northwestern Ethiopia highlands. *Mountain Research and Development 21*, 184-191.

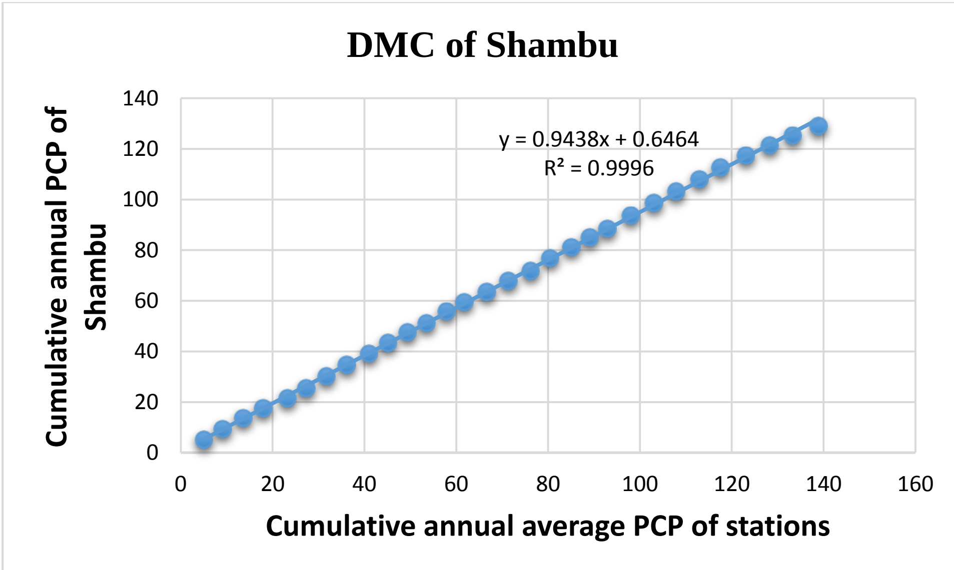
Zemenfes, T. (1995). The Polotical economy of land degradation in Ethiopia. Northeast African Studies 2. 71 - 98.

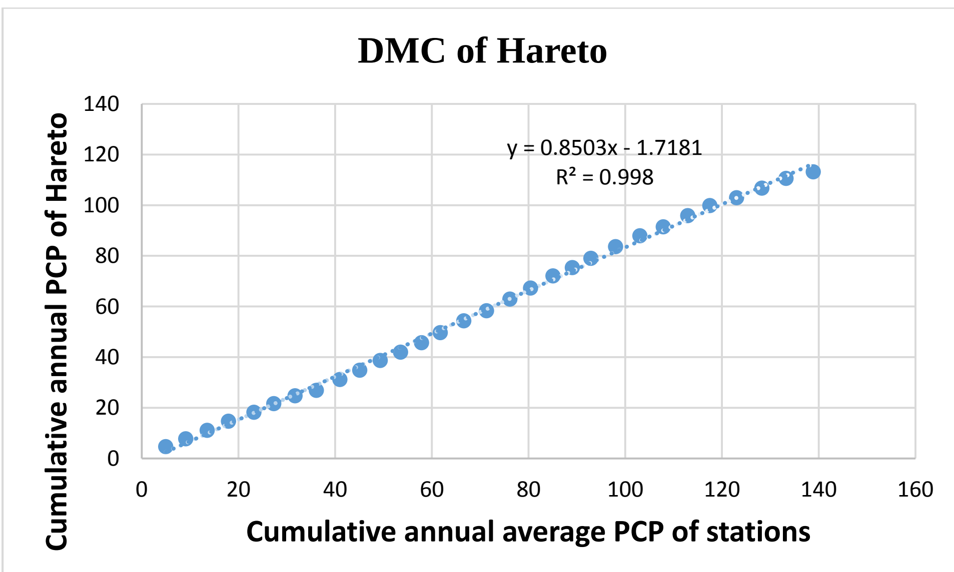
Zeray, L. (2006). Climate Change Impat on Lake Ziway Watershed Water Availability, Ethiopia. MSc. Cologne: University of Applied Sciences Cologne, Institute foe Technology in the Tropics.

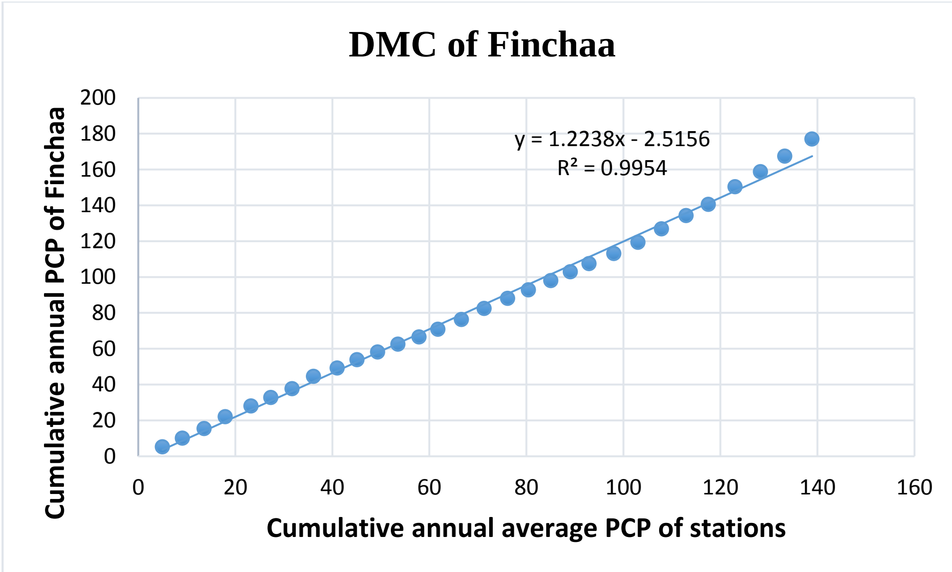
Zhang, X., Srinivasan, R., and F.Hao. (2007). Predicting Hydrologic Response to Climate Change in the Luohe River basin Using the SWAT Model. American Society of agricultural and Biological Engineers 50(3):. 901 - 910.

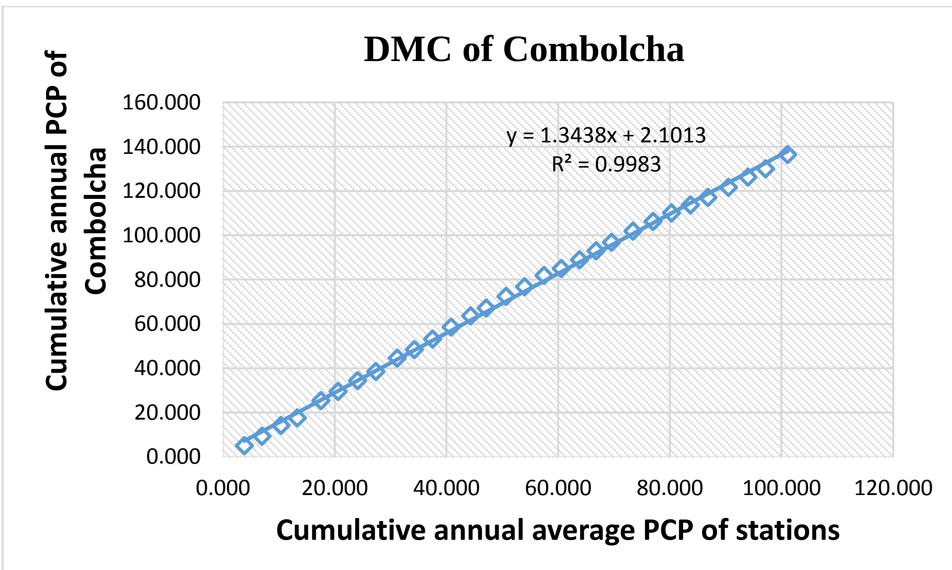
APPENDIX

Appendix I. Consistency checking for each Rainfall stations.

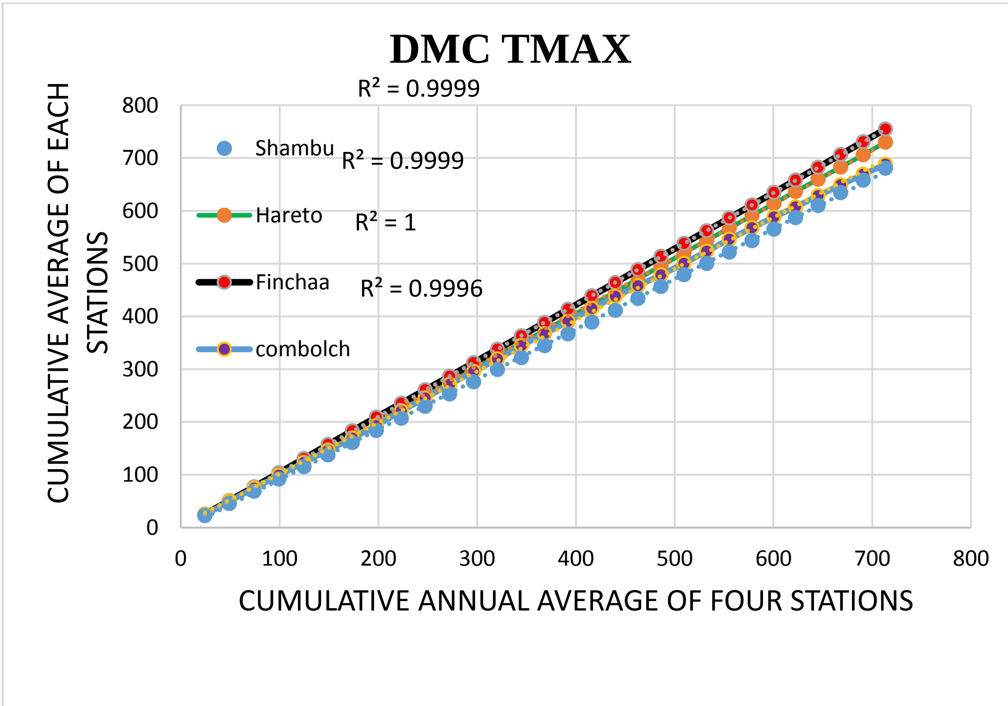


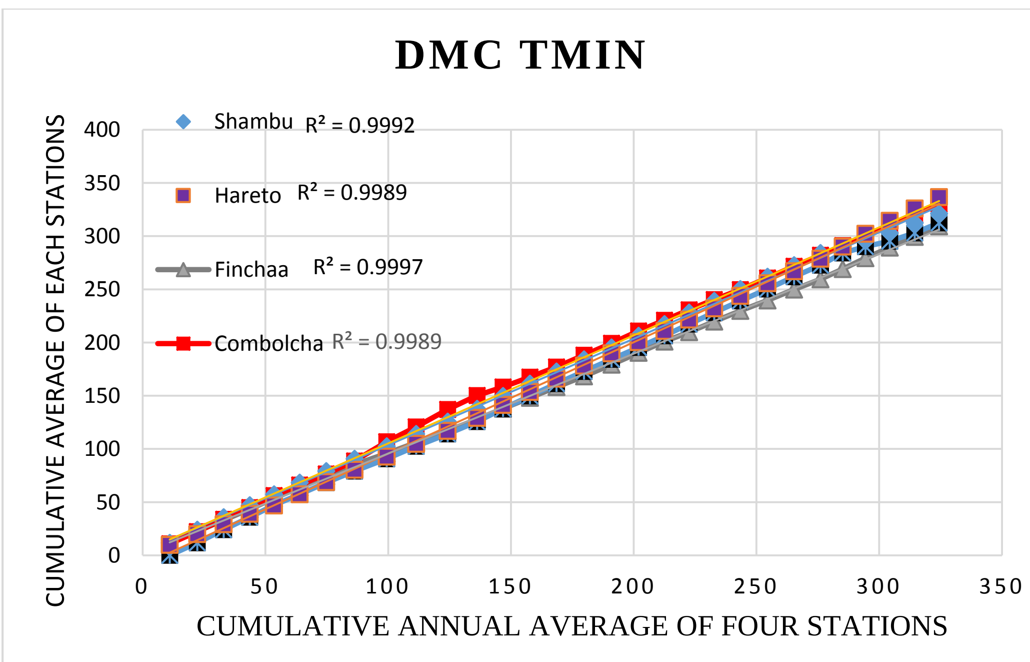



DMC of Finchaa
y = 1.2238x - 2.5156
R² = 0.9954
Cumulative annual PCP of Finchaa
Cumulative annual average PCP of stations
0
20
40
60
80
100
120
140
160
180
200
0
20
40
60
80
100
120
140
160


DMC of Combolcha
y = 1.3438x + 2.1013
R² = 0.9983
Cumulative annual PCP of Combolcha
Cumulative annual average PCP of stations
0.000
20.000
40.000
60.000
80.000
100.000
120.000
140.000
160.000
0.000
20.000
40.000
60.000
80.000
100.000
120.000

Appendix II. Consistency checking for the four maximum and minimum temperature stations respectively.



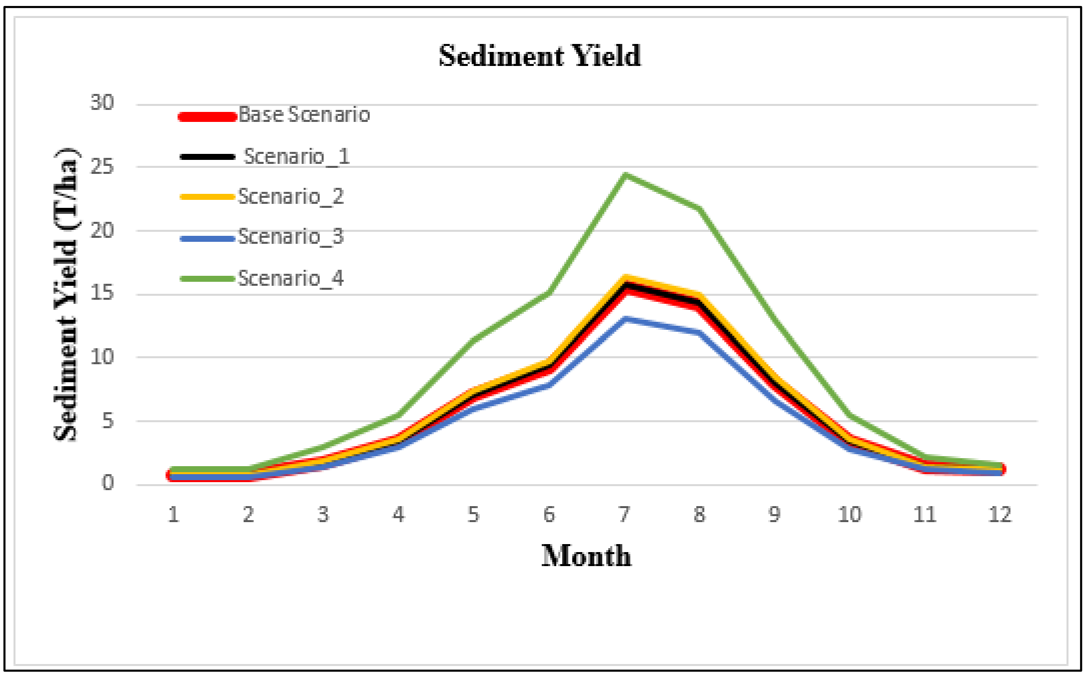


Appendix III. Sensitivity analysis parameters of flow in Finchaa watershed

Parameters		
NO.	**Name**	**Description**
1	CN2.mgt	SCS runoff Curve number for moisture condition II
2	ALPHA_BF.gw	Base flow alpha factor (days)
3	GW_DELAY.gw	Ground water Delay (days)
4	GWQMN.gw	Threshold depth of water in shallow aquifer required for return flow (mm)
5	GW_REVAP.gw	Ground water ‘revap’ coefficient
6	ESCO.hru	Soil evaporation compensation factor
7	CH_N2.rte	Manning’s roughness coefficient for main channel
8	CH_K2.rte	Effective hydraulic conductivity of the main channel (mm/hr)
9	ALPHA_BNK	Base flow alpha factor for bank storage
10	SOL_AWC.sol	Soil available water capacity (mm H_20/ mm soil)
11	SOL_K.sol	Saturated Hydraulic conductivity (mm/hr)
12	SOL_BD.sol	Moist bulk density
13	SFTMP.bsn	Snowfall temperature (^oC)
14	BLAI.crop.dat	Sub-maximum potential leaf area index
15	SLSUBBSN.hru	Average slope length (m)
16	REVAPMN.gw	Threshold water in the shallow aquifer for revap to occur (mm)
17	SOL_Z.sol	Soil depth (mm)
18	SOL_ALB.sol	Moist soil albedo
19	SMFMX.bsn	Melt factor for snow on June 21 (mm H20/ ^oC-day)
20	SMFMN.bsn	Melt factor for snow on December 21 (mm H_20/ ^oC-day
21	SMTMP.bsn	Snow melt base temperature (^oC)
22	TIMP.bsn	Snow pack temperature lag factor
23	SURLAG.bsn	Surface runoff lag time (days)
24	CANMX.hru	Maximum canopy storage (mm)
25	SLOPE. hru	Average slope steepness (m/m)
26	TLAPS.sub	Temperature lapse rate (^oC/Km)
27	BIOMIX.mgt	Biological mixing efficiency

Appendix IV. Average monthly sediment yield Basin Values

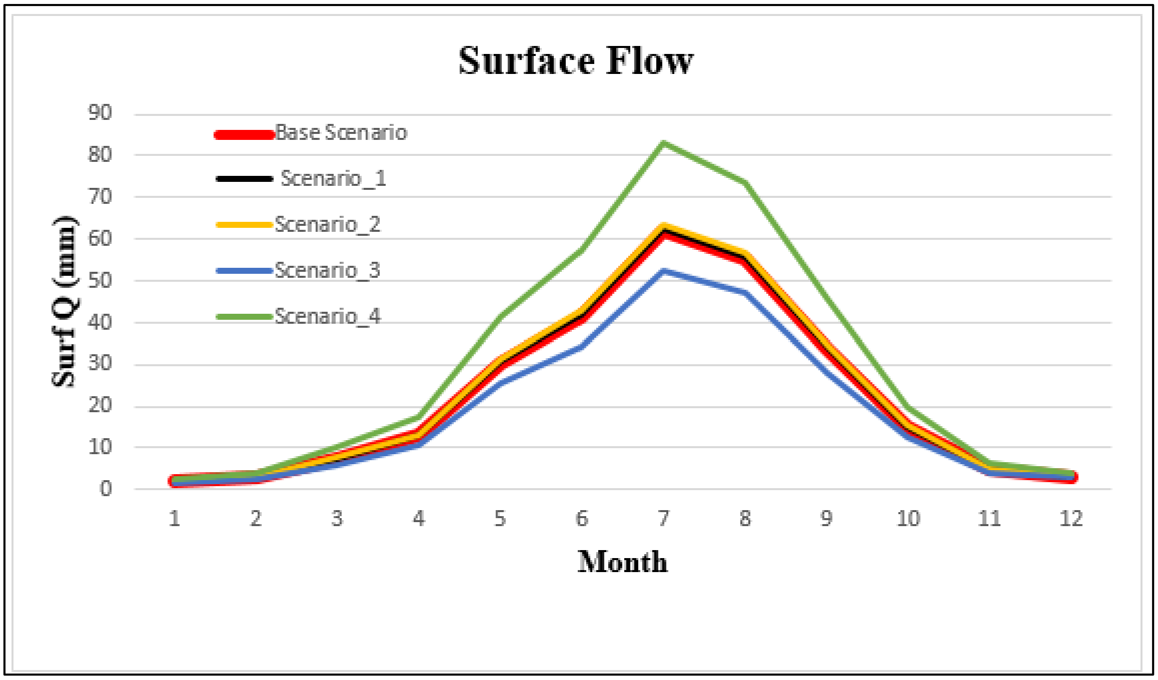
	Sed yield(T/Ha)				
Month	**Base Scenario**	**Scenario_1**	**Scenario_2**	**Scenario_3**	**Scenario_4**
1	0.78	0.78	0.82	0.65	1.18
2	0.72	0.73	0.75	0.6	1.15
3	1.73	1.75	1.82	1.44	2.94
4	3.48	3.5	3.64	2.93	5.44
5	7.07	7.12	7.4	5.96	11.3
6	9.32	9.42	9.81	7.78	15.08
7	15.62	15.79	16.44	13.13	24.44
8	14.21	14.36	14.96	11.94	21.77
9	7.99	8.07	8.42	6.64	12.82
10	3.45	3.48	3.64	2.84	5.41
11	1.38	1.38	1.43	1.16	2.12
12	1.14	1.14	1.18	0.96	1.58



Appendix IV. Average monthly sediment yield Basin Values

Appendix V. Average monthly Surface flow Basin Values

	Surf Q (mm)				
Month	**Base Scenario**	**Scenario_1**	**Scenario_2**	**Scenario_3**	**Scenario_4**
1	2.05	2.06	2.11	1.75	2.73
2	2.8	2.81	2.87	2.36	3.76
3	7.41	7.47	7.64	6.02	10.43
4	12.97	13.01	13.28	10.83	17.48
5	30.56	30.7	31.36	25.48	41.39
6	41.62	41.91	42.82	34.42	57.22
7	61.8	62.31	63.62	52.23	83.18
8	55.19	55.61	56.74	46.94	73.62
9	33.74	33.96	34.68	28.14	45.9
10	14.97	15.04	15.34	12.74	19.85
11	4.86	4.86	4.96	4.09	6.46
12	3.26	3.26	3.31	2.87	4.09



Appendix V. Average monthly Surface flow Basin Values