IMPACTS OF LAND USE LAND COVER CHANGE ON RESERVOIR SEDIMENTATION (THE CASE OF RIBB DAM, IN LAKE TANA SUB-BASIN, ETHIOPIA)

MSc THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

February _2020

IMPACTS OF LAND USE LAND COVER CHANGE ON RESERVOIR SEDIMENTATION (THE CASE OF RIBB DAM, IN TANA SUB-BASIN, ETHIOPIA)

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A THESIS SUBMITTED TO THE

DEPARTMENT OF HYDRAULIC AND WATER RESOURCES ENGINEERING,

INSTITUTE OF TECHNOLOGY, SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY

HAWASSA, ETHIOPIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN HYDRAULIC ENGINEERING

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February _2020

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY

ADVISORS' APPROVAL

This is to certify that the thesis entitled "**IMPACTS OF LAND USE LAND COVER CHANGE ON RESERVOIR SEDIMENTATION (IN THE CASE OF RIBB DAM, TANA SUB-BASIN, ETHIOPIA)"** submitted in partial fulfillment of the requirements for degree of Masters with specialization in Hydraulic Engineering, the Graduate program of the school of Biosystems Engineering, and has been carried out by **MEBRATU ESUBALEW**, **Id No PGHY /018 /10** under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the school.

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DEDICATION

I dedicated this thesis to **Simegnewu Engida, Engidaye Gessesse** and their families. They scarifies for my success and for their kindness love and support through all my way.

DECLARATION

I, **MEBRATU ESUBALEW ENGIDA**, hereby declare that this thesis submitted for the partial fulfillment of the requirements for the Master of Science in Hydraulic engineering, in the original work done by me under the supervision of Sirak Tekleab (PhD) and Tesfalem Abraham (PhD candidate) and it has not been published or submitted elsewhere for the requirement of a degree program to the best of my knowledge and belief. Materials or ideas of other authors used in this thesis have been accordingly acknowledged.

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ACKNOLEDEGMENTS

First of all my thank to Above all, creator and governor of the two worlds, the almighty GOD, his mother Saint Marry, all his Angels and Saints for his priceless and miracle gifts to me.

This work would never been completed without the support and encouragement of many people and organizations. First, I would like to express my gratitude to my major advisor Sirak Tekleab. (PhD) and my co_advisor Tesfalem Abraham (PhD candidate) for their advice, comment, kindness and help for the accomplishment of this work.

I feel a deep sense of gratitude for my family members Simegnewu Engida, Engidaye Gessesse, Yitages Esubalew, Fasikaw Esubalew, Animut Esubalew and Alebachewu Gete they formed part of my vision and thought me the good things that really matter in life.

I would like to extend my sincere gratitude to National Meteorological Agency (NMA) and Ministry of Water, Irrigation and Electricity (MoWIE) for their help by providing meteorological data and hydrological data for this study. I am also thankful to all Hawassa University staff members and special thanks to. Mihret Dananto (PhD), Dessalegn Jawesso (PhD), Markos Mathewos (PhD), Alemu Osore (PhD), Mr. Lemma Tuffa and Mr. Teshale Tadesse for their best comment and support to finalize this paper.

Finally, but most vitally a very special thanks goes out to my family and friends Mihretu Tezera, Eshet Abebe, Tgistu Abeje, Daniel Alemayehu, Mamaru Dessalegn, Alene Mitiku, Yibeltal Agegnhu, G/Hiwot Nigusse, Ashenafi Wondimu, Surafel Aragew, Getachew Tsehayu, Adane Mezemir, Petros Yohaness, Diriba Workku and Birhanu Balta for their support and encouragement from starting date to end date of this study.

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LIST of Acronyms and Abbreviations

AOI	Area of Interest
APEX	Agricultural Policy/Environmental extender Generic
ARS	Agricultural Research Service
CLUE	Conversion of Land Use and its Effects
DEM	Digital Elevation Map
ERDAS	Earth Resources Data Assessment System
EPIC	Erosion Productivity Impact Calculator
EUROSEM	European Soil Erosion Model
FAO	Food and Agricultural Organization
GIS	Geographic Information System
GPS	Global Position System
HRU	Hydrologic Response Unit
IWMI	International Water Management Institute
KINEROS	Kinematic wave overland flow
LANDFIRE	Landscape Fire and Resource Management Planning Tools Project
LULC	Land Use Land Cover
m.a.s.l	Mean at sea level
MUSLE	Modified Universal Soil Loss Equation
MoWIE	Ministry of Water, Irrigation and Energy
NMSA	National Metrological Service Agency
NSE	Nash Sutcliffe Efficiency
OPUS	Online Positioning User Service
PBIAS	Percent bias
SCS	Soil Conservation Services
SRTM	Shuttle Radar Topography Mission
SWAT	Soil Water Assessment Tools

USGS	United State Geological Survey
USHS	United Sate Geological Survey
USLE	Universal Soil Loss Equation
USDA-ARS	United State Department of Agriculture – Agriculture Research Service
WEPP	Water Erosion Prediction Project

ABSTRACT

Land use land cover (LULC) change is the challenge and continuous drivers of environmental change. Understanding the rate and process of change is, therefore, basic for managing the water resources and the environment at large. This study was intended to analyze the LULC changes impacts on sediment load from 2000 to 2018 periods, and select critical (hot spot area) sub basins and recommend best management practice for Ribb watershed of Lake Tana sub basin, Ethiopia. Both climate and hydrometric (flow and sediment) data were collected and analyzed over the period 1990 to 2018. Two time satellite imageries of the Land sat product (2000 and 2018) were used for land use change detection. The hybrid classification technique for extracting thematic information from satellite images were employed by using ERDAS model for classification of LULC. The Soil and Water Assessment Tool (SWAT) model was calibrated and validated to estimate sediment load of the watershed during the period 1992 to 2001 and 2002 to 2007 respectively. To manage the sediment load best management practices (BMP) as a scenario (filter strip, grassed water way and contouring) were implemented on 2018 LU map. The land use change detection result indicate that cultivated land has expanded from 66.87% in 2000 to 75.53% in 2018. Between 2000 and 2018 periods, it was increased by 8.66 %. The rate of increment during 2000–2018 periods were 608.915 ha/year. Similarly, settlement area had also increased by 2.09% from 2000–2018 periods. Similarly, shrub land and bare land also decreased at a rate of 412.868 and 227.651 ha/year, respectively, between 2000 and 2018 periods. Also the water body decreased at a rate of 1.593 ha/year between 2000 and 2018. The SWAT model result depict that the model give reasonable fit of sediment flux with observation during calibration and validation as evaluated with E_{NS} *(0.63) ,* R^2 *(0.67) and percent bias (17%) during calibration and* E_{NS} *(0.58) ,* R^2 *(0.71) and percent bias of (12%) during validation period. Moreover, the severity of soil loss rate was increased with the average of 26.89 ton/ha/year from 2000 to 2018 LULC, which indicates that the management practice, was weak within the watershed. The BMP scenarios depict that filter strip was significant amount of LULC conversions practice and soil loss rate had occurred in the watershed from 2000 to 2018 periods, and expected to continue in the future. Thus, appropriate conservation and management practice are very much crucial to safe guard the life of the reservoir.*

Keywords: LULC, ERDAS model, SWAT model, sediment load, Ribb watershed

1. INTRODUCTION

1.1 Background

Land use land cover change (LULC) is the most important form of global environmental change that occurs at spatial and temporal scales. This change of land use in rural and urban area is the result of deforestation, agricultural land expansions, human settlements and other factor derived by the population growth and environmental problem. Many literatures showed that population growth is the main factor for the land use change in urban or rural area (Tesfa and Bogale, 2015; Geremew, 2013; Dereje, 2010; Kassa, 2009; Hagos, 2014).

LULC change is the alteration of Earth's terrestrial surface mainly by anthropogenic activities (Turner and Meyer, 1994).Human activities have been documented as one of the main driving forces of LULC changes and simultaneous changes in natural environments (Bennett, 2010).
In turn, LULC changes greatly influence, among others, the spatial pattern of a landscape Kabba (2011) and Wang (2013) the availability of ecosystem goods and services Lawler (2014) and increase vulnerability of regional biomes and human well-being to climate change (Salazar, 2015). Continuously studying and monitoring LULC changes are particularly important in understanding the dynamics and predicting the patterns and trend of changes in a natural landscape and associated ecosystems at local, regional, and global scales, and to provide evidence-based support to improve land management policies and practices (Lu et al., 2004 ;Cotter, 2014).

These research papers also explain that land use change caused by the population mainly affect the people by itself. Analyzing the land use changes and understanding the effect of the land use change in present land use land cover is important for policy making, planning and implementing of natural resource management (Reddy and Gebreselassie, 2011).This careful analysis of land use change provides best management practices that will allow a balanced use of land for the people.

Determining the effect of land use change in watershed depends on the knowledge of past land use practices, current land use practices and most likely projected future land use practices as

affected by human distribution, economic development, technology and other factors (Tom, 2003). Land use change effect on present land use transformation became a global issue.
Natural catastrophe such as drought, floods caused by climatic change has been presented in many research papers is not commonly happening situation however human action cause sudden change in population or watershed.

The most influencing forces affecting natural vegetation's are directly related to expanding human population. The population of Ethiopia from year 1990 to 2016 is approximately doubled and population of Ethiopia is 101,783,351 based on the latest United Nations estimation (http://www.worldometers.info).This means the demands of lands are increasing as population increases. Cultivated land, which depends on the availability of seasonal rainfall, is the main economy of the country. People need land for the food production and for housing and it is common practice to clear the forest for the farming and housing activities. Therefore, the result of these activities is the land use land cover changes due to daily human action. For this reason, understanding how the land cover changes influence on the hydrology and sediment yield of the watershed will enable planners to develop policies to minimize the unwanted effects of future land use change.

Sedimentation is a process whereby soil particles are eroded and transported by flowing water or other transporting media and deposited as layers of solid particles in water bodies such as reservoirs and rivers. It is a complex process that varies with watershed sediment yield, rate of transportation and mode of deposition (Ezugwu, 2013).Sediment deposition reduces the storage capacity and life span of reservoirs as well as river flows (Eroglu et.al, 2010). Sedimentation continues to be one of the most important threats to river eco-systems around the world.

Several studies related to LULC changes in Ethiopia have indicated that the country has experienced rapid and increasingly pronounced LULC changes since the second half of the 20th century (Ariti, 2015; Reid, 2000; Muluneh, 2011; Kindu, 2013; Bewket, 2013; Minta, 2018). Unprecedented changes at the local, regional, and global level in ecosystems and environmental processes are prevailing due to this change. The detection of changes become a significant process in managing and monitoring natural resources and urban development due to quantitative analyses of the spatial distribution information during different periods of time (Mejebi, 2008).

There are a number of empirical, conceptual, and physical models to simulate catchment soil erosion. Selecting the right hydrological model for a specific catchment has always been a challenge, and field testing of watersheds and previous applicability of the model in hydrologically similar catchments could help researchers to use the proper model for their purposes. Most physical models generally require time series and spatial data as input. Besides these data, models such as APEX, EPIC, and SWAT Pandey et al. (2016) and Jeong et al. (2010) also require crop management data.

Erosion modeling is even more difficult in data-scarce environments using models like EPIC, EUROSEM, KINEROS, OPUS, and WEPP that require a large number of field input parameters for execution. Using distributed and semi-distributed hydrological models, modeling the hydrological response to land use land cover change is active research topic worldwide for example Kassa (2009), in Ethiopia, Olang & Furst (2011) in Kenya, Thomas et, al. (2015) in Taiwan and Wubishet et al. (2015) in USA are some of the paper. This modeling approach applied because observational data alone is not enough to identify the effect of land use change and also help the modeler to determine the degree to which land use change affect hydrological process. The LULC and sediment yield model applied in this study was the Soil and Water Assessment Tool (SWAT).

SWAT had be selected in the belief that the lumping nature, stationarity, and linearity problems of the rating curve could be avoided by replacing it by distributed and process-based runoff and sediment yield models. The model's ability to predict catchment soil erosion and sediment yield at different scales from small, 0.15 km^2 to basin-scale, 491,700 km^2 Chanasyk et al. (2003) Arnold et al. (2000) and Hunink et al. (2013) studies and its ability to account for the spatial heterogeneity in different land management practices are additional benefits. (Pandey et al., 2016; Arnold et al., 1995; Arnold et al., 1998).

The calibration/uncertainty analyses procedures for SWAT were carried out in an integrated platform using the standalone SWAT-CUP program that links to SWAT's output text files set.

1.2 Statement of the Problem

A proper river catchment management practice is needed for sustainable protection of the catchment. River catchments are important from hydrological and economical point of views used to absorb and transport the runoff from the rainfall and other sources. When rivers properly managed can provide fresh drinking water, food, hydropower and recreation. LULC change is an important characteristic in the runoff process that affects infiltration, interception, erosion and evapotranspiration. These changes have caused severe stress on forest and water resources in Ribb-watershed (Nyssen et al., 2004).Deforestation, expansion of cultivation and other land use activities can significantly alter the maximum and minimum flows of the river and sediment transportation. Although land-use changes in the area are a current phenomenon that expected to change the sediment processes and effects on hydrology of Ribb watershed. This might pose serious concern on the future functioning of this fragile resource if urgent action is not taken into consideration. Deforestation and overgrazing of the forest lands and expansion of the cultivated land area is activity of the people living in the watershed. The watershed is also facing high erosion by the effects of intense rainfall of the watershed that aggravates the land cover change of the watershed (Betrie et al., 2011; Nyseen et al., 2004; Shimelis et al., 2008).

Uncontrolled soil erosion, Poor land use practices, improper mitigation management systems and land degradation resulting in heavy sediment transport. This continuous change in land cover had impacts on the water balance of the watershed by changing the magnitude of the components of stream flow, which increasing the extent of the water management problem.
Most of the above applications successfully attempted to estimate the sediment yield at a small catchment scale and at a large scale in the Blue Nile. However, there is no literature that shows LULC impacts on stream flow and sediment yield at a catchment scale in the Upper Blue Nile basin. Traditional cultivated land management and LULC changes affect the Reservoir storage capacity

Figure 1.1: Sediment load problems of the study area

Therefore, the objective of this study is to estimate sediment yield under different periods based on LULC impacts in the Upper Blue Nile basin at a daily time step and assess the impact of different catchment management interventions on sediment yield.

1.3 Objective of the Study

1.3.1 General objective

The main objective of this study is to assess the impacts of LULC changes on reservoir sedimentation in Ribb dam, Lake Tana sub basin.

1.3.2 Specific objectives

The specific objectives of the study are:

- To classify (characterize) LULC of Ribb watershed during 2000 and 2018.
- To estimate the change in sediment yield due to the LULC changes between the two years (2000 to 2018).
- To show sediment yield mapping of Ribb Watershed and identify hot spots.
- To detect and determine sediment reduction scenarios in Ribb Watershed.

1.4 Research Questions

- Which LULC changes have dominant impacts on sediment yield in Ribb watershed?
- Does the LULC change have similar impacts on sedimentation?
- Which Sub_Basins have highly eroded?
- Which sediment reduction methods potentially reduce the sediment load?

1.5 Scope of the Study

This study primary focus on assessing the impacts of Land Use Land Cover changes on the hydrology and sediment yield of Ribb watershed.

The study also focused on the calibration and validation of SWAT model at the gauged stations as well as the effects of deferent land use scenarios on stream flow and sediment yield.

1.6 Significance of the Study

The LULC change has significant impacts on natural resource, socio economic and environmental system. However, to assess the effect of land use land cover changes on sedimentation is important to have an understanding of the LULC pattern and the hydrological process of the watershed. Moreover, the study presents a method to quantify LULC change and their impact on hydrology and sediment yield. This has been achieved through a method that combines the hydrological model SWAT to simulate the hydrological processes, SWAT-CUP to calibrate and validate SWAT model and GIS and ERDAS to classify LULC.

2. LITERATURE REVIEW

Under this section, literatures were cited on relevant topics such as definition and concepts of land use land cover change, land use land cover change studies in Ethiopia, application of Earth Resources Data Assessment System (ERDAS) on land use land cover change, Introduction to hydrological models, worldwide perspective of the hydrological model (SWAT), and SWAT model in Ethiopia. Generally, the reviews were focused on assessing the scientific works that were related to the subject of this study.

2.1 Land Use Land Cover Change: Definitions and Concepts

According to the International Geosphere-Biosphere Program and the International Human Dimension Program, IGBP-IHDP (1999) land cover refers to the physical and biophysical cover over the surface of earth, including distribution of vegetation, water, bare soil and artificial structures. Land use refers to the intended use or management of the land cover type by human beings. Thus, land use involves both the manner in which the biophysical attributes of land are manipulated and intent underlining that manipulation (the purpose for which the land is used e.g., agriculture, grazing, etc), which are more subtle changes that affect the character of the land cover without changing its overall classification. Definition of land use in this way establishes a direct link between land cover and the actions of people in their environment (FAO, 1998).

Land use land cover change (LULCC) is commonly grouped in to two broad categories: conversion and modification (Meyer and Turner, 1994).Conversion refers to change from one cover or use type to another (e.g. from forest to grassland), as is the case in cultivated land expansion, deforestation, or change in urban extent. Modification, on the other hand represents a change within one land use or land cover category (e.g. from rain fed cultivated area to irrigated cultivated area) due to changes in its physical or functional attributes. Both conversion and modifications of land use land cover have important environmental consequences through their impacts on soil and water, biodiversity, and microclimate, hence, contribute to watershed degradation (Stolbovoi, 2002; Lambin et al., 2003).

Land use land cover changes have been influenced by both the increase and decrease of a given population (Lambin et al., 2003).

In most developing countries like Ethiopia, population growth has been a dominant cause of land use land cover change than other forces (Sage, 1994). There is a significant statistical correlation between population growth and land cover conversion in most of African, Asian, and Latin American countries (Meyer and Turner, 1994).

Due to the increasing demands of food production, agricultural lands are expanding at the expense of natural vegetation and grasslands (Lambin et al., 2003).These changes in land use land cover systems have important environmental consequences through their impacts on soil and water, biodiversity, and microclimate (Lambin et al., 2003).

Land use land cover (LULC) changes have been identified as the main driving forces of local, regional, and global environmental changes, which have been stressed increasingly in the evaluation of anthropogenic effects on the environment (Verburg et al., 2015).

LULC changes are the results of dynamic human-environment interactions in processes operating at differing spatiotemporal scales (Aquilué et al., 2017; NRC, 2014). LULC change models have become useful research tools in land management, exploration of future landscape changes, and extent evaluation of policy proposals because of their capacity to support the analyses of LULC dynamics' causes and outcomes (Schulp et al., 2008).

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

Generally, knowing of the impacts of land use land cover change on the natural resources like water resources depends on an understanding of the past land use practices, current land use land cover patterns, and projection of future land use land cover, as affected by population size and distribution, economic development, technology, and other factors. The land use land cover change assessment is an important step in planning sustainable land management that can help to minimize agro-biodiversity losses and land degradation, especially in developing countries like Ethiopia (Hadgu, 2008).

2.2 Land Use Land Cover Change Studies in Ethiopia

In Ethiopia, the land is used to grow crops, trees, animals for food, as building sites for houses and roads, or for recreational purposes. Smallholders, who farm for subsistence, are using most of the land in the country. With the rapid population growth and in the absence of agricultural intensification, smallholders require more land to grow crops and earn a living; it results in deforestation and land use conversions from other types of land cover to cropland.

As population increases the need for cultivated land, grazing land, fuel wood and settlement areas also increase to meet the growing population demand for food and energy, and livestock population. Therefore, population pressures, lack of understanding and weak management are considered as the major causes for the deforestation and degradation of natural resources in Ethiopia (Kassa, 2009).

Soil erosion and land degradation is a major watershed problem in many developing countries including Ethiopia. Because of the rugged terrain or the topographic area, the rates of soil erosion and land degradation in Ethiopia are high. For more than 34% of the land area of Ethiopia the soil depth is already less than 35 cm (SCRP, 1996).

Ethiopia loses about 1.3 billion metric tons of productive soil every year and the degradation of land through soil erosion is increasing at a high degree (Hurni, 1989).Ethiopia has ample water resources, which can be appropriately utilized to enhance socio-economic development of its people. Due to under-development of this resource among others, the people of Ethiopia have been exposed to major problems such as impacts of drought and flood, land use change, shortage of clean water supply and inadequate energy supply (Hailemariam, 1999).

Ethiopia experiences persistent land, water, soil and environmental degradation due to localized and global climatic changes. Many Reservoirs around the world are losing averagely about one percent of their storage capacity annually causing serious problems for Hydropower, irrigation, water supply and flood control due to sedimentation problems (WCD, 2000).

Man-made reservoirs usually satisfy multiple objectives including flood control, irrigation, hydropower generation, water supply, boating, fishing and recreation.

The reservoir sedimentation is a serious offsite consequence of soil erosion that threatens the sustainability of dams built for various purposes in many parts of the world as well as throughout Ethiopia with different climatic conditions.

It depends on the river regime, flood frequencies, reservoir geometry and operation, sediment consolidation, density current, and possible land use change over the life expectancy of reservoir. The impacts of land use change on the reservoir and water resources are mainly reflected in changes in the water cycle, water quantity and water quality (Shi, et al., 2000).

The magnitude of changes on the stream flow due to land use changes varies with catchments and other factors such as climate change and human activities. Although LULC change is expected to have adverse impacts on irrigation reservoir and socio economic development globally, the degree of the impact will vary across nations.

The LULC changes may have far-reaching implications to Ethiopia for various reasons, mainly as its economy largely depends on agriculture (Hurni, 1990). Thus, changes in LULC have occurred at all times in the past, are presently ongoing, and are likely to continue in the future (Fu, 2003).

According to the configuration in topology Blue Nile Basin is generally divided in to 16 Sub-basins, among them Ribb Sub-basin is one of the primary sub-basin which experiences LULC change and the lack of advanced water infrastructure to use the full potential of available water resources. Therefore, the study of the various impacts of LULC change on reservoirs over the coming century has become a priority, for watershed management and development strategies.

The implementation of this reservoir generates to irrigate land for rice and minimize the food scarcity from the surrounding area and used to prevent floods at the downstream of the reservoir. Therefore, assessing the possible impact of LULC change on the irrigation reservoir event is essential for future development as well as for managing the current reservoir development.

2.3 LULC Classification

The general Land use land cover classes and definitions are list on the following table

Table 2.1: LULC Classification of Ribb Watershed (National Land Cover Database 1992)

LULC Class	Description
Water	Areas of open water, generally with less than 25 percent vegetation/land cover.
Built up (Settlement) (Residential)	Areas characterized by a high percentage (20 percent or greater) of constructed material (concrete, asphalt, buildings, etc.)
Mixed Forest	Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.
Shrub land	Areas dominated by shrubs; shrub canopy accounts for 25 to 100 Percent of the cover. Shrub cover is generally greater than 25 percent when tree cover is less than 25 percent.
cultivated land	Areas dominated by vegetation that has been planted or is intensively managed for the production of food, feed, or fiber; or is maintained in developed settings for specific purposes. Includes cultivated crops, row crops, small grains, and fallow fields.
Bare land	The area that is neither any land cover rather than listed in this classification.

2.4 Influences of Land Use Land Cover Pattern on Streamflow

There are many factors affecting streamflow, such as soil type, land cover and precipitation. One of the most important issues in water resource management is to understand the impact of land use changes on streamflow.

The land cover change, in many parts of the world has become a global issue, as a result contributed to the present complete transformation of land cover types. This continuous change in land cover may have both immediate and long lasting impacts on hydrological processes and the local and regional water balance by altering the balance between precipitation, evapotranspiration (ET) and the resultant run-off. Land use land cover affects runoff in the form of accelerated or retarded overland flow because of slow or fast infiltration rate and initial abstraction due to canopy cover (Jinno et al., 2009).

The amount and type of vegetative land cover is one determinant of the water yield of a drainage basin. Forests produce higher rates of evapotranspiration and interception (the storage of water on leaf surfaces) than do grass or shrub lands, all of which influence the amount of water that is available for direct drainage into streams or for aquifer recharge (Farley et al., 2009).

Interception plays a more important role in water balance during precipitation events. Leaves and forest floor leaf-litter capture a considerable amount of water and thus encourage its slow infiltration into the soil and finally it recharges groundwater supplies stored in aquifers and supplies the return flow of water to stream beds during periods of dry weather (Knighton, 1998). The conversion of the land surface from native cover to managed cropland has an effect on the evapotranspiration, infiltration and overland runoff characteristics of a watershed. Crops need less soil moisture than forests; therefore, the rainfall satisfies the shortage of soil moisture in agricultural lands more quickly than in forests there by generating more runoff. The increased removal of native vegetation and soil compaction decreases soil infiltration capacity. Hence, this leads to an increase in stream flow. Depending on the type of product being grown, croplands tend to have a percentage of bare ground even during the peak of the growing season, and may be completely bare prior to being planted.

In both instances, most of the precipitation that lands on these denuded areas will be discharged directly into the stream channel rather than infiltrating into the soil or evaporating/transpiring from the plant surfaces. As a result, conversion to cropland tends to increase water yield compared to native vegetation (Fisher and Mustard, 2004).

Besides the above factors, physical changes resulting from urbanization also affects the water budget through reduction of interception of rainfall due to removal of trees; removal of natural vegetation and change in the drainage patterns; loss of natural depressions which temporarily store surface water; loss of rainfall absorbing capacity of humus on the forest floor; creation of impervious surfaces (rooftops, roads, sidewalks, driveways) etc.

In urban and suburban areas, much of the land surface is covered by buildings and pavement, which do not allow rain and snowmelt to soak into the ground. Studies have indicated that soil compaction, as a result of urban growth is more likely to influence flood responses than the presence of forests (Bajracharya, 2015).

Impervious surfaces prohibit infiltration of water to the soil during precipitation events, thus inhibiting groundwater recharge and increasing overland runoff during precipitation events (Fisher and Mustard, 2004).

Generally, such changes of land use land cover may alter the hydrological cycle either through increasing high flows or through diminishing the low flows and assessing these flows is the core of this study. Information on flows in rivers, particularly low flows, became a greater priority to protect and quantify water resources and to meet the data requirements of ongoing developmental needs. The ability to estimate magnitude and frequency of low flows in river streams and ungauged catchments is important for water supply planning, waste-load allocation, reservoir storage design, maintenance of quantity and quality of water for irrigation, recreation and environmental flow requirements for wildlife conservation (Smakhtin, 2001).

In Ethiopia Previous, studies of hydrological impact of LULC change have been done in different parts of regions. For example, Tadele (2007) reported that the alteration of natural forest into farmland and settlements had increased the mean monthly discharge for wet months and decreased for dry seasons.

Tekleab et al. (2014) demonstrated that land management practices (e.g. ploughing activities in unfavorable land slopes, ploughing across the contour, poor soil and water conservation measures and shallow soil depth contributed towards the change in flow hydrographs in the Jedeb watershed, upper Blue Nile basin). Bewket and Sterk (2005) reported a decrease of the dry season flows in Chemoga catchment (adjacent to the Jedeb catchment), attributed to clearance of natural vegetation cover, increased agricultural expansion, and growing areas of eucalyptus plantation.

2.5 Impact of LULC Change on Sediment Load

Population growth and urban development within the watershed may have many negative consequences on water resources. Notable among them are the effects on flooding, erosion and water quality. Human activities such as the construction of roads, buildings, and parking lots result in the loss of pervious land surfaces.

The loss of pervious land surface considerably reduces the infiltration there by increasing the total runoff amount generated by a given rainfall event. Additionally, construction, agriculture, mining, and tree felling in the watershed may accelerate natural erosion rate.

It will accelerate erosion rate may increase the sediment supply to surface water (Nelson and Booth, 2002).Additionally, according to the Intergovernmental Panel on Climate Change (IPCC, 2007), the earth's climate is changing due to increased emission of greenhouse gases.
In what follows, the impacts of LULC change to sediment yield are briefly reviewed, Nelson and Booth (2002) studied how human activities changed predevelopment sediment transport rates. To reveal the impact of human activities, they developed the watershed-scale sediment budget for an urbanizing watershed through the evaluation of significant sources, quantities and delivery of sediment.

Soil erosion and sedimentation by water involves the processes of detachment, transportation, and deposition of sediment by raindrop impact and flowing water (Foster and Meyer, 1977; Wischmeier and Smith, 1978). Spatial and temporal information on runoff, soil erosion, and sediment yield of a catchment can afford a useful perspective on the availability of water, rate of soil erosion, and soil loss in the catchment.

The dynamics and processes of soil erosion and sediment yield are influenced by the spatial and temporal characteristics of the input variables affecting them and by controls exerted by the land surface. The controls related to land surface include elevation, soil, vegetation cover, and underlying geology.

2.6 Sedimentation Process, Extent and Effect on Reservoir

Soil erosion is a multifaceted dynamic process by which productive soil surface is transported and accumulated at a distant place by detaching from its original place. It produces bare land at surface where the soil has been detached and deposited in low land areas of the landscape or in water bodies downstream in a process known as sedimentation. Sedimentation and soil erosion are concurring environmental processes with diverse negative impacts (Mahmood, 1987).

The negative impacts include the removal of nutrient rich topsoil so that subsequent reduction of agricultural productivity in upland areas and at the same time if deposited in Lake, River bed and reservoirs it reduce the storage volumes (Upadhyay et al., 2012). All of the water that reaches a stream and its tributaries conveys sediment eroded from the entire surface. The total sum of erosional debris and nutrients exported from such a drainage basin is its sediment yield. Sediment yield is generally expressed either as a volume or weight basis. Obtaining an average weight for the sediment helps for conversion between the two forms of expression and calculating the total weight from the measured volume of sediment.

Depending on sediment size, the sediment load transported by streams can be classified as coarsest, finer particles and the dissolved loads. The first group (coarsest) moves on near or bed of the stream and is bed load of the river, which contains boulders, cobbles and as well as sands. The second groups (the finer particles) are silt and clay, which carried in suspension by turbulent action of the flowing water and moves long distance at the velocity of the flowing water. The third group (dissolved load) is composed of chemical compounds taken into solution by the water moving on or in the soils of the drainage basin. Hence, these three types of sediment constitute the total sediment load of the stream and results the sediment yield of the drainage basin (Turowski, 2010).

2.6.1 Impact of sedimentation on reservoirs

Soil erosion and the associated runoff create an offsite negative effect on lowland areas in general but specifically flooding and the deposition of sediment in reservoirs. The construction of a dam blocks the flow of sediment downstream, results to downstream erosion of these sedimentary depositional environments, and increased sediment build-up in the reservoir.

Even though the rate of sedimentation differs for each dam and each river, eventually all reservoirs reduces storage capacity due to the accumulation of sediment through time. Diminished storage capacity results in reduced availability of water for irrigation, decreased ability to produce hydroelectric power, and if left unaddressed, may ultimately result in the expiration of the dam and river (De and Poesen, 2005)

In Ethiopia, accelerated sedimentation in reservoir providing hydropower and irrigation water has resulted in loss of these intended services. The rationing based electric power distribution recently experienced in the country and frequent power cuts are also partly attributed to the loss of storage capacity of hydroelectric power reservoirs which is a result of sedimentation impacts (Tamene et al., 2006).

Table 2.2: Soil Loss Classification (Haregeweyn et al., 2017)

Soil loss rate (ton/ha/year)	Severity Class
<5	Very Slight
5 to 15	Slight
15 to 30	Moderate
30 to 50	Severe
>50	Very Sever

2.6.2 Factors affecting sedimentation

Sedimentation that is accomplished by decreasing the velocity of the water being treated to a point below which the particles will no lengthier remain in suspension. When the velocity no longer supports the transport of the particles, gravity will remove them from the flow. Several factors affect the separation of settleable solids from water.

The most common types of factors to consider are: particle size (when a wide range of particle sizes are present in the feed, differential settling rates between small and large particles lead to modification of the effective density of the suspension), density and concentration (the upward velocity of the fluid is greater at higher concentrations which causes a decrease in the apparent settling velocity), Velocity gradient (the velocity gradients in the fluid surrounding the particles are greater due to the closeness of the particles) and the ability of particles to aggregate at higher concentrations. In addition to density, particle size and concentration, and fluid viscosity, other obvious factors like topography, Watershed area, vegetation cover and soil erodability affect the sedimentation rate at the starting point of sedimentation as soil erosion.

2.7 Watershed Management (Sediment Reduction Methods)

Watershed management includes the treatment of land by using appropriate biological (agronomic or vegetative measures) and physical measures, which is economically, environmentally and socially acceptable. Natural resources development, conservation and management constitute the foundation of watershed planning (MoARD, 2005).

The management should be carried out on the watershed basis. The task of watershed management includes the treatment of land by using most suitable biological and engineering measures in such a manner that, the management work must be economical and socially acceptable. Soil and water conservation is the major part of the watershed management work for development and sustainable utilization of natural resource. To stabilize the resources engineering or biological conservation measures are important.

Physical measures

Soil and water is conserved artificially by applying physical measures or engineering measure. In this way, the previous nature of the land surface arrangement and profile will be changed for suitable conservation structure arrangement. Physical measures are effective in retarding runoff velocity, and consequently store sediment or safely dispose excess runoff water. In this study the physical measures selected is Contouring which is commonly used by SWAT model in the management operation to reduce soil erosion and sedimentation of reservoir. Contouring is in SWAT by altering curve number (CONT-CN) to account for increase surface storage and infiltration and USLE practice factor (CONT-P) to account for decreased erosion.

Agronomic (vegetative measures)

Soil erosion is mainly caused by poor land use practices like over grazing, over cultivation, deforestation and cultivating along the slopes, continuous depletion of soil organic matter. Applying of watershed management practice on land resources highly important to those land degraded by traditional land uses. Thus, biological (vegetation) soil and water conservation measures utilize the role of vegetation in helping to minimize soil erosion by water or wind. There are a number of vegetative measures used to reduce soil erosion. However, for this research work filter strip and grassed waterway were selected. Filter strip is a strip of dense vegetation located to intercept runoff from upslope pollutant sources and filter it. Filter strip remove contaminants by reducing flow velocity which results in the deposition of particulates. In its area increased infiltration and reduce runoff volume. Filter strip used algorithm used in SWAT. was derived from (White and Arnold,2009).

The other sediment reduction vegetative cover selected for this study was Grassed waterway. Grassed waterways are vegetated channels, which transport runoff from a field. It has an ability to reduce flow velocity, and protects the waterway from the scouring potential of concentrated flow. Grassed waterways generally broad and shallow channels; but the channel in SWAT has a side slope of 8:1. The Grassed waterways trap sediments and other contaminants (Arnold et al., 2011).

2.8 Application of ERDAS on LULC Change Detection

Image classification:

Basically, there are two-image classification techniques, which are employed for land cover classification. Supervised classification is one of; a method of land cover type classification using the sample polygons (ground truth points) from the known land cover types. The other type of classification is; Unsupervised classification; which is type of land cover classification from the satellite image data when the user doesn't know how many land cover types are present in the field. For this study, supervised type of classification was used using the known ground truth points and by connecting ERDAS Imagine 2015 with Google Earth and synchronizing the images. In Supervised Classification, the classification process has been controlled by creating, managing, evaluating, and editing signatures using the Signature Editor (Nedeljkovic, 2004).

Signatures are specific areas to which the names are assigned for supervised classification. Signatures are used to break the different classes like forest, cultivated, water and the like classes into as many subclasses as per classification requirement. Some tools such as the Signature Editor require were grown using an AOI layer which were created in the layer creation option. To perform complex classifications with signatures that were derived from more than one training method (supervised and/or unsupervised, parametric and nonparametric) merge signatures option was employed. The supervised classification is the most common method in obtaining land use/cover information (Rajan, 2008).

In this study, after data preprocessing, a training sample was selected according to spectrum features. Unlike the conventional classifications of land use land cover, the maximum likelihood classification was used to map the land use land cover of watershed. After classifying the image using supervised classification, the accuracy of classification was checked using ground control points.

2.9 Hydrological Models

Models are simplified representative systems that conceptualize real systems. The best model is the one, which give results close to reality with the use of least parameters and model complexity. Models were mainly used for predicting system behavior and understanding various hydrological processes.

Hydrologic models are simplified, conceptual representations of a part of the hydrologic cycle. Their objectives are giving figures to various flows in the hydrological system they also have an important role as pedagogical and research tools.

They are made of mathematical representations of the key processes like evapotranspiration, infiltration and transfer in streams.

Hydrological models transform input meteorological variables into an output hydrological variable over a time. They were primarily used for hydrologic prediction and for understanding hydrologic processes. The prediction ability of these models makes them suitable as management tool for planning and decision making in the watershed.

Various hydrological models have been developed across the world to find out the various impacts on hydrology and water resources. Based on process description, the hydrological models can be classified into three main groups: lumped models, semi-distributed models and distributed models (Cunderlik, 2003).

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 physical features of hydrologic processes and usually involve certain degree of empiricism. These models are not usually applicable to event-scale processes. If the interest is primarily in the 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. 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 large amount of (often-unavailable) data. However, the governing physical processes are modelled 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 in to a number of smaller sub basins. The main advantage of these models is that their structure 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. **(**1993), HEC-HMS US-ACE (2001), HBV Bergström (1995) are considered as semi-distributed models.

According to Moradkhani and Sorooshian (2009) in lumped models, the entire river basin is taken as a single unit where spatial variability is disregarded and hence the outputs are generated without considering the spatial processes where as a distributed model can make predictions that are distributed in space by dividing the entire catchment in to small units, usually square cells or triangulated irregular network, so that the parameters, inputs and outputs can vary spatially.

Recently, hydrological simulation models including: SWAT, MIKE-SHE, HSPF, WASIM-ETH, DHSVM, HEC-HMS and others have been developed partly to quantify the influence of change in land use, land cover and management practices on the hydrologic cycle. There are several criteria, which can be used for selecting the right hydrologic model. Since every research has its own specific requirements and needs, most of the criteria are mainly research purpose dependent (Juraj, 2003).

The World metrological organization (2008 and 2009) reports include the following factors and criteria as being relevant when selecting a model:

- The general modeling objective; e.g. hydrological forecasting, assessing human influences on the natural hydrological regime or climate change impact assessment.
- The type of system to be modelled; e.g. small catchment, river reach, reservoir or large river basin.
- The hydrological elements to be modelled; e.g. floods, daily average discharges, monthly average discharges, water quality, amongst others.
- The climatic and physiographic characteristics of the system to be modelled.
- Data availability with regard to type, length and quality of data versus data requirements for model calibration and operation.
- Model simplicity, as far as hydrological complexity and ease of application are concerned.
- The possible transposition of model parameter values from smaller sub catchments of the overall catchment or from neighboring catchment.

- The ability of the model to be updated conveniently on the basis current hydro metrological conditions.

The selection of a particular model is a key issue to get satisfactory answers to a given problem. For this study the selection is focusing on models that are used for land use change studies, since such studies would need a very good representation of the spatial variability with special attention to the land use land cover and sediment simulation related inputs and processes. Hence, the scope of this study was to apply the models for the specified purpose and the model selection was made from the existing hydrological models that have been successfully verified by others in different places. The selection was then based on the combined analysis of the above steps and the accessibility of the models from the cost and user friendliness aspects.

As a result, since SWAT has used successfully to simulate impacts of land use on hydrological processes and distinguish the roles they played on different varieties and sizes of watersheds Xing et al. (2009) SWAT model would be selected for this study.

The model has been widely used in different watersheds across the world and proved to be an effective tool to examine hydrological responses to land use cover changes. In some parts of Ethiopian watersheds SWAT has been successfully applied by different researchers.

For instance, Asres and Awulachew (2010), Tekleab (2008) and Tekle (2010) has been used to model the hydrological process, stream flow, sediment yield and water balance. From their study, the overall performance of the model in most cases is at a reasonable accuracy. Therefore, using this tool hydrological responses are critically evaluated, through calibration and validation.

2.10 SWAT Model

The SWAT (Soil and Water Assessment Tool) watershed model is one of the most recent models developed at the USDA-ARS (Arnold et al., 1998) during the early 1970’s. SWAT model is semi-distributed physically based simulation model and can predict the impacts of land use change and management practices on hydrological regimes in watersheds with varying soils, land use and management conditions over long periods and primarily as a strategic planning tool (Neitsch et al., 2011).

The interface of SWAT model is compatible with ArcGIS that can integrate numerous available geospatial data to accurately represent the characteristics of the watershed. In SWAT model, the impacts of spatial heterogeneity in topography, land use, soil and other watershed characteristics on hydrology are described in subdivisions.

There are two scale levels of subdivisions; the first is that the watershed is divided into a number of sub-watersheds based upon drainage areas of the attributes, and the other one is that each sub-watershed is further divided in to a number of Hydrologic Response Units (HRUs) based on land use and land cover, soil and slope characteristics.

The SWAT model simulates eight major components: hydrology, weather, sedimentation, soil temperature, crop growth, nutrients, pesticides, and agricultural management (Neitsch et al., 2011). Major hydrologic processes that can be simulated by the this model include evapotranspiration, surface runoff, infiltration, percolation, shallow aquifer and deep aquifer flow, and channel routing (Arnold et al., 1998).Stream flow is determined by its components (surface runoff and ground water flow from shallow aquifer).

2.10.1 SWAT model application worldwide

The SWAT model has good reputation for best use in agricultural watersheds and its uses have been successfully calibrated and validated in many areas of the USA and other continents (Ndomba, 2008; Tripathi et al., 2003). The studies indicated that the SWAT Model is capable in simulating hydrological process and erosion/sediment yield from complex and data poor watersheds with reasonable model performance statistical values.

Ndomba (2008) was applied the SWAT model in modeling of Pangari River (Tanzania) to evaluate the applicability of the model in complex and data poor watersheds. Tripathi et al. (2003) applied the SWAT model for Nagwan watershed in India with the objective of identifying and prioritizing of critical sub watersheds to develop an effective management plan and the model was verified for both surface runoff and sediment yield. Accordingly, the study concluded that the SWAT model could be used in ungauged watersheds to simulate the hydrological and sediment processes. SWAT has gained international acceptance as a robust interdisciplinary watershed-modeling tool as evidenced by international SWAT conferences, hundreds of SWAT-related papers presented at numerous other scientific meetings, and large number of articles published in peer-reviewed journals (Gassman, 2007).However, Cibin et al. (2010) indicated that SWAT model parameters show varying sensitivity in different years of simulation suggesting the requirement for dynamic updating of parameters during the simulation. The same study also indicated that sensitivity of parameters during various flow regimes (low, medium and high flow) is also found to be uneven, which suggests the significance of a multi criteria approach for the calibration of the model.

2.10.2 SWAT model application in Ethiopia

The SWAT model application was calibrated and validated in some parts of Ethiopia, frequently in Blue Nile basin. Through modeling of Gumara watershed (in Lake Tana basin), Awulachew et al. (2009) indicated that stream flow and sediment yield simulated with SWAT were reasonable accurate. The same study reported that similar long-term data could be generated from ungauged watersheds using the SWAT model. A study conducted on modeling of the Lake Tana basin with SWAT model also showed that the SWAT model was successfully calibrated and validated (Setegn et al., 2009). This study reported that the model could produce reliable estimates of stream flow and sediment yield from complex watersheds.

Gessese (2008) used the SWAT model performed to predict the Legedadi reservoir sedimentation. According to this study, the SWAT model performed well in predicting sediment yield to the Legedadi reservoir. The study further put that the model proved to be worthwhile in capturing the process of stream flow and sediment transport of the watersheds of the Legedadi reservoir. In addition to the above, Setegn et al. (2009) tested the SWAT model for prediction of sediment yield in Anjeni gauged watershed.

The study found that the observed values showed a good agreement at Nash-Sutcliff efficiency (ENS) of 80 percent. In light of this, the study suggested that the SWAT model could be used for further analysis of different management scenarios that could help different stakeholders to plan and implement appropriate soil and water conservation strategies.

Tekle (2010) through modeling of Bilate watershed also indicated that SWAT Model was able to simulate stream flow at reasonable accuracy. The literature reviewed and presented above showed that SWAT is capable of simulating hydrological and soil erosion process with reasonable accuracy and can be applied to large and complex watersheds.

3. MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location and topography

The Ribb watershed is part of the headstream areas of the Lake Tana and it is located at about 685 km northwest of Addis Ababa (the capital city of Ethiopia) and 132 km to Bahir Dar, which is the regional capital city.

It is located at a geographic coordinates of 37° 59’45”E and 12° 02’30”N (figure 3.1). Ribb watershed along the main river course shows that, it was characterized as a steep mountainous watershed up to the Ribb dam site (at about 56 km course); below this point, the river slope was getting flatter. The Upper Ribb watershed (844 Km^2) was characterized as a mountainous, wedge shaped and a steep sloped. The highest elevation of the watershed is about 4,112 m in its southeastern part, where at the dam site the elevation drops below 1,900 m. Addis Zemen, Debre Tabor, Ibnat and Gassay towns are located on the divide line, near, and inside the Upper Ribb watershed and the watershed covers a surface area of 133,587ha.

Ribb River, which traverses the watershed, is the major river within the watershed and is a large tributary to Lake Tana. Agriculture is the predominant economic activity in the watershed and the main source of livelihood.

The land escape of the area is highly rough with high mountain range on the south and closely distributed and their escarpments in the central and northern parts of the watershed, which are dissected deep and narrow bedded gorges and valleys as well as plains on the top of the hills. Gunna Mountain is the source of Ribb Rivers, 84km long and has 34 other small tributaries.

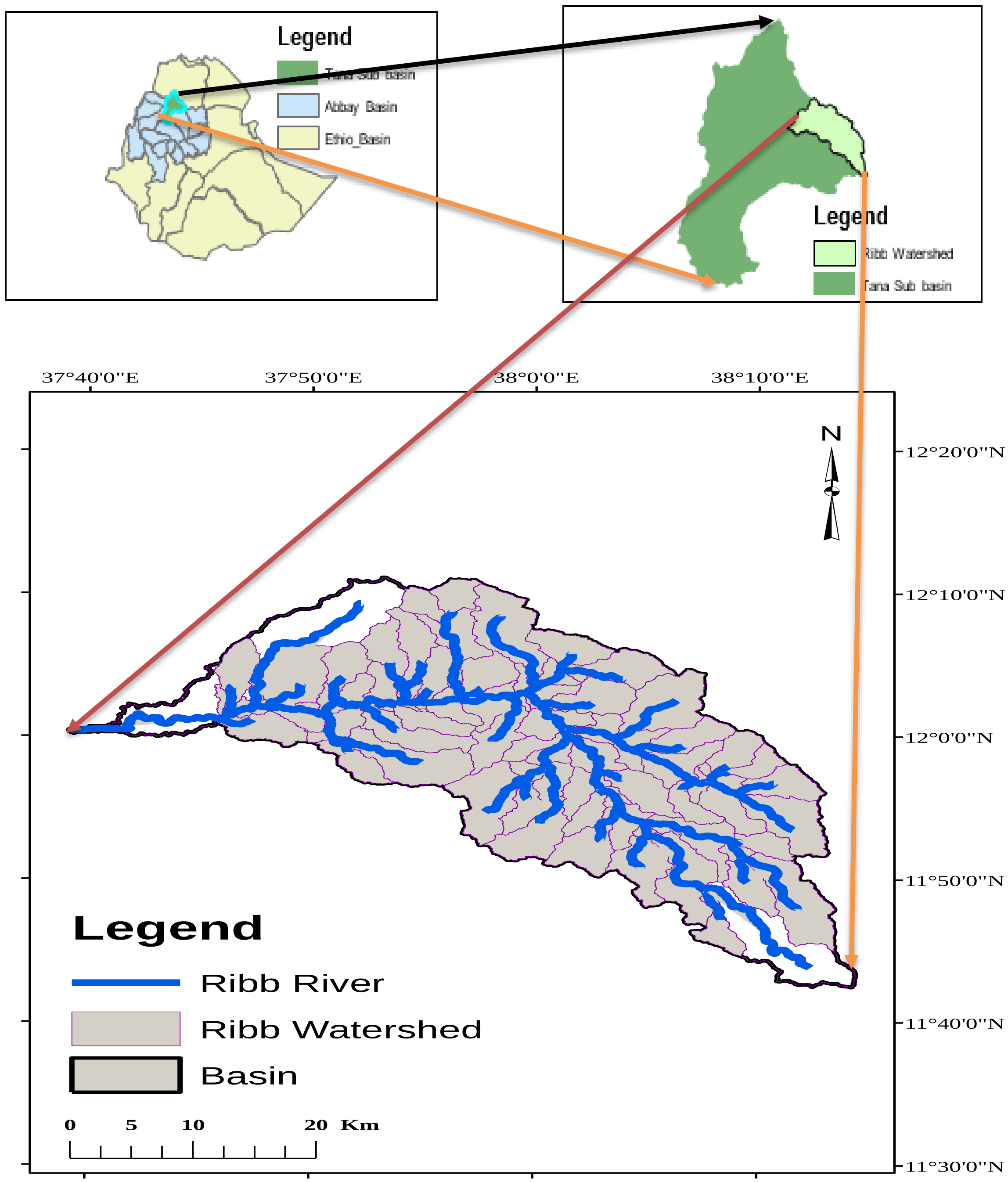

Figure 3.1: Location map of the study area

3.1.2 Geology

According to Ribb dam site investigation report of geologists, Ribb basin that is the sub basin of Lake Tana basin is dominated by a huge volcano system named as Gunna mountain shield volcano. The common rock type for this material is basalt with large amount of interbedded lava, volcanic ash and other acidic rocks such as rhyolite and trachyte with rare ignimbrites. Agglomerates and paleo-soils are also common. The other smaller volcanoes located in northern part of the basin are also considered having been active during the same geological period as Gunna volcano. At the end of the Ribb River (near Addiszemene), the area is completely overlain by recent flood materials, which are mainly covered by silt to clayey deposits (Getnet, 2011).

3.1.3 Climate

There is high spatial and temporal variation of rainfall in the study area. The main rainfall season which accounts around 70-90% of the annual rainfall occurs from June to September, while small rains also occurs during December to March.

The monthly rainfall distributions of the study area indicate that July and August are the wettest months of the year in all the selected stations.
The mean monthly rainfall of Addis Zemene, Debre Tabor, Gassay and Woreta stations for the time period of 1990-2018 is shown in Figure 3.2.

Ribb watershed is characterized with High wurch on southern edges, wet dega and Wet Woyna Dega in the northern area agro-climatic zones, with altitude ranges from 1,788m a.s.l near Lake Tana to 4,112m a.s.l at Gunna Mountain. The watershed area represents humid, with moderately cool to high frost, agro-climate. Mean annual rainfall over the Ribb dam site watershed is larger than 1400 mm . Rainfall over the Ribb watershed is mono-modal. The mean monthly precipitation and temperature were 426mm and 15.5^{o}c respectively.

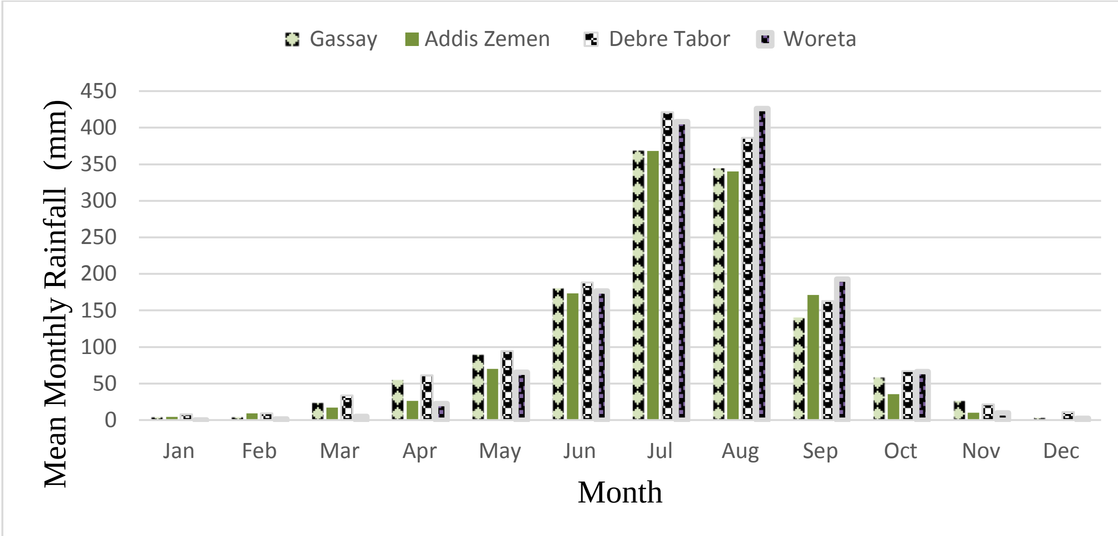

Figure 3.2: Long-term mean monthly rainfall distribution of the study area (1990-2018)

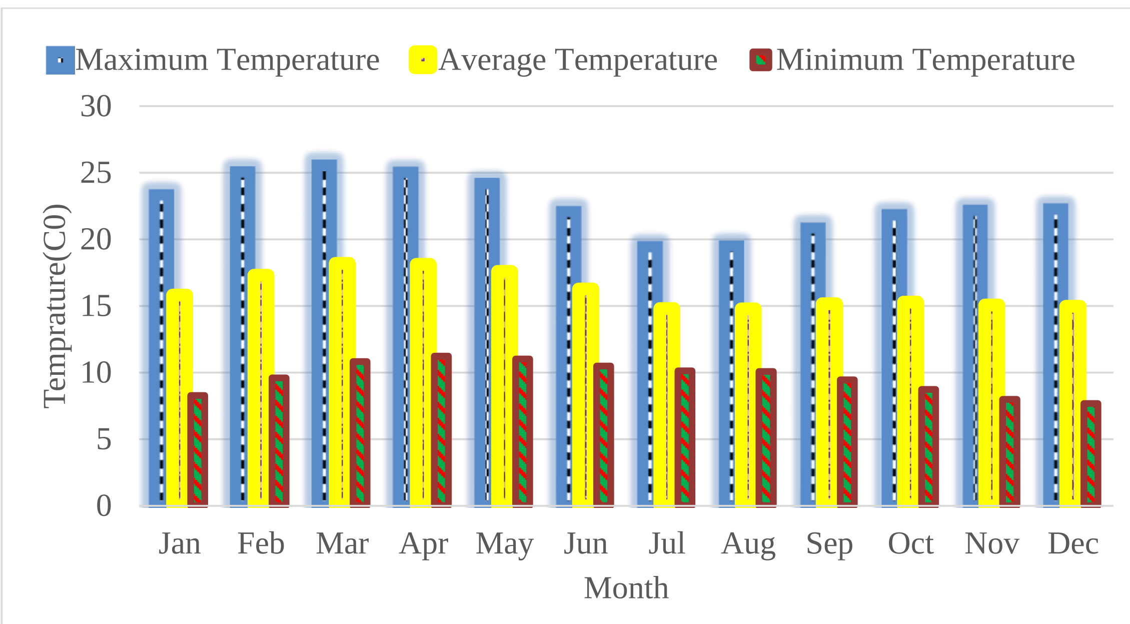

Figure 3.3: Long -term monthly temperature distribution of study area (1990-2018)

3.2 Materials

The main tools (materials) used for input data preparation and analysis were: Arc GIS 10.4.1, Arc SWAT 2012, SWAT-CUP, ERDAS, Weather generator, Microsoft Office Word 2016, Microsoft Excel 2016, DEM, Soil map, Meteorological data and Hydrological data.

3.3 Model Input Data Collection and Analysis

SWAT model is highly data intensive that requires specific information about the watershed such as topography, land use land cover, soil properties, weather data, and other land management practices. These data were collected from different sources and databases. Generally, the necessary data collected for this study can be classified as spatial and time series data (Figure 3.4). Spatial data used in this study were digital elevation model (DEM), land use/cover and soil map of the study area. Figure 3.4, shows the way of data collection up to model run. In this figure, like flow data transfer, data filling, consistency and homogeneity test will be discussed in section (3.5, 3.6 and 3.7) and in addition to this watershed delineation (flow direction and accumulation, stream networking, outlet selection and watershed delineation) again will be discussed in the section 3.5.

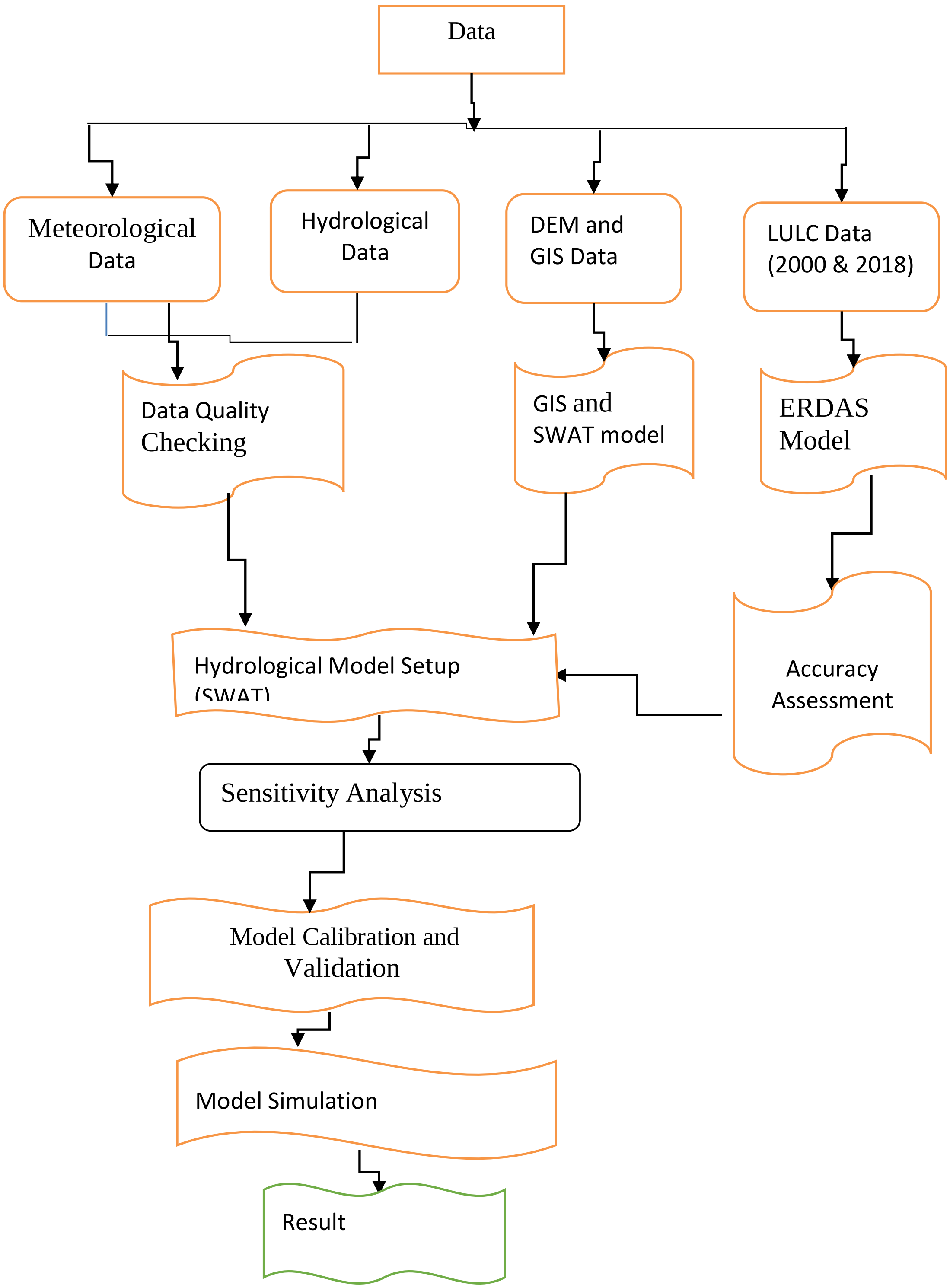

Figure 3.4: Conceptual framework

3.4 Data Availability and Analysis

For proper implementation of this study, different tools like Arc GIS, ERDAS and SWAT model would be used to compile the SWAT input files. The systematic study of land use land cover impacts requires good and adequate data to assess the changes clearly. Parameterization of SWAT model and assessment of hydrologic impacts of land use change were performed based on the spatial and time series data sets available and other data sets obtained by remote sensing.

3.4.1 Time series data

Time series data that were collected for proper implementation of this study were precipitation, minimum and maximum temperature, wind speed, relative humidity, solar radiation and hydrological data. Climate data were obtained from the national meteorological agency (NMA) of Ethiopia whereas hydrological data were collected from Ethiopian ministry of water, irrigation and electricity (MoWIE). The data availability and sources of the selected hydro-climatic stations were presented in Table 3.2

The selection of hydro-climatic stations has been implemented based on the following three criteria: (i) gaps (missing value) in the time series, (ii) homogeneity of the time series, and (iii) consistency.

Filling the missing data

Rainfall data play a central role in developing rainfall - runoff - soil loss models. Measured precipitation data are important to many problems in hydrologic analysis and design. For gauge that require periodic observation, the failure of the observer to make the necessary visit to the gage may result in missing data. Damage of recording gauge is another problem that results in incomplete data records and instrument failure because of mechanical or electrical malfunctioning can result in missing data.

For this study, the two procedures for estimating daily totals rely on the data from any adjacent stations. The locations of the adjacent stations are such that they are close to and approximately evenly spaced around the site with the missing data. When the difference between the average annual rainfall at any of the adjacent stations and the missing data station is, greater than10% a normal ratio method is normally used (Silva et al., 2007).

$$P_X = \frac{N_X}{n}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \cdots \ldots \ldots \ldots \ldots \frac{P_n}{N_n}\right] \qquad 3.1$$

Where P_x is the precipitation for the station with missing records and P_1, P_2, P_n are the adjacent stations precipitation values. N_1, N_2, N_n are the long-term mean annual precipitation values at the respective stations and "n" is the number of stations surrounding the station X.

$$percent\ of\ differrence = \left[\frac{N_x - N_i}{N_x}\right] * 100 \qquad 3.2$$

In which N_x is the normal annual rainfall amount from the missing data station and N_i is the normal annual rainfall amount from one of the nearby stations (Richards, 1998). The normal ratio method was adopted to fill missing air temperature data.

Areal Precipitation

The average rainfall over the basin has to be determined from the point measurements for use in practical hydrological applications. In order to achieve accurate estimation of the spatial distribution of rainfall, it is necessary to use interpolation methods, for this, the Thiessen polygon method is considered as the most important in engineering practice. This method assigns weight at each gauge station in proportion to the catchment area that is closest to that gauge. Thiessen polygon was used also for this study for its sound theoretical basis and availability of computational tools. Although it is widely used in engineering practice, this method has also its shortcomings. For example, in mountainous areas, an irregular spatial distribution of precipitation can be formed over small distances, and for such circumstances, the Thiessen polygon method can yield inaccurate results. A Thiessen polygon result in the Arc GIS gives the following areal distribution of rainfall in the four metrological stations.

Table 3.1: Areal Precipitation Coverage

Station Name	Longitude (degree)	Latitude (degree)	Elevation (m)	Areal Precipitation Coverage (km^2)
Addis_Zemene	37.77	12.12	1940	422.31
Debre_Tabor	37.99	11.87	2612	532.65
Gassay	38.13	11.80	2789	324.73
Woreta	37.70	11.92	1819	56.18

Consistency test

A consistent record is the characteristics of the record have not changed with time. Adjusting for gauge consistency involves the estimation of an effect rather than a missing value. The checking for inconsistency of the record was done by the double-mass curve technique. This technique was based on the principle that when each recorded data comes from the parent population, they are consistent. The double mass curve technique was used to adjust precipitation records to take account of non-representative factors such as change in location or exposure of rain gauge. The accumulated totals of the gauge in question were compared with the corresponding totals for a representative group of nearby gauge. If significant change in the regime of the curve was observed, it should be corrected (Dahmen and Hall, 1990).

Before precipitation records were used in such studies, they should be tested to ensure that any trends detected were due to meteorological causes and not to changes in gauge location, in exposure, or in observational methods. If the changes detected are not due to meteorological causes, a precipitation record can usually be adjusted by coefficients determined from the double-mass curve using equation 3.3.

The double mass curve is used to check the consistency of many kinds of hydrologic data by comparing data for a single station with that of a pattern composed of the data from several other stations in the area. The double-mass curve method was applied for consistency check in this study as shown in the figure 3.5

$$P_{cx} = P_x \frac{M_c}{M} \qquad 3.3$$

Where P_{cx} is corrected precipitation x at any time period, P_x is the original recorded precipitation, M_c is corrected slope of double mass curve and M is original slope of double mass curve.

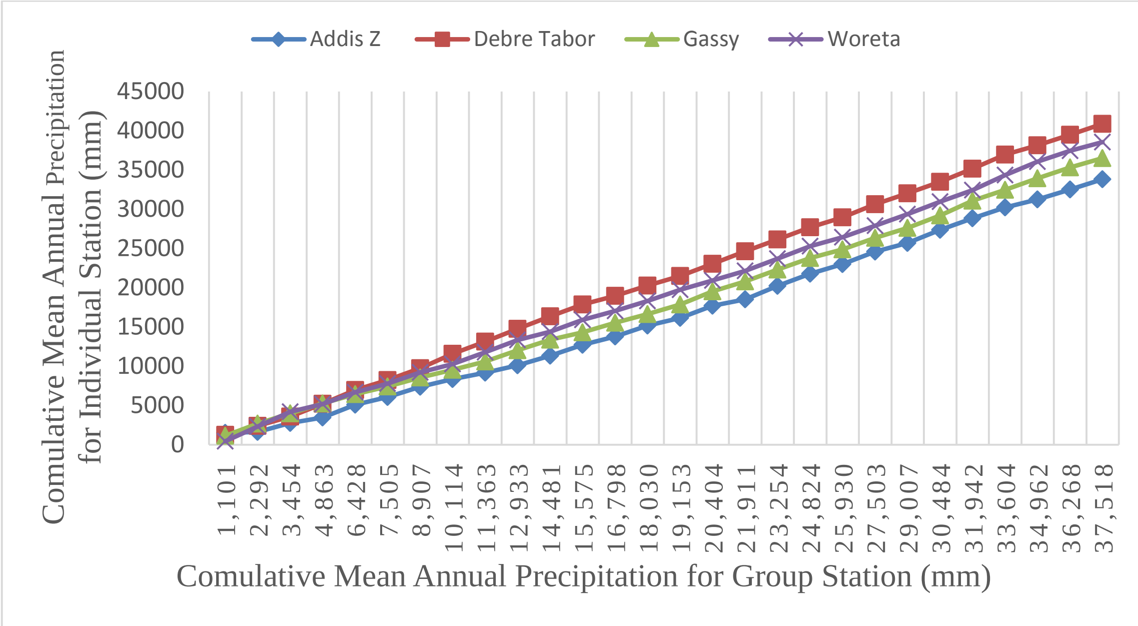

Figure 3.5: Consistency test of all stations used for Ribb Watershed

According to the double mass curves above since the stations used in this study has not undergone a significant breaks in their slope all the stations were found to be consistent for the period of study.

Homogeneity Test

Availability of a long-term, continuous and homogeneous precipitation series is always essential for climate and hydrologic studies.

Inhomogeneity resulting from different factors may introduce a bias in a time series by hiding true climatic patterns. Consequently, it is important to assess the homogeneity of long climate records before they can be used reliably.

The non-dimensional rainfall record is one of the methods to check homogeneity of the monthly rainfall data. In this method, the recorded precipitation data of the selected station in the watershed was plotted to compare the stations with each other. Non_dimensional values of the monthly precipitation of each station were computed using equation 3.4

$$P_i = \frac{P_{i,ave}}{P_{ave}} * 100 \qquad 3.4$$

Where P_i is the non-dimensional value of precipitation of the month in the station i, $P_{i,ave}$ is the over years averaged monthly precipitation for the station i, and P_{ave} is overall years averaged yearly precipitation of the station i.

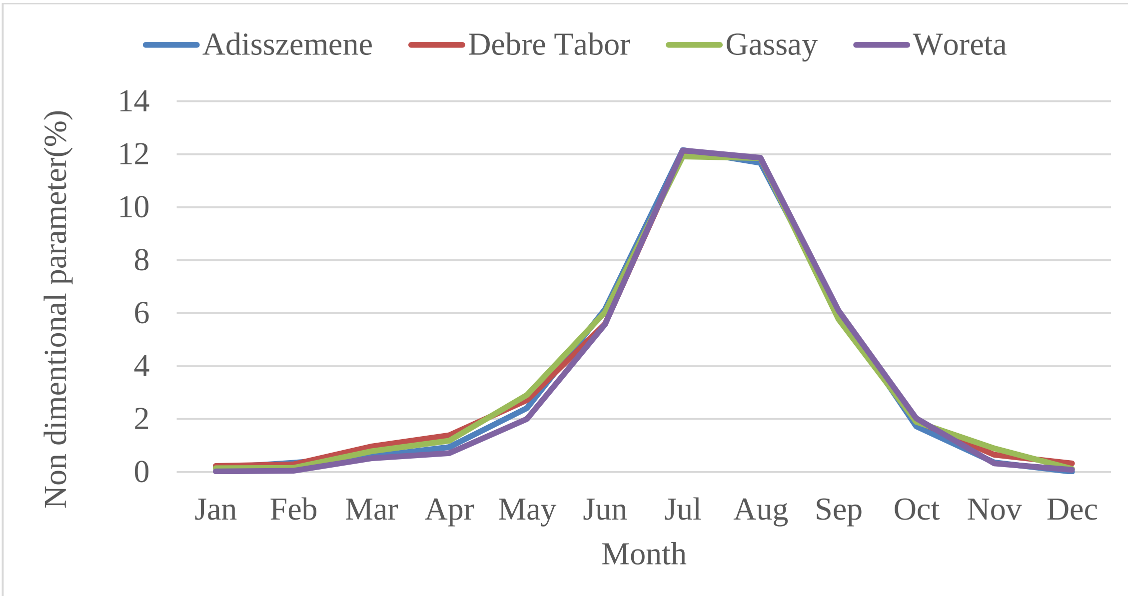

Figure 3.6: Homogeneity test of rainfall stations

3.4.1.1 Hydrology

The Ribb River, which is a major tributary to Lake Tana, originates at mainly Gunna Mountain at the elevation of 4112m a.s.l. Some of the major tributary stream includes Hamusit, which collects surface runoff from the eastern parts and Kolay, which collects from western parts (Getnet, 2011). The river flows generally in a westerly direction and empties into Lake Tana. Daily flows of Ribb River recorded for 18 years (1990-2007) was used.

The gauging stations is located near Addis Zemen at Bahir Dar to Gonder highway bridge (1,592Km^2) and the river discharges mean annual average of 15.17m^3/s (1990-2007). The upper section of the valley runs to the north, following the Gunna flows direction, while downstream of the dam site it runs westwards to join Lake Tana.

Filling of Missing Stream Flow

Before beginning any hydrological analysis, it is important to make sure that the data are homogenous, sufficient, and complete data. Based on visual examination, stream flow records of Ribb river near Addiszemene has a good quality of flow data that shows strong serial correlation. There was a relation between values of one day to the previous and coming days especially during low flows.

The station has a small number of missing data in the study base line (1990-2007). Flow in Ribb River depends on the rainy season, which occurs from June to September and light rains were experienced in other seasons.

Hence filling of the missing data was made by making a relation within the data of the gauge itself. The methods used for filling of missing flow data are linear regression, recession curve method and interpolation. For this study linear regression method was applied due to the missing data were observed only during the short periods.

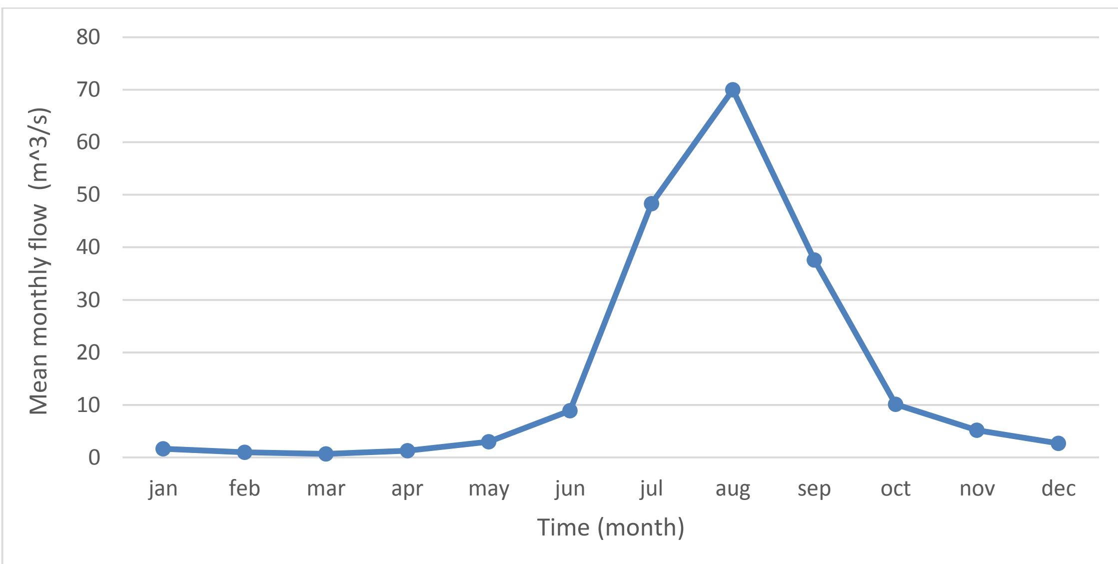

Figure 3.7: Mean monthly average discharge of Ribb River near Addis Zemen

(1990-2007)

3.4.2 Spatial data

Spatial data sets that were collected for this study was digital elevation model (DEM), land use and soil. The 30 m resolution DEM that clipped from the ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) and land cover satellite data were obtained from the NASA website, where as the Soil data was collected from Ethiopian ministry of water, irrigation and electricity (MWIE) (Table 3.2).

Table 3.2: Details of Spatial Data

Sr. No.	Data type	Resolution	Source
1	DEM	30m x 30m	MoWIE
2	Landsat image	30m x 30m	NASA Website
3	soil	30m x 30m	MoWIE

3.4.2.1 Digital Elevation Model (DEM)

The DEM was used to delineate the watershed and to analyze the drainage patterns of the land topography. Topography could be defined by a DEM that describes the elevation of any point at specific area of a given spatial resolution. A Digital Elevation Model of 30 m by 30m, in the Grid format and projected was used in this study and the original DEM in geographic coordinate system was obtained from Ethiopian Ministry of water, Irrigation and Energy bureau GIS Department and the study area DEM was extracted/delineated from SWAT shown (figure 3.9).A 30-m resolution DEM were be used in extracting stream network and delineating watershed and sub-watersheds.

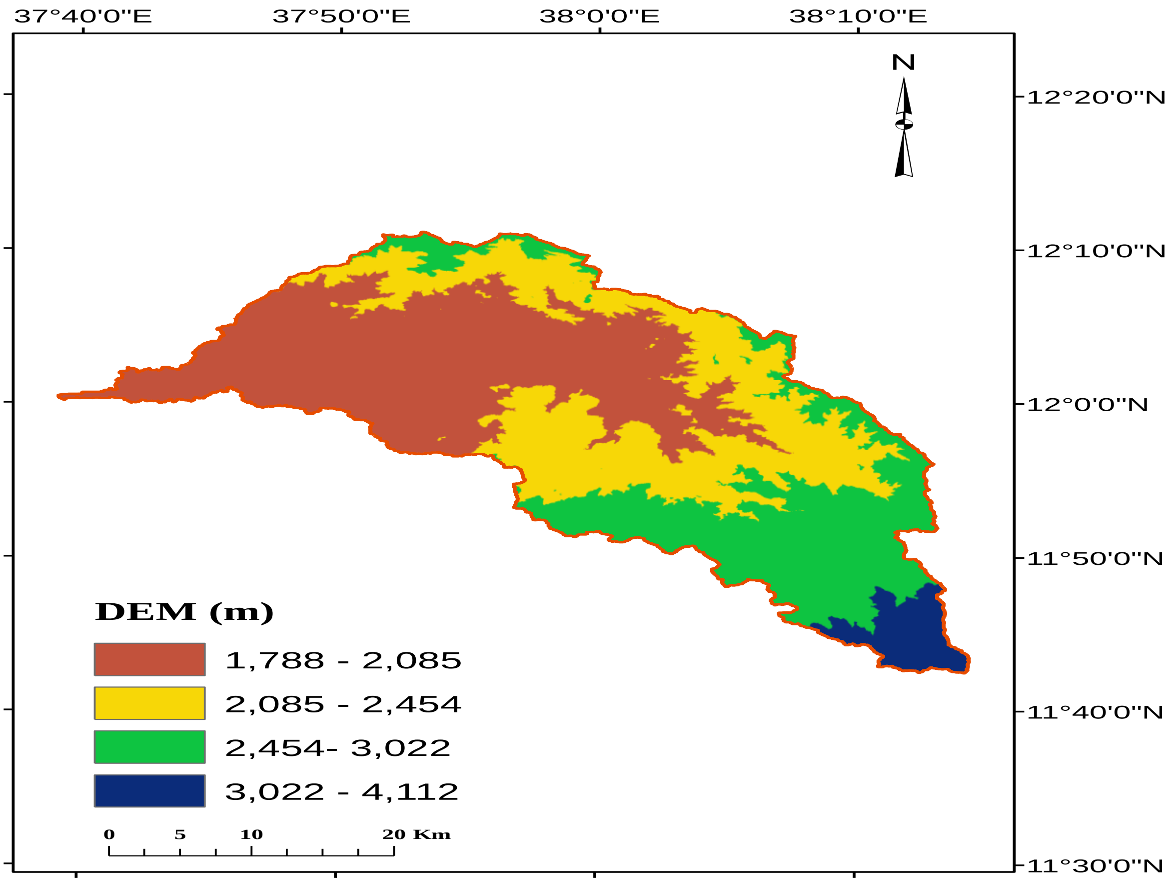

Figure 3.8: Digital elevation model of Ribb watershed

3.4.2.2 Land use land cover

Image Classification

Two satellite images (Landsat-7ETM+ 2000 and Landsat-8 OLI–TIRS 2018) with 30 m spatial resolution were used for the LULC change analysis of the studied watershed. Details of the images characteristics were tabulated in table 3.3. The data required for the study were collected from various sources. Landsat data were downloaded free of charge from U.S Geological Survey (USGS) Center for Earth Resources Observation and Science (EROS) (https://earthexplorer.usgs.gov/).

Since the objective of this study requires the land use land cover impacts, LULC image classifications were carried out to extract useful thematic information Boakye et al. (2008) from the Landsat images .Preprocessing tasks such as geometric and radiometric corrections Giriraj et al. (2008), Schulz et al. (2010), Teferi et al. (2010), Mosammam et al. ((2016), Temesgen et al. (2018) were applied before classifying the images.

Image classifications were undertaken using the hybrid classification technique, which combines both unsupervised and supervised classification techniques (Teferi et al., 2010; Solomon et al., 2014). The hybrid classification technique improves the classification accuracy better than using either unsupervised or supervised classification techniques alone (Lillesand and Kiefer, 2000). Primarily, unsupervised classification using Iterative Self-Organizing Data Analysis (ISODATA) clustering Boakye et al. (2008) and Teferi et al. (2010) method was undertaken as a baseline for collecting ground truth points. Using signature editor of unsupervised classes, a pixel based supervised classification with Maximum Likelihood Classification (MLC) algorism Solomon et al. (2014) and Temesgen et al. (2014) was undertaken using the ground truth points collected from each LULC category. The LULC classes together with their descriptions were presented in Table 2.1.

In classifying the 2000 and 2018 images, reference data from Google earth images from the corresponding time periods were collected. ERDAS Imagine 2015 and Arc GIS10.4.1 software were used for image classification and mapping purposes, respectively. Since SWAT has a predefined land use identified by four letter codes and uses these letter codes to link land use map of the study area to SWAT land used at a bases in the GIS interface the two predefined land use land covers maps (LULC of 2000 and 2018) were converted in to SWAT code land use land cover which is embedded in SWAT land use databases.

Lastly, the look up table of land use land cover types in SWAT compatible way was prepared which is basic for loading of the land use land cover of the study area in to the project set up. The classified land use land cover of the study area of the two reference years are summarized below.

Table 3.3: Satellite Images Used For LULC Change Analysis and Their Characteristics

Satellite image	Path/Row	Sensor	Resolution	No.of bands	Date of acquisition	cloud cover
Landsat_7	169/52	ETM+	30	8	2000-01-14	0
Landsat_8	169/52	OLI-TIRS	30	11	2018-01-17	0

Accuracy assessment

There is no classification created from remote sensing data that can be completely accurate as error originate from different sources including the classification algorithm itself. The accuracy assessment was used to determine the correctness of the classified image. It was performed using confusion matrix. Using the original image and the Google Earth Image as a reference, randomly selected points were compared with the corresponding classification. Table 4.1 and 4.2 show a confusion matrix for the two Landsat images.

Accuracy assessment is to quantitatively determine how effectively pixels were grouped in to the correct feature classes in the area under investigation. Accuracy is defined as "correctness" i.e. it measures the agreement between a standard assumed to be correct and a classified image of the unknown quality. Accuracy assessment compares two source of information:

1. Pixels or polygons from a classification map developed from remotely sensed data and
2. Ground reference test information, if the image classification corresponds closely with the standard, it is to be "accurate".

In a statistical context, high accuracy means that bias is low (that estimated values are consistently close to an accepted reference data).

Ground Verification

Ground truth is factual data that has been observed or measured, and can be analyzed objectively it should not be secondary. Traditionally, the accuracy is determined empirically by comparing with corresponding reference or ground data wherein the results are tabulated in the form of square matrix known as confusion matrix.

Source of Classification Error

In manual interpretation, errors are caused by:

- Misidentification of parcels
- Errors in registration
- Excessive generalization
- Variations in detail of interpretation, and other factors

Data Requirements, Sampling Approach and Sampling Size

Since it is impractical to have a complex pixel-by-pixel "ground truth" map adequate subset or sample number of points (pixels) is needed for there to be a rigorous accuracy assessment of classification. One must use an appropriate sampling technique that meets statistical requirements. A stratified random sample is a multinomial sampling methods, and therefore is an appropriate sampling method to be used with the kappa statistic. With the stratified random approach, points are stratified by map category, and simple random sampling is employed with each stratum (Stehman, 1992).

Once the sampling design has been determined, the number of sample points must be determined. The number of reference pixels required for accuracy assessment depends on the minimum level of accuracy (Appendix B .1 and Appendix B .2).

Overall accuracy

The overall accuracy gives the overall results of the confusion matrix. It was calculated by dividing the total number of correct pixels (diagonals) by the total number of pixels in the confusion matrix.

$$\text{All over accuracy} = \frac{total\ number\ of\ corrected\ diagonal\ pixel}{Total\ number\ of\ pixel\ in\ the\ matrix} \qquad 3.5$$

Producer's Accuracy

The producer's accuracy tells us how well a certain area could be classified. It is obtained by dividing the number of correctly classified pixels in the category by the total number of pixels of the category in the reference data. The producer's accuracy is also known as an Omission Error, which is the probability of a reference pixels being classified correctly. It gives only the proportion of correctly classified pixels.

$$\textbf{Producer's Accuracy} = \frac{Number\ of\ corrected\ pixel\ in\ the\ digonal}{column\ total\ in\ the\ matrix} \qquad 3.6$$

User's Accuracy

It is the ratio between the total number of pixels correctly belonging to a class (diagonal elements) and the total number of pixels assigned to the same class by the classification procedure (row total). This quantity explains the probability that a pixel of the classified image truly corresponds to the class to which it has been assigned.

$$\textbf{User's Accuracy} = \frac{Number\ of\ corrected\ pixel\ in\ the\ digonal}{row\ total\ in\ the\ matrix} \qquad 3.7$$

Kappa Coefficient (K)

Kappa is a measure of the difference between the observed agreements between two maps as reported by the diagonal entries in the error matrix.

$$K = \left[\frac{(TS*TCS)-(\sum CT*RT)}{(TS^2)-(\sum CT*RT)}\right] * 100\% \qquad 3.8$$

Where:

TS=Total number of sample

CT=Column total

RT=Raw total

TCS=Total corrected sample

The resulting kappa measures compensates for chance agreement in the classification and provides a measure of how much better the classification performed in comparison to the probability of random assigning of pixels to their correct categories.

Accuracy assessment was done to understand the representation of the classified images on the ground (Congalton, 1991; Congalton and Green, 2002; Congalton, 2005; Temesgen et al., 2014; Mosammam et al., 2016).

Accuracy assessment was commonly reference to other images (Congalton, 1991; Congalton and Green, 2002; Foody, 2002; Congalton, 2007; Mekuria, 2005; Gessesse and Kleman, 2007; Schulz et al., 2010; Teferi et al., 2010). To do accuracy assessment for the classified images, 380 random sample points in ERDAS 2015 was created. Reference points were collected for the 2000 and 2018 classified images from the corresponding Google Earth images (i.e. 20 February 2000 and 14 January 2018, respectively). Then, the classified images were compared with the reference images by means of error matrix (Foody, 2002; Schulz et al., 2010; Rientjes et al., 2011; Ariti et al., 2015). Various measures of accuracy assessment such as producer accuracy, user accuracy Congalton (1991) overall accuracy and Kappa coefficient were done.

Land use land cover change

Change analysis is usually done to demonstrate the patterns of changes and to make useful decisions. Several research illustrated after classification comparisons e.g. Gete and Hurni, (2001), Belay (2002), Schulz et al. (2010), Abate (2011), Rawat and Kumar (2015) and Mosammam et al. (2016) between the subsequent periods were made to illustrate the changes between the periods. Conversion matrix between 2000 and 2018 periods were also done to distinguish the changes of each category at the expense of others (Mekuria 2005; Giriraj et al., 2008; Diress et al., 2010; Teferi et al., 2010; Abate 2011; Rientjes et al., 2011). Percent of change and rate of change were also computed to demonstrate the magnitude of the changes experienced between the periods using equations 3.9 and 3.10 respectively (Ebrahim and Mohamed, 2017; Abate, 2011; Temesgen et al., 2014).

$$percent\ of\ change = \left(\frac{X-Y}{Y}\right) * 100 \tag{3.9}$$

$$rate\ of\ change\ (ha/year) = \left(\frac{X-Y}{Z}\right) \tag{3.10}$$

Where, X is area of LULC (ha) at time 2, Y is area of LULC (ha) at time 1, Z is time interval between X and Y in years.

3.4.2.3 Soil data

Soil types have a great influence on runoff potential through making impact on infiltration rate of the catchment. During modeling of watersheds using SWAT tool, one of the main inputs the model needs is the soil properties for the basin. The soil data needed can be divided into physical characteristics (required) and chemical characteristics (optional).

Hydrological soil type and parameters classification considers the physical properties of soils including texture, infiltration capacity, and particle size and soil structure. They had been obtained from Ethiopian Ministry of water, Irrigation and Energy bureau GIS Department.
They play a large role in determining the movement of water and air within the HRU

According to soil data of MWIE, in Ribb watershed four main soil types are found, which include Lithosols, Cambisols, Luvisols and Vertisols.

These soil types are different in texture, structure, depth, infiltration capacity and chemical property. In the study area, textures vary greatly both vertically within the soil profile and spatially across the area. Almost every possible texture can be found somewhere in the study area.

Vertisols has a capacity of higher infiltration because of its crack during the dry season and during the summer, the soil attains its field capacity, which leaves much of the precipitation forms surface runoff which generating higher stream flow. There are Vertisols in valleys along rivers and streams particularly around the proposed dam/reservoir site up to river gauging station.

Luvisols soil formed in the south to north through south-west (large belt crossing from north-east west and west-north) of the watershed from the basaltic rock capare deep, well structured, inherently well drained and relatively productive agricultural soil. The second large group of soil in the watershed is Lithosols on the northern reach with some at the north east and very small on the southern part.

This soil is on hill slopes partly on continued hard rocks and partly gravels. The soil is limited in depth having calcareous material or cemented layer within 30 to 40cm depth. The major soils of the watershed are therefore Luvisols (51.97%), Lithosols (31.80%), and Vertisols (15.76%) in their respective area coverage.

The soils seem to have derived from basalt sand tuffs. They are brownish to reddish in color, clay-to-clay loam and sandy-to-sandy loam in texture, well-drained but very shallow on steep slopes. The Luvisols, Lithosols and Vertisols have good inherent fertility and agricultural productivity, although those some portion of Lithosols on the mountain ranges and hillsides are severely eroded and further prone to soil erosion (Table 3.4 and Figure 3.10).

Hence in order to integrate soil map with the SWAT model it is necessary to make user soil database containing the above characteristics of the soil.

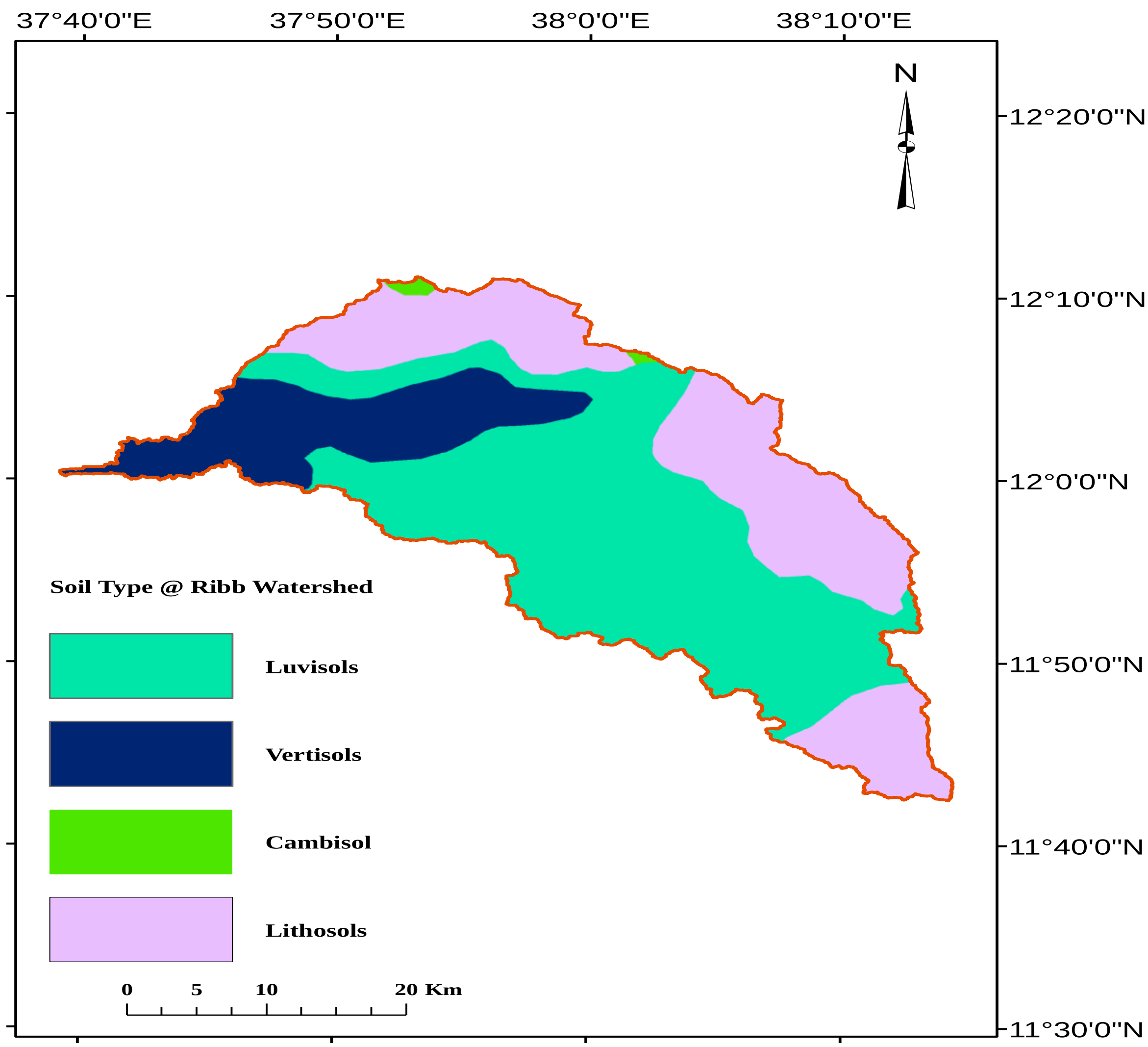

Figure 3.9: Soil type at Ribb dam watershed

Table 3.4: Soil Type of Ribb Watershed

Sr.No.	Types of Soil	Coverage (%)
1	Luvisols	51.97
2	Lithosols	31.80
3	Vertisols	15.76
4	Cambisols	0.46

3.5 Model Setup

SWAT model set up involved five steps including data preparation, sub-basin discretization (Watershed Delineation), HRU definition, parameters sensitivity analysis and calibration and uncertainty analysis.

3.5.1 Watershed delineation

After model input preparation, model setup was the next step. The database containing user soils and weather generator was copied to the new folder that contains all the necessary input data. The watershed delineation was performed using 30 m resolution DEM using Arc SWAT12 watershed delineator.

First the SWAT project setup was created using the folder contain all input data and SWAT12 database. The watershed delineation process consists of six major steps, DEM setup, stream definition, outlet and inlet definition, watershed outlet selection and adding reservoir and calculation of sub basin parameter.

User selected threshold stream definition plays important role in determining the detail of the stream network and the size and number of watershed. The smaller the number of hectares the more detailed the drainage network delineated. Ribb River watershed was delineated in to 32-sub water shade with an area of 1,335.87km^2 by selecting the outlet at Bahir Dar to Gonder Road near Addis Zemen station. During the watershed delineation process the elevation of the watershed ranges from 1788 to 4112 a.m.s.l. The highest elevation of the watershed is about 4,112 m in its southeastern part, where at the dam site the elevation drops below 1,900 m. The description of the delineation process was described in the following section.

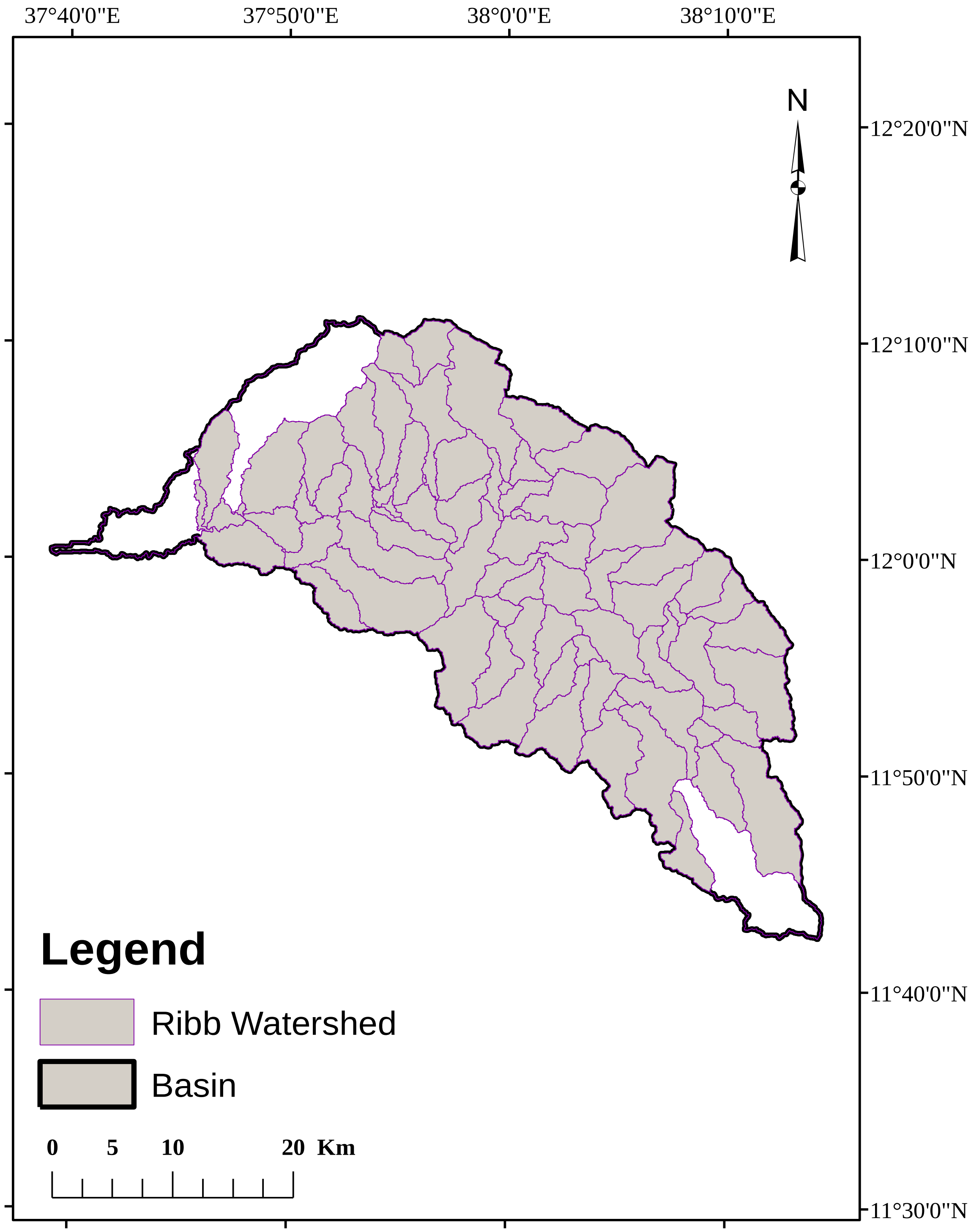

Figure 3.10: Ribb watershed sub basins

3.5.2 Hydrologic response unit analysis (HRU)

After the overlay of the land use, soil and slope maps was completed, the next step was HRU definition. Dividing the watershed in to unique land use, soil and slope combinations help the SWAT model to reflect difference in hydrological conditions for the different land use, soil and slope. There are two options in the model to define HRU. The first one is a single HRU to each sub-watershed and the second one is multiple HRUS to each sub watershed based on threshold values. Threshold value is used to remove minor land use/covers in sub basins, minor soil with in a land use/cover area and minor slope classes in a soil classes with in a soil on specific land use/cover area (Geremew, 2013).

For this study, multiple options and 15% land use threshold, 15% soil threshold and 10% slope threshold was used for HRU definition. This means minor land use less than 15% in sub-watershed was removed, minor soil less than 15% in a land use was removed and minor slope classes less than 10% in a soil classes with in specific land use/cover was removed.
Ribb River Catchment was divided in to 469 HRUs and 78 sub-watersheds, each HRUs contain unique land use land cover, soil and slope combinations.

3.5.3 Slope classification

HRU analysis in in Arc SWAT requires slope class in addition to land use land cover and soils. SWAT lets the user to choose slope classification option as single or multiple and defines the range of the slope as necessary as possible if multiple slope class was selected. In this study an option of considering different slope classes for HRU definition was selected and the slope classes was classified in four range and the range were 0-5%, 5-10%, 10-15% and above 15%. The slope classification was made based on the DEM data used during the watershed delineation.

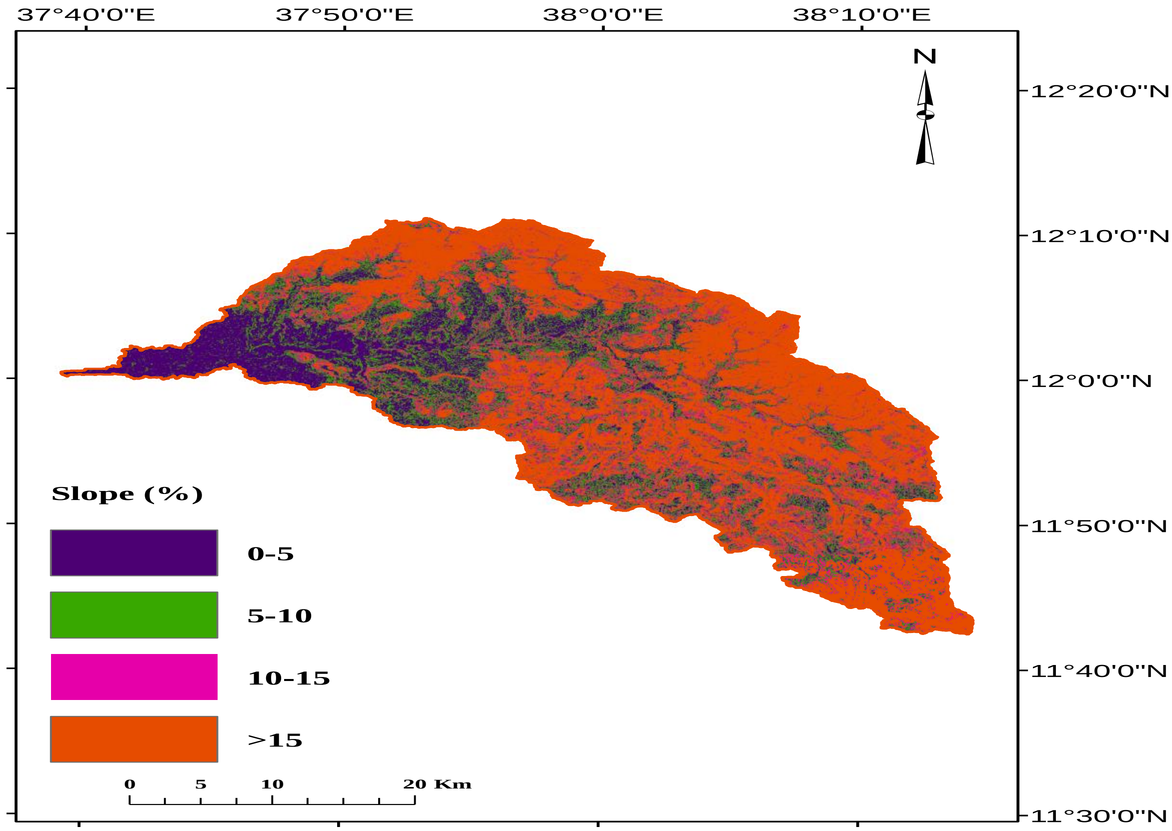

Figure 3.11: Slope classification of Ribb watershed by SWAT model

After all the overlay operation of the land cover map, soil map and slope were performed, the next step was determination of the distribution of hydraulic response units within the watershed. Defining the HRU having unique land use and soil combination enables the model to reflect the model differences in evapotranspiration and other hydrologic conditions for different land use land cover and soils. In this study, the HRU distribution was determined by assigning multiple HRU to each sub watershed so that runoff and sediment was predicted separately for each HRU and routed to obtain the total runoff and sediment yield for the watershed. In multiple HRU definition a threshold percentage of 15%, 15%, 10% were used to represent land uses, soils and slope classes respectively in each sub basin.

3.5.4 Weather data

The SWAT model has a built-in weather generator to generate climate data for the whole basin using time series data of a single gauging station, which was used by (Schoul & Abbaspour, 2006). Weather data is needed by the SWAT model to simulate the hydrological process. The

data required for this study was collected from four stations within and around the study area: Addis Zemen, Debre Tabor, Gassy and Woreta. SWAT requires daily precipitation, maximum and minimum temperature, solar radiation, wind speed, and relative humidity as inputs.
The available weather data were obtained from Ethiopian National Meteorological Service Agency.

After sub-basin discretization writing up of the prepared weather data to the model were done. From the four weather stations, Debre Tabor was selected as a synoptic station for the weather generator. Missing values of climatic variables were supplied as the model input. These missed weather data were generated by model itself. SWAT uses the weather generator program (WXGEN) to generate weather data. It is used in SWAT model to generate climatic data or to fill missing data using monthly statistics which is calculated from existing daily data.

WXGEN parameter and location table of climate data (daily precipitation data files, maximum and minimum temperatures, wind speed, relative humidity and solar radiation which was calculated from the daily available sunshine hours data) were loaded with the missing data filled with a missing data identifier of -99 to link them up with the required files already created for the purpose. After loading all the input data and generating the required database files, SWAT model was initially run on daily basis using default parameter values. The entire simulation period is from 1990 to 2018.

3.5.5 Hydrological Balance

The model estimates relevant hydrologic components such as evapotranspiration, surface runoff and peak rate of runoff, ground water flow and sediment yield for each HRUs unit. SWAT is imbedded in a GIS interface. Arc GIS extension is a graphical user interface for the SWAT which is evolved from Arc SWAT which is an ArcView extension developed for an earlier version of SWAT(Arnold et al., 1998; Neitsch et al., 2011). The hydrologic cycle simulated by SWAT was based on the water balance equation (3.11).

$$\mathrm{SW_t} = \mathrm{SW_o} + \sum_{i=1}^{t} (\mathrm{R_{day}} - \mathrm{Q_{surf}} - \mathrm{E_a} - \mathrm{W_{seep}} - \mathrm{Q_{gw}}) \qquad 3.11$$

In which, SW_t is the final soil water content (mm water), SWo is the initial soil water content in day i (mm water), t is the time (days), R_{day} is the amount of precipitation in day i(mm water),

Q_{Surf} day is the amount of surface runoff in day i (mm water), E_a is the amount of evapotranspiration in day I (mm water), W_{seep} is the amount of water entering the vadose zone from the soil profile in day i (mm water), and Q_{gw} is the amount of return flow in day i (mm water). To estimate surface runoff two methods are available. These are the soil Conservation services (SCS) curve number Procedure USDA Soil Conservation Service USDA (1972) and the Green & Ampt infiltration method Green and Ampt (1911).

In this study, the SCS curve number method was used to estimate surface runoff. Hargreaves method was used for estimation of potential evapotranspiration (Hargreaves et al, 1985). The SCS curve number is described by equation (3.12).

$$Q_{surf} = \frac{(R_{day} - 0.2S)^2}{(R_{day} + 0.8S)} \qquad 3.12$$

In which, Q_{surf} is the accumulated runoff or rainfall excess (mm),R day is the rainfall depth for the day (mm), S is the retention parameter (mm).

The retention parameter is defined by equation (3.13).

$$S = 25.4\left(\frac{100}{CN} - 10\right) \qquad 3.13$$

The SCS curve number is a function of the soil's permeability, Land use and antecedent soil water conditions.

SCS defines three antecedent moisture conditions: I – dry (wilting point), II – average moisture, and III – wet (field capacity)

The moisture condition I curve number is the lowest value that the daily curve number can assume in dry conditions. The curve numbers for moisture conditions I and III are calculated from equations (3.14 and 3.15).

$$CN_I = \frac{CN_{II}}{2.3 - 0.013 * CN_{II}} \qquad 3.14$$

$$CN_{III} = \frac{CN_{II}}{0.43 + 0.0057 * CN_{II}} \qquad 3.15$$

In which CN_I is the dry condition curve number, CN_{II} is the average moisture condition curve numbers, and CN_{III} wet condition antecedent moisture curve number.

SWAT model divides a catchment into sub catchments. Each sub catchment is connected through a stream channel and further divided into a Hydrologic Response Unit (HRU). The HRU is a unique combination of a soil and vegetation types within the sub catchment.

Table 3.5: Default Selected Flow Parameters (Setegn et al., 2008)

Flow Parameter	**SWAT CUP Code**	Min Value	Max Value
SCS Runoff Curve Number	CN2	-0.2	0.2
Base Flow Alpha Factor (Days)	ALPHA_BF	0	1
Groundwater Delay (Days)	GW_DELAY	0	500
Soil Evaporation Compensation Factor	ESCO	0	1
Available Water Capacity of The Soil Layer	SOL_AWC	0	1
Groundwater "Revap" Coefficient.	GW_REVAP	0.02	0.2
Threshold Depth of Water in The Shallow Aquifer For "Revap" to Occur (Mm).	REVAPMN	0	500
Depth From Soil Surface to Bottom of Layer.	SOL_Z	0	3500
Channel Effective Hydraulic Conductivity	CH_K2	-0.01	500
Threshold Depth of Water in The Shallow Aquifer Required Return Flow to Occur (Mm).	GWQMN	0	5000
Plant Evaporation Compensation Factor	EPCO	0	1
Maximum Potential Leaf Area Index	BLAI	0.5	10
Maximum Canopy Index (Mm)	CANMX	0	100
Soil Conductivity (Mm/H)	SOL_K	0	2000

(MUSLE) (Williams, 1975).

$$Sed = 11.8(Q_{surf} * q_{eak})^{0.56} K_{USLE} * C_{USLE} * P_{USLE} * LS_{USLE} * CFRG \qquad 3.16$$

Where: Sed is defined as Sediment yield for a single event (Mg),

Q_{surf} is volume of surface runoff (m^3),

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

K_{USLE} is the USLE soil erodability factor

C_{USLE} is the USLE crop management factor or cover management factor,

P_{USLE} is the USLE support practice factor,

LS_{USLE} is the USLE topographic factor, and

CFRG is the coarse fragment factor.

3. 5.6 Model parameterization

SWAT model has many flow and sediment related parameters (table 3.5 and 3.6). The parameters range in the study area were fixed based on the literature previously adopted.

Table 3.6: Default Selected Sediment Parameter (Setegn et al., 2008)

Parameter	**SWAT CUP Code**	Min Value	Max Value
USLE support practice factor	USLE_P	0.00	1.00
USLE soil erodability factor	USLE_K	0.00	0.65
Linear factor for channel sediment routing	SPCON	0.0001	0.01
Exponential factor for channel sediment routing	SPEXP	1.00	1.50
Channel erodability factor	CH_COV1	-0.05	0.6
Channel cover factor	CH_COV2	-0.001	1.00
Channel erodability Factor	Ch_Erod	0.00	1.00
USLE cover factor	USLE_C	0.00	1.00

3.5.7 Model sensitivity analysis

A sensitivity analysis was done to identify the most sensitive parameters of SWAT for the model calibration and validation. Before calibration and validation, SWAT model sensitivity analysis was analyzed by using different hydrological parameters for both flow and sediment yield (Setegn et al., 2010; Setegn et al., 2009). It is important to identify sensitive parameter for a model to avoid problems known as over parameterization (van Griensven et al., 2006).

The sensitivity analysis was performed by using SWAT interface for a period of 1990-2018 for Ribb watershed using different hydrological parameters.

3.5.8 Model calibration

There are three calibration approaches widely used by the scientific community. These are the manual calibration, automatic calibration and a combination of the two. Manual calibration is the most widely used approach. However it is tedious, time consuming, and success of it depends on the experience of the modeler and knowledge of the watershed being modeled (Van Griensven and Meixner, 2007). Automatic calibration involves the use of a search algorithm to determine best-fit parameters. It is desirable as it is less subjective and due to extensive search of parameter, possibilities can give results better than if done manually.

SWAT has two built-in calibration tools. The manual calibration approach helps to compare the measured and simulated values, and then to use the expert judgment to determine which variable to adjust, how much to adjust them, and ultimately assess when reasonable results have been obtained. The auto-calibration technique was used to obtain an optimal fit of process parameters that is based on a multi-objective calibration and incorporates the Shuffled Complex Evolution Method algorithms (Green and Van, 2008).

Auto-calibration methods were implemented for the minimizing the difference between measured and predicted, stream flow and sediment yield. To calibrate and validate the SWAT model I have used SWAT Calibration Uncertainty Program 2012 version 5.1.2, the model use three types of algorithms including: Sequential Uncertainty Fitting (SUFI-2),Parameter Solution (Para Sol) and Generalized Likelihood Uncertainty Estimation(GLUE). For this study auto-calibration or Sequential, uncertainty fitting (SUFI-2) algorithms method was applied due to its easy implementation in comparison to other producers and the low number of model runs needed to reach good simulation.

The main objective of this calibration process is to create agreement between the sub basins simulated flow versus observed flow by adjusting the flow parameters in the recommended range. Before proceed to calibration process, the performance of the model was evaluated based on the SWAT simulation default results. All these statistical performance indicators were not in the acceptable limit which requires an adjustment for those most sensitive parameters through manual calibration.

The model calibration was run for a period of 12 years from Jan/1/1990 to Dec/31/2001. Of these periods of simulation, the first two year (1990 and 1991) was set as a worm up period. Therefore, the calibration performed for 10 years from Jan/1/1992 to Dec/31/2001.

Calibration for sediment yield carried out for a period of 10 years from Jan/1/1992 to Dec/31/2001. The default sediment parameters were adjusted by varying it iteratively in the recommended ranges until the acceptable limit of statistical performance evaluators optimized. Model calibration was performed by comparing simulated sediment yield versus observed sediment yield of gauging station based on sediment rating curve developed under (section 3.2.1.2).

Sediment yield calibration and sediment parameters adjustment continued iteratively until the simulated and observed sediment yield fitted and satisfactory model performance indicators obtained. The corresponding statistical model performance evaluators were checked between simulated and observed sediment yield graphically in monthly basis. This process was continued and rerun the model (Figure 4.5) until the satisfactory results obtained within the limited range. After adjusted of all the initial sediment parameters value, the following final results were accepted.

3.5.9 Model validation

Model validation is the process of representing that a given site specific model is capable of making sufficiently accurate simulation. The degree of accuracy of parameter estimates was assessed by applying the model to different data set that will not be used for calibration.

The goal of validation is to assess whether the model is able to forecast field observations for time periods that is different from the calibration period.

The model was validated by using an independent set of observed flow data that was not used for model calibration. Validation shows that once the simulated variable successful with corresponding observation, the model and its parameters are considered as the representative of the system of the study watershed.

The validation period of this study was from Jan/1/2002 to Dec/31/2007 and it is a total of six years (Figure 4.4).

Validation involves model run with unchanged flow parameters which was adjusted during calibration process. Based on the validation agreement between observed and simulated flow data on the monthly basis, the model performance indicator which was determined during calibration process also determined in this validation step.

In a similar manner, validation was done for flows again; it was applied for sediment yield. This step proceeds when the calibration period for sediment yield resulted in a good agreement between simulated and observed sediment yield. It was approved by statistical performance indicators result. Therefore, it was satisfactorily fitted value of sediment parameters.

The sediment yield validation period was performed from Jan/1/2002 to Dec/31/2007. It was conducted with an independent sediment measured data that was not used during the calibration period.

3.5.10 Model performance evaluation

Model evaluation is an essential measure to verify the strength of the model. In this study, three model evaluation methods were used by Moriasi et al. (2007) model evaluation guideline. These methods are (i) Nash-Sutcliffe efficiency (NSE), (ii) percent bias (PBIAS), and (iii) ratio of the root mean square error to the standard deviation of measured data (RSR). The Nash-Sutcliffe efficiency (NSE) is computed as the ratio of residual variance to measured data variances (Nash and Sutcliffe, 1970).

The Nash-Sutcliffe is calculated using equation 3.17.

$$NSE = 1 - \left[\frac{\sum_{i=1}^{n}({X_i}^{obs} - {X_i}^{sim})^2}{\sum_{i=1}^{n}({X_i}^{obs} - X^{obs\_mean})^2}\right] \tag{3.17}$$

Where:

${X_i}^{obs}$= observed variable (flow in m^3/s or sediment concentration in mg/l).

${X_i}^{sim}$= simulated variable (flow in m^3/s or sediment concentration in mg/l).

X^{obs_mean}= mean of n observed values.

n = number of observations.

The Percent bias (PBIAS) measures the average tendency of the simulated data to be larger or smaller than their observed counterparts (Gupta et al., 1999). The PBIAS is calculated with equation (3.18).

$$PBIAS = \left[\frac{\sum_{i=1}^{n}({X_i}^{obs} - {X_i}^{sim}) * 100}{\sum_{i=1}^{n}({X_i}^{obs})}\right] \tag{3.18}$$

The ratio of root mean square error to the standard deviation of measured data (RSR) is calculated as the ratio of the Root Mean Square Error (RMSE) and standard deviation of the observed data Moriasi et al. (2007) as shown in equation (3.19).

$$RSR = \frac{RMSE}{STDEV_{obs}} = \frac{\sqrt{\sum_{i=1}^{n}({X_i}^{obs} - {X_i}^{sim})^2}}{\sqrt{\sum_{i=1}^{n}({X_i}^{obs} - X^{obs\_mean})^2}} \tag{3.19}$$

Table 3.7: 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	0.75 < NSE < 1.0	$PBIAS \le \pm 10$
Good	0.65 < R^2 < 0.75	0.65 < NSE < 0.75	$\pm 10 \le PBIAS \le \pm 15$
Satisfactory	0.50 < R^2 < 0.65	0.50 < NSE < 0.65	$\pm 15 \le PBIAS \le \pm 25$

Unsatisfactory	$R^2 < 0.50$	NSE < 0.50	$PBIAS \geq \pm 25$

3.6 Operation and Management Practice in SWAT Model

After all calibration, validation, applicability of the model performance ensured and performance of the model well evaluated, the next procedure was identifying highly soil loss sub basins in the watersheds. This step used in this study to implement sediment reduction methods or management practice or operation practice. Therefore, In the process of planning water resource project, practical measures to prevent the occurrence of soil erosion are important. Comprehensive planning of land and water management is adapted to local Conditions. It is important to coordinate measures involving vegetative planting, engineering practices, conservation tillage and sheet and gully erosion control so as to secure the best integrated benefits of various conservation measures (Dilnesaw, 2006).

3.6.1 Scenario input Analysis

In order to analyze the effect of human activities in the watershed, on surface runoff and sediment yield in relation to management practices, it is necessary to develop scenarios. The following scenarios were developed in this study to observe the changes in the sediment yield.

Scenario 1: Baseline Scenario

A baseline scenario, assumed to reflect current conditions that was initially executed prior to performing the scenario simulations. Each scenario was then run for the same simulation period, except with modified management inputs, dimension change to provide a consistent basis for comparison of the scenario impacts on the amount of sediment reduced. After calibration were completed for flow and sediment, this simulation were re-run for 28 years period (1990-2018). This simulation represented the current conditions or is a baseline, which will be used as a point of reference. The baseline scenario corresponds to the current land management practices without applying conservation measures.

Scenario 2: Filter strip

Filter strip in SWAT model simulated in the procedure of year, month and day schedule for the following parameter. Management operation (MGT_OP), for the simulation filter strips (FILTER_I) and VFSI, ratio of field area to filter strip area (FILTER_RATIO) most common values 30-60, fraction of HRU which drains to the most concentrated 10% of the filter strip area (FILTER_CON). 10% of the filter strip can receive between 0.25 and 0.75 of runoff from the entire field. Fraction of flow within the most concentrated 10% of the filter strip which is fully channelized (dimensionless). For this study, filter strip of 10m width were placed for all HRUs.

Scenario 3: Grassed waterways

As that of filter strip, grassed waterway also has a parameter inputs in SWAT model. The simulation step performed based on the parameters such as simulation of grassed waterway (GWATI), Manning's value for overland flow (GWATN, default 0.35), calculating sediment in grassed waterway (GWATSPCON), depth of grassed waterway from top of bank to bottom (m) (GWATD), average width of grassed waterway (m) (GWATW), length of grassed waterway (km) (GWATL) and average slope of grassed waterway channel (m) (GWATS).

Scenario 4: Contouring

Contouring in SWAT model is simulated by adjusting by both erosion and runoff parameters. The USLE practice (TERR_P) factor, the slope length (TERR_SL) and curve number (TERR_CN) are adjusted to simulate the effect of terracing. The appropriate curve number (CN) was set for this study based on cover type, hydrologic condition and hydrologic soil groups (Arnold et al., 2011). On the other hand, the USLE crop practice (P) factor also selected based on the slope range (Haan et al., 1994). TERR_SL should be a maximum of the distance between terraces (Arnold et al., 2011). For this study 35% reduction slope length were applied.

4. RESULTS AND DISCUSSION

4.1 Land Use Land Cover Analysis

Conversions of LULC from one category to another are common phenomena in LULC studies (Belay 2002). The diagonals in the matrix from the tables are the persistence while the of-diagonals are the conversions from one category to the others.

4.1.1 Accuracy assessment

Overall accuracy

The results show that the overall accuracy for the maps of 2000 and 2018 were 88% and 93% respectively. According to Anderson et al. (1976), the minimum accuracy value for reliable land use land cover classification is 85 %. The other authors eg. Bedru (2006) explains that the expected accuracy is determined by the users themselves depending on the type of application the map product would be used later. Accuracy levels are accepted by users may not acceptable by other users for certain task (Bedru, 2006). Therefore, based on table 4.1 and 4.2 the classification carried out in this study produces an overall accuracy that fulfils the minimum accuracy level defined by Anderson for both land cover maps of Ribb watershed.

Producer's Accuracy

The overall result of the producer's accuracy ranges from 85 % to 96%. The lowest values were misclassified due to similar spectral value of different land cover classes. For instance, cultivated land with Bare land, water with bare land, forest with shrub land, etc. somehow affects the level of classification.

User's Accuracy

In this study, the user's accuracy ranges from 85% to 96%. The lowest value "shrub land and cultivated land" were, to some extent, misclassified because of the similarity spectral properties of shrub land and cultivated land.

Kappa coefficient

A kappa coefficient of 0.85 and 0.92 were obtained for of 2000 and 2018 LULC maps respectively based on equation 3.7 under section 3.3.3. According to Monserud (1990) a kappa values greater than 0.85 are rated as very good indicators of the classified image in reporting the ground truths.

Table 4.1: Confusion Matrix for the Classification of 2000 LULC

Class		W	F	B	S	C	U	Total	**UA**
Classification	W	23	0	2	0	0	1	26	88
	F	0	25	0	2	1	1	29	86
	B	1	0	26	1	0	1	29	90
	S	0	2	0	23	1	0	26	88
	C	1	0	2	0	22	0	25	88
	U	0	1	0	0	0	21	22	95
	Total	25	28	30	26	24	24		
PA		92	89	87	88	92	88		**OA = 88**

Note: W= water, F= mixed forest, B= bare land, S= shrub land, C= cultivated land, U= urban, UA= User accuracy, OA= allover accuracy and PA= accuracy

Table 4.2: Confusion Matrix for the Classification of 2018 LULC

Class		W	F	B	S	C	U	Total	**UA**
Classification	W	15	0	1	0	0	1	17	88
	F	0	16	0	1	0	0	17	94
	B	0	0	20	1	0	0	21	95
	S	0	1	0	21	1	0	23	91
	C	0	0	1	0	24	1	26	92
	U	1	0	0	0	0	25	26	96
	Total	16	17	22	23	25	27		
PA		94	94	91	91	96	93		**OA = 93**

Note: W= water, F= mixed forest, B= bare land, S= shrub land, C= cultivated land, U= urban, UA= User accuracy, OA= allover accuracy and PA= accuracy

4.1.2 Land use land cover map

Figure 4.1and 4.2 shows the two land use land cover maps 2000 and 2018 that have been generated from Landsat 7 ETM+ and Landsat 8 OLI_TIRS imagery classification respectively. Cultivated land and Residential shows incremental line and forest area, bare land, shrub land, and water body shows decrement over the last 19 years. The land use land cover map of 2000 in the figure 4.1 shows that the total cultivated land and coverage class was about 66.87 % of the total area of the watershed. It increased rapidly and became 75.53 % of the watershed in 2018 land use land cover map (Figure 4.1 and 4.2). This is mainly because of the population growth that make happen the increase in demand for new cultivation land and settlement, which in turn resulted shrinking on other types of land use land cover of the area except water body after construction of the dam. On the land use land cover map of the year 2000 the total mixed forest coverage was about 4.52% of the total area of the watershed. On the land use land cover map of the year 2018 it reduced to 2.9% of the total area. This is most probably because of the deforestation activities that have taken place for the purpose of cultivated land.

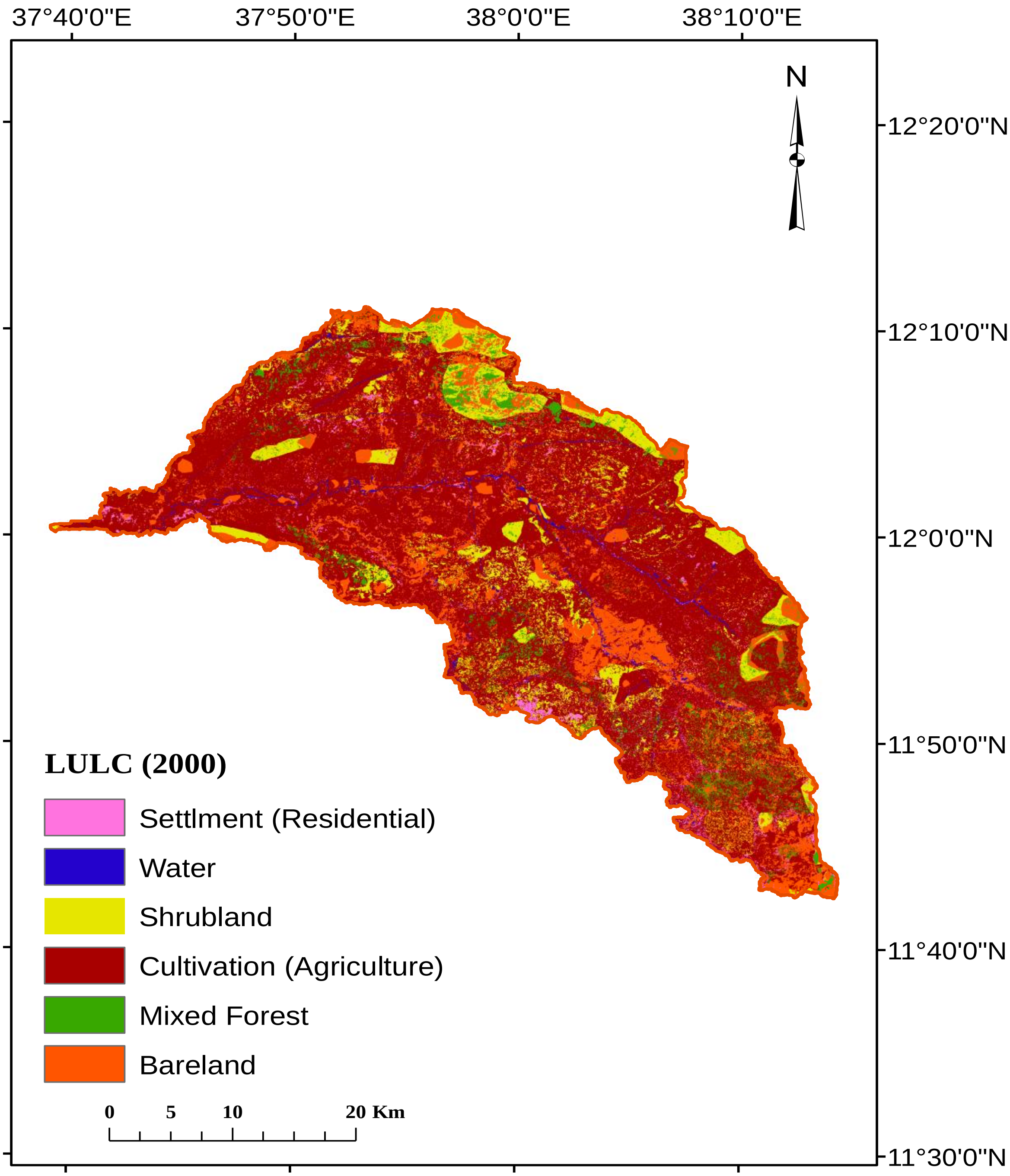

Figure 4.1: LULC map of Ribb watershed, 2000

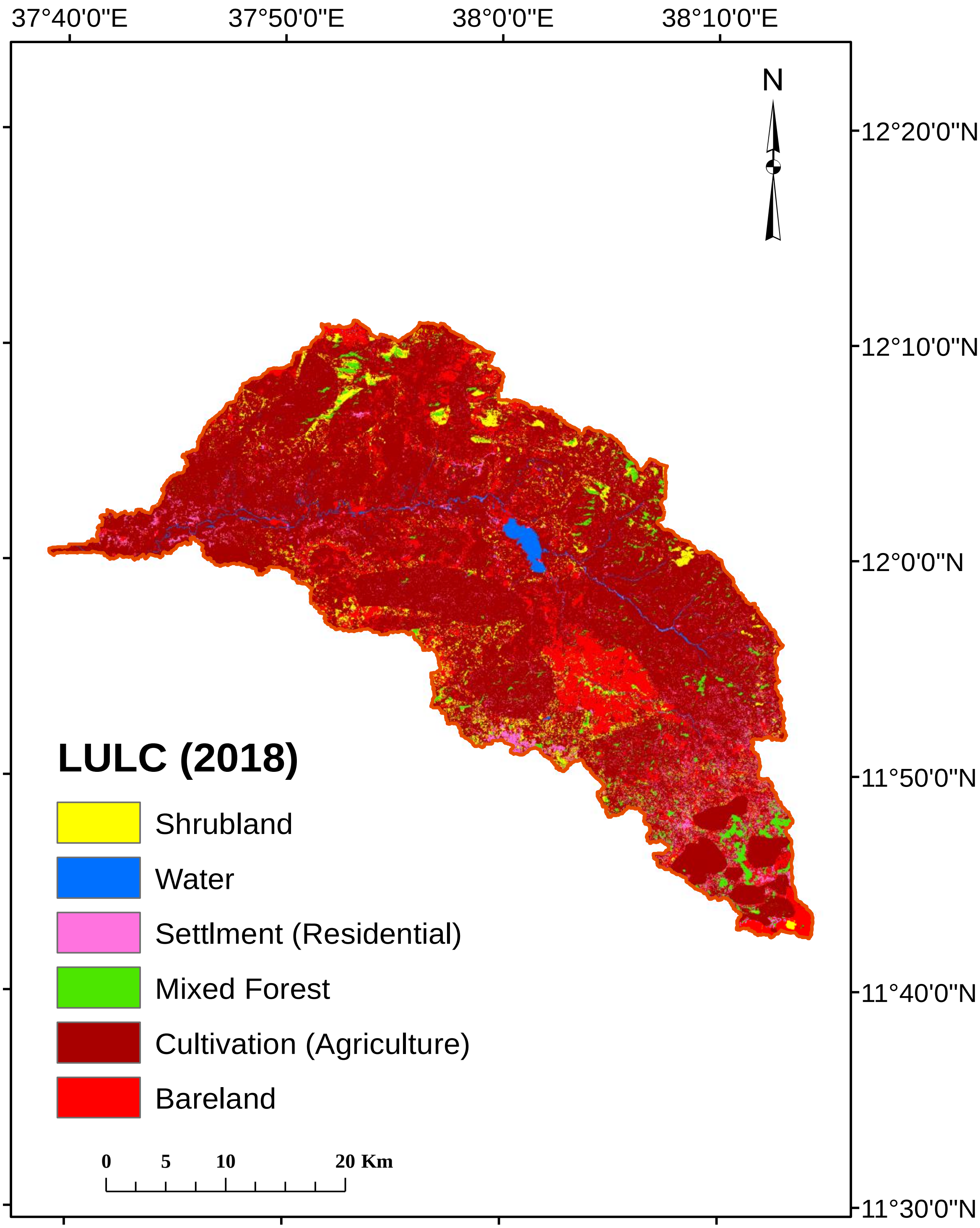

Figure 4.2: LULC map of Ribb watershed, 2018

4.1.3 Land use land cover change analysis

Analysis of LULC patterns in the studied watershed indicated the growth of cultivated land and built up area at the expense of vegetative cover types over the last two decades. During these periods, cultivated land has expanded from 66.87% in 2000 to 75.53% in 2018.Between 2000––2018 periods, it was increased by 8.66 %. The rate of increment during 2000–2018 periods were 608.915 ha/year. Similarly, settlement area had also increased by 2.09% from 2000–2018 periods.

During 2000–2018 periods, settlement area increased by 147.611 ha/year. The rapid percent change taken place in settlement area during these periods is associated within Debre Tabor town to the study site as had been seen most of the increased in settlement area occurred in the southeastern areas of the studied watershed. This reason was also mentioned during focus group discussions of cultivated land development agents. In contrast, forest, shrub land, bare land and water body had decreased in the whole study periods except after construction of the dam. For example, mixed forest coverage decreased by 1.62% from 2000 to 2018. Similarly, shrub land and bare land also decreased at a rate of 412.868 and 227.651 ha/year, respectively, between 2000 and 2018 periods. Also the water body decreased at a rate of 1.593 ha/year between 2000 and 2018.

The finding of this research is consistent with other studies carried out by Gete and Hurni (2001) in Dembecha area of northwestern Ethiopia, Gessesse and Kleman (2007) in South Central Rift Valley Region of Ethiopia, Rientjes et al. (2011) in Upper Gilgel Abbay catchment of Blue Nile basin, Gebremicael et al. (2013) in Blue Nile basin, Temesgen et al. (2014) in Dera District of northwestern Ethiopia and Solomon et al. (2014) in Birr and Upper-Didesa watersheds of Blue Nile basin, where the cultivated land increased significantly where forest land was shrinking. A study in Shomba and Michity catchments of Kefa zone Mekuria (2005) also indicated the conversion of vegetative lands into non-vegetative lands between 1987 to 2001 periods mainly for the expansion of cultivated land and settlement. Studies by Ebrahim and Mohamed (2017) in Geleda catchment and Solomon et al. (2010) in Koga watershed also reported the growth of cultivated lands at the reduction of forest cover in the respective study periods.
The results of the previous studies showed that the same fact. For example, Denboba (2005) reports 75 % of the Shomba catchment in the south western part of Ethiopia was converted to

farmlands and settlements from other land uses between the years 1967 to 2001. Zeleke and Hurni (2001) reported that 99 % of the forest covers was converted to cultivated land at Dembecha area in the northern part of the country between 1957 and 1995. Bewket (2003) identifies cultivated land conversion of 79 % of the Riverine forests of the Chemoga watershed within the Blue Nile basin in about 40 years (1957 – 1998).

Table 4.3: Area and Percent of LULC Class from 2000 to 2018 in the Ribb Watershed

Land use land cover type	Land use land cover				LULC	
	2000		2018		2000-2018	
	Area		Area		%	Rate (ha/year)
	(ha)	(%)	(ha)	(%)		
cultivated land	89329.01	66.87	100898.4	75.53	8.66	608.915
Mixed forest	6044.892	4.52	3869.292	2.9	-1.62	-114.505
Settlement	3680.997	2.76	6485.6	4.85	2.09	147.611
Water	1740.016	1.3	1709.746	1.28	-0.02	-1.593
Shrub land	14039.76	10.51	6195.277	4.64	-5.87	-412.868
Bare land	18754.2	14.04	14428.83	10.8	-3.24	-227.651

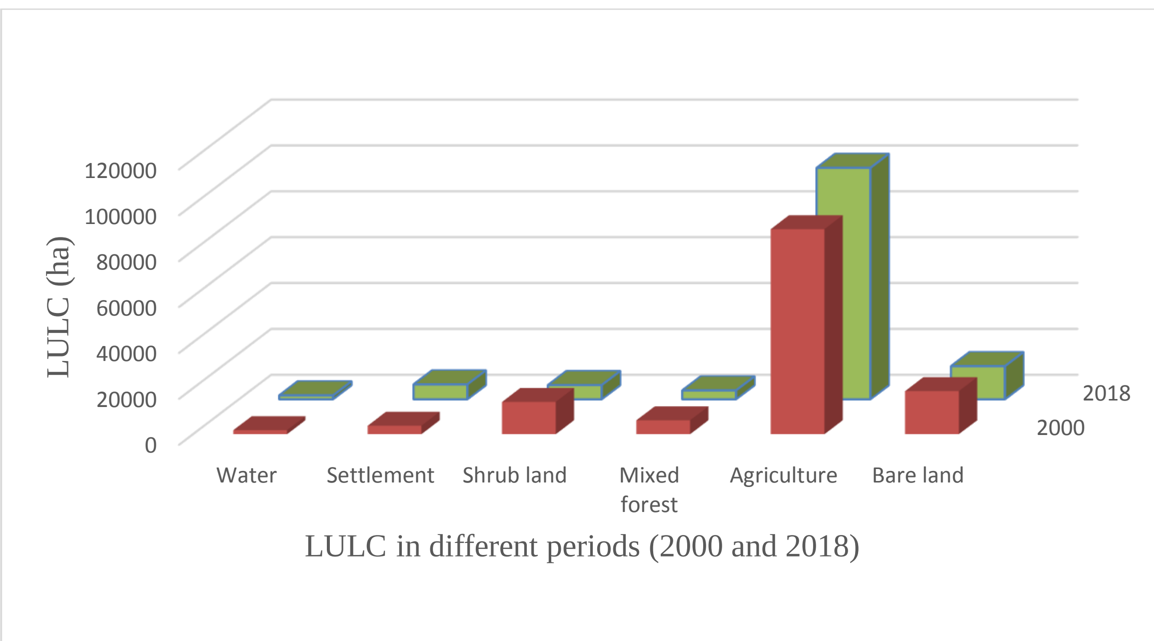

Figure 4.3: LULC change between the two periods (2000 and 2018)

4.1.4 LUCC at sub-watershed level

As discussed under chapter three, SWAT2012 was used to delineate 78 sub-watersheds. This sub-section discusses the LUCC that occurred at each sub-watershed to get better insights of the land use land cover conversion at a finer spatial scale. Figures 4.1 and 4.2 illustrate the pattern of LULC changes in each sub- watershed during the two periods.

The percentage of increase in cultivated land and settlements has almost occurred in all sub-watersheds in the second period with a higher percentage than the first period.

4.2 Implications of Land Use Land Cover Changes

As discussed earlier, the upper part and middle reach of the watershed are predominantly affected by the LUCC during the 1975 to 2004 period. There are several reasons why forest is being cleared, as often mentioned by the local farmers and local governments, is population growth in the area that causes an increase in farmland and settlement and uncontrolled use of firewood from the upper part of the watershed. The reduction in vegetation cover at the study area decreases infiltration and increases surface runoff that alters the completely hydrological regime.

4.3 Flow Simulation and Sensitivity Analysis

Once the SWAT model for Ribb watershed were compiled using SWAT interface, a stream flow sensitivity analysis was performed on model parameters. This was done to identify the influential parameters on the modeled stream flow. It is important to identify sensitive parameters for a model to avoid problems known as over parameterization (Garde and Raju, 2000). The parameter sensitivity analysis was carried out using SWAT-CUP 2012 version (SUFI-2 algorithms) for Ribb watershed. Ten (10) hydrological parameters were tested for sensitivity analysis for the prediction of stream flow for this watershed.

The sensitive parameters analyzed for stream flow calibration in Ribb watershed were soil evaporation compensation factor (ESCO), base flow alpha factors (ALPHA -BF), available water capacity (Sol-Awc in mm water/mm soil), ground water delay (Gw-Delay, days), ground water “revap” coefficient (Gw-Revap), channel effective hydraulic conductivity (Ch-K2, mm/h), threshold depth of water in the shallow aquifer for “revap” or percolation to the deep aquifer to occur (REVAPMN, mm), threshold depth of water in the shallow aquifer required for return flow to occur (GWQMN, mm), soil depth (Sol-Z, mm) and SCS Curve Number II (CN2). Linear parameter for calculating the maximum amount of sediment that can be restrained during channel sediment routing

(Spcon), channel cover factor (Ch-Cov1 & Ch-Cov2), channel erodability factor (Ch-Erod), USLE equation support practice factor (USLE-P) exponent parameter for calculating sediment restrained in channel sediment routing (Spexp) and USLE equation topographic factor (USLE-K) was used for sediment yield calibration (6- hydrological parameters).

Global Sensitivity Analysis (GSA) was used to carry out sensitivity analysis of the hydrological parameters chosen for calibration process. Inside GSA t-stat and p-value statistical measurement were used. T-sat was used to provides a measure of sensitivity, larger absolute values are more sensitive parameters, whereas, p-value was used to determine the significance of the sensitivity. A value close to zero has more significant. So, by using SUFI-2 algorithms (applied due to its easy implementation in comparison to other procedures and the low number of runs needed to reach good prediction) calibration techniques or (p-value & t-stat statistical measurements) SCS Curve Number II (CN2) was the most significant and sensitive hydrological parameters for flow simulation in Ribb watershed. GW_DELAY and Sol-Awc were the second and third significant parameter for this watershed. Similarly, sediment sensitivity or significance were done by Global Sensitivity Analysis method (t-stat & p-value), exponent parameter for calculating sediment restrained in channel sediment routing (Spexp) due to the influence of sediment flow by Lake Tana or effect of natural reservoirs and USLE equation topographic factor (USLE-K) due to maximum variation of watershed elevation range were the most sensitive hydrological parameter for Ribb watershed respectively.

4.3.1 Model calibration for stream flow

Figure 4.4 presents the calibration output for flow simulation. The model result indicates that the model could able to reproduce the observation with reasonable accuracy. The model performance as evaluated possess R^2 of 0.82, NSE of 0.67, and PBIAS of -10.25% which shows a good agreement between the observed and simulated flows of monthly time scale (see table 4.6). Therefore, the model is applicable in the Ribb Dam watershed at this model performance indicator and the flow parameters. In general, the calibrated result argued the SWAT model has an ability to predict flow and sediment.

The simulated result slightly overestimated in some months of the years. This indicates that the model overestimates some of the monthly peak flows of the simulated period. On the other hand, the simulated result is less than that of the measured flow for this calibration period. This was as a result of high rainfall and occurrence of runoff which has high record period. But the time series trend of the gauged flow was well fitted for monthly time steps.

4.3.2 Model validation for stream flow

The model performance as evaluated possess R^2 of 0.87, NSE of 0.75 and PBIAS of -7.53% and all these shows there was a good agreement between simulated and observed flows.

In general, the model in the validation period indicates that the statistical performance indicators that fitted during calibration period are the representative set of flow parameters for Ribb Dam watershed for further study using the SWAT model.

Table 4.4: Calibration and Validation Results near Addis Zemen Gauging Station

Period	Description	R^2	NSE	PBIAS (%)
1992-2001	Calibration	0.82	0.67	-10.25
2002-2006	Validation	0.87	0.75	-7.53

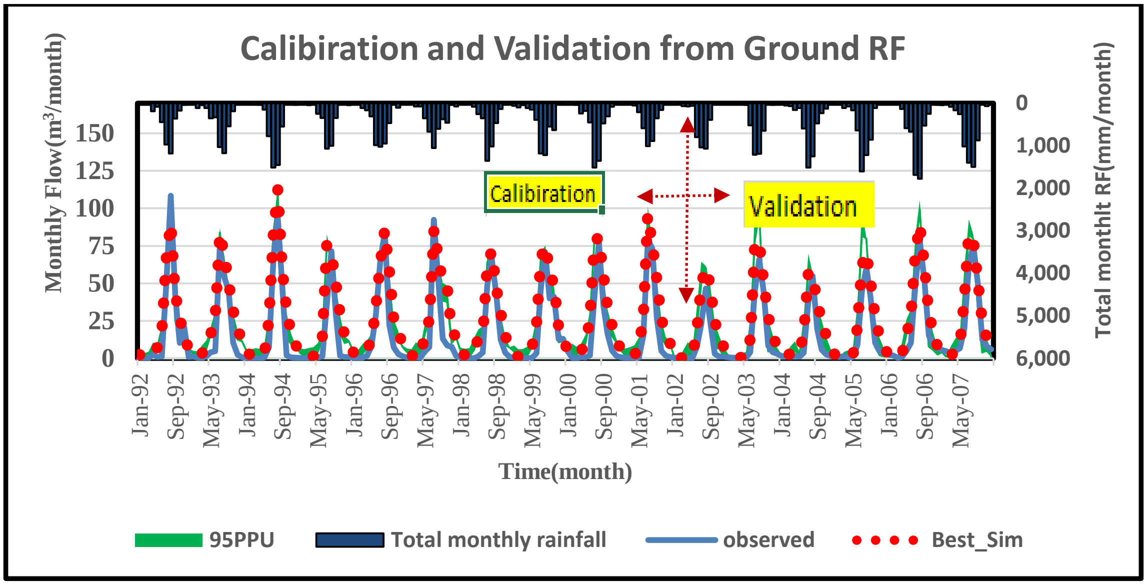

Figure 4.4: Calibration and Validation of flow data

4.3.3 Sediment yield and Sensitivity analysis

Sensitivity analysis was applied to identify the sediment sensitive parameters that influence the modeling of sediment yield. In this step, around six sediment parameters were identified. But the default relative sensitive parameters are USLE_P support practice factor, USLE_C cover factor high to low degree of sensitivity were produced even though the calibration not yet done at this step.

4.3.4 Model calibration for sediment load

A like to flow calibration, the performance of the model between measured and simulated sediment yield were determined by using R^2, NSE and PBIAS respectively as 0.67, 0.63 and 17%.

Table 4.5: Selected Sediment Parameter and Its Fitted Value, p Value and t_Stat

Parameter	Fitted Value	P Value	t_stat	Rank
USLE_K	0.033475	0.00	-183.5	1
SPCON	0.009757	$2.749*10^{-9}$	6.008	2
CH_COV1	-0.004175	0.00418	2.8712	3
CH_COV2	0.332834	0.3711	-0.8948	4
USLE_P	0.1685	0.6919	0.39641	5
SPEXP	1.19075	0.9370	-0.07905	6

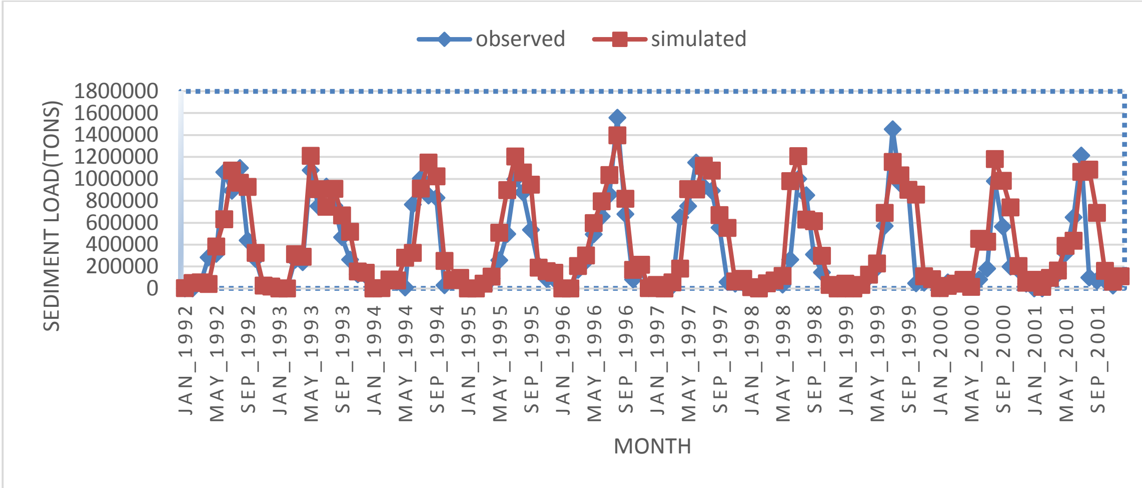

Figure 4.5: Model Calibrations for Sediment Load (Ribb River near Addiszemene gauging station)

4.3.5 Model validation for sediment load

During this validation step, a good agreement was observed between the simulated and observed sediment yield that determined R^2, NSE and PBIAS was 0.71, 0.58 and 12% respectively. This model performance test shows that the model can simulate sediment yield further outside of calibration period.

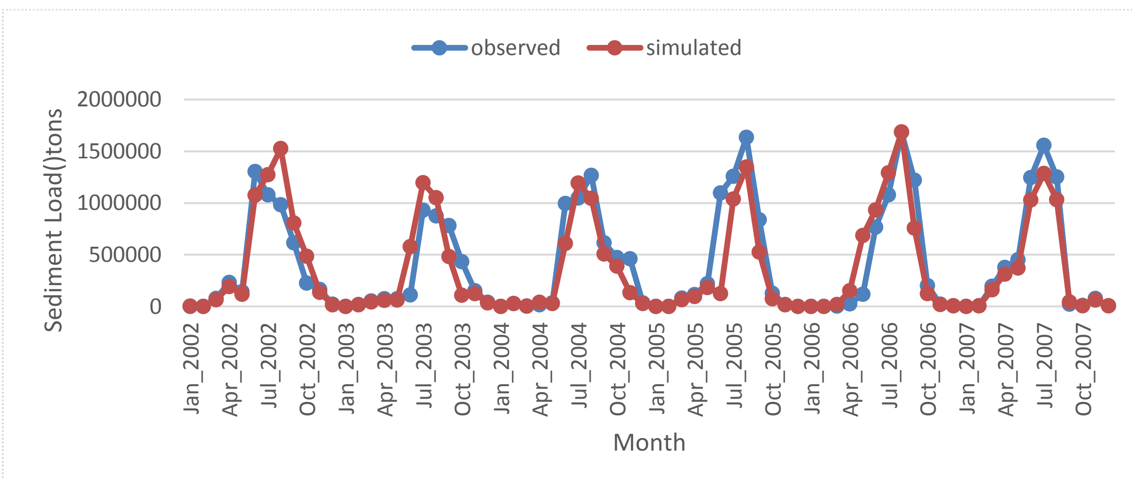

Figure 4.6: Model validation for Sediment Load (Ribb River near Addiszemene gauging station)

Table 4.6: Calibration and Validation Results of Sediment Flow at Ribb Gauged Station

Period	Description	R^2	NSE	PBIAS (%)
1992-2001	Calibration	0.67	0.63	17
2002-2006	Validation	0.71	0.58	12

In Ethiopia, a number of studies indicates the existence of sever soil erosion and sedimentation problems in different parts of the country. For instance some of the evidence research shows as an average annual soil loss of 42 ton/ha/year (Hurni, 1993), 35 ton/ha/year (FAO, 1986) and 57 ton/ha/year (Girmay, 2009).The problem, however, is severe in the highlands of the country. In this area, soil erosion ranges from 16 to 300 ton/ha/year (Hurni, 1988). Balabathina et al. (2019) estimates annual soil loss in Megech watershed (which is located near to Ribb watershed) varies 41.54 to 75.92 ton/ha/year. However, in this study estimates 2,235,090 tons and 4,157,725 tons. This corresponds to specific suspended sediment yield of 31.26 ton/ha/year and 58.15ton/ha/year for 2000 and 2018 LULC data respectively, which is higher than the above-mentioned estimates for the dam site. Therefore, this shows an increasing of soil loss rate in the study area.

4.4 Soil Loss of Selected Watershed

Erosion and sediment delivery to the reach of each sub-basin was not uniform. This was as a result of rainfall distribution, runoff, soil erodability, management practice and slope. In the Ribb Dam watershed the most sediment yielding sub-basins and their severity index of these sub basins were listed under appendix A.1 and A.2 for both 2000 and 2018 LULC data above the dam axis. These sub basins were covered by bare land, shrub land, cultivated land, and mixed forest land and of the two land use land cover types. For instance, sub basin 78 (66.25% of cultivated land, 2.25% of shrub land, 22.25% of, bare land and 9.25% of mixed forest), sub basin 46 (43.25% of cultivated land, 12.25% of shrub land, 37.25% of, bare land and7.25% of mixed forest).

The slope of these high sediment yielding sub basins are more than 15% slope area coverage. However, sub basin 74, 46, 5, 78 and 4 has greater than 15% slope.

Table 4.7: Comparison of Annual Sediment Yield for Randomly Selected Sub Basins under LULC Change

Sub_Bsins	Dominant LULC		Mean annual SY (ton/ha)		Change (2000-2018)	% of change
	2000 LULC	2018 LULC	2000 LULC	2018 LULC		
4	FRST	RNGB	15.70	21.45	5.75	26.81
5	RNGB	AGRC	12.30	17.21	4.91	28.53
24	BARR	AGRC	8.74	15.35	6.61	43.06
46	BARR	AGRC	11.10	22.75	11.65	51.21
57	AGRC	RNGB	21.59	14.30	-7.29	-50.98
59	AGRC	AGRC	22.13	17.30	-4.83	-27.92
61	AGRC	BARR	20.57	13.88	-6.69	-48.20
62	BARR	AGRC	9.76	15.60	5.84	37.44
67	AGRC	BARR	26.65	14.75	-11.9	-80.68
71	RNGB	AGRC	16.39	23.15	6.76	29.20
74	RNGB	AGRC	13.27	18.00	4.73	26.28
78	RNGB	AGRC	14.53	26.53	12	45.23

NB RNGB: Shrub land, FRST: Mixed Forest, AGRC: Cultivation, BARR: Bare Land

As it could be seen from the above table the recent land use (2018 LULC) of sub basin 78 contributes the highest mean annual sediment load (26. 53ton/ha/year) to Ribb dam reservoir from the randomly selected sub basins. This sub basin was mostly shrub land and bare land cover during 2000 LULC and had been largely changed to cultivated land in 2018 land use land cover whereas sub basin 71 (23.15ton/ha/year) and sub basin 46 (22.75 ton/ha/year) contributes to the second and third most sediment source to Ribb dam watershed from the randomly selected sub basins which both dominantly have cultivated land, but sub basin 24 was located at the downstream of Ribb dam and it hasn't significant impact for the dam. However, some of the sub watersheds (sub watershed 67, 57 and 61) have decreased their annual sediment yield with a great change by 80.68%, 50.98% and 48.2% respectively as land use land cover changed from 2000 LULC to 2018 LULC. The left side for 2000 and right side for 2018 LULC map of soil loss shown below.

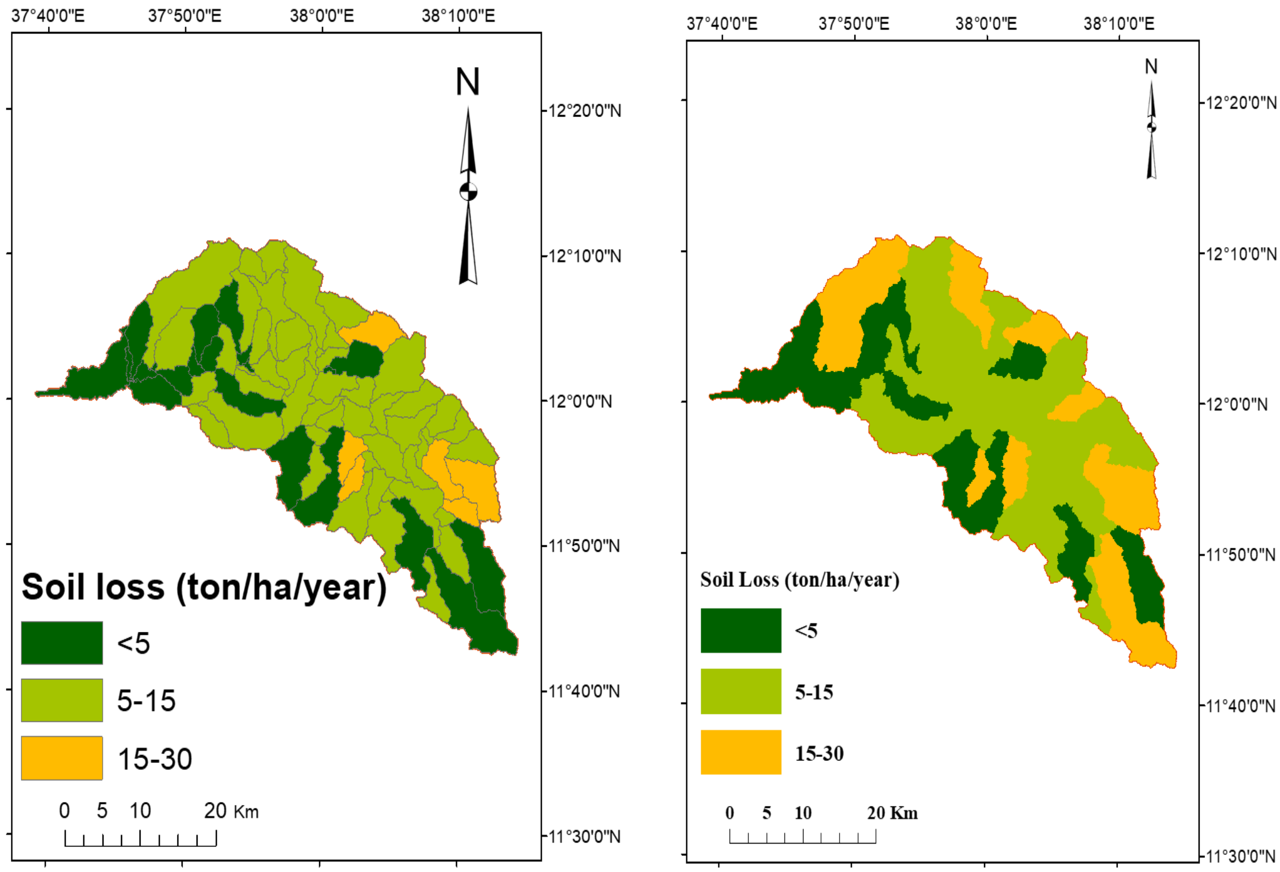

Figure 4.7: Spatial distribution of soil loss in Ribb watershed, 2000 and 2018

LULC

4.5 Sediment Reduction Methods

There are assumed as influential as sediment reduction methods assessed for this study.

As discussed in section 3.6, the selected sub basins to apply these management operations were sub basin 46, 4, 5, 74, 59, 78, 71, 24 and 62 and the following scenario results were obtained.

Scenario 1: Base line scenario

In this step, it was considered only the existing sediment yield value (figure 4.8)

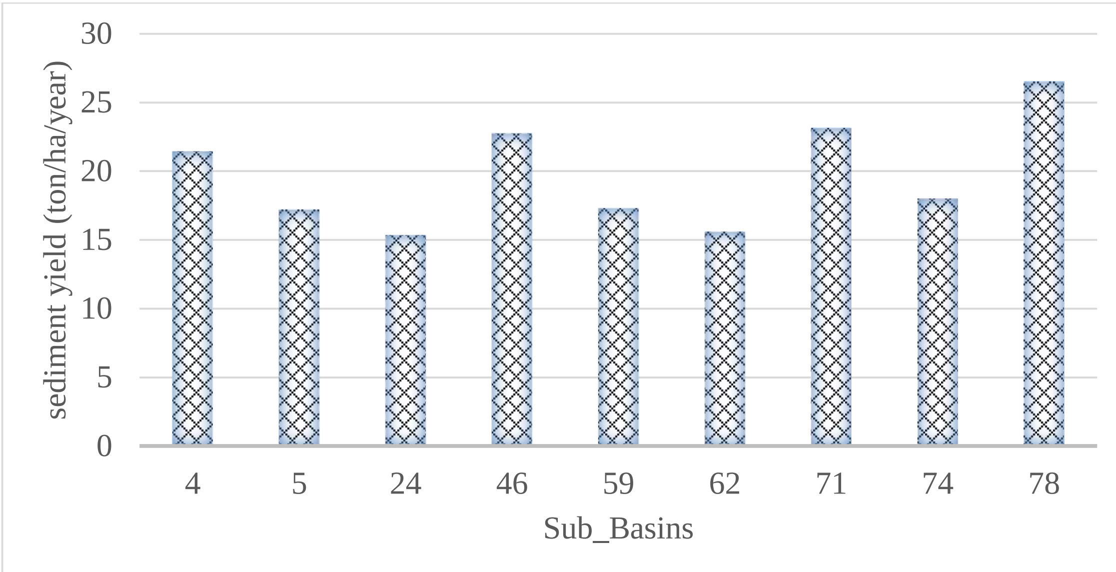

Figure 4.8: Annual sediment yield at critical sub basins (scenario 1)

Scenario 2: Filter strip

By applying of vegetative filter strips (VFS) in the selected critical sub basins mean annual sediment yield was reduced by 25% to 61.5% due to 10m width of filter strip as a result of this average sediment yield reduced to 7.93 ton/ha/year from baseline condition that is 40.24% reduction. For instance, sub basin 62 has a great reduction due to its gentle slope, mean annual sediment reduction of 61.5% (Figure 4.9).

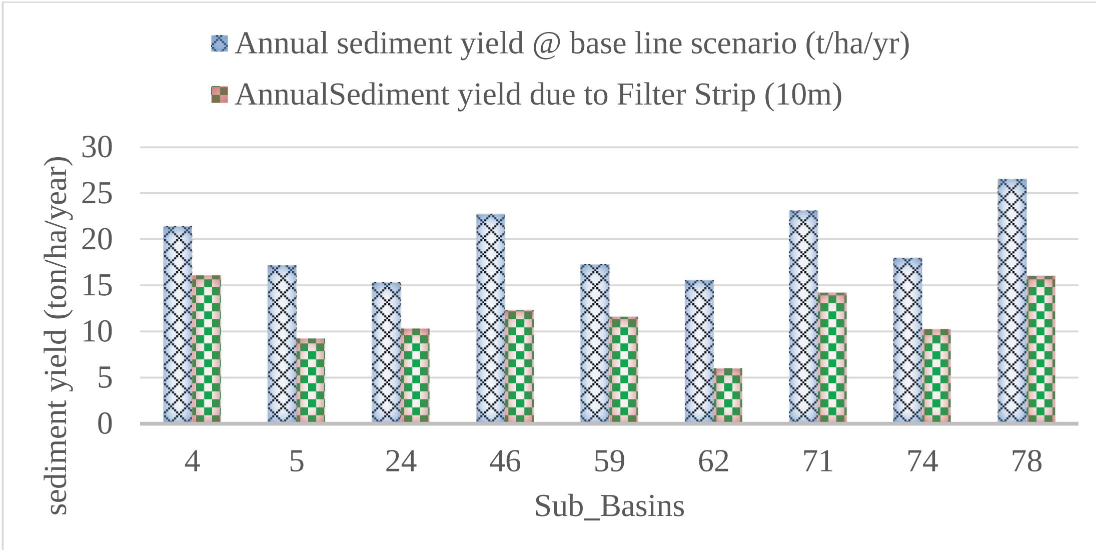

Figure 4.9: Annual sediment yield at critical sub basins (scenario 2)

Scenario 3: Grassed waterway

In this selected scenario, the mean annual sediment yield was 15.07 ton/ha/year (Figure 4.10) which was reduced 4.64 ton/ha/year from the baseline existing mean annual sediment yield. In general, due to this scenario the sediment yield were reduced for all critical sub basins, Specifically, sub basin 62 reduced to 5.1 ton/ha/year.

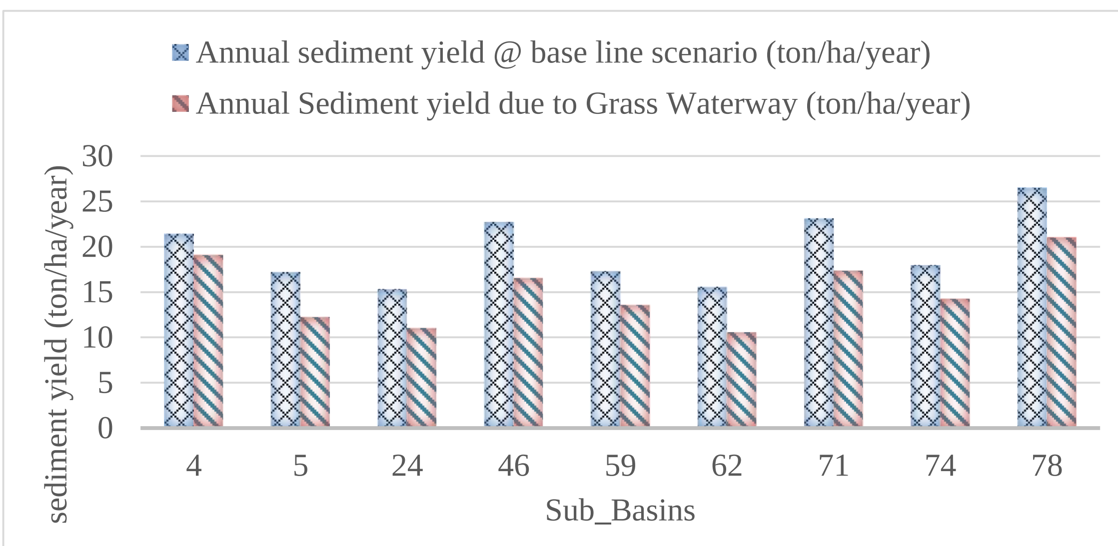

Figure 4.10: Annual sediment yield at critical sub basins (scenario 3)

Scenario 4: Contouring

Contouring is constructed across a slope on a contour. It was simulated in SWAT by adjusting both erosion and runoff parameters. Based on this, the following result was obtained mean annual sediment yield 14.25 ton/ha/year, which was reduced by 16% to 52.31%. Specifically, in figure 4.11, sub basin 62, 78 and 74 reduced by 52.31%, 31.24% and 31.10% respectively.

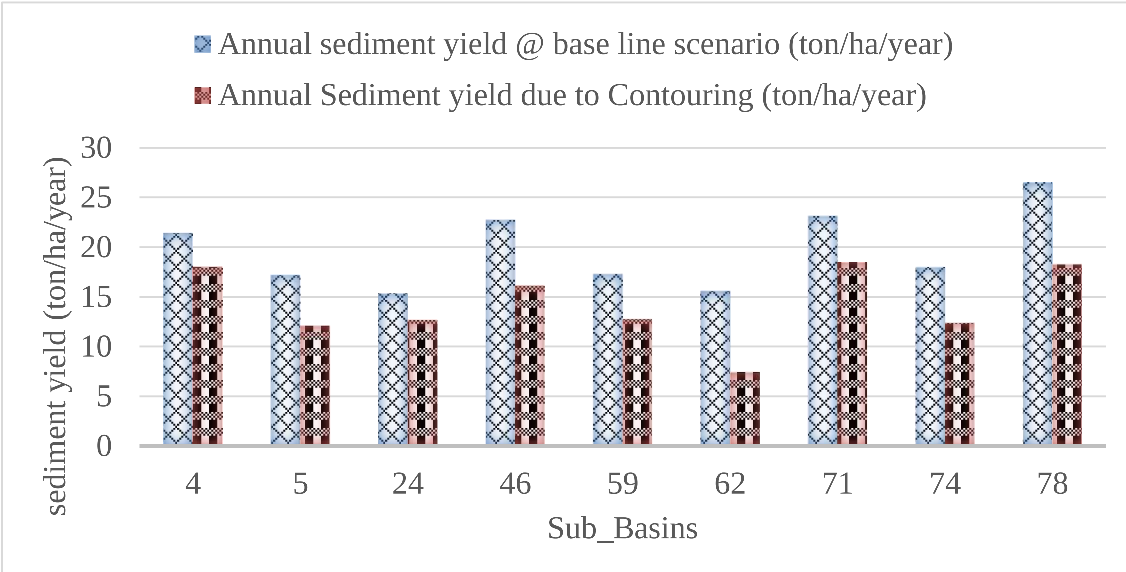

Figure 4.11: Annual sediment yield at critical sub basins (scenario 4)

4.5.1 Scenario comparison

Management practices were important options to conserve soil and reduce sediment yield of prone areas in the watershed. Based on this concept, running the model with different watershed management scenarios applied in the watershed and an interesting result were obtained. The impact of watershed management options on the selected critical sub basins level showed a wider spatial variability on sediment reduction from baseline conditions as shown in table 4.11. Mean annual sediment yield reduced to 7.93 ton/ha/year by applying filter strips of 10m width. On the other hand, grassed waterways and contouring simulated in the model and satisfactory result were obtained. These results were 4.64 ton/ha/year and 5.46 ton/ha/year by applying grassed waterway and contouring respectively.

Best management practice applied in the model to see the effectiveness of sediment reduction methods. As shown in the table 4.11 and 4.12 filter strip of 10m width has high sediment reduction potential as compared to grassed waterway and contouring

Table 4.8: Mean Annual Sediment Yield at Different Scenarios (ton/ha/year)

Critical Sub_Bsins	Scenario 1	Scenario 2	Scenario 3	Scenario 4
4	21.45	16.0875	19.09	18.02
5	17.21	9.23	12.23	12.0913
24	15.35	10.32	11.02	12.69
46	22.75	12.30	16.53	16.11
59	17.30	11.59	13.59	12.75
62	15.6	6.00	10.56	7.44
71	23.15	14.20	17.35	18.46
74	18.00	10.25	14.25	12.40
78	26.53	16.00	21.00	18.24

Table 4.9: Averaged Mean Annual Sediment Yield at Different Scenarios (ton/ha/year)

Scenario 1	Scenario 2	Scenario 3	Scenario 4
19.71	11.78	15.07	14.25

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study clearly indicated the impact of LULC changes on sediment yield of Ribb watershed. Among the major land uses in the watershed, cultivated and built-up area indicates an increment whereas water, mixed forest, shrub land and bare land was withdrawing during 2000 to 2018 periods and it had increased the annual sediment yield.

The sediment yield in the Ribb dam watershed was spatially distributed. But when looked at the sub basins due to sediment yield there was an increment in numbers during 2018 LULC as compared to 2000 LULC , which indicates that mostly the land use land cover changes were changed in to cultivation

In general, sediment yield in Ribb watershed was increased from the year 2018 as compared to 2000, but in a few sub basins the rate of soil loss was indicated that decline in the year 2018 period due to the activities of watershed management practice in the northeast part of the river at the upper section of Ribb dam.

This study showed that management scenarios were greatly influence on sediment yield. As discussed in the results and discussion part, the mean annual sediment yield of critical sub basin was 19.71 ton/ha/year. By applying management scenarios this result showed that, the sediment yield become decreased. For instance, it was reduced to 11.78-ton /ha/year due to filter strip of 10m width. In addition, grassed waterways and contouring reduced efficiently the sediment yield from baseline condition. However, filter strip 10m width was most effective among applied management scenarios.

To generalize the sediment yield of the study area, the mean annual sediment yield estimated 31.26 ton/ha/year and 58.15 ton/ha/year for 2000 and 2018 LULC respectively. Thus the study conclude that the sediment rate is increasing over time and call for an urgent watershed management interventions in order to decrease the sediment rate entering into the Ribb dam and for sustainable management of water and sediment fluxes in the watershed.

5.2 Recommendations

The result of the study could help different stakeholders, policy makers and managers to plan and implement appropriate soil and water conservation strategies, and it could help to develop a plan for sustainable use of the reservoir to ensure its functions for the next generations.

Non-tolerable sediment source areas (hot spot areas) of Ribb dam reservoir were identified and prioritized in this study for feature management plan of mitigating sedimentation to the reservoir. Hence, more attention and prioritization have to be given first for these sub watersheds. However, before implementing any watershed management activities an alternative soil and water conservation scenarios suitable for prioritized sub watersheds must be done.

The Model prediction output depends on the quality of input data. One of the constraints in conducting this research work was lack of continuous measured suspended sediment data. The sediment data used for this study were generated from sediment rating curves developed from limited sediment measurement data. There is therefore, possible discrepancy of actual sediment and sediment data derived based on rating curves. However, superior results can be obtained if detail suspended sediment data are used. Hence, responsible bodies should give due attention to the time and frequency of sampling, method of sampling and recording of reliable sediment data together with flow measurement.

This study recommend watershed management options as an important sediment reduction method based on the comparable result of the previous study in the watershed. In some amount at the north east part of Ribb reservoir there is started watershed management practice by forming farmer association by applying conservation practice like filter strip, contouring and other best management practice (BMP) and it indicates that the reduction of soil loss, therefore this conversation management practice should be join with other BMP and continued to the other part of the watershed specially at the critical (spot area) sub basins and conserve the environment.

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APPENDIX

Appendix A .1

Ribb watershed sub basins and soil loss rate severity index (2000 LULC)

Very Slight		Slight			Moderate
38	16		27	50	71
34	19	41	24	39	57
35	29	45	37	49	61
33	26	66	48	46	67
28	32	74	54	40	4
25	36	62	55	5	59
30	7	9	56	3	
31	8	10	78	76	
17	43	6	58	77	
42	72	11	63	51	
14	70	18	1	52	
21	65	15	2	64	
12	68	22	75	60	
13	53	47	69		
20	23	44	73		

Appendix A .2

Ribb watershed sub basins and soil loss rate severity index (2018 LULC)

Very Slight			Slight					Moderate
38	8	45	29	68	9	75	76	46
34	18	66	32	53	10	69	77	5
35	15	36	54	6	73	51	50	74
33	22	7	55	11	67	52	1	4
28	47	61	56	14	39	64	37	59
25	44	42	41	13	49	60	70	78
30	27	16	58	20	57	3	43	71
31	12	19	63	23	40	65	48	24
17	21	26	72		2			62

Appendix B .1

Ground Coordinates of 2000 LULC Image with Google Earth

Shrub land		Urban		cultivated land	
X	Y	X	Y	X	Y
353,056.45	1,328,051.89	358,994.41	1,326,947.78	394,893.17	1,310,858.12
353,766.15	1,327,763.25	359,650.80	1,327,981.06	394,402.05	1,312,063.87
354,609.80	1,326,889.63	358,031.40	1,329,162.32	394,558.24	1,314,050.15
355,097.63	1,326,744.75	353,126.18	1,329,744.57	390,885.24	1,315,262.05
355,808.22	1,326,691.21	355,591.58	1,331,059.42	390,366.73	1,318,183.93
355,008.18	1,325,940.91	354,338.90	1,332,182.54	387,503.01	1,318,852.16
355,544.76	1,325,457.67	357,282.56	1,332,468.50	390,634.65	1,319,181.81
356,868.68	1,325,655.71	362,937.16	1,333,883.08	389,169.07	1,327,079.00
357,581.13	1,325,450.42	362,467.86	1,337,890.53	385,432.11	1,328,064.31
358,355.55	1,326,688.22	363,917.02	1,340,138.14	381,858.50	1,328,350.13
358,483.62	1,329,951.32	366,678.84	1,339,845.25	378,740.61	1,325,281.25
358,998.89	1,330,415.93	366,628.14	1,340,607.14	374,301.47	1,325,609.28
359,970.50	1,330,213.80	367,133.52	1,340,363.04	371,586.41	1,327,081.14
357,245.48	1,334,310.50	367,658.13	1,340,289.92	369,428.44	1,328,640.80
359,236.02	1,334,417.54	367,864.63	1,340,806.83	365,534.81	1,332,647.72
360,726.94	1,334,164.98	375,209.26	1,336,806.43	369,130.82	1,335,673.00
361,551.49	1,332,899.13	376,879.40	1,336,094.27	370,744.26	1,339,157.37
363,182.92	1,332,925.48	377,527.51	1,335,044.55	363,239.40	1,336,508.31
365,251.40	1,337,138.32	378,709.88	1,336,296.69	359,357.38	1,336,005.05
365,497.02	1,338,368.99	380,572.29	1,336,549.23	359,258.45	1,331,667.47

367,123.30	1,337,748.23	381,511.61	1,337,777.20	356,086.20	1,329,084.96
360,999.02	1,341,901.38	383,003.10	1,338,738.46	351,576.35	1,330,460.04
363,219.64	1,341,605.48	382,773.64	1,335,801.01	349,528.42	1,329,360.26
364,928.96	1,342,882.47	383,244.55	1,334,122.71	361,621.77	1,337,435.78
366,776.90	1,341,587.98	385,429.06	1,332,542.21	361,267.96	1,340,326.60
366,619.92	1,343,232.83	386,561.71	1,331,307.00	364,421.88	1,339,027.97
368,573.81	1,342,066.82	387,119.42	1,330,277.51	364,747.79	1,341,904.37
366,685.23	1,345,107.95	388,093.71	1,329,310.69	370,802.74	1,346,746.60
368,321.74	1,345,755.98	389,566.83	1,330,088.92	372,851.19	1,344,582.17
370,301.62	1,348,776.02	391,993.46	1,329,046.16	375,297.15	1,341,645.48
374,028.30	1,348,542.29	395,189.92	1,327,033.28	378,934.96	1,341,058.52
377,678.17	1,345,779.24	397,149.50	1,327,035.00	381,974.70	1,340,508.29
377,396.79	1,344,100.56	395,899.72	1,325,320.21	384,653.44	1,337,147.25
380,168.90	1,345,479.36	397,856.07	1,322,292.80	391,745.26	1,336,124.46
382,211.98	1,344,107.51	401,042.35	1,319,818.91	396,322.59	1,335,247.12
385,107.81	1,343,170.54	388,830.23	1,312,149.06	400,148.64	1,333,849.22
388,239.06	1,341,318.03	391,706.43	1,311,694.49	402,484.87	1,331,772.67
390,201.64	1,341,125.36	392,212.04	1,310,978.20	406,044.12	1,325,819.53
389,172.96	1,338,128.41	392,562.63	1,310,314.72	408,074.86	1,322,751.96
387,855.75	1,337,384.02	394,120.05	1,310,884.66	411,853.07	1,316,416.85
Water		Bareland		Forest	
X	Y	X	Y	X	Y
404,715.55	1,320,522.62	349,785.09	1,331,067.44	412,907.75	1,298,492.71
403,002.85	1,322,016.24	352,269.40	1,329,993.13	415,450.65	1,297,863.86

402,981.17	1,323,328.34	353,010.33	1,328,450.26	414,921.61	1,302,459.82
401,639.08	1,323,538.74	355,580.43	1,328,405.58	413,718.94	1,302,445.48
400,541.63	1,324,300.76	359,203.27	1,327,746.83	412,312.92	1,302,388.48
399,067.40	1,325,789.54	361,778.47	1,327,733.63	412,281.34	1,303,241.55
395,651.20	1,325,278.01	362,394.17	1,330,157.38	412,978.65	1,304,131.82
397,355.21	1,327,193.35	362,899.87	1,333,482.37	413,461.39	1,305,334.46
395,206.55	1,327,582.03	364,447.23	1,333,006.46	411,738.87	1,304,976.76
394,231.60	1,327,786.15	365,807.75	1,330,114.64	409,988.60	1,305,110.08
393,228.90	1,329,299.29	367,658.63	1,329,652.39	410,170.61	1,306,918.21
392,494.70	1,330,003.55	370,977.17	1,330,873.46	408,330.46	1,305,948.78
390,789.34	1,332,040.93	372,228.93	1,329,895.36	408,045.60	1,304,119.72
390,027.23	1,332,011.74	374,658.38	1,327,938.90	407,317.87	1,304,401.45
388,599.77	1,331,996.88	377,153.31	1,327,989.88	405,862.80	1,304,479.98
386,890.18	1,331,785.05	378,035.90	1,327,713.87	406,894.72	1,306,404.33
386,638.59	1,332,538.56	379,973.09	1,325,456.70	405,876.69	1,307,432.27
384,667.62	1,331,553.22	381,470.17	1,324,199.66	404,039.36	1,309,357.25
382,950.71	1,330,750.39	382,935.95	1,323,004.91	400,976.82	1,309,142.20
382,104.95	1,331,083.93	383,832.75	1,324,192.92	399,539.55	1,308,889.81
381,002.16	1,331,824.44	384,814.83	1,325,124.61	397,154.22	1,309,774.35
377,559.80	1,330,940.26	386,127.98	1,322,856.03	397,820.11	1,312,298.08
375,873.73	1,331,536.63	389,164.78	1,321,590.83	395,878.37	1,313,656.13
374,416.54	1,329,841.36	392,454.38	1,318,815.44	395,041.28	1,315,579.46
372,954.67	1,329,357.18	395,956.58	1,318,154.37	393,453.91	1,316,338.38

371,817.52	1,330,134.30	397,009.66	1,316,688.47	391,920.74	1,316,111.64
370,766.78	1,330,396.63	397,965.24	1,319,776.23	389,967.77	1,316,010.72
368,524.22	1,330,729.22	398,846.07	1,318,475.39	388,034.70	1,316,345.94
365,129.68	1,329,378.04	399,709.38	1,316,498.95	389,419.53	1,317,863.66
363,638.13	1,329,426.56	400,779.91	1,317,873.49	390,643.37	1,319,967.34
361,434.97	1,328,897.17	402,399.73	1,316,878.70	387,676.69	1,319,637.49
357,517.66	1,329,379.14	403,351.62	1,315,837.09	390,032.61	1,325,827.07
354,561.62	1,329,985.39	403,693.53	1,314,089.09	390,764.00	1,327,891.83
354,058.71	1,330,988.35	405,389.36	1,313,307.88	392,701.08	1,327,660.77
352,623.01	1,330,229.89	406,857.18	1,312,236.78	390,542.06	1,338,379.42
353,055.11	1,332,590.17	409,164.28	1,310,225.80	386,836.98	1,338,192.60
350,883.22	1,331,057.26	410,761.56	1,309,085.11	385,709.66	1,339,613.33
349,763.94	1,329,706.72	412,553.67	1,306,864.62	386,774.72	1,341,147.65
349,210.03	1,330,093.88	414,198.10	1,305,636.05	384,188.97	1,344,301.64
349,480.90	1,331,278.64	413,570.32	1,301,565.22	378,919.35	1,343,725.22

Appendix B .2

Ground Coordinates of 2018 LULC Image with GPS and Google Earth

Shrub land		Urban		cultivated land	
X	Y	X	Y	X	Y
366,123.72	1,340,427.95	390,240.59	1,311,148.43	390,009.25	1,310,917.46
366,635.90	1,340,342.97	390,519.53	1,311,197.25	390,452.32	1,310,914.38
367,365.75	1,340,335.12	390,214.83	1,311,455.03	390,761.30	1,311,157.82
368,060.08	1,339,591.27	390,831.44	1,311,410.87	390,978.28	1,311,200.02

367,802.31	1,339,602.38	391,406.08	1,311,410.84	391,203.22	1,311,640.37
367,785.98	1,339,788.59	392,247.55	1,311,374.47	391,717.49	1,311,358.28
367,589.82	1,339,871.08	392,455.61	1,311,094.54	391,961.13	1,310,909.59
367,446.99	1,339,875.78	392,430.91	1,310,547.45	366,885.89	1,340,633.43
367,308.24	1,339,821.71	392,545.78	1,310,346.02	366,766.43	1,340,913.75
367,600.14	1,339,653.42	393,307.76	1,310,413.77	367,418.50	1,341,077.62
367,598.61	1,339,517.15	392,068.28	1,311,530.83	367,777.43	1,341,187.72
367,585.84	1,339,370.69	393,373.23	1,310,413.88	367,993.49	1,340,340.96
367,575.91	1,339,289.78	394,169.43	1,310,640.57	367,334.74	1,340,141.40
367,426.21	1,339,396.46	406,645.57	1,303,100.99	366,846.34	1,340,081.91
367,398.08	1,339,285.41	406,364.51	1,303,413.66	366,642.84	1,339,045.42
367,389.56	1,339,150.75	406,591.22	1,303,801.77	365,944.29	1,338,589.32
367,367.08	1,339,064.57	407,454.74	1,302,871.18	366,564.79	1,338,093.35
367,208.77	1,339,116.93	407,115.16	1,303,656.49	366,064.43	1,337,948.00
367,060.64	1,339,309.94	387,661.71	1,338,991.58	366,662.39	1,337,706.35
367,076.45	1,339,122.77	387,988.28	1,339,498.69	367,302.67	1,338,370.92
367,081.62	1,338,957.57	387,741.06	1,340,017.33	367,869.41	1,338,818.18
367,101.09	1,338,812.71	373,465.39	1,340,090.31	368,274.40	1,339,327.82
367,353.09	1,340,359.12	373,699.15	1,339,823.33	368,238.56	1,340,049.60
393,753.49	1,310,883.29	367,723.84	1,340,050.25	367,861.14	1,340,335.89
393,622.37	1,310,868.75	367,634.05	1,340,380.99	368,143.11	1,340,317.35
393,737.86	1,310,967.91	368,104.45	1,340,564.82	368,117.56	1,340,089.70
393,584.76	1,310,977.58	367,866.38	1,340,791.63	368,111.11	1,339,870.45

393,692.85	1,311,146.03	367,561.97	1,340,616.04	368,214.81	1,340,298.21
393,596.94	1,311,175.26	367,340.95	1,340,870.83	368,115.03	1,340,894.67
393,454.68	1,311,175.12	367,330.23	1,340,630.84	367,845.70	1,341,094.11
393,347.05	1,311,171.54	367,120.14	1,340,536.52	367,603.10	1,341,049.08
393,349.94	1,311,080.22	367,089.24	1,340,309.91	367,596.51	1,340,780.83
393,278.56	1,310,930.78	367,108.66	1,340,065.70	367,353.55	1,340,106.28
393,193.57	1,310,941.78	366,858.95	1,339,834.29	367,097.26	1,339,881.93
393,039.37	1,310,938.15	366,357.11	1,339,360.18	366,892.67	1,340,079.57
392,966.97	1,311,006.60	366,376.78	1,339,718.19	366,823.90	1,339,604.61
392,929.80	1,311,119.33	366,433.76	1,340,056.58	366,394.63	1,340,660.52
392,954.50	1,311,389.02	366,426.14	1,340,365.42	366,288.45	1,340,864.16
392,925.84	1,311,611.85	366,639.54	1,340,601.31	366,040.69	1,340,923.15

Water		Bareland		Forest	
X	Y	X	Y	X	Y
365,067.61	1,329,459.36	390,747.97	1,313,398.03	385,863.48	1,314,609.33
365,053.92	1,329,364.08	390,901.58	1,313,166.99	386,523.93	1,314,641.10
365,073.42	1,329,268.02	390,889.93	1,312,982.27	386,794.02	1,314,807.80
365,181.45	1,329,453.67	390,771.50	1,312,925.60	386,972.71	1,314,613.30
365,167.15	1,329,271.68	390,997.11	1,312,760.72	386,971.84	1,314,762.11
365,293.02	1,329,205.84	391,008.50	1,312,603.67	387,128.39	1,314,839.14
365,301.58	1,329,065.54	390,983.34	1,312,415.08	387,097.63	1,314,912.16
365,415.31	1,329,168.07	390,813.41	1,312,391.59	387,017.32	1,314,978.42
365,485.46	1,329,098.88	390,687.41	1,312,368.54	388,559.94	1,313,940.66
365,507.72	1,328,989.11	390,733.46	1,312,116.78	388,515.46	1,314,131.39

365,646.32	1,328,972.25	391,195.55	1,312,228.10	388,354.80	1,314,138.71
365,659.56	1,328,845.27	391,462.47	1,312,665.88	388,233.73	1,314,153.70
365,517.04	1,328,861.16	391,753.97	1,312,665.61	388,074.77	1,314,124.27
365,507.85	1,328,768.15	391,722.95	1,313,096.71	388,061.76	1,314,238.82
365,478.91	1,328,696.54	391,960.62	1,313,087.16	388,087.59	1,314,375.25
365,471.74	1,328,590.04	391,960.25	1,312,887.56	388,069.24	1,314,461.51
365,304.26	1,328,722.07	391,823.17	1,312,673.29	388,008.45	1,314,074.38
365,303.72	1,328,595.20	392,109.00	1,312,639.83	388,045.33	1,313,954.94
365,372.06	1,328,646.35	392,401.20	1,312,643.99	388,047.29	1,313,865.46
364,629.36	1,329,898.50	392,428.19	1,312,851.60	388,089.38	1,313,758.32
392,532.99	1,330,060.99	392,436.25	1,313,088.53	388,068.72	1,313,614.90
392,310.03	1,330,070.80	392,277.00	1,312,298.28	387,930.63	1,314,160.58
392,020.84	1,330,065.69	392,231.71	1,312,102.50	387,906.33	1,314,028.57
391,950.60	1,329,854.55	391,992.43	1,312,088.29	387,908.79	1,313,918.44
391,781.11	1,329,788.17	392,712.76	1,311,393.76	387,929.96	1,313,811.60
391,779.11	1,329,654.24	393,137.12	1,311,688.94	387,857.43	1,314,187.81
391,708.75	1,329,790.74	393,406.13	1,311,630.49	387,817.48	1,314,043.83
391,579.03	1,329,608.51	392,713.73	1,311,404.53	387,824.02	1,313,933.27
391,495.94	1,329,619.65	393,153.32	1,310,650.64	387,796.98	1,314,187.01
391,443.34	1,329,553.15	395,025.72	1,310,430.82	387,765.47	1,314,013.08
391,441.08	1,329,459.39	394,835.41	1,310,249.18	387,728.31	1,313,855.07
391,558.24	1,329,466.69	394,878.74	1,310,035.53	388,136.87	1,312,440.70
391,684.39	1,329,355.36	392,170.17	1,330,289.58	388,235.99	1,312,316.62

391,731.63	1,329,252.88	391,953.16	1,330,446.71	388,300.71	1,312,118.02
391,698.73	1,329,170.97	391,764.67	1,330,439.66	388,502.65	1,312,113.64
391,698.64	1,329,036.65	391,628.30	1,330,793.12	388,257.05	1,311,902.96
391,874.95	1,328,963.93	391,759.19	1,330,097.44	388,017.82	1,311,902.27
391,950.64	1,328,757.77	391,543.27	1,329,993.58	388,253.55	1,311,381.12
392,129.14	1,328,714.99	391,266.59	1,329,529.67	388,388.28	1,311,434.90