2023-12

IMPACTS OF LAND USE LAND COVER DYNAMICS ON THE STREAMFLOW OF BERESSA RIVER, ABAY BASIN, ETHIOPIA

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Ezezachew Yirade Woldekiros

A thesis submitted to the School of Research and graduate studies of Bahirdar Institute of Technology, BDU in partial fulfillment of the requirements for the degree of master's science in Hydraulic Engineering.

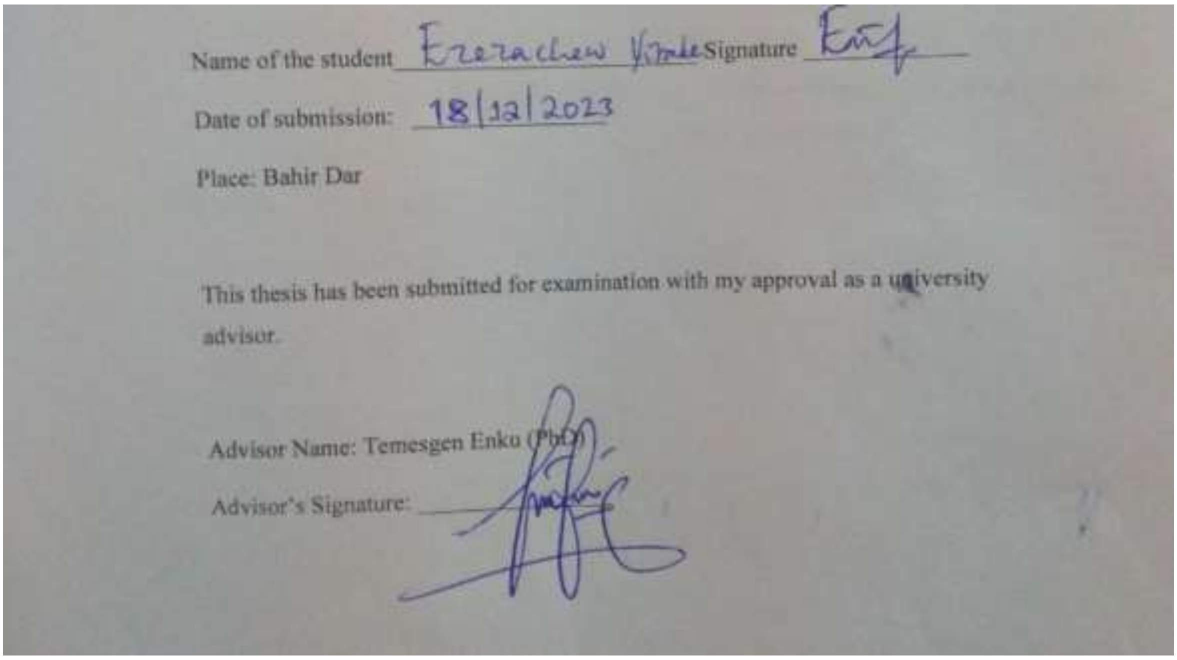
Advisor Name: Temesgen Enku (PhD)

December 2023

Bahirdar, Ethiopia

DECLARATION

I declare that this Thesis work entitled “Impacts of land use land cover dynamics on the Stream flow stream flow of Beressa River, Abay basin, Ethiopia” for the fulfillment of the degree of Master of Science in hydraulic engineering at Bahir Dar university institute of Technology, submitted by me is my original work which has not been submitted in any form for another degree in this university or other institute and that all resources of material used in this thesis work have been duly acknowledged.



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Date of submission: 18/12/2023

Place: Bahir Dar

This thesis has been submitted for examination with my approval as a university advisor.

Advisor Name: Temesgen Enku (PhD)

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Approval of thesis for defense result

I hereby confirm that the changes required by the examiners have been carried out and incorporated in the final thesis

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As members of the board of examiners, we examined this thesis entitled ***"Impacts of land use land cover dynamics on the stream flow of Beressa River, Abay basin, Ethiopia"***. We hereby certify that the thesis is accepted for fulfilling the requirements for the award of the degree of Masters of Science in "Hydraulic Engineering".

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iv

ACKNOWLEDGMENTS

First and foremost, I would like to thank the Almighty God for giving me courage through all challenges I faced in the completion of this thesis. A big thanks to express for Amhara Water Irrigation and Energy Bureau for sponsoring my master's program. I express my deep sense of gratitude to my advisor, Dr. Temesgen Enku for his assistance, invaluable comments, suggestions, and best guidance of all my work and encouragement showed towards me, which was very helpful and very much precious.

I would like to extend gratitude to Ethiopian Water Energy, Abbay Basin Authority and Ethiopia meteorological agency Kombolcha branch for giving me the information that I need since without it my research was not possible.

Finally, I would like to extend my deepest sense of gratitude to my family and friends for their support and encouragement in the successful completion of this thesis.

ABSTRACT

Land use land cover change is the central form of global environmental change that occurs at spatial and temporal scales. This study aimed to evaluate the impacts of land use/land cover (LULC) changes on the streamflow of the Beressa watershed. The study used three times series of Landsat images Landsat 5 TM 1990, Landsat ETM+ 2000, and Landsat 8 OLI-TIRS 2013. The study used ERDAS EMAGINE 2014 software through maximum likelihood classification techniques to classify Landsat images with the help of Google Earth for the preparation of LULC maps for 1990,2000 and 2013 years. The SWAT CUP semi-automated Sequential Uncertainty Fitting (SUFI2) was used to calibrate and validate the model parameters of streamflow. Three SWAT models set up were run to evaluate the impacts of land-use changes on the streamflow of Beressa watershed using three differentyears 1990, 2000, and2013. Sensitivity, calibrationvalidation, and uncertainty analysis were conducted using Sequential Uncertainty Fitting–version 2 (SUFI-2) in SWAT-CUP (Calibration and Uncertainty Program) using streamflow historical data.Land cover change analysis showed that the agriculture land increased by 6.3%,barren land increased by5.5%, the water bodies increased by 158.8% and the urban areas increased by 195%, whereas the forest decreased by32% and the grassland decreasedby 26.1% from 1990 to 2013. Model calibration and validation were conducted for both land use using measured data at the Beressa gauge calibration approach in a monthly basis. In the 1990's land use calibration was from 1991-1995 and validation was from1996-1998, for 2000's land use calibration was from 1999-2003 and validation was from 2004-2006, and for the 2013 calibration was from 2006 -2011 and validation was from 2012 -2014. Results from calibration for both land use showed a good result (0.62 to 0.82 for NSE and 0.77 to 0.82 for R^2) between observed and simulated stream flow on a monthly base. The results of validation were acceptable (0.65 to 0.80 for NSE and 0.76 to 0.86 for R^2). Average monthly stream flows of the Beressa watershed decreased from the year 1990 to 2000 by 1.46 m^3/s and increased from the year 2000 to 2013 by 0.40m^3/s.

Keywords: Beressa Watershed, LULC, stream flow, SWAT, SUFI2

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

AOI –Area of interest

CSA – Central   Statistical Agency

DEM – Digital Elevation Model

DMC-Double Mass Curve

ENMA-Ethiopia National Meteorological Agency

ENS- Efficiency of Nash-Sutcliffe

ERDAS - Earth Resources Data Analysis System

ET-Evapotranspiration

FAO- Food and Agriculture Organization

GIS- Geographic Information System

GLUE- Generalized likelihood Uncertainty estimation

GUI-Graphical User Interface

HRU- Hydrologic Response Unit

LULC-Land Use Land Cover Change

MoWIE- Minster of Water Irrigation and Energy

MUSLE-Modified Universal Soil Loss Equation

NSE-Nash Sutcliffe Simulation Efficiency

SUFI2-Sequantial Uncertainty fittings

SWAT -Soil and Water Assessment Tool

SWAT-CUP- Soil and Water Assessment Tool-Calibration and Uncertainty

TM –Thematic mapper

USGS-Unite states of Geological survey

UTM-Universal Transverse Mercator

List of Figures

List of tables

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Land use land cover change is the central form of global environmental change that occurs at spatial and temporal scales. This change in land use in the rural and urban areas is the result of deforestation, agricultural land expansions, human settlements, and other factors derived from population growth and environmental problem.Many studies showed that population is the main driving forces for land use land cover changes in urban and rural area(Ayele et al., 2019; Bekele et al., 2019; Bufebo & Elias, 2021a; Gebregergis et al., 2016; Guyu & Aduwa, 2020; Kindu et al., 2015; Ogato et al., 2021).

The land use and land cover changes are caused by a number of natural and human driving forces (Meyer et al., 1994). Natural effects such as climate changes are only over a long period of time, high intensity of rainfall and steep relief (Desta, 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 & Hedlund, 2000**)**as it is common in developing countries.

Land cover and use directly impact the amount of evaporation, groundwater infiltration, and overland runoff that occurs during and after precipitation events. These factors control the water yields of surface streams and groundwater aquifers and thus the amount of water available for both ecosystem function and human use (Mustard et al., 2004). Changes in land cover and use alter both runoff behavior and the balance that exists between evaporation, groundwater recharge, and stream discharge in specific areas and in entire watersheds, with a considerable consequence for all water users (Sahin & Hall, 1996).

Land use land cover plays a vital role in water transport in the hydrologic cycle and primarily aids in reducing overland flows. Due to its effect on evaporation, transportation and solar radiation interception, land use land cover is a driving factor in the energy balance within the hydrologic cycle (Ma et al., 2009). Debirebirehan town islocated in Beressa watershed. It has been expanding radically for the last fifteen years an intensive conversion of rural land to urban development like a residential houses, building, and various types of industries area(Dagne Amdetsion, 2017).

The Beressa river catchment, a tributary of Jemma sub-Abay sub basin experienced land use land cover due to rapid population growth demanded land for cultivation, more trees for domestic fuel wood consumption and more area for settlement for the past three decade years(Meshesha et al., 2016). For this reason, understanding how the land cover changes influence the hydrology of the watershed will enable planners to develop policies to minimize the unwanted effects of future land cover changes.

The main intention of this study to analyze the impacts of land use land cover changes on the stream flowfor Beresa riverwatershed through the integration of Remote Sensing, Geographic Information System (GIS), and Soil and Water Assessment Tool (SWAT model).

1.2. Statement of the Problem

Meshesha et al. (2016), analyzed be land use and land cover change dynamics by using GIS and remote sensing from 1984 to 2015 in the Beressa watershed. The result shown that 30 years generalized change of 18.2 % increase in agricultural land, 50.6%, decrease in grassland, 101 % increase in waterbody and 59.7% increase in settlement in Beressa watershed due to rapid population growth demanded more land for cultivation, more trees for domestic fuel wood consumption and more area for settlement had been responsible for the drastic change in the land use/land cover change in the last three decades in the Beressa watershed.According Negash et al. (2022) quantified the changes in streamflow because of land use land cover changes on mojo watershed. The result showed that due to due to the ongoing expansion of cultivated land and urbanization, increased yearly streamflow by 3%, wet month streamflow by 8.1%, and reduced dry season flow by 8.9%. The yearly flow grew by 1.4%, the wet seasonal flow by 3.8%, and the dry seasonal flow decreased by 8.1% when comparing land-use maps from 2005 and 2018.

The quantification of the impacts of Land Use Land Cover (LULC) change on river basin hydrology will allow local governments and policymakers to develop and execute effective and appropriate solutions to mitigate the impact of future LULC change(Abraham & Nadew, 2018).

There are no well and detailed studies in the Beressa watershed regarding with effects of LULC change on stream flow not known until now. Thus, study aimed to fill this gap and evaluate LULC changes and their impact on streamflow of the watershed.Therefore, a strong need is identified for the hydrological techniques and tools that can assess the effects of land cover changes on the hydrologic response of a watershed. Such techniques and tools can provide information that can be used for water resources management at a watershed.

1.3. Objective of Study

1.3.1. GeneralObjective

The main objective of this study was to model the impacts of land use and land cover change on the stream flow of Beressa River watershed by using Soil and Water Assessment (SWAT model) for the past 24 years (1990-2013).

1.3.2. Specific Objective

1) To map land use land cover of the Berresa watershed for the years 1990, 2000 and 2013.
2) To identify the LULC changes of theBeressa watershed forthe last 24 years.
3) To determine the effects of LULC changes on stream flow response of the Beressa watershed in the past 24 years.

1.4. Research Question

To address the above objectives, the following research questions were designed: -

1) What is the magnitude of land use land cover changes in Beressa watershed?
2) Is there a significance LULC changes in the past 24 years?
3) How does the land use land cover changes affect the streamflow inthe Beressawatershed?

1.5. Significance of Study

The land use land covers dynamics has significant impacts on natural resources, socioeconomics, and environmental system. Quantification of the effects of land use land covers changes on the hydrology response a catchment has a long catchment has long been an area of interest for the hydrological community, and renewed interest has come from the trend towards integrated management of land and water, together with the prospect of climate change impacts. However, to assess the effects of land use and land cover change on stream flow, it is important to understand the land use land cover Patterns and the hydrological processes of the watershed. Understanding the types and impacts of land use and land cover change is an essential indicator for resource base analysis and development of effective and appropriate response strategies for sustainable management of natural resources in the country in general and at the study area in Particular. This study's:

I. It will find measure of the knowledge how land use land cover dynamic influences in the stream flow of the watershed enable all concerned water users' sectors in managing water resources in the study area.
II. It will support integrated water resources management with in watersheds.
III. It will help to an effective and appropriate response strategy to minimize the undesirable effects of future land use/ cover change or modifications.
IV. It will bring up some predictive measures for a sustainable water management for BeressaRivers.

1.6. Scope of the Study

This research was conducted at North shoa Zone, Amhara National Regional State on Beressa watershed. It emphasized the effects of the land use/cover dynamics on watershed streamflow only in terms of surface runoff, ground water, seasonal change, and land use/landcover change in Beressa watershed.Forthe objective of this study spatial data like (DEM, Soil and LULC maps) and climate data used to run SWAT models for simulation of stream flow. Hydrological data like flow was also used for modeling Beressa watershed. The SWAT CUP was used to calibrate and validate flow for three land use land cover maps of 1990, 2000 and 2013. Land use and land cover classification was carried out using ERDAS IMAGINE 2014 software and maximum likelihood of supervised classification techniques was applied in this study. The impacts of land use land changes for a year's 24 from 1990-2013were evaluated bycomparing streamflow in different years byusing SWAT for each land use /cover data separately by keeping other SWAT modelvariables constant. Finally,simulated stream flow of study area was compared for1990, 2000 and 2013 and effectsof land use land cover change were known.

1.7. Limitation of study

Since the BeressaRivergauge is not functional after 2014 G.C. Because of the observed data time series from 1988 to 2014, the study did not consider other land use land cover. This study only considers the land use land cover maps between the observed flow data for a better representation of land use land cover changesimpacts on streamflow.

1.8. Thesis Organization

This paper was organized into five chapters. Chapter one is an introduction part where the background, statement of problem, objective of study, research question, significance of study, scope of the study and limitation. In chapter two, review of literature related to land use land cover definition, cause of land use land cover changes, land use land cover changes in Ethiopia, impacts of land use land cover changes on streamflow, hydrological models, selection of hydrologicalmodels,SWAT. InChapter three describes materials and methods this including description of the Study Area, data collection and analysis and all general framework of the study are elaborated. The fourth chapter describes with the result and discussion include land use land cover change detection and its impact on ofstream flow and overall performance evaluation of the model are made. Finally, in section five, conclusion and recommendations of the study are provided.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Definitionand Concept of Land Use/ Land Cover

The term land use and land cover have been used often interchangeably in literature, though they represent different things. The term land cover refers to the physical cover of the land. It can be defined as the biophysical state of the earth's surface and immediate sub-surface, includingbiota, soil, topography, surface water and groundwater and human structures (Herold et al., 2006; Meyer et al., 1994). On the other hand, land use refers to the intended use or management of the land cover type by human beings (FAO, 1998).It involves both the manner in which the biophysical attributes of land are manipulated and the intent underlining that manipulation (the purpose for which the land is used e.g., agriculture, grazing, etc.), which are more subtle changes that affect the character of the land cover without changing its overall classification.

2.2. Land Use /Land Cover Change

LULC is the change in purpose or management in land use or cover(Mengistu, 2009), this land use and land cover change information used for land related policy measures for politicians and discovering the major causes and effect for the research group (Europeancommunties, 2001).There are two categories through which LU/C change can be occurs; i) land use/land cover conversion and ii) land use/cover modification. Conversion refers to change from one cover or use type to another, as is the case in agricultural expansion, deforestation, or change in urban extent. Land use and land cover modification, on the other hand, involves the maintenance of broad cover or use type in the face of change in its attributes (Lambin et al., 2003).These land use/cover changes mainly related to human activities and environmental impact further land use change have impact on soil and water(Lambin et al., 2003).The cause of LULCC as (Lambin et al., 2003) classified in to two direct cause of land use change by human activities this physical action on land cover/use directly affect land cover of the watershed and underling cause this causes are fundamental force that operate direct cause formed by complex of social, political, economic, demographic, cultural and biophysical factors.

In developing country like Ethiopia land use change mainly affected by the population growth and their uncontrolled activities in the land (Geremew, 2013).Change in land use/ cover as a result of farming, grazing, deforestation and urbanization will affect hydrological process by increasing surface runoff, soil erosion and sedimentation(Olang & Fürst, 2011). when forest land is lost and changed to developed land(transformed to urban or industrial) or agricultural land the base flow decreases the result will be increase in soil erosion, this happen because in forest land the soil water demand is higher because the forest need more water which leads to lower soil erosion (Geremew, 2013). In case of agricultural land, the water demand of the crop is low related to the forest land, this decreases water demand of soil.

2.3. Causes of Land Use Land Cover Changes

The main driving force to land use land cover changes agricultural expansion ,policy change and social unrest, population pressure ,shortage of farm land ,and biophysical factors(Bufebo & Elias, 2021b).

Understanding the mechanisms leading to LULC changes in the past is crucial to understand he current changes and predict future LULC dynamics. Hence, LULC change research needs to deal with the identification, qualitative description and parameterization of factors which drive changes in land use/land cover as well as the integration of their consequences and feedbacks (Hussein Ali, 2009). As a result, underlying causes also tend to be complex, formed by interactions of social, political, economic, demographic, technological, cultural, and biophysical variables. Accordingly, major causes of land use/land cover change are natural variability, economic and technological factors, demographic factors, institutional factors, cultural factors and globalization. Natural variability, natural environmental changes interact with the human decision-making processes that cause land use/land cover change while economic and technological factors influence land use decision making by altering prices, taxes etc. on land use inputs and products.

According to (Lambin et al., 2003)land-use change is driven by a combination of the followingfundamental high-level causes. These are resource scarcity leading to an increase inthe pressure of production on resources, changing opportunities created by markets, outsidepolicy intervention, loss of adaptive capacity and increased vulnerability, and changes in socialorganization, inresource access, and in attitudes. Some of the fundamental causes leadingto land use and land cover change are mostly endogenous, such as resource scarcity, increasedvulnerability and changes in social organization and exogenous factors such aschanging market opportunities and policy intervention.

2.4. Land Use and Land Cover Change in Ethiopia

Land use/land cover (LULC) change is one of the challenges which strongly influence the process of Agricultural development and the food security situation in Ethiopia. With an area of 1,130,000 km^2 and as one of the most populous countries in Africa, Ethiopia is experiencing huge land use/land cover dynamics from natural vegetation to farming practices and human settlement. This problem is more severe in the highlands which account nearly 44% of the country's landmass and which has been cultivated for millennia(Mengistie Kindu, 2013).

Regasa et al. (2021) was carried out a review of land use land cover change in Ethiopian basin by reviewing 25 a total of articles published from 2011 to 2020. The result shown in each article, in most of the studied basins, agricultural land, water body, commercial farm, built-up/settlement, and bare/rock outcrop increased during the last decades in a dramatic manner, while the area covered by forest, grazing land, and shrub land decreased. Such changes are mostly connected with increasing human pressure on the Ethiopian environment, driven by the need of improving the socioeconomic situation of the local population.

Yihun (2020)conducted study on land use Land cover detection and its effectson stream flow and sediment yields inJedeb and Chemoga watershed. The result revealed that 29 years generalized change of 62.3 % increase in agricultural land, 57.8% reductions in forest cover, 52.4% decrease in grass land, 64.2% reduction in shrub land, 145.2 % increase in bare land and 46.5% increase settlement in Jedeb watershed. Similarly, the study revealed that 47.3% increase in Agricultural land, 81.8% reduction in forest cover, 148.9% increase in Grass land, 89% decrease in shrub land, 10.7% increase in bare land and 96.9% decrease in water body in Chemoga watershed.

Getu Engida et al. (2021) evaluated the land use land cover changes impacts on hydrology process in the upper baro basin and showed a drastic decreased of grass land andshrubland, while increased of agricultural land and settlementover the past 30years from 1987 to 2017.

All of the research examined revealed that, during the last few decades, Ethiopian lands transitioned from natural to agricultural land use, waterbody, commercial agriculture, and built-up/settlement. Some areas of the forest land, pasture land, swamp/wetland, shrub land, rangeland, and bare/rock out cropland cover classes were converted to other LULC class types, owing to rising anthropogenic pressure. In conclusion, these publications confirmed that LULC changes are a direct outcome of both natural and human effects, with anthropogenic pressure from globalization serving as the primary driver. However, the majority of the studies presented LULC details for the previous decades within a single spatial region, but did not address the difficulty of estimating future LULC changes at the watershed scale(Regasa et al., 2021).

2.5. Impactsof Land Use/Land Cover Change on Stream Flow

Changes in LULC and their hydrological effects have attracted great attention inhydrology. LULC changes are recognized to have major impacts on a series ofhydrological processes, such as runoff, evapotranspiration, and groundwater flow(Woldesenbet, 2017).Several studies have shown that there were significant effects of LULC changes on hydrological processes in different parts of Ethiopia (Aredo et al., 2021; Choto & Fetene, 2019; Getu Engida et al., 2021). Most of these studies pointed out that LULC changes were the principal causes of a considerable increase in runoff.

Aredo et al. (2021)was focused on impacts of land use land cover changes on stream flows in Shaya watersheds for wet months and dry months from the years 1987 to 2015.The result showed that the mean monthly increased by 19.82m^3/s for wet months and decreased for dry months by 7.06 m^3/s .Generally, the analysis indicated that flow during the wet months has increased, while during the dry months decreased from 1987-2015 due to expansion of settlement and agricultural area, while there was a decrease of bare land, forest, and bush land in the catchment.similarly according Achugbu et al. (2022),Stream flow increased during the dry period due to afforestation and decreased due to deforestation.

Tesfaw et al. (2023) assessed impact of land use / land cover changes on water resources in tana sub basin for the years 1986, 2000 and 2014. The result showedthat, the average annual water yield increased by 14.88 and 12.6%, base flow increased by 18.4% and decreased by 7.16%, surface runoff increased by 12 and 16.16%, evapotranspiration decreased by 18.39 and 13.49%, for 2000 and 2014, respectively, compared to baseline 1986 due to forest land and grassland decreased continuously and increased of cultivated land. Similarly Chakilu et al. (2015)evaluating the Land use/cover Dynamics and its impact on Stream flow of Gumara watershed. The result showed that the steam flow decreased from 0.53 m^3/s to 0.43 m^3/s.

2.6. Previous Studies in the Watershed

Meshesha et al. (2016) was Analyses of land use and land cover change dynamics using GIS and remote sensing during 1984 and 2015. Based on this study major land-use change drivers in Beressa watershed Rapid population growth demand more land for cultivation, more trees for domestic fuel wood consumption and more area for settlement had been responsible for drastic change in the land use/land cover

2.7. Image classification

Land-cover maps are commonly created from remotely sensed data through unsupervised or supervised classification techniques (Haque & Basak, 2017).Image classification refers to the extraction of differentiated classes or themes, usually, land-cover and land-use categories, from raw remotely sensed digital satellite data (Ayele, 2017).Image classification using remote sensing techniques has attracted the attention of the research community, as the results of classification are the backbone of environmental, social, and economic applications (Lu and Weng, 2007).Because image classification is generated using remotely sensed data, many factors cause difficulty to achieve a more accurate result. Some of the factors include the characteristics of a study area, availability of high resolution remotely sensed data, ancillary and ground reference data, suitable classification algorithms, and the analyst's experience, and time constraints (Vien, 2011)These factors highly determine the type of classification algorithm used for image classification. Various image classification methods are applied to extract land-cover information from remotely sensed images. There are several classification methods and each method is specific to the data and the locations because in each location land categories are varies and have different values in the image. For instance, the image value(Berhanu, 2017)of agricultural land is dependent on the type of crop that grows on that land (Behailu, 2010).Even the same crop in different climates can have different colors, which changes the color of the image. Moreover, the seasons also affect the color of land-covers. Thereare different approaches to classification. According to Araya

(2009),Image classification can be done based on three objectives which are: Type of learning (Supervised and Unsupervised), Assumptions on data distribution (Parametric, Non-Parametric), and Number of outputs for each spatial unit (Hard and Soft) Moreover, there are also objectives regarded levels of classification, which are; Pixel-based Classification and Object-oriented Image Segmentation and supervised Classification.

2.7.1. Pixel-Based Classification

Pixel-based classification is the traditional method of image classification. This is mainly based on the pixel reflectance values of the image (Kousalya et al., 2012)). According to the type of learning, there are mainly two kinds of pixel-based classification supervised and unsupervised (Al-Ahmadi and Hames, 2009). The supervised classification relies on the prior knowledge of the study area (Canada Centre for Remote Sensing, (Deng et al., 2010). Supervised classification is a procedure for identifying spectrally similar areas on an image by identifying “training” sites of known targets and then extrapolating those spectral signatures to other areas of unknown targets(Wen et al., 2011). There are different algorithms for supervised classification; the classic classifiers are minimum distance, parallel pipelined, and maximum likelihood methods. The maximum likelihood algorithm uses a maximum likelihood procedure derived from Bayesian probability theory; it applies the probability theory to the classification process. This method is a supervised method that uses the training sites, from these sites it determines the class center and the variability in the raster values in each band for each class. This helps to determine the probability of the cell to be belonging to a particular class defined in training sites. The probability is depending on the distance from cell to class center, class size, and the shape of the class in spectral space. The maximum likelihood classifier computes the class probabilities and classifies the cell where the probability is higher (Fekadu, 2017).

2.7.2. Training Site Selection

The unsupervised classification was used in the image classification before fieldwork to understand the general land-cover classes of the study area. This is because unsupervised classification is automated and requires little knowledge of the study area. Classification of the Land sat images was carried out within ERDAS IMAGINE

2014. The maximum iterations were set to 10 and the number of classes set to six for each image to ensure consistency in the results.

According to their spectral signature using different band combinations, the classified images were assigned a class in the output raster. The LULC classes were confused when classified by the unsupervised scheme. Settlements and cultivated land were highly mixed because most of the settlements are intermingled within the agricultural field. However, the natural forest was easily separated from other classes in all images. Based on the unsupervised classification, sample training sites were selected for data collection during fieldwork. The class assignment was achieved through a comparison of the classified image with field observation.

2.7.3. Supervised Classification

Handing larger than incredible the image analyst supervises the pixel categorization process by specifying, to the computer algorithm, numerical descriptors of various land-cover change recognition current in the representation of land-use change clearly shows that area.

Training samples that express the typical spectral pattern of land-use and land-cover classes are defined. Pixels in the image are similar numerically to the training samples and are labeled to land-cover classes that have a similar integral part of a logarithm. All the classification techniques like the maximum likelihood classification (MLC), parallelepiped and minimum distance to mean classification may be applied to get the best classification technique (Behailu, 2010).The maximum likelihood classification assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class (Roy et.al., 2015). Each pixel is assigned to the class that has the highest probability (that is, the maximum likelihood). Maximum Likelihood is among commonly used supervised classification methods used with remote sensing image data. The Maximum Likelihood classification method is well known for the analysis of satellite images (Lu and Weng, 2007). So far, satellite image interpretation using the maximum likelihood approach was mostly applied for land-cover classification and monitoring of land-use changes (Shalaby and Tateishi, 2007) showing overall high accuracies (mostly over 80%). MLC classification is based on a parametric approach that involves the assumption of the selected classes of signature in the normal (Al-Ahmadi & Al-Hames, 2009)). The disadvantage of maximum likelihood classification is training classes are generally based on field identification and not on spectral properties therefore spectral signatures are forced. Training data selected by the analyst may notbe representative of the condition present throughout the image. Training data can be time-consuming and costly and unique categories are not represented in the training data. The support vector machine (SVM) algorithm is not suitable for large data sets. SVM does not perform very well when the data set has more noise i.e. target classes are overlapping. In cases where several features for each data point exceed the number of a training data sample, the (SVM) will underperform. In supervised classification, the serving to establish the identity of the owner and location of certain representative patches of the land-cover types present in a landscape need to be identified before classification. Occurring at the beginning field input is normally required for acceptable map accuracy (Ehsan and Kazem, 2013).

2.8. HydrologicalModels

Hydrologic modeling has proved to be very important tool that can be applied to understand and explain the effects of LU/LC change on hydrologic response of a catchment(Baldyga, 2005). Hydrological models are mathematical descriptions of components of the hydrologic cycle. They have been developed for many different reasons and therefore have many different forms. However, hydrological models are in general designed to get a better understanding of the hydrologic processes in a watershed and of how changes in the watershed may these phenomena and for hydrologic prediction(Kassa & Foerch, 2007). They are also providing valuable information for studying potential impacts of changes in land use and land cover or climate change.

The hydrological models can be divided into three basic groups based on the process description (Perazzoli et al., 2013).

Lumped models: Parameters of lumped hydrologic models do not vary spatially within the basin and thus, basin response is evaluated only at the outlet, without explicitly accounting for the response of individual sub-basins. The parameters often do not represent the physical features of hydrologic processes and usually involve a certain degree of empiricism.

These models are not usually applicable to event-scale processes. If the interest is primarily in discharge prediction only, then these models can provide just as good simulations as complex physically-based models.

Distributed models: Parameters of distributed models are fully allowed to vary in space at a resolution usually chosen by the user. The distributed modeling approach attempts to incorporate data concerning the spatial distribution of parameter variations together with computational algorithms to evaluate the influence of this distribution on simulated precipitation-runoff behavior. Distributed models generally require a large amount of (often-unavailable) data. However, the governing physical processes are modeled in detail, and if properly applied, they can provide the highest degree of accuracy.

Semi-distributed models: Parameters of semi-distributed (simplified distributed) models are partially allowed to vary in space by dividing the basin into a number of smaller sub-basins. The main advantage of these models is that their structure is more physically-based than the structure of lumped models, and they are less demanding on input data than fully distributed models. SWAT(Arnold et al., 1998),HEC-HMS (ACE, 2010), HBV (Lindström et al., 1997) are considered as semi-distributed models.

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. Their emphasis is placed on infiltration and surface runoff. Typically, event models have no provision for moisture recovery between storm events and, therefore, are not suited for the simulation of dry-weather flows. On the other hand, continuous-process models simulate instead of a longer period, predicting watershed response both during and between precipitation events. They are suited for simulation of daily, monthly or seasonal streamflow, usually for long-term runoff volume forecasting and for estimates of water yield. Generally, for this study, the semi-distributed model (SWAT) were selected because of their structure is more physically based than the structure of lumped models. Table 2. 1 dictates the comparison/difference of three semi-distributed models for hydrological application.

Table 2. 1.Summary of comparison of specific hydrological models.

Description	**SWAT**	**HEC -HMS**	**HBV**
Model Type	Semi-distributed Physically-based Long-term	Semi-distributed Physically-based Long-term	Semi-distributed Conceptual Model
Model objectives	Predict the impact of land management practices on water and sediment	Simulate the rainfall-runoff process of watershed	Simulate the rainfall-runoff process and floods Temporal
Temporal Scale	Day	Day	Day
Spatial Scale	Medium	flexible	flexible
Process modeled	continuous	continuous and events	continuous and events
cost	Public Domain	Public Domain	Public Domain

Source: The author reviews from different literature

2.8. Hydrological Model Selection Criteria

There are many criteria which can be used for choosing the right hydrologic model. These criteria always project dependent, since every project has its own specific requirements and needs. Further, some criteria are user dependent, such as the personal preference for graphical user interface (GUI), computer operating system, input out management system and structure. There are various criteria that can be used for selecting a hydrological model for a specific problem. These criteria are project dependent because every project has its own requirements, need, and objectives. Yet, some criteria are also user-dependent or and therefore subjective.

Based on the suggestions from Cunderlik (2003)Rodda et al. (2011)he following factors and criteria were used as being relevant when selecting models:

- The type of system to be modeled; e.g. small catchment, river reach, reservoir, or large river basin.
- Hydrologic models that need to be modeled to estimate the desired outputs adequately (is the model capable of simulating a single event or continuous process).
- The general modeling objective; e.g. hydrological forecasting, assessing human influences on the hydrological regime or climate change impact assessment.
- The hydrological element to be modeled and required model outputs important to the project and therefore to be estimated by the model; e.g. floods, daily average discharge, monthly average discharge, water quality, and others.
- Data availability with regard to type, length, and quality of data versus data requirements for model calibration and operation. Can all the inputs required by the model be provided within the time and cost constraints of the project?
- Model simplicity, as far as hydrological complexity and ease of application are concerned.
- The possible transition of model parameter value from smaller sub-catchment of the overall catchment or from neighboring catchments.
- The ability of the model to be updated conveniently on the basis of current hydro-meteorological conditions.
- Price (openness) or (does the investment appear to be worthwhile for the objective of the project

In addition, the model must be readily and freely available within available documentation and should be applied over a range of catchment sizes from large to global.

For this study SWAT (semi distributed model) is selected because its structure is more physically based than the structure of the lumped model, freely available and meets the objective of this study.

2.9. Soil and Water Assessment Tool (SWAT)

SWAT model is a semi distributed; time continuous watershed simulator operating on daily time step (Arnold et al., 1998). It is developed for assessing the impact of management and climate on water supplies, sediment and agricultural chemical yields in watersheds and larger river basins. The model is physically based and allows simulation of a high level of spatial detail by dividing the watershed into a large number of sub watersheds. The major components of SWAT include hydrology, weather, erosion, plant growth, nutrients, pesticides, land management and stream routing. The program is provided with an interface in Arc GIS (Arnold et al., 2012) for the definition of watershed hydrologic features and storage as well as the organization and manipulation of the related spatial and tabular data.

2.10. Description of Selected Model

SWAT is semi-distributed, physically based, continuous time, a widely used and flexible modeling tool, which addresses many aspects of catchment (Lo, 2015). One of the main advantages of SWAT is it can be used to model watersheds with less monitoring data (Geremew, 2013); (Mechal et al., 2015)). The interface of SWAT model is compatible with Arc-GIS that can integrate many available geospatial data to accurately represent the characteristics of the watershed (Geremew, 2013).

Weather variables for computing the hydrologic balance in SWAT 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 (Weather generator can be download from the SWAT web site http://swat.tamu.edu/software) other than these DEM (Digital Elevation Model), soil map, land use map also needed for the model.

Simulation of the hydrology of a watershed can be separated into two major parts. The first part is the land phase of the hydrologic cycle. The land phase of the hydrologic cycle controls the amount of water, sediment, nutrient and pesticide loadings to the main channel in each sub basin. The second division is routing phase of the hydrologic cycle which can be defined as the movement of water, sediments, nutrient etc. through the channel network of the watershed to the Outlet.

2.10.1 Hydrological Components of SWAT

The hydrology component of the SWAT model is based on water balance equation. The water balance in the SWAT model relates soil water, surface runoff, interception, daily amount of precipitation, evapotranspiration, percolation, lateral subsurface flow, return flow or base flow, snowmelt, transmission losses and ponds. The percolation and return flow or base flow considered in SWAT for hydrological modelling is only the percolation to shallow aquifer from vadose zone and base flow to the channel from the shallow aquifer. The groundwater flow from deep aquifer is not considered because the water that enters the deep aquifer is assumed to contribute to the stream flow somewhere outside the watershed. According to (Arnold, 1993), the water in the stream is contributed by surface runoff, lateral flow from soil profiles and return flow/base flow from shallow aquifer. The water percolated to the deep aquifer is assumed lost from the watershed system and is not included in the water balance (Neitsch et al., 2011). Equation 2.1 is used to determine the soil water content of the watershed.

$sw_t = Sw_o + \sum_{i=1}^{t}(R\ day - Qsurf - Ea - Wseep - Qgw)$----------------[2.1]

Where Swt the final soil water content (mm) ,**Swo**the initial water content (mm),**t** is time (days),**Rday**is the amount of precipitation on day i (mm),**Qsurf** is the amount of surface runoff on day i(mm),**Ea** the amount of evapotranspiration on day i(mm),**Wseep**is the amount of water entering the vadose zone from the soil profile on day i(mm) and **Qgw** is the amount of return flow on day i (mm))

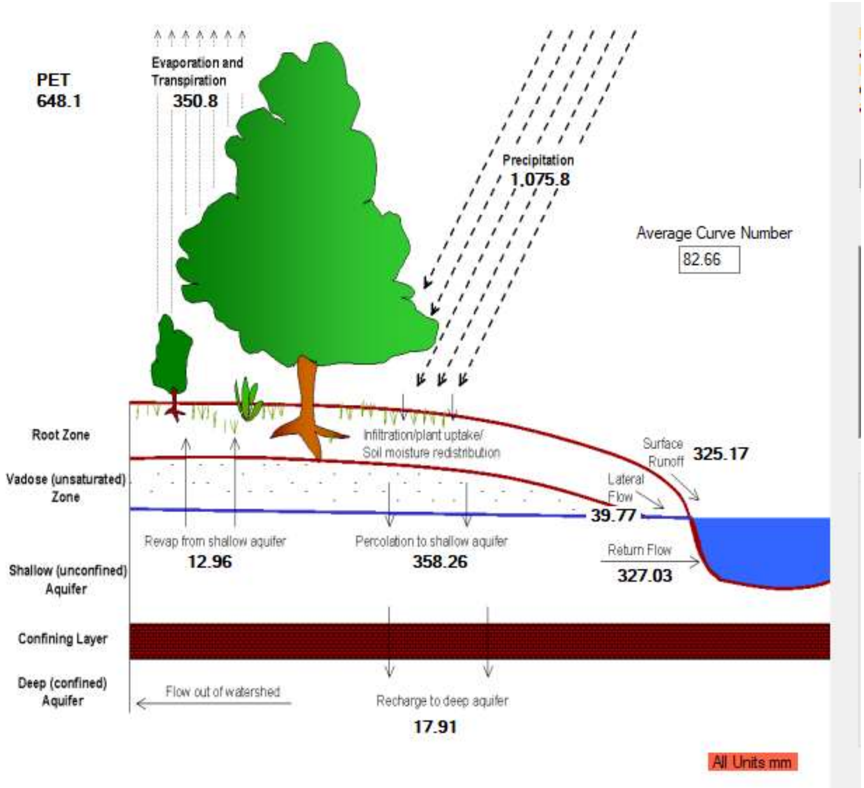


Figure 2. 1. Hydrological Cycle of SWAT Model.

2.10.2 Surface Runoff

Using daily or sub -daily rainfall amount, SWAT simulates surfacerunoff volume and peak runoff rate for each HRU.SWATprovides two methods forestimating surfacerunoff volume the SCS curve number method and Green and infiltration method. The later method is best for estimating runoff volume precisely, it is sub daily time step data requirement makesit difficult to be used for the case of our country. Therefore, theSCS curve number method was adopted. The general equation for SCS curve method is expressed by the equation 2.2

$$Q_{surf} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)} \text{------------------------------} [2.2]$$

Where Q_{surf} is the accumulated runoff or rainfall excess (mm)m,$R_{day}$is the rainfall depth for the day (mm) water,$I_a$is initial abstraction which includes surface storage, interception and infiltration prior to runoff (mm water) ,and S is retention parameter (mm water).The retention parameter S calculated by using equation2.3

$$S = 25.4 * \left(\frac{1000}{CN} - 10\right) \text{--------------------} [2.3]$$

Where, CN is the curve number for the day andits value is the function of land use practice, soil permeability and soil hydro group. The initial abstraction (Ia), iscommonly approximated as 0.2S and the equation 2.2 becomes

$$Q_{surf} = \frac{(R_{day} - 0.2S)^2}{(R_{day} + 0.8S)} \text{------------------------------} [2.4]$$

2.10.3 Peak Discharge

The peak discharge or peak surface runoff rate is the maximum value flow rate passing a particular location during a storm event. The peak runoff rate is an indicator of the erosive powerof a storm and is used topredict sediment loss. SWAT calculates the peak runoff rate with a modified rational method see equation 2.5

$$Q_{peak} = \frac{c * i * Area}{3.6} \text{----------------------------------} [2.5]$$

Where Q_{peak} is peak of runoff rate (m^3/s) , c is the runoff coefficient ,i is the rainfall intensity (mm/hr) ,sub basin area (km^2) and 3.6 is conversion factor.

2.11. Swat -Calibration and Uncertainty Programs (CUP)

Distributed watershed models are increasingly being used to support decision-making in land use change. These models should pass through a careful calibration and uncertainty analysis. Large scale distributed models are difficult to calibrate and to interpreter the calibration because of large model uncertainty, input uncertainty and parameter non-uniqueness. To perform parameter calibration and uncertainty analysis different programs are introduced. SWAT-CUP is one of the programs which is currently used by different researchers.

SWAT-CUP is a public domain and any calibration, uncertainty or sensitivity can be linked to SWAT. The program links Generalized Likelihood Uncertainty Estimation (GLUE), Parameter Solution (ParaSol), Sequential Uncertainty Fitting (SUFI2) and Markov Chain Monte Carlo (MCMC) procedures to SWAT (Abbaspour et al., 2015). It enables sensitivity analysis, calibration, validation and uncertainty analysis of SWAT models. SUFI method determines uncertainty through the sequential and fitting process in which iteration and unknown parameter estimates are achieved before the final.

2.12. Model Performance

For evaluation of model performance, (Da Silva et al., 2015) describe model evaluation guidelines for quantification of accuracy in watershed modeling. The evaluation was performed by visual and statistical comparison of the measured and simulated data. The graphical method provided an initial overview. The statistical criteria were used to evaluate the performance of the model.

The Nash and Sutcliffe simulation efficiency (NSE) describes the deviation from the unit of the ratio of the square of the difference between the observed and simulated values and the variance of the observations. The value of the coefficients varies from minus infinity to one with the latter value indicating perfect agreement between the simulated and observed data. A smaller NSE value indicates a poorer fit between the simulated and observed data. It is possible to obtain a negative value of the NSE indicating that the average of the observational data provides a better fit to the data compared to the simulated data. There are no existing standards describing the range of the values of the statistical parameters that would indicate acceptable performance of the model (Loague & Green, 1991)

CHAPTER THREE

3. MATERIAL AND METHODOLOGY

3.1. Description of the Study Area

3.1.1. Location

The study area of Beressa watershed is found in the North Shoa zone administrative of Amhara National Regional States and drain to Abbay basin. It is about 130 km far from Addis Ababa. Geographically, the area is lies between9° 31' 0"- 9° 41' 30"N and39° 30' 30"- 39° 41' 0"E. The altitude of the area ranges from 2739 m to3681m.a.s.l, in deeply dissected valleys of Beressa River and the mountain ranges respectively. The total area of the watershed, upstream of the gauge station is 210km^2.

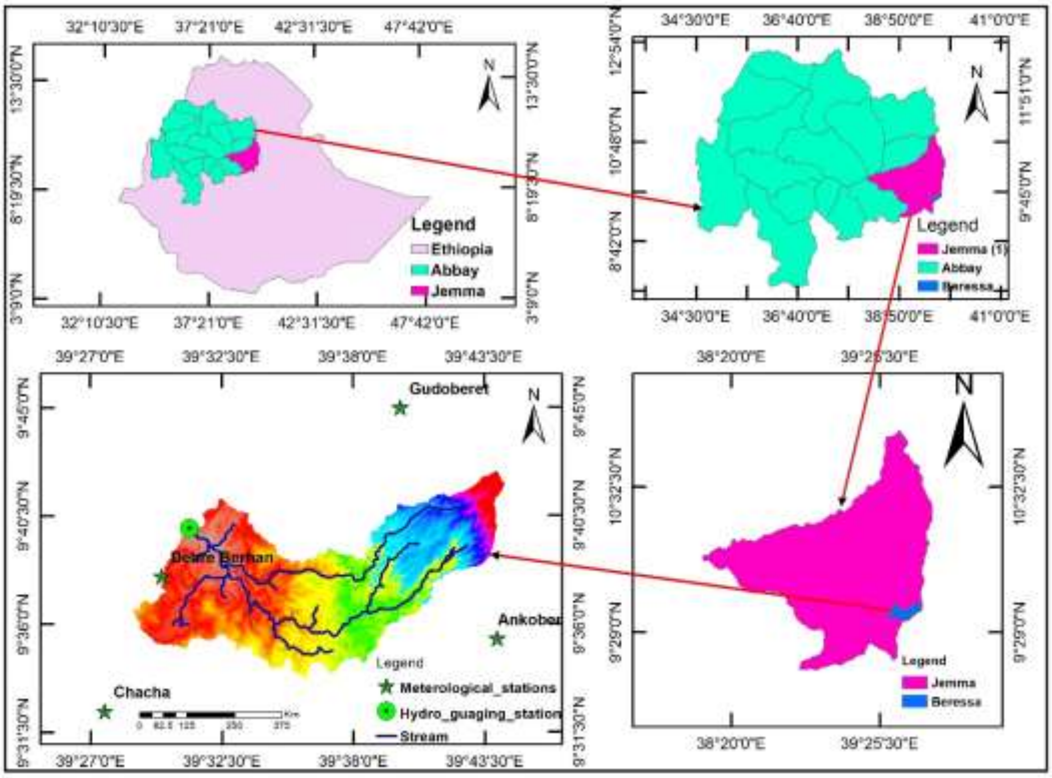


Figure 3. 1. Location of studyarea.

3.1.2. Topography

The study is located on the central parts of North western Ethiopian plateau and southeastern parts of the Jemma river basin. Its eastern part is bounded by the rift margin. The altitude of the area ranges from 2739 to 3681m.a.s.l, in deeply dissected valleys of Beresa River and in the mountain ranges.

3.1.3. Drainage

In the study area, numerous narrow and shallow river valleys originated from mountain ranges and formed the Beressa Perennial River. Beressa River flow to Jemma River which is one of the main tributaries of Blue Nile River. Small valleys originated from ridges and hills form dense dendritic drainage patterns in the area. These small valleys and streams are controlled by inferred and main faults, joints, fractures, or a combination of them. The topography of the area is the main expression of the north-westerly oriented drainage.

3.1.4. Climate of Study Area

The climate of Ethiopia is mainly controlled by seasonal migration of Inter-tropical convergence zone (ITCZ) and its associated atmospheric circulation but the topography has also an effect on the local climate. The traditional climate classification of the country is based on altitude and temperature shows the presence of five climatic zones namely: Wurch (cold climate at more than 3000m altitude), Dega (temperate like climate-highland with 2500-3000 m altitude), WoinaDega (warm 1500-2500 multitude), Kola (hot and arid type, less than 1500 m in altitude), and Bereha (hot and hyper-arid type) climate (NMSA, 2001) and Beresa watershed elevation is found between 2739-3681m m. Based on thisargro-climate Beressa watershed is grouped under Dega-wurch.

The area is characterized by three distinct seasons and bimodal precipitation patterns with small peaks in April and the main rainy season is between mid-June to mid-September with peaks in July. The three distinct seasons are locally known as Bega (October to January), Belg (February to May), and Kiremt (June to September). The maximum volume of precipitation is observed during Kiremt when the area receives 90% of the annual rainfall.

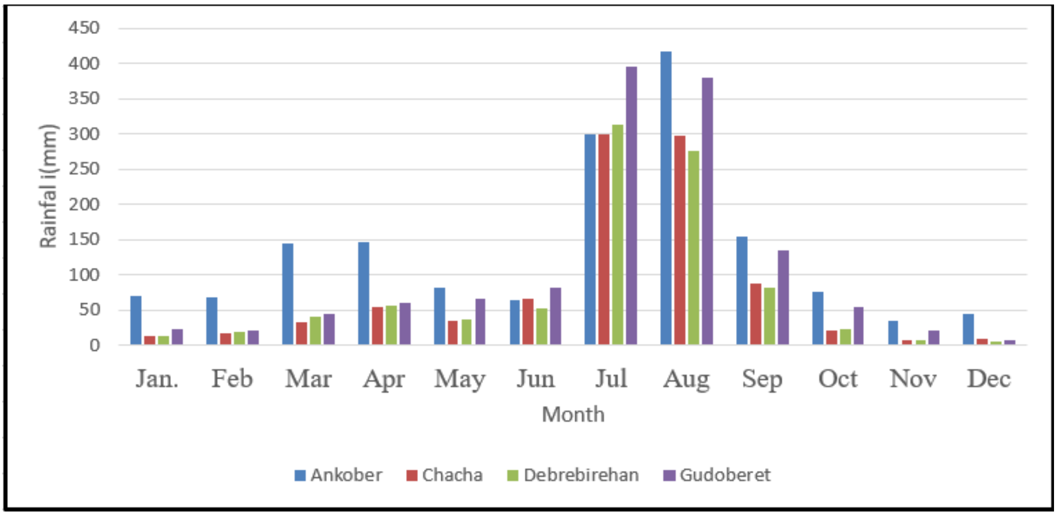


Figure 3. 2. Mean monthly rainfall station around Beressa watershed (1988-2014).

3.1.3.1. Temperature and Other Climatic Data

The maximum, minimum and average monthly temperature of Debrebirehan synoptic station is shown below figure 3.3.

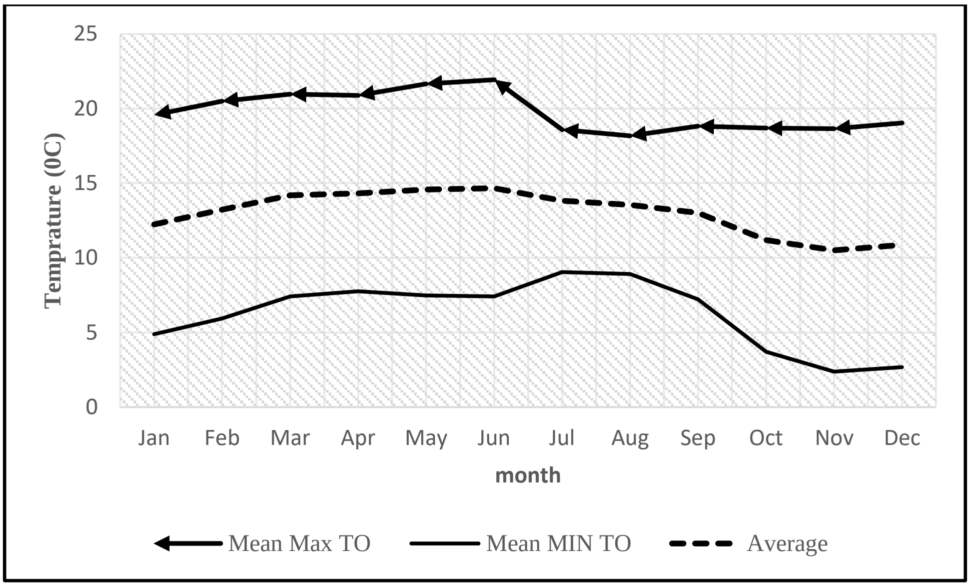


Figure 3. 3.Mean monthly temperature of Debrebirehan Station.

Relative humidity, solar radiation and wind speed are needed to calculate evaporation. Data from Debrebirehan station class-I stations were available for the watersheds. The mean annual relative humidity, wind speed and solar radiation/sunshine hour of Debrebirehan stations were estimated about 60.65%, 2 m/s and 14.38 MJ m^{-2} days $^{-1}$from collected records.

3.1.5. Land use /land cover

The land use and land cover of an area depends on climatic factors, land escape, agroecology, land use practice, and agricultural activities of the area. According to Mesheshaet al. (2016) the land use land practice of Beressawatershed includes cultivated land, forest, grass, settlement, barrenland water bodies and themajor portion of land use type in study was cultivated land which cover 66% from total watershed.

3.2. Materials

The material and software used for the whole study were presented in the following table (Table 3.1).

Table 3. 1. Different computer software / tools and their purpose used in this study.

No	material and software	version	Purpose
1	Arc GIS	10.8	To arrange Spatial data and prepare their Map

2	SWAT	2012	To delineate watershed and simulation hydrological model
3	SWAT CUP	2019	To calibrate and validate SWAT output
4	ERDAS EMAGINE	2014	For Landsat Image process, image classification and accuracy assessment
5	Global mapper	2015	To process a DEM and coordinate convert
6	Google Earth Pro	7.3.1	Investigation of study area
7	MS EXCEL	2019	Statistical analysis, Chart and graphs
8	GPS	Garmin	Reading outlet and ground truth point
9	weather Generator	v01803	Weather generator preparation
10	Endnote	x7	Reference

3.3. Data Collection

For a completion ofthis research a variety of data such as streamflow, Digital ElevationModel, land use /land cover, soildata, daily climatic variables (daily of precipitation, wind speed, relativehumidity, sunshine hours and minimum and maximum temperature) werecollected from EthiopiaNational Meteorological Services (ENMS) and Abbay Basin Authority. Generally different data and sources used for this study were presented in the following table (table 3.2).

Table 3. 2. Data sources used for this study.

No	Types of Data	Source	Purpose
1	Stream flow	Abbay Basin Autority	Calibration and validation
2	DEM	http://earhexplorer.usgs.gov.	Watershed delineation
3	Land use/ Land cover	http://earhexplorer.usgs.gov.	Land use /land cover detection
4	Soil	Ethiopia and FAO soil data base	HRU analysis and definition
5	Meteorological data	EMA at kombolcha Metrological districts	SWAT simulation

3.3.1. Digital Elevation Model

Digital Elevation Model (DEM) data was required to calculate the flow accumulation, stream networks, and watershed delineation using SWAT watershed delineator tools. A 30m by 30m resolution Digital Elevation Model was downloaded from the official website the United States Geological Survey (USGS) and was accessible by using this link http://earhexplorer.usgs.gov. The data was available in the coordinate systems of GCS_1984 raster form with resolution 30m by 30 m. It was projected into coordinate system into Adindan UTM Zone 37 N which is the zone of the study area.

3.3.2. Soil Data

Soil data is one of the major input data for the SWAT model with inclusive and chemical properties. SWAT model requires soil physical and chemical properties such as soil texture, available water content, hydraulic conductivity, bulk density, and organic carbon content for different layers of each soil type. These data were collected from the Ethiopia soil database and FAO Soil database. The major soils types in the study area are Euritic Vertosols and EurticCambisol.

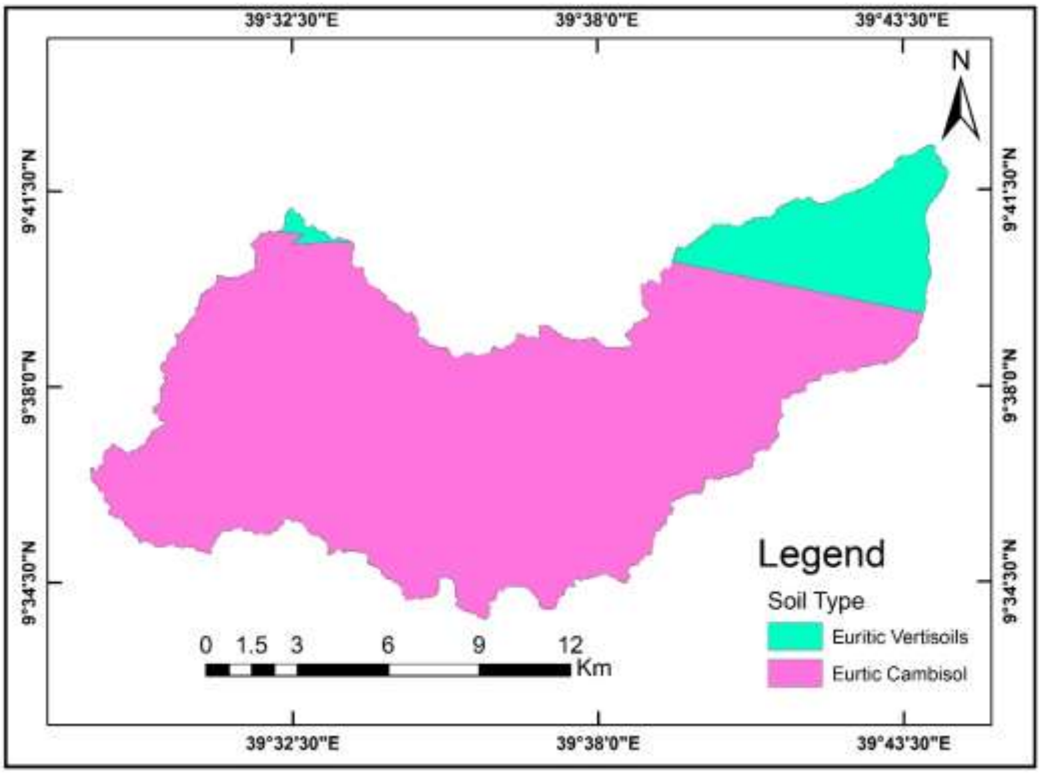


Figure 3. 4. Major Soil map for Beressa watershed

To integrate the study area of soil map with SWAT model, a user soil data base which contains physical and chemical properties of soil was prepared for each soil layers and adds to user soil data bases. The lookup table was also prepared to integrated to soil map to user SWAT databases by using Arc GIS 10.1

Area of coverage of study area are presented as shown table

Table 3. 3. Soil types of Beressa watershed and their area coverage's

Soil type	S name	Area (ha)	%
EuriticVertisoils	Be9-3c-26	2527.15	12.05

EurticCambisol	Vp14-3a-286	18451.067	87.95

3.3.3. Land use /land cover data

Land use is one of the highly influencing the hydrological properties of the watersheds. It is one of the main input data of the SWAT model to describe the Hydrological Response Units (HRUs) of the watersheds. For this study, three land uses and land covers were downloaded for the years 1990, 2000, and 2013 from USGS Earth Explorerby using path 168 and row 53. The selections of the Landsat images date were free from cloud cover (less than 10%) and in the same season. To link the grid values to the SWAT land use/land cover data base, a lookup table was prepared that specifies the 4-letter SWAT code for each land use/land cover type.

Table 3. 4. General information of Landsat image acquired.

No	Images	Resolution	Path	Row	Date of acquisition	Sources
1	Landsat 5	30*30	168	53	18/12/1990	http://earhexplorer.usgs.gov
2	Landsat 7	30*30	168	53	29/12/2000	http://earhexplorer.usgs.gov
3	Landsat 8	30*30	168	53	01/12/2013	http://earhexplorer.usgs.gov

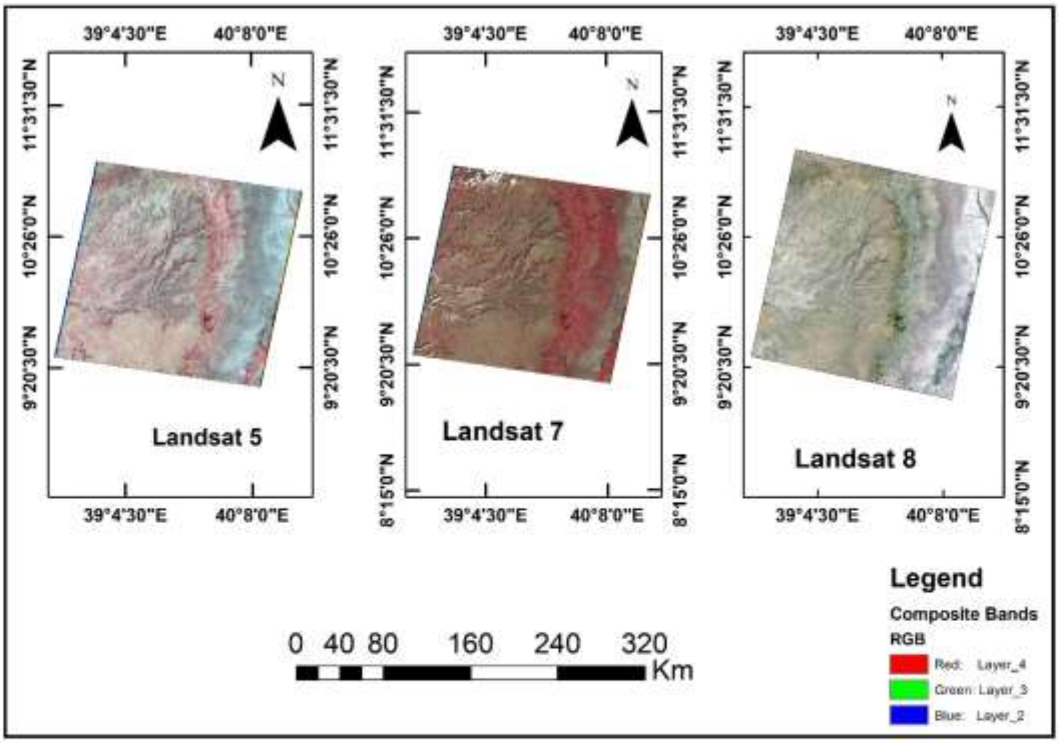


Figure 3. 5. Satellite image raw data of year 1990, 2000 and 2013

3.3.4. Metrological Data

Weather data are among the main demanding input data for the SWAT simulation. The weather input data required for SWAT simulation includes daily data of precipitation, maximum and minimum temperature, relative humidity, wind speed and solar radiation. These were obtained from the Ethiopian National Meteorological Agency at kombolcha branch. The weather data used were represented from four stations in and around Beressa watershed, such as Debrebirehan, Chacha, Ankober andGudoberet stations. Debrebirehan station the first classes that has records on all climatic variableswhereas Ankober and chacha stations contain rain fall data and gudoberet data contains maximum – minimum temperature in addition to rainfall . The climatic data used for this study covers 27 years from January 1988 to December 2014.

However, missing values were identified in some of the climatic variables. These values were assigned with no data code (-99) which then filled by the weather generator embodied in the SWAT model from monthly weather generator parameters values. The monthly generator parameters values were estimated from Debrebirehan station.

3.3.5. Streamflow

Availability of dataon hydrological variables such as riverflow data are necessary for calibration andvalidation of the model. The stream flow data collected from Abbay basin Authority has a longer time series data. Berresa station near Debrebirehan (station code 112007) which is located at 9.67 N and 39.52 E hasgot time series data lasting from 1988 -2014.According to stream discharge recorded at Beressa river gauge station (1988-2014), the monthly average flow is shown in table 3.5.

Table 3. 5.Monthly Average Flow (1988-2014) in m^3/s.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.23	0.25	0.29	0.43	0.56	0.58	11.86	24.60	6.22	0.80	0.31	0.24

3.4. Methods

The study was used ERDAS IMAGINE 2014 software for land use and land coverclassification and accuracy assessment by using different Landsat image. After the landuse and land cover classification process was finished stream flow simulated with in land use and land cover classified map using SWAT model. Then finally in order to model Beressa watershed and to know the impact ofland use and land cover change on stream flow, the simulated streamflow was calibrated and validated by SWAT CUP-2019 software usingobserved flow data that were collected.

3.4.1. Landsat image classification

3.4.1.1 Pre-processing

Raw satellite image will not be directly utilized for features identification and other relatedapplications due to the limitation to properly identify each features of the image. Hence, pre-processing is done before the main data analysis and extraction of information. Preprocessinginvolves two major processes: geometric correction and radiometric correction orhaze removal. Remote sensing imageries are inherently subjected to geometric distortions. Accordingly, in this study the following pre-processing was performed:

Step 1, Projecting from WGS 1984 to UTM ZONE 37.

Step 2, Subset study area.

Step3, removing cloud using image masking and

Step 4, Band combinations Example; Land sat 8 bands 5-4-3(R-G-B), Land-sat TM bands 4-3-2 (R-G-B) and ETM+ 4-3-2 (R-G-B) because multispectral image bands assist in subsequent human interpretation or machine analysis. There are many options of radiometric correction for this study histogram equalization and haze reduction methods employed using ERDAS Imagine 2014. First select tagged image file format (tiff) from the data source and adding the data then raster tab radiometric (which is the collection of tools for adjustment of brightens value of image finally haze removed.

For this study, the image classification was done using the combination of bands false color combination (4, 3, 2) for Landsat images TM and ETM + of 1990 and 2000 and band false color combination(5,4,3) for Landsat8(2013) since those band combination helps to visualization of the image in their false colors combination. Previous study data such like (Meshesha et al., 2016) and Google Earth was used as a source of information for interpreting a major land cover class.

For this study area the land use land cover type classification was produced using ERDAS IMGINE2014. Before classification the imagery data land use land cover has to difference used pervious data such as the previous study like (Meshesha et al., 2016). There are six different types of land use land have been identified for Beressa river watershed. They are farm land, grazing land, forestland, and waterbody, urban and barren land.

Different classification techniques are presented in the literature. For this study the supervised classification type applied. It is the most common type of classification technique in which all pixels with similar spectral value are assigned in to land cover classes. For this study the land cover was produced based on supervised classification through the steps such as selecting of the training sites which are representative for the land cover classes and by performing the classification using the Maximum likelihood classifier.

The supervised classification was applied after defined area of interest (AOI) which is called training classes. Training samples for 1990, 2000 and 2013 images were collected using Google Earth and for each classis. Using google earth around 278 training sites were collected from each year’s land use and land cover data (1990, 2000, and 2013) with a proportion of above 30 samples for each land use

The training sites were selected in agreement with downloads Landsat images and Google earth pro. The supervised classification was done by ERDAS IMAGINE 2014. Finally, six types of land use land cover such as, agriculture, forest, urban area, grassland, bare land and water body were produced.

3.4.2. Accuracy Assessments

The accuracy of an image classification assessment was accomplished by doing an error matrix. An error matrix is a square assortment of numbers defined in rows and columns that represent the number of sample units (i.e., pixels, clusters of pixels, or polygons) assigned to a particular category relative to the actual category as confirmed on the ground. The rows in the matrix represent the classified LULC map data, while the columns represent the reference/ ground truth point data that will collect during fieldwork or from Google Earth.

An accuracy assessment was done for the classified land use land cover image by using ERDAS IMAGINE 2014. From the classifier, 180 points were generated randomly for each classified land use land cover image. All the randomly generated points were identified by the user and assigned in different classes. This process was done for the supervised Classification images (i.e. 1990, 2000 and 2013) of study area. An Error matrix and Kappa statistics were also generated from reference and classified data from the report section of ERDAS Imagine 2014 software. The references were produced from Google Earth (by observing and recording identifiable Coordinate points of features) and GPS points during field work.

The overall accuracy gives the overall results of the confusion matrix. It is calculated by dividing the total number of correct pixels (diagonals) by the total numbers of pixels in the confusion matrix. The producer's accuracy tells us how well a certain area can beclassified and obtained by dividing the numbers of correctly classified pixels in the category by the total numbers of pixels of the category in the reference data. User's accuracy is the ratio between the total numbers of pixels correctly belonging to a class (diagonal elements) and the total numbers of pixels assigned to the same class by theclassification procedure (row total). User's accuracy explains the probability that a pixel of the classified image truly corresponds to the class to which it has been assigned.

$$\textbf{Over all accuracy} = \frac{\text{total numbers of corrected classified pixels (diagonal)} * 100}{\text{total numbers of reference pixels}} \text{--[3.1]}$$

Producer accuracy= $\frac{\text{the numbers of corrected classified pixels in each catagory}*100}{\text{total numbers of reference pixels in that catagory (the column total)}}$-[3.2]

Kappa coefficient= $\frac{Ts*TCS-\sum(column\ total*row\ total\ )}{TS^2-\sum(column\ total-row\ total)}*100$ ----------------[3.3]

Where TS=Total sample

TCS = Total corrected sample

Using Google earth as a reference, 180 randomly selected points were selected and compared with each corresponding classification for the validation of each classified images.

3.4.3. Soil data preparation

The soil data base was prepared and added to the SWAT user soil data base using SWAT Map window from MWSWAT extension by preparing look up table by using ArcGIS soil data andthe soil type specified from FAO soil data are clay, sandy loam and loam in the watershed. To integrate the soil map with SWAT model, a user soil data base which contains textural and chemical properties of soils was prepared for each soil layers and added to the SWAT user soil data bases and the soil map prepared with look up table is loaded from disk with fixing value from soil grid loading soil map have been done from look up table SWAT soil classification table was filled and reclassification checked during the work

3.4.4. Land use land cover change detection

The study used image to detect the general trends of land use/ cover changes over the past 24 (1990-2013) years. In order to detect change over time of the study period an image of 1990, 2000 and 2013 were taken and image with the best quality and low cloud cover during dry seasons with in less than10% cloud cover.

The magnitude change for each land use class was calculated by subtracting the area coverage from final year and initial year as shown in Eq. 3.4.

Magnitude =area final year-initial year------------------- (3.4)

Percentage change for each land use type can be calculated by dividing magnitude change by the initial year and multiplied by 100**.**

$\boldsymbol{LULCC\%=\frac{magnitude\ of\ change(\ area)*100}{area\ of\ intail\ year}}$**------------ (3.5)**

To obtain annual rate of change for each land use type, magnitude of change betweencorresponding years was divided by the number of study year i.e. 1990 – 2000 (10years) and 2000–2013 (13 years), respectively.

Generally, the study was used the following generalized flow chat or conceptual Framework

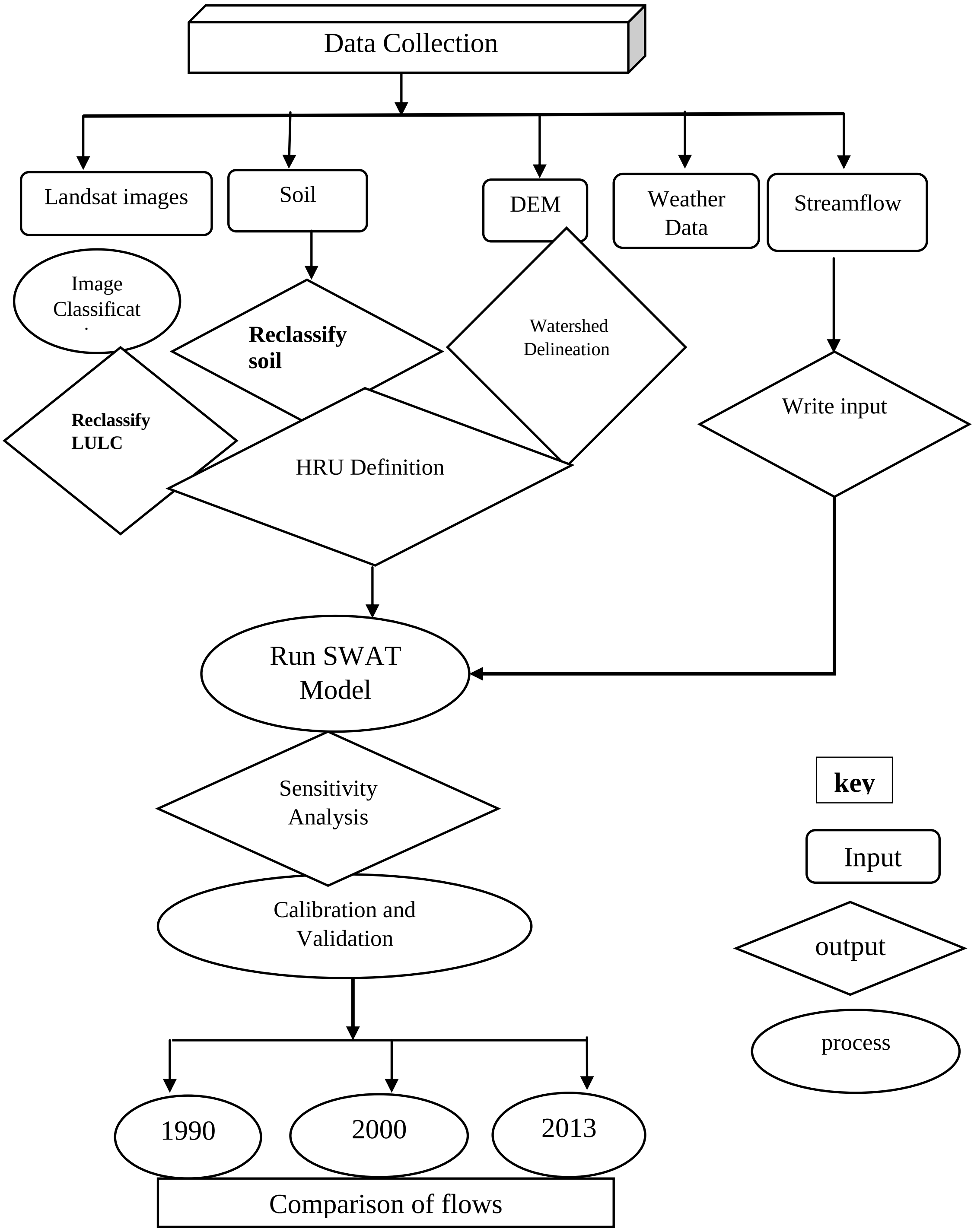


Figure 3. 7. Overall framework of study.

3.5. Data Quality Analysis

3.5.1Meteorological Data Quality Analysis

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

3.5.1.1Visual Inspection

The first method in data quality control is by visual inspection. This can be done by checking if the date and time record is complete, unphysical values (like negative value). The visual inspection was done by plotting time series data against time by using Microsoft excel. The percentage of missing data points for four precipitations stations from 1988-2014 is as shown in table 3.6from below table Debre birehan station has 90 missing data which accounts about 0.91% of the total collected data's. The next three stations Chacha, GudoberetandAnkober, whichhave higher missing data's comparesto Debrebirehan stations.

Table 3. 6 Percent of missing precipitation for selected stations

Name of station	Data points	Missing point Data	Data without missing	%missing	Remark
Debrebirehan	9862	90	9772	0.91	1988-2014
Chacha	9862	669	9193	6.78	1988-2014
Ankober	9862	533	9329	5.40	1998-2014
Gudoberet	9862	651	9211	6.6	1988-2014

3.5.1.2Filling of Missing Data

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

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

For this study, arithmetic mean and normal ratio method were used. According to Richard H. (1998), the two formulas are described below.

In Station Average Method

$$\boldsymbol{P_{X}} = \frac{1}{M}\left[P_1 + P_2 + P_3 + \cdots \ldots\ldots P_m\right] \text{----------------------------------} [3.6]$$

Normal Ratio Method

Where $P_{X=}$ where the missing precipitation records

P_1, p_2 . PmPrecipitation records at the neighboring stations

M=Numbers of neighboring stations

$$\mathbf{P_x} = \frac{N_X}{N}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \cdots + \cdots \frac{P_m}{N_m}\right] \text{----------------------------------} [3.7]$$

Where P_X=Missing value of precipitation to be computed

N_X=Average value of rainfall for the station in question for recording period

P_1,P_2…..P_m= Rainfall of neighboring station during missing period

N_1, N_2……Nm= Average value of rainfall for the neighboring station

N=Number of stations used in the computation

3.5.1.3 Checking Homogeneity of stations

Homogeneity analysis is used to identify a change in the statistical properties of the time series. Thecauses can be either natural or man-made. These include alterations to land use andrelocation of the observation station. Therefore, to select the representative meteorologicalstation for the analysis of areal rainfall estimation, checking homogeneity of group stations isessential, the homogeneity of the selected gauging stations monthly rainfall records was computed by equation 3.8

$$pi = \frac{pi,av*100}{pav} \text{------------------------------} (3.8)$$

Where,

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

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

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

In the Beressa watershed there are two rainy seasons; heavy rainfall from Jul-August and small peaks rainfall in April. The data recorded in the selected stations of the study areashows that a bi-modal rainfall pattern which has two peaks for two rainy seasons. The selectedstations are also plotted for comparison with each other. Figures 3.5 show the result ofhomogeneity analysis. As it is shown in the Figure 3.5 same-modes and pattern of the stationsare observed and hence group stations selected are homogenous.

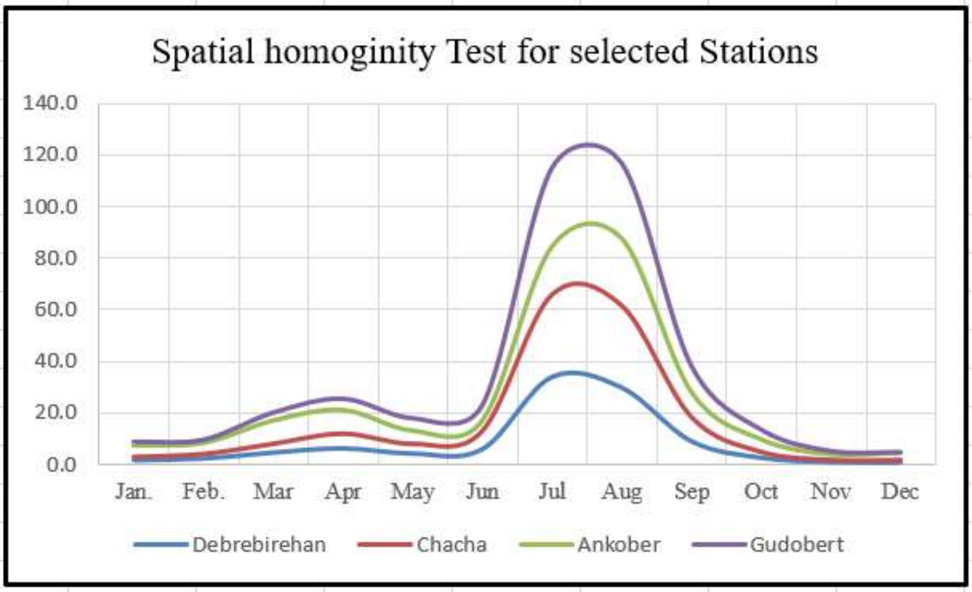


Figure 3. 6 Homogeneity test of selected stations with in and around the Beressa Watershed

3.5.1.4 Double Mass Curve

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 gauges. 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 forcorrections 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 show 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.

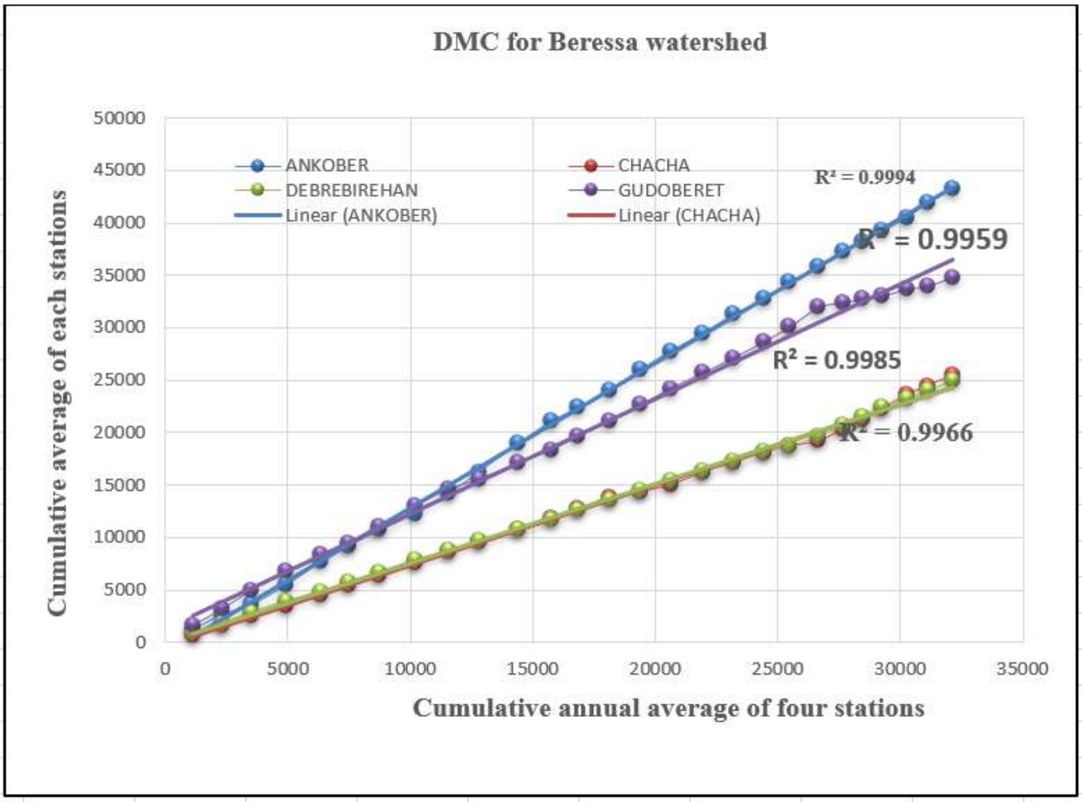


Figure 3. 7. Consistency checking for the four Rainfall stations within and around watershed.

3.5.1.4 Thiessen Polygons

Thiessen polygon method is one way of calculating areal precipitation. The method gives weight to satiation data in proportion to space between stations. Lines are drawn between adjacent stations on map. The area of each polygon inside the sub basin area is calculated. This factor is then used as weight of station studies within that the polygon according the proportion of the total watershed area that is geographically closed to each of the rain gages.

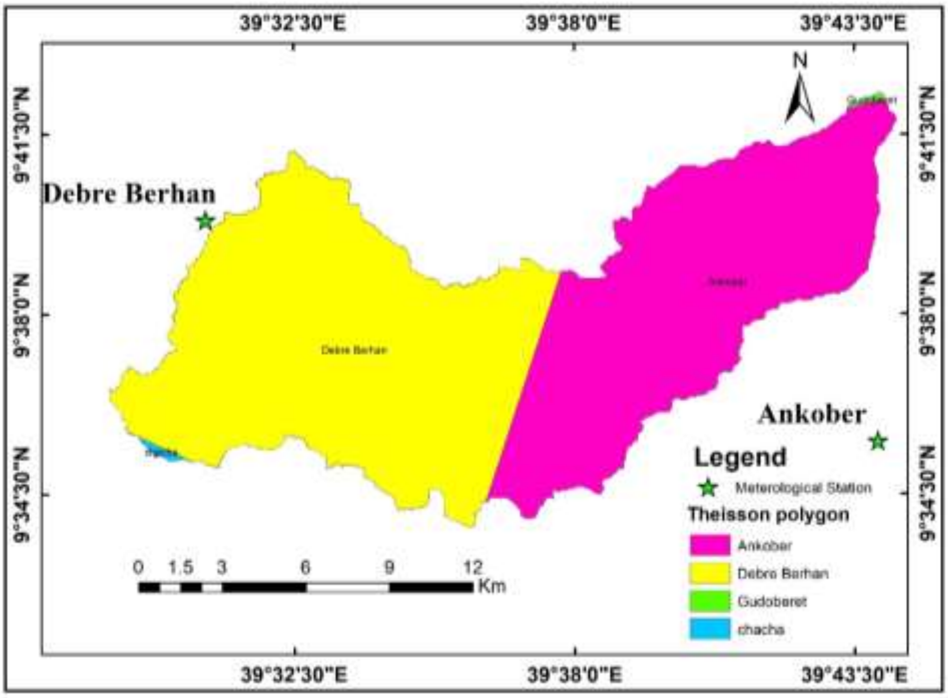


Figure 3. 8. Thiessonpolygon forBeressa watershed.

Thiessen polygon is drawn by using Arc view GIS software. After drawing the polygon, it is necessary to find percentage of area that each rainfall station represents. To determine mean areal rain, fall amount of each station multiplied by area of its polygon and the sum of those products is divided by total area of the catchment. Each polygon area is assumed to be influenced by the rain gauge station inside it, i.e., if P1, P2, P3 ... pn are the rainfalls at the in individual stations, and A1, A2, A3 ... An are the areas of the polygon surrounding these stations, (influence areas) respectively, the average depth of rainfall for the entire basin is given by equation 3.9

$Pav = \frac{P1A1+P2A2......+PnAn}{A1+A2+\cdots An}$----------- (3.9)

Where:Pav…………….... Average areal rainfall (mm),

P1, P2, P3…. Pn are the precipitation of stations 1, 2, 3…n, respectively

A1, A2, A3An are the area coverage of stations 1, 2, 3n respectively in the Thiessen polygon.

The advantage with the method is that is easy to understand and disadvantage is that it doesnottake in to account the geographic nature of rainfall and those change in station net that works it necessary to redo the procedure. (Table 3-7) below is result obtained from Thiessen polygon showing area covered by each percentage of area.

Table 3. 7.Thiessen polygon result for meteorological station

Name of stations	Area by each polygon (km^2)	Area ratio	Mean annual rainfall (mm)	% of Area coverage
Debrebirehan	115.72	0.55	925	55
Chacha	0.5	0.002	942	0.2
Gudoberet	0.2	0.001	1288	0.1
Ankober	93.4	0.447	1600	44.7

3.5.1.5 Solar radiation

SWAT model requires solar radiation in the day, the sunshine hour data of Debrebirehan station collected from NMA was converted to solar radiation by using an empirical equation developed by Angstrom (Equation 3.7). The Angstrom-Prescott equation (Prescott, 1940) related extraterrestrial radiation to solar radiation in the given location and the average fraction of possible sunshine hours (Muzathik et al., 2011)

$$R_s = R_a(\mathbf{a}+\mathbf{b}(\frac{n}{N}) \text{---} \mathbf{3.10}$$

Where

R_S is solar radiation or short-wave radiation.

R_a is extra-terrestrial radiation.

n is actual of sunshine hours (hour).

N is the maximum possible duration of sunshine or daylight hours (hour).

n/N is relative sunshine duration.

a and **b** are empirical coefficients.

Expressing the fraction of extraterrestrial radiation reaching the earth on overcast days (n=0) and a+b fraction of extraterrestrial radiation reaching the earth on clear day (n=N). N and Ra are computed by (equation 3.11)

$$N = \frac{24 * \grave{\omega}s}{\pi} \text{----- (3.11)}$$

$$Ra = \frac{24(60)}{\pi} * Gsc * dr * [\grave{\omega}s sin\varphi sin\delta + cos\varphi cos\delta sin\grave{\omega}s]$$

Where:

Ra is extraterrestrial radiation (MJM-2day-1)

Gsc is solar constant =0.0820MJM-2 Min-1

dris inverse relative distance Earth –sun

ῳ is latitude of the site (rad)

δ solar declination (rad) and

ὠs sunset hour angle (rad)

(Allen et al., 1998)suggested the value of a=0.25 and b=0.5 and as the inverse relative distance Earth-sun, dr, latitude of the site, ῳ and solar declination are calculated by the equation (3.10).

$dr = [1 + 0.033cos(2\pi J/365)]$--------- (3.911)

$$\varphi = \text{Lat} * 180/\pi$$

Where; Lat-latitude in degree

$$\delta = 0.409\sin(2\pi J/365 - 1.39)$$

J is the number of the day in the year between 1(January) and 365 or 366 (31 December). The sunset hour angle, ὠs could be computed from the equation (3.7).

ὠs =Cos-1[-tan (ῳ) tan (δ)]

3.5.2. Hydrological Data Quality Analysis

3.5.2.1. Streamflow Data

streamflow data were required for performing sensitivity analysis, calibration and validation of the model. These data were also collected from Abbay basin Authority. The flow data at Beressa gauged station were collected and arranged as per the requirement of the SWAT model. It is used for the Soil and Water Assessment Tool (SWAT) calibration and validation. The stream flow data covers a time period of 27 years from 1988 to 2014 and is used for calibration and validation. Monthly stream flow data is presented in Appendix 2. The minimum discharge is 0 m3/s and the maximum discharge is 51.6 m3/s. The flow data shows a strong serial correlation the value on one day is closely related to the value on the previous and following days especially during the period of low flow season November to February and heavy rainfall from June to August is the main cause of variation of flow in the study area. The gauging station has good stream flow records with a small number of missing data below 0.01%. Therefore, months with a few days of missing data were filled by averaging from neighboring year data

3.5.3Land use land cover data analysis

3.5.3.1 Image pre-processing and processing

Pre-processing functions involves the process required prior to the classification of landuse land cover or main data analysis to improve the ability to interpret the image componentsqualitatively and quantitatively. This study was done using Landsat imageries of different bands to identify changes in land use and land cover distribution inthe Beresa watershed over 24 years period from 1990 to 2013. For the helpof supervised image classification using ERDAS Imagine 2014 software imageprocessing such as layer stacking, image composition and sub setting of imagesBeressa watershed shape file was carried out. Layer stacking was done for 7images for landsat5, 7 and 8 images. Finallycomposited in to three bands (3, 2, 1) for Land sat 5and Land sat 7 and Landsat 8 (4, 3, 2) into a single layer. After the layer stacking and compositing processes were finished, the shape files of Beressa watershed was used for sub- setting ofsatellite image by using the sub-set tool.

3.5.3.2. Land use land cover classes

Before starting classification of the satellite image data, land use and land cover classes was differentiated using the available data source such as previous research, local knowledge and other information in study area. Six different types of land use have been identified for Beressa watershed (Meshesha etal, 2016). These are agricultural (cultivated land), forest, Grassland, settlement (urban), water and barrenland.

Table 3. 8 The LULC classes of the study watershed and their operational definitions

land use land cover classes	Swat Code	Descriptions
Cultivated land	AGRC	Areas used for crop cultivation, both annuals and perennials and the scattered rural settlements closely associated with the cultivated fields
Forest	FRST	Land covered with dense trees which includes evergreen forest land, mixed Forest and plantation forests like Eucalyptus trees and Acacia
Grassland	RNGE	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 plant species
Barren land	BARR	Areas with degraded lands, and bare ground.
Urban	URBN	areas were dominantly covered by dense houses
Water bodies	WATR	Areas that are water reservoirs, waterlogged and throughout the year, the rivers and its main tributaries

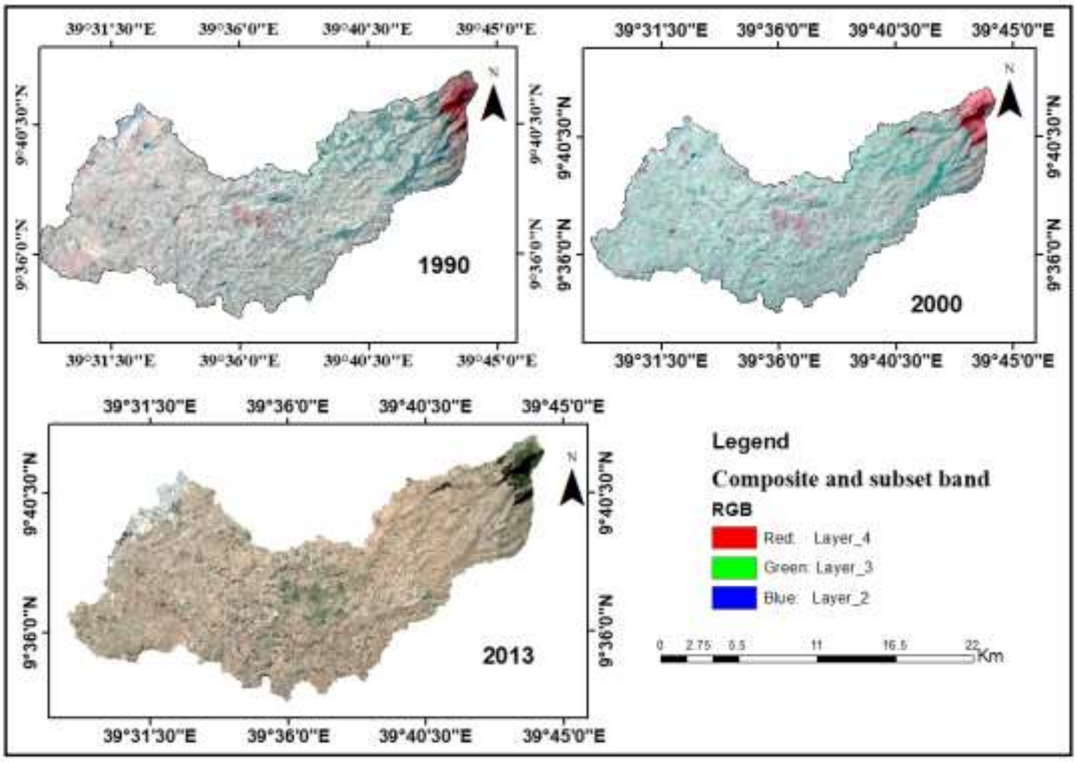


Figure 3. 9. Layer stacked and clipped satellite images ofBeressa watershed.

3.6. Swat Model Setup

3.6.1 Water Delineation

The watershed and sub watershed delineation performed using 30m*30 m resolution DEM data using Arc SWAT model watershed delineation function. The watershed delineation process consists of five major procedures, DEM setup, stream definition, outlet selection watershed and calculation of sub-basin parameters. Once, the DEM setup completed and the location of outlet specified on the DEM, the model automatically calculates the flow direction and flow accumulation. Subsequently, stream networks, sub watersheds and topographic parameters were calculated using the respective tools. The stream definition and the size of sub basins carefully determined by selecting threshold area or minimum drainage area required to form the origin of the stream. Beressa riverwatershed was delineated into 27 sub basins with a delineation of 209.78 km^2 byselected outlet in Beressa rivergauge station located in sub basin 1. During thedelineation process the elevation of the watershed ranges from 2739 m to 3681m a.m.s.l.

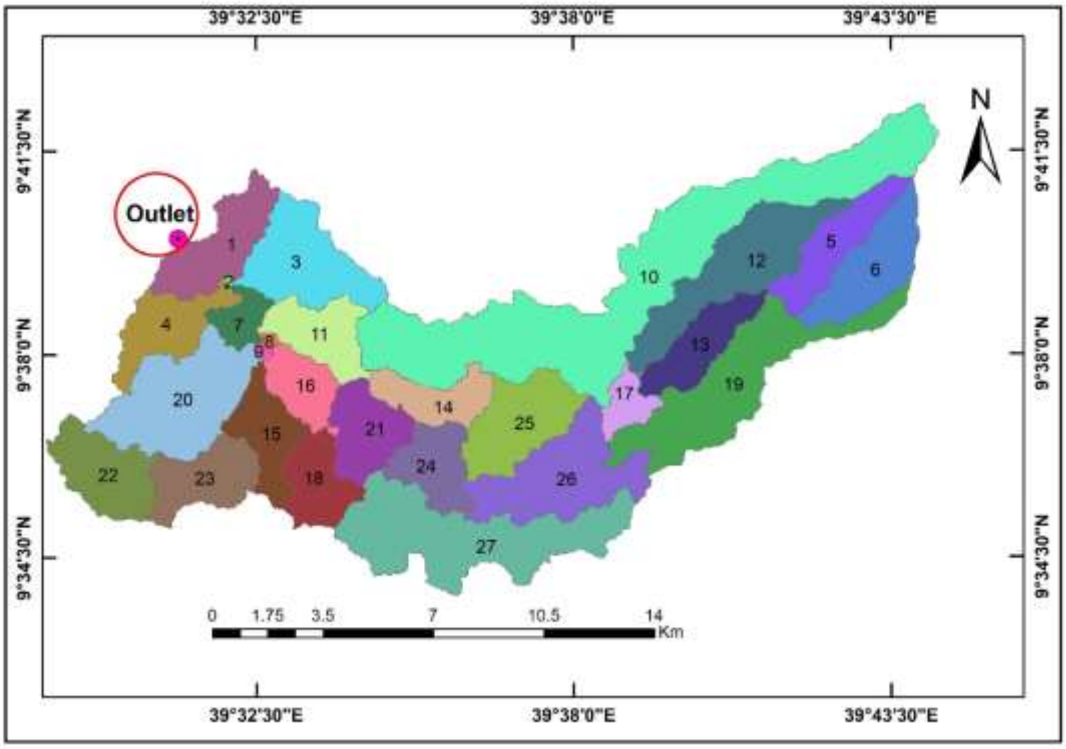


Figure 3. 10. Sub basins and outlet in Beressa watershed

3.6.2. Slope

The slopes of the study area derived from DEM input. Arc SWAT allows to classified slopes whendefining Hydrological response unit. According to (Berhanu et al., 2013) Ethiopian slope classification was grouped into six classes(0-3%,3-8%,8-15%,15-30%,30-50% and 50%). But SWAT model multiple slope classification maximum group was five. For this study the slope classification was five and as shown below table.

Table 3. 9. The slope classification of Beressa watershed.

Classes	Slope Range	Area (ha)
1	0-3%	1374.717
2	3-8%	5853.825
3	8-15%	6819.651
4	15-30%	5735.239
5	>30 %	1191.554

3.6.3. HRU Analysis

After completed an overlay of land use land cover, soil, and slope map, the next step was defined Hydrological response unit. Dividingthe watershed into unique land use land cover, soil, and slope combination with the help of Arc SWAT model to analyzed different hydrological conditions for the different land use, soil, and slope. There are two options for the SWAT model to define the Hydrological Response Units. The first one a single HRU for each sub-basin watershed and the second one a multiple HRUs for each sub-basin watershed based on threshold values.

For this study, multiple HRUs used, 10% land use threshold, 20% soil threshold, and 10 % slope threshold were used for HRU definition. This means minor land use less than 10% in sub-watershed was removed and minor slope classes less than 10% in land use and soils were removed. For this study the watershed divided into **260**HRUs and 27 sub basins, each HRUs had unique land use, slope and soils combination.

Surface runoff was estimated using the SCS Curve Number approach (SCS, 1985).While Potential Evapotranspiration (PET) was determined using the Penman-Monteith (Allen et al., 1989)method due to the presence of all the required climate variables for calculating PET.

3.6.4. Model Simulation

SWAT model wassetup and run on daily basis from January 1988 to December 2014by left 3years warmup period for land use land cover of all the study periods.

3.6.5 Sensitivity Analysis, Calibration and Validation

Sensitivity can bedefinedas theprocess ofdetermining the rate of changes in the SWAT model output to changes in parameters (mode inputs). Two kinds of sensitivity analysis was performed during identified sensitivity parameters(Abbaspour, 2015). These are Global and one-at time analysis. For this study the global sensitivity analysis was carried out by SUFI-2 was examined. Global sensitivity estimates the average changes in the objective functions from changes in each parameter, while all others parameters are changings. Global sensitivity analysis required larger numbers of simulation (Perry, 2014) for this study the numbers of simulation for calibration was 500.

In this study, fifteen streamflow parameters were used for sensitivity analysis (Table 3.10) based on previously done research papers (Ayele et al., 2017; Gashaw et al., 2017; Setegn et al., 2008)

Calibration is a method of changing model parameters, within the recommend parameter spacing, using the observed data to provide a similar response over time while validation is a process of evaluating the representation of the calibrated model parameters for simulating the measured data using an independent dataset (Arnold et al., 2012). A monthly time-step calibration and validation of the SWAT model in this study was undertaken using the SWAT Calibration and Uncertainty Program (SWAT CUP, version 5.1.4) using the Sequential Uncertainty Fitting (SUFI-2) algorithm (Abbaspour, 2014). The observed streamflow data measured during 1988–2014 periods was divided into warm-up (1988-1990), calibration and validations (1991-2014) periods.

Table 3. 10. List of flow parameters and their initial ranges used for Sensitive analysis

Parameters	**Definition**	**Rage**	
		Min	**Max**
CN2	SCS runoff curve number (dimensionless)	-0.2	0.2
ALPHA_BF	Base-flow alpha factor (days)	0	1
GW_DELAY	Groundwater delay (days)	30	450
GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur (mm)	0	5000
GW_REVAP	Groundwater “revap” coefficient (dimensionless)	0.02	0.2
REVAPMN	Threshold depth of water in the shallow aquifer for “revap” to occur (mm)	0	500
RCHRG_DP	Deep aquifer percolation fraction (dimensionless)	0	1
SOL_AWC	Available water capacity of the soil layer (mm H2O/mm soil)	-0.25	0.25
SOL_Z().sol	Maximum rooting depth of soil profile (m)	-0.25	0.25
SLSUBBSN	Average slope length (m)	10	150
HRU_SLP	Average slope steepness	0	1
CANMX	Maximum canopy storage (mm)	0	10
ESCO	Soil evaporation compensation factor (dimensionless)	0	1
SOL_K().sol	Soil conductivity (mm h-1)	-0.25	0.25
CH_K2.rte	Effective hydraulic conductivity in the main channel (mm h-1)	0	150

3.5.6 **Model Performance Evaluation**

For model performance evaluation used both graphical techniques and quantitative statistical analysis to compare simulated and observed data. For this research the statistical parameters (ENS, PBIAS and R^2) used for model evaluation for quantification of accuracy in watershed modeling.

The coefficient of determination (R^2) describes the proportion of variance in measured data by the model. It indicates the linear relationship between simulated and observed data and ranges from zero (model is poor) to one (model is good).

The R^2 is calculated using the following equation

$$\boldsymbol{R^2} = \frac{(\sum_1^n \left(Q_{S} - Q_{Sav}\right) * (Q_m - Q_{mav})^2)}{\sum_i (Q_m - Q_{mav}{}^2) * \sum_i (Q_S - Q_{sav})^2}$$

Where Q_S simulated value, Q_{Sav}average simulated value,Q_m,measured value and Q_{mav}average measured value

The Nash and Sutcliffe simulation efficiency (ENS) describes the deviation from the unit of the ratio of the square of the difference between the observed and simulated values and the variance of the observations. The value of the coefficients varies from minus infinity to one with the latter value indicating perfect agreement between the simulated and observed data. A smaller ENS value indicates poorer fit between the simulated and observed data. It is possible to obtain negative value of the NS indicating that the average of the observational data provides a better fit to the data compared to the simulated data.

NS is recommended and widely used in literature (Moriasi et al., 2007) therefore there is a lot of reported values for use as evaluation guidelines. NS, in a simplified explanation by (Moriasi et al., 2007) is an indication of how well the plot of observed versus simulated data fits the 1:1 line. ENS is computed as shown in the following equation.

$$\boldsymbol{NSE} = \boldsymbol{1} - \frac{\sum_1^n (Q_m - Q_s)^2)}{\sum_i (Q_m - Q_{mav})^2}$$

Where $Q_{S=}$ simulated value
Q_m= measured value
Q_{mav}=average measured value

Percent bias (PBIAS) measures the average tendency of the simulated data to be larger or smallerthan their observed counterparts (Gupta et al., 1999). The optimal value of PBIAS is 0.0, withlow-magnitude values indicating accurate model simulation. Positive values indicate modelunderestimation bias, and negative values indicate model overestimation bias. For streamflowPBIAS Values up to ±25 are considered acceptable (Gupta et al., 1999). PBIAS is computedusing equation.

$$PBIAS = \frac{\sum_{i}^{n}(Q_m - Q_s)}{\sum_{i}^{n} Q_s}$$

Where $Q_{S=}$ simulated value

Q_m= measured value

Table 3. 11. General performance ratings for monthly time step (Moriasi et al, 2007)

Performance rating	R^2	NSE	PBIAS%
Very Good	0.75 < R^2<1	0.75 < NSE<1	PBIAS<10
Good	0.65 < R^2<0.75	0.65 < NSE <0.75	10< =PBIAS <15
Satisfactory	0.5< R^2<0.65	0.5 < NSE <0.65	15 < =PBIAS <25
Unsatisfactory	R^2<=0.5	NSE <=0.5	PBIAS > 25

CHAPTER FOUR

RESULT AND DISCUSSION

4.1. LULC changes in the Beressa watershed

4.1.1. Accuracy assessment of the classified images

The accuracyassessment reports of the three classified LULC maps are presented in Table 4.1. The result shown that an overall accuracy of 88%, 90% and 92% were obtained for the 1990, 2000 and 2013 LULC maps, respectively. A Kappa coefficient of 0.86, 0.89 and 0.90 were also obtained for the 1990, 2000 and 2013 classified images, respectively.According to Monserud(1990), Kappa coefficients between 0.70-0.85 indicated the very good classification of the classified image while Kappa coefficients in the range between 0.85 and 0.99 shows its excellent performance. Hence, the obtained excellent for all classified images in this study can be used for further analysis and use.

Table 4. 1The accuracy assessment reports of the 1990, 2000 and 2013 classified images.

LU/LC Types for 1990	Agriculture	Barren land	Forest	Grassland	Urban	Water	Row total	User acc (%)
Agriculture	**90**	6	0	2		0	98	92
Barren land	3	**28**	0	0	1	0	32	88
Forest	0	0	**21**	2	0	0	23	91
Grassland	0	0	3	**17**	0	0	20	85
Urban	0	0	0	0	**5**	0	5	100
Water	0	0	0	0	0	**2**	2	100
Column total	93	34	24	21	6	2	180	
Pro acc(%)	97	82	88	81	83	100		
	Kappa coefficient		**0.86**	**Overall accuracy**		**88%**		

LU/LC Types for 2000	Agriculture	Barren land	Forest	Grass	Urban	water	Row total	User acc (%)
Agriculture	**110**	5	0	0	0	0	115	96
Barren land	0	**27**	0	1	1	0	29	93
Forest	0	0	**15**	1	0	0	16	94
Grass	0	0	2	**10**	0	0	12	83
Urban	0	1	0	0	4	0	5	80
Water	0	0	0	0	0	**3**	3	100
Column total	110	33	17	12	5	3	180	
Pro acc(%)	100	82	88	83	80	100		
	Kappa coefficient		**0.89**	**Overall accuracy**		**90%**		

LU/LC Types for 2013	Agriculture	Barren land	Forest	Grass	Urban	water	Row total5	User acc (%)
Agriculture	**122**	5	0	0	0	0	127	96
Barren land	0	**30**	0	0	1	0	31	97
Forest	0	0	**7**	1	0	0	8	88
Grass	0	0	1	**5**	0	0	6	83
Urban	0	1	0	0	**5**	0	6	83
Water	0	0	0	0	0	**2**	2	100
Column total	122	36	8	6	6	3	180	
Pro acc(%)	100	83	88	83	83	67		
Kappa coefficient			**0.90**	**Overall accuracy**		**92%**		

4.1.2. Trends and rates of LULC changes

The LULC maps of the study watershed during the 1990, 2000, and 2013 periods and the coverage of each LULC types in each period are given in Fig. 4.1 and Table 4.2, respectively. The result indicated that agriculture land, Barren land,urban and water bodies were increased from 61.4% to 62.3%, 17.0% to 17.7%, 0.5% to 0.7% and 0.039 % to 0.043 %, whereas forest and grassland were decreased from 7.5 % to 7% and 13.6 % to 12.2% during 1990-2000 periods, respectively (Table 4.2). Similarly, agriculture land, Barren land, urban and water bodies were increased from 62.3% to 65.2%, 17.7% to 17.9%, 0.7% to 1.6% and 0.043 % to 0.1%, whereas forest and grassland were decreased from 7 % to 5.1% and 12.2 % to 10% during 2000-2013 periods, respectively(Table 4.2).

The expansion of agriculture land at the expense of forest, and grassland in the study watershed between 1990to 2013 periods is aligned with many studies in the Ethiopian Highlands (Berihun et al., 2019; Gashaw et al., 2017; Woldesenbet et al., 2017). For example, Gashaw et al. (2017) has reported the expansion of cultivated land at the reduction of forest, shrub land and grassland in the Andassawatershd during 1985-2015 periods. There was also an increase of cultivation land and decrease of shrubland in the Lake sub-basin between 1986 and 2010 periods (Woldesenbet et al., 2017). The area covered by natural vegetation showed was also decreased in Kasiry catchment (Upper Blue Nile Basin) during 1982–2016/17 periods (Berihunetal., 2019). (Getachew & Melesse, 2012)also found that urban settlement and cultivated land were increased significantly in Angereb watershed during 1985 and 2011 periods while forest and grassland were reduced in these periods.

Similarly the waterbodies increased from 1990 to 2013 because of some water harvesting ponds and Lutral earthen dam were constructed during the study periods

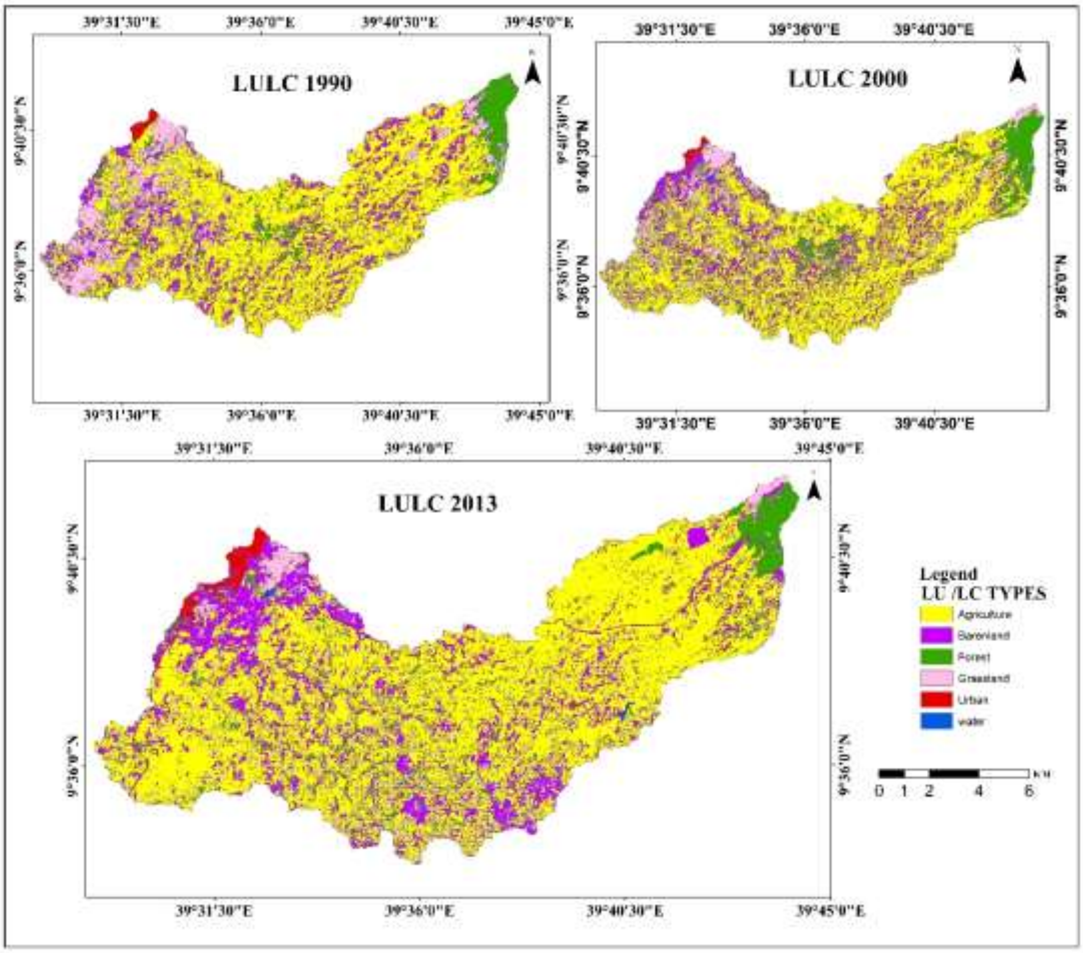


Figure 4. 1. The LULC maps of the Beressa watershed in 1990,2000 and 2013

Table 4. 2The area coverage of each LULC types in the Beressa watershed in 1990, 2000 and 2013 periods

	1990		**2000**		**2013**	
	Area		Area		Area	
LU/LC Types	Ha	%	Ha	%	Ha	%
Agriculture	12871	61.4	13076	62.3	13684	65.2
Barrenland	3569	17	3724	17.7	3765	17.9
Forest	1572	7.5	1461	7	1068	5.1
Grassland	2843	13.6	2557	12.2	2101	10.0
Urban	115	0.5	152	0.7	339	1.6
Water	8	0.04	9	0.04	21	0.10
Total	**20978**	**100**	**20978**	**100**	**20978**	**100**

4.2. Land cover detection

Comparing land-cover maps, changes in land-cover from 1990 to 2013 with respect to the total area of the watershed presented table4.3. Theanalysis showed 6.3% increase inagricultural land,5.5% increase in barrenland, 158.8% increase in urbansettlement, 32% reductionin forest, 26.1% reduction in grass land in the study area in the span of 24 years.

The increase in agricultural areas because of increased demand of population growth, additional cultivated land required for growing crops. As result of this farm land expanded negatively contribution for reduction of on grass and forest covers. Settlement area also increase due to populationgrowth andconverted other lands such as grass and forest land into settlement land use cover.

Table 4. 3.LULC changes statistics of Beressa watershed

LU/LC	Change in land use land cover in (ha) and % of share					
	1990-2000		2000-2013		1990-2013	
	area (Ha)	%	area (Ha)	%	area (Ha)	%
Agriculture	205	1.6	608	4.6	813	6.3
Barrenland	154	4.3	41	1.1	195	5.5
Forest	-111	-7.1	-392	-26.9	-503	-32.
Grassland	-286	-10.1	-456	-17.8	-742	-26.1
Urban	37	32.5	187	122.6	224	194.9
Water	1	9.3	12	136.8	13	158.8

4.3. Streamflow Modeling

4.3.1. Sensitivity Analysis

Sensitivity analysis of the simulated stream flow for the sub-basin was performed using the daily observed flow data for identifying the most sensitive parameter and for further calibration of the simulated stream flows. Amongst the fifteen streamflow parameters considered for sensitivity analysis (Table 3.3), eight of them are sensitive to the output variable. The eight most sensitive streamflow parameters fromhigh to low sensitivity are CN2, SLSUBBSN,RCHRG_DP,HRU_SLP, ALPHA_BFSOL_K(..), CH_K2 and GWQMN (Table 4.4).

Table 4. 4.The sensitive streamflow parameters in the study watershed and their sensitivity ranks

Parameter Name	t-Stat	P-Value	Ranks
CN2.mgt	58.26	0.000	1
SLSUBBSN.hru	-10.69	0.000	2
RCHRG_DP.gw	-6.28	0.000	3
HRU_SLP.hru	6.24	0.000	4
ALPHA_BF.gw	5.15	0.000	5
SOL_K(..).sol	4.29	0.000	6
CH_K2.rte	-3.32	0.001	7
GWQMN.gw	-2.90	0.004	8

4.3.1. Calibration and Validation

The calibration period was from 1991 to 1995 for land use 1990, from 1999 to 2003 for land use 2000 and from 2007 to 2011 for land use 2013. After the program was simulated 500 times for four iteration for stream flow parameters acceptable values of r-factor and p -factor are reached, then the parameters are the desired parameters ranges. Further goodness of fit can be quantified by the R^2 and NSE between observation andbest final simulation. The final steps after calibration was validation. The validation period was from 1996 to 1998 for land use 1990, from 2004 to 2006 for land use 2000 and 2012-2014 for land use 2013.The result of calibration and validation in successive iteration with 500 simulations using both land use land cover results based on the calibrated parameter ranges are displayed in Table 4.5, 4.6 and 4.7.

Table 4. 5. Summary of calibrated and validated performance criteria's analysis results for 1990 land use for flow variable.

Performance criteria	Calibration (1991-1995)	Validation (1996-1998)
R^2	0.77	0.79
NSE	0.62	0.67
Mean monthly flow(m3/s)		
Observed	5.10	5.78
Simulated	5.05	6.32

The result of calibration and validation for land use land cover 1990 as shown above table 4.5. The calibration period was conducted from January 1991 to December 1995, which was five years and the validation period carried out three years from

January 1996 to December 1998. The overall performance of the model during calibration has been measured using coefficient of determination (R^2) and Nash Sutcliff Efficiency (NSE) value as 0.77 and 0.62 respectively. But also, theoverall performance of model during validation has been measured using coefficient of determination (R^2) and Nash Sutcliff Efficiency (NSE) value as 0.79 and 0.67 respectively

Table 4. 6Summary of calibrated and validated performance criteria's analysis results for 2000 land use for flow variable.

Performance criteria	Calibration (1999-2003)	validation (2004-2006)
R^2	0.77	0.86
NSE	0.73	0.65
Mean monthly flow(m3/s)		
Observed	3.61	2.65
Simulated	4.87	4.86

The result of calibration and validation for land use land cover 2000 as shown above table 4.6. The calibration period was conducted from January 1999 to December 2003, which was five years and the validation period carried out three years from January 2004 to December 2006. The overall performance of the model during calibration has been measured using a coefficient of determination (R^2) and Nash Sutcliff Efficiency (NSE) value as 0.77 and 0.73respectively.But also, the overall performance of the model during validation has been measured using a coefficient of determination (R^2) and Nash Sutcliff Efficiency(NSE)valueas0.86 and 0.65 respectively.

Table 4. 7Summary of calibrated and validated performance criteria's analysis results for 2013 land use for flow variable.

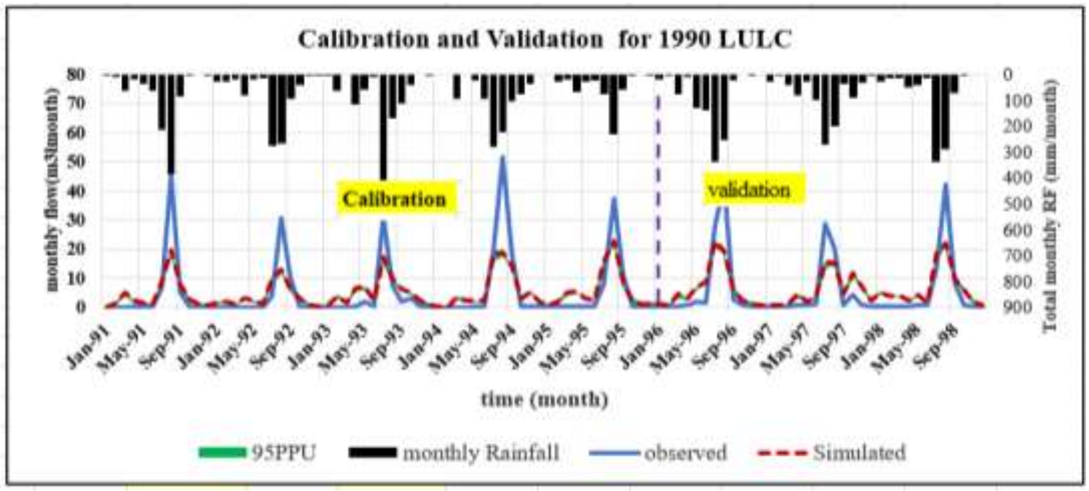
Performance criteria	Calibration (2007-2011)	validation (2012-2014)
R^2	0.82	0.83
NSE	0.82	0.80
Mean monthly flow(m3/s)		
Observed	2.90	4.37
Simulated	2.84	5.26

The result of calibration and validation for land use land cover 2013 as shown above table 4.14. The calibration period was conducted from January 2007 to December 2011, which was five years and the validation period carried out three years from January 2012 to December 2014. The overall performance of the model during calibration has been measured using coefficient of determination (R^2) and Nash Sutcliff Efficiency (NSE) value as 0.82and 0.82 respectively. But also, the overall performance of model during validation has been measured using coefficient of determination (R^2) and Nash Sutcliff Efficiency (NSE) value as 0.83and 0.80respectively.

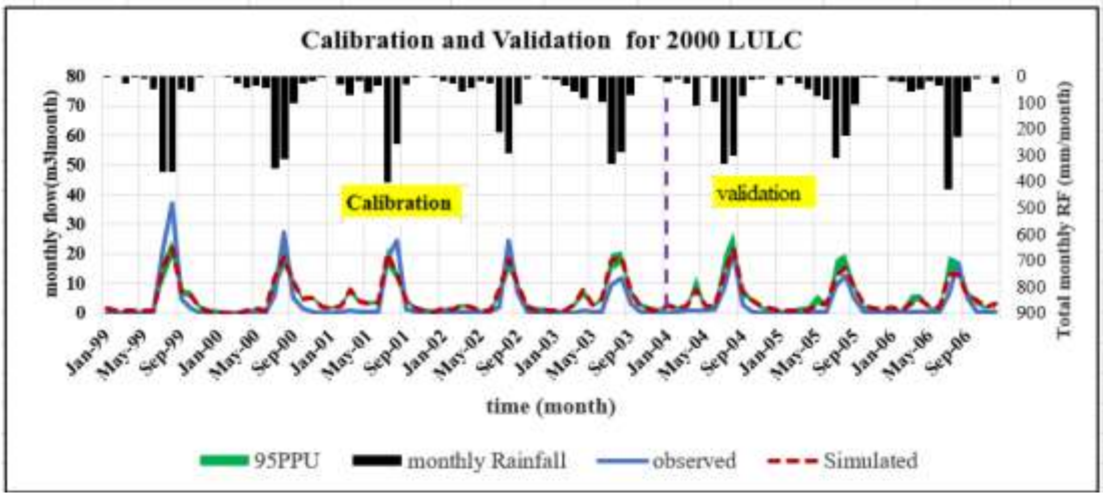
Generally, Different studies that were conducted in the upper Blue Nile basin also showed similar results. For example, Jemberie et al. (2016) reported that SWAT model shows a good match between the measured and simulated flow of Dedissa watershed both in calibration and validation periods with (ENS = 0.76 and R2= 0.80) and (ENS=0.7and R2= 079), respectively. Similarly modeling of the lake Tana basin Setegn et al. (2008)indicated that the average monthly flow simulated with SWAT model were reasonably accurate with ENS =0.81and R2=0.85 for calibration and ENS 0.79 and R^2= 0.80 for validation periods. This indicates that SWAT can give sufficiently reasonable result in the upper Blue Nile basin and hence the model can be used in this similar watershed.

The following line graph shows the relationship between observed and simulated stream flow as well as monthly rainfall in Beressawatershed during calibration and validation of land use land cover maps of year 1990, 2000 and 2013. As we can see from the graph there was a great relation between stream flows of observed and simulated. There was also good relation between stream flow and rainfall during modeling of Beressawatershed since the stream flow may be depend on amount of rainfall. When high amount of rainfall was occurred, it corresponds to peak flow.

A. 1990



B.2000



C.2013

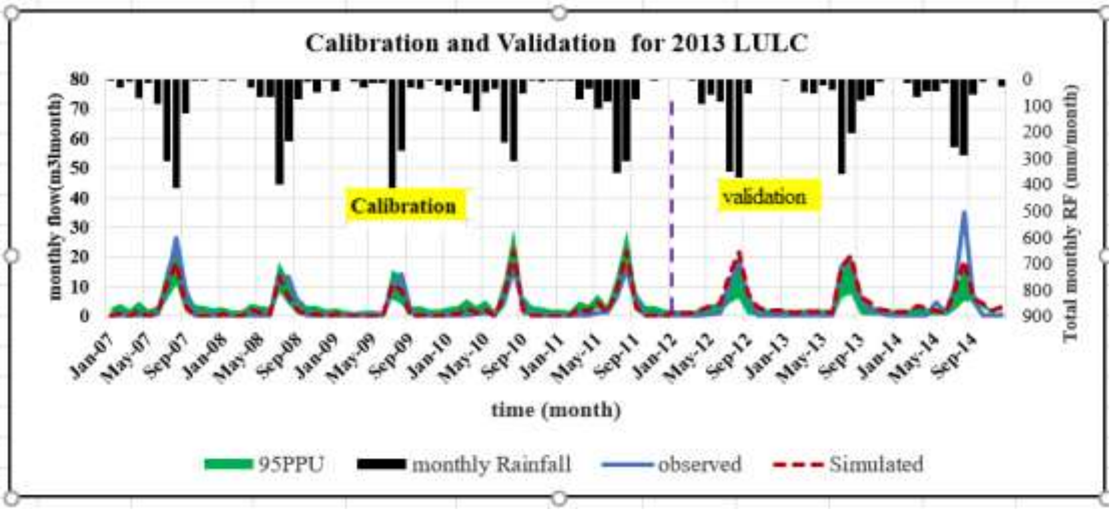


Figure 4. 2 The relationship between observed and simulated flow in Beressa watershed

4.4. Effects of Land Use Land Cover Change on Streamflow

After calibration and validation of stream flow for both land use land cover SWAT model was run using a calibrated and validated parameter. This helps to evaluate the land use land cover change effects in watershed. To evaluate the effects of the stream value results for thedifferent years were compared based on validated parameters were presented in table 4.8 based on the availability of flow data for calibration and validation ,evaluation of land use changes in stream flow was conducted for Beressa gauge station using three land use land cover

Table 4. 8 Mean annual stream flow in (m^3/s) results for validation periods

	1990 LULC	2000 LULC	2013LULC	Mean monthly flow change	
				1990-2000	2000 - 2013
Stream flow(m^3/s)	6.32	4.86	5.26	-1.46	0.4

The stream flow for three land use land covers were compared based on the validation result (Table 4.8). The mean annual monthly stream flow of Beressa watershed higher decrease from a year 1990 to 2000 by 1.46m^3/s and increase by 0.4 m^3/s from a year 2000 to 2013. Generally, the stream flow has decreased with the magnitude of 1.06 m^3/s during a study of periods (1990 to 2013). The decreasing of stream flow duringstudy periods (1990-2000) due to high percentage decreased of grass land by 10.1% and forest by 7.1% and the increased of stream flow during periods (2000 to 2013) due to incremental of agricultural land and built up area which increased surface runoff (peak flow).

4.4.1. Change on Seasonal Stream flow

Months January, February and March were considered as a dry periods andmonths June, July andAugust were taken to wet period forevaluating thechange of stream flow. The amount of streamflow was decreased by 0.9 m^3/s for 1990 to 2000 and increased by1.41m^3/s for 2000 to 2013 during wet season. There also changes in streamflow in the dry periods with decrease ofstreamflow by 0.5 m^3/s and 0.6 m^3/s for first and second periods respectively (Table 4.9).

In generally the stream flow for the periods of 2000 to 2013increase in wet season dueto increase of cultivated land by6.31 %and by 195% built up area whichimplies agricultural land and built up increased surfacerunoff. on the other hand the stream flow has showed decreased trend for the whole dry study periods due to expansion of agriculture results in reduction of water infiltrating into the ground and stored for base flow.

Table 4. 9Dry and wetperiod season average stream flow results of 1990, 2000 and 2013.

years	1990	2000	2013	change Detection	
				1990-2000	2000-2013
Dry Period	2.17	1.67	1.07	-0.5	-0.6
Wet period	12.18	11.19	12.6	-0.9	1.41

4.4.2. Change on surface run off and ground water flow

To assess the change in the contribution of the components of stream flow due to changein LULC of Beressawatershed, analysis was made on the surface run off (SURQ) and ground water flow (GWQ). Table 4.10 represents the SURQ and GWQ of thestreamflow simulated based on 1990, 2000and 2013 LULC map for similar periodof time

Table 4. 10. SURQ and GWQ of Beressa watershed during different years LULC maps simulation.

			Changes in mm			
			2000-1990		2013-2000	
LULC maps	SURQ	GWQ	SURQ	GWQ	SURQ	GWQ
1900	404.2	22.45				
2000	405.61	22.21	1.41	-0.24	1.8	-0.89
2013	407.41	21.32				

As shown (Table 4.10) SURQ and GWQ components of stream flow during simulation of1990 map were404.2 mm and 22.45 mm, during simulation of 2000 LULC map were 405.61mm and 22.21 mm, during simulation of 2013 LULC map were 407.41mm and 21.32mm forstudy watershed.

The contribution of surface run off has increased from 404.2mm to 407.41 mm whereas the ground water flow has decreased from 22.45mm to 21.32mm due to the generalize land use land cover change occurred between the periods of 1990 to 2013. This isbecause of the expansion of agricultural land and urban over the expense of forest that results inincrease of SURQ following rainfall events. We can explain this in terms of crop soilmoisture demands and rest time for infiltration. In the first case crop need less soilmoisture than forests therefore rain satisfy the soil moisture deficit in agricultural lands more quickly than in the forest land there by generating more surface run off where thearea under cultivated land is more. And this causes variation in the soil moisture andground water storage. In the second because forest retard the time for surface flow of rainfall events and gave more time for infiltration whereas the expansion of agriculturallands reduce water infiltrating rate in to the ground by decreased the time of rest duringrainfall events.

Therefore, discharge during dry months which mostly come from base flow decrease, whereas the discharge during the wet season increase. These results indicated that theLULC change have significant impacts infiltration rates, run off production and the waterretention capacity of the soil in the watersheds

CHAPTER FIVE

5.CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The main objective of this study assessed the impacts of the land use land cover dynamics on stream flow of Beressa watershed between the years 1990 and 2013 using distributed hydrological model (SWAT). In this study, spatial data and GIS were integrated with a hydrological model to evaluate the impacts of land use and land cover changes on the stream flow of the Beressa watershed. The impacts of the land cover change on stream flow were analyzed statistically using the hydrological model, SWAT

Land use land cover changes were detected for the past 24 years from 1990 to 2013 for Beressa watershed. Agriculture lands and urban areas increased from a year to a year because of increasing population and expansion of Debrebrihan town. The study uses ERDAS IMAGNIE 2014 software to produced land use land cover maps for 1990, 2000 and 2013.

The result of image classification showed 24 years generalized change of 6.3 % increase in agricultural land, 5.5% increase inbarren land,195% increase in urban settlement, 158.8 % increase in water bodies,32. % decrease in forestand 26.1 % decrease in grass land in Beressa watershed.

Streamflow from the watershed were determined from SWAT model. The model evaluation statistics of stream flow a gave a good result of NSE and R^2 both for calibration and validation. Results from calibration for both land use show an acceptable range (0.62 to 0.82 for NSE and 0.77 to 0.82 for R^2) between observed and simulated streamflow in a monthly base. The results of validation were acceptable (0.65 to 0.80 for NSE and 0.79 to 0.80 for R^2.

The average monthly stream flows of Beressa watershed decrease from year 1990 to 2000 in 1.46 m3/s and increase from year 2000 to 2013 in 0.4 m^3/s. The decreased of flow may be due to radical change of land use land covers especially the detrimental of forest in7.1% (between 1990and2000). Theincreased of stream flow between year 2000 and 2013 was due to high percentage increase ofcultivated land in 4.65 %and establishment of settlement in 122.64% in the watershed.

Seasonal stream flow of Beressawere decreased by0.9 m^3/s for 1990 to 2000 and increased by1.41 m^3/s for 2000 to 2013 during wet season. There also changes in streamflow in the dry periods with decrease ofstreamflow by 0.5 m^3/s for a year 1990 to 2000 and 0.6 m^3/s for a year 2000 to 2013.

5.2. Recommendation

Based on the present study result the following recommendations have suggested;

- Improvement of vegetation covers to reduce surface runoff and increase groundwater in study area.
- In this study the model simulation considered only land use land cover change effects by assuming all other variables constant. But change in climate, slope and soil management activities will also contribute great impact on rainfall runoff process of the watershed. Therefore, there is a need for further research to ascertain the hydrological impacts of climate change, slope and soil in the watershed.
- Effects on the availability observed data of Beressa, now a day Beressariver gauge is not functional, it is highly recommended to establish good gauging networks of hydrological stations.
- The research was conducted by evaluating the effects of land use and land cover changes on stream flow. However, further research of this kind can be computed on the assessment of the impacts of LULCC on Sediment yields.
- In this study the model simulation considered only land use land cover change.Integrating land use change models with hydrologic models could be applied to predict the impacts of land use changes on the stream flow in the watershed and the country in general. This helps for stakeholders and decision makers to make better choices for land and water resource planning and management.
- To conduct a very accurate land-use land-cover classification and change detection using the higher resolution satellite imagery is recommended which increases the quality of the work.

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APPENDIX

Appendix 1List of hydrological and Meteorological stations in and around Beressa watershed.

Station	Easting	Northing	Elevation	Mean Rainfall(mm)
Debre Berhan	554859	1064913	2750	925
Chacha	550484	1054588	2774	942
Ankober	580544	1060168	2970	1600
Gudoberet	573120	1077844	3100	1288

Appendix 2. Monthly mean stream flows of Beresa River Catchment in period of 1988– 2014

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1988	0.21	0.20	0.24	0.29	0.34	0.37	6.23	36.70	10.63	0.61	0.20	0.17
1989	0.17	0.16	0.18	0.31	0.19	0.24	3.12	14.52	4.14	0.31	0.23	0.24
1990	0.20	0.25	0.28	0.68	0.30	0.25	8.14	12.46	16.99	0.41	0.16	0.16
1991	0.15	0.14	0.15	0.20	0.30	0.39	6.58	45.34	5.01	0.31	0.14	0.13
1992	0.14	0.14	0.13	0.15	0.14	0.17	3.94	30.65	10.38	0.44	0.18	0.14
1993	0.12	0.16	0.13	0.31	1.79	0.31	31.10	7.41	1.89	3.26	0.20	0.15
1994	0.14	0.13	0.17	0.20	0.28	0.38	19.48	51.57	18.40	0.30	0.29	0.25
1995	0.22	0.21	0.24	0.38	0.38	0.42	7.95	37.40	11.04	0.36	0.34	0.37
1996	0.35	0.32	0.58	0.98	1.89	1.56	27.78	42.34	2.95	0.59	0.56	0.49
1997	0.48	0.46	0.53	0.83	0.68	1.32	28.73	20.57	0.72	4.16	0.81	0.34
1998	0.44	0.30	0.31	0.56	0.88	0.61	13.32	42.16	8.26	0.85	0.25	0.18
1999	0.16	0.12	0.16	0.13	0.17	0.36	21.42	36.81	4.83	1.47	0.10	0.05
2000	0.04	0.05	0.04	0.06	0.16	0.13	5.81	27.05	5.21	1.70	0.33	0.04
2001	0.07	0.44	0.69	0.32	0.42	0.24	18.58	24.41	1.18	0.00	0.00	0.00
2002	0.38	0.36	0.42	0.33	0.41	0.56	2.15	24.40	6.87	0.27	0.19	0.23
2003	0.22	0.25	0.18	0.78	0.37	0.55	9.34	11.72	3.17	0.24	0.02	0.03
2004	0.01	0.43	0.62	0.76	0.66	1.32	8.32	20.88	2.62	0.41	0.17	0.13
2005	0.12	0.10	0.11	0.17	0.31	0.33	9.01	12.60	4.84	0.36	0.22	0.26
2006	0.24	0.26	0.28	0.36	0.35	0.40	6.12	16.90	4.99	0.29	0.24	0.25
2007	0.21	0.22	0.22	0.48	0.30	0.65	10.69	26.19	9.14	0.42	0.28	0.23
2008	0.22	0.19	0.17	0.20	0.32	0.43	12.95	13.42	4.66	0.33	0.34	0.26
2009	0.28	0.21	0.21	0.30	0.28	0.40	8.65	14.17	1.60	0.48	0.27	0.35
2010	0.33	0.34	0.35	0.94	1.31	0.50	6.02	16.65	3.95	0.50	0.36	0.36
2011	0.32	0.31	0.38	0.45	1.09	1.42	6.16	16.09	5.21	0.51	0.42	0.39
2012	0.40	0.37	0.34	0.52	0.77	1.34	9.73	18.80	6.40	0.53	0.45	0.43
2013	0.35	0.34	0.36	0.48	0.46	0.52	17.06	18.39	6.64	1.83	1.35	0.53
2014	0.14	0.16	0.16	0.21	4.56	1.27	9.89	35.01				

Appendix 3. Mean monthly Rainfall station for Debrebirehan

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1988	11	55.07	19.46	83.1	16.2	16	286.2	290	153.1	12.1	0	0
1989	2.3	40.5	97.6	42.7	1.4	41.1	211.4	177.4	67.7	18.6	0	30.7
1990	0	62.2	23.26	59.5	0.9	1.6	321	217.2	168.7	0.6	0	0
1991	4.8	8.3	64.6	21	37.59	63.7	215.6	387.5	86.6	6.4	0	6.4
1992	30	26.7	19.4	80.2	19.3	13.3	277.6	267.6	92.9	41.9	0.5	1.8
1993	6.9	63.2	0	116.9	60.5	9.1	408.06	168.4	112.82	43.2	0	1.1
1994	0	0	95.6	0	23.2	92.7	281.7	222.9	101.7	79.32	36.5	0
1995	0	28.5	19.1	68.4	26.5	23.3	79.32	233.8	60.4	5.1	0	1.7
1996	21	2.8	75.4	9.7	129.2	138	336.4	252.5	24.3	0	3	0
1997	30	4	41.2	82.4	25.9	96.9	272.1	200.6	34.8	89.7	30.5	0.1
1998	27	13.2	14.9	49.3	43	13.5	337.3	289	70.6	5.2	0	0
1999	6.9	0	26.5	2.8	11.8	48.9	362.4	365.1	52.4	59.6	1.4	0
2000	0	2.56	25.9	47.3	37.1	46.6	352.4	317.5	105.2	28.5	18.8	6.8
2001	0	33.8	71.2	21.36	64.6	34.9	406.3	260.4	32.2	4.1	0	3.4
2002	18	28	60.6	46.1	18.4	29.1	214.4	295.8	109.1	10.3	0	8.4
2003	16	36.3	60.2	85.7	3.8	99.5	334.1	288.7	74.2	2.56	0	7.4
2004	24	12.26	29.7	113.3	5.6	99.7	334.7	301.3	78.9	14	11.8	0
2005	34	4.5	28.6	49.5	76.4	91.1	310.7	228.3	106.8	0.7	1.5	0
2006	17	24.4	61	48.3	19.8	35.2	432.6	232.2	59.8	8.6	0	26.3
2007	2	30.9	8.9	71.8	13.6	93.2	309.9	414.6	128.5	4.9	5.7	0
2008	0.3	1.7	0	34.6	67.9	66.4	397.7	234.8	77.9	9.9	51.6	1.2
2009	47	0	8.2	31.4	14.9	15.7	423.4	273.2	31.3	36.6	1.2	25.3
2010	47	25.2	55.7	119.3	51.5	35.4	242.3	312.2	53.8	0.3	8.5	3.9
2011	0.3	7	76.8	38.6	111.2	84.4	357.4	312.3	79	0	4.3	0
2012	0	0	5.2	93.3	57.9	86.8	351.6	404.5	55.4	0	0	0
2013	0.8	0	48.8	54.2	23.9	40.1	358.5	204.4	79.6	63.1	11.5	0
2014	0	16	67.7	44.1	46.9	16.8	260.3	291	110	55.9	0	0

Appendix 4 Mean monthly Rainfall station for Chacha

year	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
1988	79.9	74.8	79.96	77.38	79.96	77.38	79.96	79.96	77.38	79.96	77.38	77.38
1989	1.1	6.4	66.68	74.8	0.3	66.8	250.7	303.7	111.8	2	0	15.1
1990	1.8	82.4	29.1	38.1	60.7	2.9	373.2	432.4	244.3	1.1	0	0
1991	19.3	35.1	37.3	8	9.8	85	321.5	391.7	180.1	15.5	0	0
1992	59.4	75.4	22.9	31.5	22.9	17.4	248.8	318.8	63.7	34.9	0	0
1993	0	2.7	0	101.2	64	18.2	454.5	337.9	108.8	8.9	0	0
1994	0	0	45.7	18.8	15.2	78	164.1	150	72.1	0	11.1	1.2
1995	0	8.2	11.1	34.6	25.7	22.5	204.3	212.1	42.3	0	0	16.1
1996	21.5	0	54.6	34.6	60.18	74.8	352.8	284.4	11.1	0	7.98	77.38
1997	10.2	0	43.78	77.38	77.38	77.7	149.6	153.4	0	215.8	71.9	16.7
1998	0	0	4.3	38.3	30.4	27.9	440.8	302.8	242.3	117.5	0	0
1999	0	0	0	5.7	2.5	34.7	290.4	259.4	64.8	0	0	0
2000	0	0	0	11.6	3.5	32.5	170.6	272.1	20.7	4.6	0	0
2001	2.58	72.22	79.96	77.38	79.96	105.76	331.8	356	35.1	0	0	4.9
2002	18.1	14.1	64.9	96.8	25.8	89.3	245.2	306.2	55	2.2	0	1.6
2003	1	6.9	29.3	43.5	2.7	121.6	422	338.6	102.7	0	0	2.3
2004	14.6	2.7	31.8	66.5	0	157.6	439.1	275	115.7	35.9	8.2	2.1
2005	46.9	0	6.7	72.6	44.5	77	272.8	286.9	121.5	0	0	0
2006	18.6	15.4	37.2	57.1	23	64.3	436.3	275.9	104.3	0	7.4	28.9
2007	2.9	6.9	10.3	149.4	9.1	124.3	297.2	436.7	102.8	6.1	5.3	0
2008	0	1.8	0	27.5	99.5	118.4	348.3	266.5	87.4	5.3	21.7	0
2009	40.3	0	14.6	5	15.2	13.6	305.1	428.9	75.8	3.8	2.1	13.3
2010	3.2	23.3	31.5	59.3	93.4	68	337.5	367.7	71.8	0	0	7.9
2011	0	0	21.2	71.9	43	65.4	279.4	350.5	88.9	0	0	0
2012	0	0	29.3	61.1	8.7	95.2	364.7	361.8	37.9	0	0	0
2013	0	0	36.2	77	35	66.4	343.56	191.28	76.08	42.6	6.4	0
2014	2.1	20.8	75.78	35	29.2	12.3	138.7	302.3	76.5	13.7	0	0

Appendix 5 Mean monthly Rainfall station for Ankober

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1988	95.8	90.2	46.6	143.5	12.7	9.4	275.1	363.2	224.8	31.4	0	0.1
1989	5.8	99	268.2	230.1	15.6	50.8	146.9	298.1	75.2	70.5	3.2	196.5
1990	60.5	290.3	77.3	151.8	1.9	1.3	252.7	222.4	188.8	23.6	2.8	0.3
1991	1	135.3	189.6	40.2	15.9	32	154.8	266.8	135.5	9.9	5.1	52.5
1992	109.6	27.7	16.4	122.5	22.7	14.6	250	249.5	48.1	13.8	2	31.5
1993	74.2	107.6	11.4	302.4	201.6	32	311.1	168.7	173.3	106	0.5	1.6
1994	1.8	2.9	159.4	70	46.7	55.9	410	306	267.7	17.7	85.7	18.7
1995	0	81.6	264.8	180.6	75.1	24.8	321.6	488.2	110.7	2.6	4.3	69
1996	32.2	0.6	226	80.6	144.1	129.6	393.9	347.2	81.3	10.2	16.6	0.2
1997	136	122.84	136	129.87	21.4	127.4	154.2	261.2	73.2	436.7	167.1	1.3
1998	210.9	126.7	104.5	70.8	107.3	45.6	297.7	394.6	178.4	185.5	3.5	0
1999	104.4	0	88.3	38.2	33.9	22.2	337	557.2	156.3	245.3	4.9	136
2000	0	127.23	136	131.61	136	131.61	161.5	438.6	347.3	124.9	197.2	79.3
2001	54.4	74.4	466.5	101.3	57.8	267.9	406.5	111.6	35.8	13.1	21.3	30.4
2002	149.5	0	118.1	62.6	55.5	52.5	237.8	370.1	168.6	0	0	126.1
2003	136	24.5	147	340.9	32	146.2	476.9	468	232.2	0	23.2	56
2004	232.5	72	108	530	5	134.8	524.5	685.1	195.6	159	20.6	56.9
2005	57	0	166	163	272.5	71	413	614	264	0	16	0
2006	96	54	365	214	12.5	78	297	392	171	118	0	148
2007	32	108	75	184	51	49	437	423	116	43	41	0
2008	72	0	0	149	107	109	301	264	143	72	131.61	136
2009	136	122.84	136	131.61	59	5	326	367	60	69	36	56
2010	28	145	283	91	205	28	336	951	140	13	37.4	13.39
2011	10	0	100	104	265.5	57	136	947.4	131.61	0	99	0
2012	0	0	28	61	67	42	239	326	155	30	0	0
2013	42	13	50	71	65	10	355	610	130	59	6	0
2014	0	20	129	62	98	0	148	389	181	220	0	0

Appendix 6 Mean monthly Rainfall station for Gudoberet

	Jan	feb	mar	Apr	may	Jun	jul	aug	sep	oct	nov	dec
1988	25.4	20.8	11.2	30.8	8.2	1.7	462.9	160.4	50.6	25.4	0	0
1989	0	35.1	104.1	27.7	0	84.3	57.53	26.6	8.6	2.6	0.2	1.1
1990	0.9	13.4	1.6	11.3	0.7	18.6	256.1	189.9	88.9	4	0	0
1991	4	7.1	0.1	4.3	49.39	73.49	65.8	70.8	13.1	0.7	0	3.5
1992	5	5.4	0.2	10	109.35	0.4	12.8	101.5	77.5	33	0.2	6.7
1993	63.3	17.5	19.4	19.5	56.5	56.5	82.6	49.6	71	36.5	0	0.1
1994	109.35	98.8	109.4	105.8	44.9	86.2	409.8	408.5	244.6	47.3	176	3.2
1995	0	31.9	61.6	67.2	92.4	34.9	567.2	411.1	107	17	0	32.7
1996	14.8	0	87.4	61.1	156	151.4	589.7	338	88.3	27.3	10.4	0
1997	30.8	0	45.5	73.4	51.2	134	399.7	326.7	121.1	212.2	38.8	0
1998	125.9	90	17.2	28	48.5	43.8	469.1	460.7	167.5	38.1	0	0
1999	10	0	13.7	11	20.9	94.2	593.6	480	123.5	173.7	9.2	0
2000	109.35	0	7.03	94.1	109.35	30	368.5	467.4	209.2	86.3	69.4	14.5
2001	0	22.2	146.7	29	89	41.6	546.8	434.6	91.7	13.5	0	14.5
2002	11	0	76.6	82.4	6.4	43.6	366.9	501.4	209	19.7	0	14.4
2003	11.8	16	35.03	81.4	28.4	144	349.3	374.5	165.1	0	10.5	14.5
2004	22	8.1	79	108.9	3	183.2	373	495.9	152.8	70.2	52.4	0
2005	25.4	2.2	11.9	36	52	75.1	370.3	263.9	75.4	12.6	4.8	0
2006	41	19	30.9	43.5	35.2	110.3	507.2	443.7	249.7	94.2	5	62.4
2007	4.6	25.3	79.9	112.9	32.6	117.6	375.5	780.4	227.3	73	79.2	0
2008	15.7	3	0	91.3	131.5	135	646	321.5	144.1	68.3	34.4	0
2009	8.1	4.4	13.9	58.2	109.35	37.5	433.6	399.1	33.7	69.9	12.9	0
2010	0	28.9	70.1	78.3	128.1	75.3	455.9	551.8	154.1	5.1	3.1	14.4
2011	2	98.8	69.9	96.7	140.2	82.6	340.9	591.2	385.2	1	29	0
2012	0	0	1	98.8	171.3	305.3	518.6	504.7	135.3	12.3	0	2
2013	1.4	0	4.2	60.6	35.6	10	693.2	522.5	107	77.5	20.1	0
2014	0	0	92.7	111.9	91.4	21.7	385.7	584.7	140.2	218.8	0	0

Appendix .7 Format for measured monthly mean stream flows of Beresa River Catchment for SWAT-CUP

value	variable_ month year	Flow (m^3/sec
1	FLOW_OUT_1_1991	0.209
2	FLOW_OUT_2_1991	0.199
3	FLOW_OUT_3_1991	0.242
4	FLOW_OUT_4_1991	0.29
5	FLOW_OUT_5_1991	0.337
6	FLOW_OUT_6_1991	0.367
7	FLOW_OUT_7_1991	6.234
8	FLOW_OUT_8_1991	36.702

9	FLOW_OUT_9_1991	10.625
10	FLOW_OUT_10_1991	0.605
11	FLOW_OUT_11_1991	0.197

Appendix .7 Parameter value ranges for calibration of sediment with SUF-2 for land use land cover 1990

Parameter_Name	Fitted_Value	Min_value	Max_value
1:V__ALPHA_BF.gw	0.16	0.10	0.21
2:R__CN2.mgt	0.21	0.18	0.21
3:V__GWQMN.gw	3455.89	3208.51	3862.96
4:V__RCHRG_DP.gw	0.89	0.52	0.98
5:V__SLSUBBSN.hru	35.05	31.32	60.99
6:V__CH_K2.rte	164.43	122.82	166.43
7:R__SOL_K(..).sol	0.02	-0.11	0.06
8:V__HRU_SLP.hru	0.61	0.50	0.63

Appendix .8Parameter value ranges for calibration of sediment with SUF-2 for land use land cover 2000

Parameter_Name	Fitted_Value	Min_value	Max_value
1:V__ALPHA_BF.gw	0.150	0.065	0.158
2:R__CN2.mgt	0.120	0.078	0.169
3:V__GWQMN.gw	4462.051	4112.761	4650.130
4:V__RCHRG_DP.gw	-0.119	-0.219	0.172
5:V__SLSUBBSN.hru	123.271	109.539	134.506
6:V__CH_K2.rte	111.518	93.267	114.149
7:R__SOL_K(..).sol	-0.180	-0.297	-0.180
8:V__HRU_SLP.hru	0.356	0.315	0.390

Appendix .8Parameter value ranges for calibration of sediment with SUF-2 for land use land cover 2013

Parameter Name	Fitted Value	Min_value	Max_value
1: V__ALPHA_BF.gw	-0.052	-0.245	0.029
2:R__CN2.mgt	0.188	0.077	0.265
3:V__GWQMN.gw	4036.817	3752.250	4670.207
4:V__RCHRG_DP.gw	0.513	0.108	0.645
5:V__SLSUBBSN.hru	46.740	33.518	75.629
6:V__CH_K2.rte	66.110	52.324	86.617
7:R__SOL_K (...).sol	-0.184	-0.244	-0.148
8:V__HRU_SLP.hru	0.486	0.389	0.523