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IMPACT OF LAND USE LAND COVER CHANGE ON STREAM FLOW AND SEDIMENT YIELD IN TEMCHA WATERSHED, BLUE NILE BASIN, ETHIOPIA

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June 29, 2018

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DECLARATION

I, the undersigned, declare that the thesis comprises my own work. In compliance with internationally accepted practices, I have acknowledged and refereed all materials used in this work. I understand that non-adherence to the principles of academic honesty and integrity, misrepresentation/ fabrication of any idea/data/fact/source will constitute sufficient ground for disciplinary action by the University and can also evoke penal action from the sources which have not been properly cited or acknowledged.

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I dedicate this work to all my family.

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Abstract

Land use Land cover change is a very important issue considering global dynamics and their responses to environmental and socio-economic drivers. It is a challenge to predict land use changes and their effects on water availability and erosion rates. This study assesses the impact of land use land cover change on stream flow and sediment yield using SWAT model in Temcha watershed in the Blue Nile Basin. Three different years of 1986, 1999 and 2013 land use land cover maps were produced from satellite images by ERDAS Imagine software using the Maximum Likelihood Algorithm of Supervised Classification. The accuracy of the classified images was assessed using confusion matrices. The result indicated that cultivated land increased from 49.50 % to 87.44 %, while Grazing land has decreased from 10.97% to 6.31%, Forest area has decreased from 21.83% to 5.94% and Bush land decreased from 17.70% to 0.31% between 1986 to 2013. This change caused an increase of mean monthly stream flow for wet months by 2.23m^3/s while the dry season decrease by 0.58m^3/s and an increase of mean monthly sediment yield for wet months by 67.11 ton/day while the dry season decrease by 6.45 ton/day. The model results indicated a good agreement and correlation with the observed stream flow data with NSE = 0.74, R^2 =0.75, and RSR = 0.51 and sediment transport observed data with NSE =0.68, R^2= 0.70, and RSR = 0.56 values. From this study it can be concluded that Temcha watershed has experienced a significant change in land use land cover over the past 28 years. The changes in land use has resulted an increase of surface runoff and Sediment yield. It is suggested that the watershed needs for local governments and other stakeholders to apply proper soil and water conservation management and watershed development.

Key words: Temcha watershed, land use change, sediment yield, SWAT, ERDAS Imagine.

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ABBREVATIONS /ACRONYMS

ADSWE	Amhara Design & Supervision Works Enterprise
ANRS	Amhara National Regional State
BoWIE	Bureau of Water Irrigation & Energy
CN	Curve Number acronyms
DEM	Digital Elevation Model
ERDAS	Earth Resources Data Analysis System
FAO	Food and Agriculture Organization
GIS	Geographic Information System
HBV	Hydrologisika Bayraans Vattenbalans-avediling
HEC-RAS	Hydraulic Engineering Centre-River Analysis System
HEC-HMS	Hydraulic Engineering Centre-Hydrologic Modeling System
HRU	Hydrologic Response Unit
ITCZ	Inter-Tropical Convergence Zone
LS	Lump Sum
LULC	Land use and land cover
MoWIE	Minster of Water, Irrigation and Electricity
NMA	National Metrological Agency
NRCS	Natural Resource Conservation Service
NSE	Nash Sutcliff Efficiency
RMSE	Root Mean Square Error
RSR	Ratio of root mean square error to the measured deviation of measured data

SRTM	Shuttle Radar Topography Mission
SWAT	Soil and Water Assessment Tool
US	United States
UTM	Universal Transverse Mercator
USDA	United States Department of Agriculture
USDA-ARS	United States Department of Agriculture-Agricultural Research Service
HYDATA	Hydrological Database and Analysis System

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1. INTRODUCTION

1.1. Background

Land use and land cover change (LULCC) is a locally pervasive and globally significant environmental trend and has become a process of paramount importance to the study of global environmental change (Demessie, 2015). LULC is a widespread phenomenon and has contributed to the existing high rate of soil erosion and land degradation in the highlands of Ethiopia. Specifically, it has significant eco-hydrological impacts on soil physical and hydrological properties (Teferi et al., 2013). Land use planning and management are closely related to the sustainability of water resources as changes of land use are linked with amount of water through relevant hydrological processes. The effect of the land cover changes has impact on the stream flow of the watershed by changing the magnitude of surface runoff and ground water flow. The change in land use controls the water yields of surface streams and groundwater aquifers and thus the amount of water available for both ecosystem function and human use.

Land use change plays a significant role in water quality and quantity and there is a great need to integrate land change science, hydrology and water resources management in future research initiatives. (Hari Krishna et al., 2014). Land cover change strongly influences seasonal stream flow and alters the annual hydrograph of river flow in the basins (Guo et al., 2008). The potential effects on water resources due to land use/cover change and global climate change in the past few decades have been of great concern. Land clearing, agricultural activities, construction, mining, urban and industrial development, and similar activities can have a major impact on the quantity and rate of surface runoff, and on the rates of erosion and sediment transport that take place.

The knowledge on how land use/cover change influence watershed hydrology will enable local governments and policy makers to formulate and implement effective and appropriate response strategies to minimize the undesirable effects of future land use/cover change or modifications. Given that impacts of land use/cover change on water resources are the result of complex interactions between diverse site-specific factors and offsite conditions, standardized types of responses will rarely be adequate. General statements about land–water interactions need to be continuously questioned to determine whether they represent the best available information and whose interests they support in decision-making processes (FAO, 2002).

Understanding the implications of changes in land cover and land use is a fundamental part of sustainable land planning and development. On one hand, transformation of land cover and land use by human action can affect the integrity of a natural resource system and the output of goods and services of the ecosystem. On the other hand, by careful planning, the development of new patterns of land cover and land use can enhance the well-being of people. Modeling tools have changed the scientific framework for analysis of land use systems, from one that is descriptive to one that is more quantitative which addresses both spatial and temporal dynamics (Hari Krishna et al., 2014).

Land and water resources degradation are the major problems in the Ethiopian highlands. Poor land use practices and improper management systems have played a significant role in causing high soil erosion rates, sediment transport and loss of agricultural nutrients. So far limited measures have been taken to combat the problems (Setegn, 2008).

Ethiopia experiences pervasive land, water and environmental degradation due to localized and global climatic anomalies. These leave the country to recurrent crop failures and severe food shortages. Low soil fertility coupled with temporal imbalance in the distribution of rainfall and the substantial non-availability of the required water at the required period are the principal contributing factors to the low and declining agricultural productivity. Hence, proper utilization of the available soil and water resources is essential to Ethiopia's agricultural development and achievement of food security (Setegn, 2008). As a result, understanding the catchment dynamics in relation to the hydrology is an essential component to tackle the improper watershed alterations. Therefore, in this study we analyse the impact of land use land cover change on the hydrology of Temcha watershed in Blue Nile basin especially in stream flow and sediment yield.

1.2. Problem of Statement

Temcha watershed has been continuously under severe land resources degradation which is caused by a combination of natural phenomenon and man's action such as destruction of the forest resources through deforestation, overgrazing and inappropriate agricultural practices. As a result, soil and water erosion, sedimentation, increasing demand for water, flooding, pollution, and climate change becoming challenges to attainment of the social and economic developmental goals of the country in general and the watershed in particular. So far no effective measures have been taken to combat soil erosion and other problems. To solve the existing soil erosion problems and to implement mitigation measures there is a need to identify the most erosion sensitive areas in the watershed and to understand the processes and evaluate the magnitudes of the impact crucially. Therefore, in this study attempts to evaluate the impacts of land cover change on sediment yield and the stream flow of the Temcha watershed is carried out. This finding will enable stakeholders, local governments and policy makers for planning and implementations of appropriate measures.

1.3. Objective of the study

1.3.1. General objective:

The main objective of this study is to investigate the impact of land cover land use dynamics on the stream flow and sediment yield on Temcha watershed.

1.3.2. Specific objectives:

The specific objectives of the study are presented as follows:

- To detect the land use and land cover dynamics for 3 time periods in the watershed
- Modeling the stream flow & sediment yield by using soil and water Assessment Tool (SWAT) in the watershed.
- To evaluate the response of stream flow & sediment yield due to the land cover land use dynamics in the watershed.

1.4. Research Questions

This study was designed to answer the following question

- What are land use land cover changes & trends for the past 28 years (from 1986 to 2013) in the study watershed?
- How can SWAT model simulate stream flow & sediment yield in the watershed?
- What impact does land use and land cover change would have on stream flow and sediment yield of the watershed?

1.5. Scope of the study

This study is limited to the analysis of land use land cover change and its impacts on sediment yield and stream flow in the Temcha watershed. while land use land cover change effects on water quality, nutrients, pesticide, best management practices effect on sediment yield and stream flow etc. of the watershed are not consider in this study. This is due to lack of money, short time period and other supportive materials for the collection and analysis of data.

1.6. Significance of the study

The significance of the study would enable assessment of sustainability of land use systems. It is important to have an understanding of the land use and land cover patterns and the hydrological processes of the watershed. Understanding the types and impacts of land use and land cover change is essential indicator for resource base analysis and development of effective and appropriate response strategies for sustainable management of natural resources in the country in general and at the study area in particular. The information can also be applied to forecast the likely effects of any potential changes in land use/ land cover on water resource system. The study will provide the change rate and its effect on stream flow and sediment yield which is very vital in natural resource management & planning.

1.7. Structure of the Thesis

In this study the impact of land use cover change was detected using spatially semi-distributed SWAT model for three different years' land use data in five Chapters: Chapter one is an introduction section where the background, statement of the problem, objectives of the study, research questions and significance of the study are discussed. In Chapter two, Literature review where land use and land cover changes, Land use classification, Image Classification, Application of Remote sensing on land use and land cover changes, Effect of Land cover land use change on hydrology, Overview on sediment transport, hydrological models, SWAT model, review related previous studies are discussed. In Chapter Three, Materials and Methods section in which Description of the study area, Data Type and Collection, filling missed data and quality analysis, Image classification and accuracy assessment, model setup, sensitivity analysis calibration and validation, model performance evaluation are discussed. The fourth chapter describes the result and discussion which are land use and land cover analysis, stream flow modeling and evaluation of stream flow due to land use and land cover change. The land use and land cover analysis including land covers maps and accuracy assessment. The stream flow and sediment yield modeling includes sensitivity analysis, calibration and validation of stream flow & sediment yield simulation, the performance evaluation of the model and evaluation of stream flow and sediment yield due to land use land cover change. Finally, in chapter five, conclusions and recommendations of the study are provided.

2. LITERATURE REVIEW

2.1. Land Use and Land Cover Changes

Land cover refers to the physical and biophysical characteristics or state of Earth's surface and immediate, captured in the distribution of vegetation, water, desert, ice and other physical features of the land, including those created solely by human activities e.g., settlements. **Land use** refers to the intended use or management of the land cover type by human beings. Thus, land use involves both the manner in which the biophysical attributes of land are manipulated and intent underlining that manipulation for instance for the purpose for which the land is used e.g., agriculture, grazing, etc. (FAO, 1998a).

LULC is always caused by multiple interacting factors originating from different levels of organization of the coupled human environment systems. It is the result of complex interactions between several biophysical and socio-economic conditions which may occur at various temporal and spatial scales. The mix of driving forces of LULC varies in time and space, according to specific human-environment conditions. Understanding the underlying LULC drivers is an important input for planning and decision making (Malik and Bhat, 2014).

Historic land use cover change in Ethiopia is not properly known. Future understanding of land use/ cover change will need to be greatly improved with systematic methods and designs addressing land use change research. In order to understand the forces of change, it will be necessary to conduct studies that explicitly reveal the variations in change characteristics. The data needed to develop mitigation strategies that project land use/ cover change for specific intervals into the future could be generated and refined for use in land use classification (Netsanet, 2007). In Ethiopia, too fast population growth and uneven spatial distribution of population have been affecting resource use, leading to its gradual deterioration. Rapid population growth is resulting in increased demands for additional arable land which is surely not adequately available. Population growth leads further to unnecessary natural resource exploitation such as forest clearing both for farming and settlement purposes, and land fragmentation which has a direct adverse effect on erosion and water resource.

The researches that have been conducted in different parts of Ethiopia have shown that there were considerable land use and land cover changes in the country. Most of these studies indicated that croplands have expanded at the expanse of natural vegetation including forests and shrublands; for example, (Wolka et al, 2014) in south part of Ethiopia, (Husein, 2016), (Tesfa, 2015), (Ahmed, 2018) in northern part of Ethiopia

According to many literatures, population growth has a paramount impact on the environment. For instance, population pressure has been found to have negative effect on Riverine vegetation, scrublands and forests in Kalu district (Tekle and Hedlund, 2000), Riverine trees in Chemoga watershed (Bewket, 2003), and natural forest cover in Dembecha Woreda north-western Ethiopia (Gete and Hans, 2001). Similarly, Pender et al. (2001) report that the population growth has significant effect on land degradation, poverty and food insecurity in the northern Ethiopian highlands.

Generally, Ethiopia is at a crossroad and needs to improve its biophysical resources in order to feed its growing population. Understanding the driving forces of land use development in the past is use for managing the current situation with modern GIS tools, and modeling the future, able to develop plans for multiple uses of natural resources and nature conservation. The knowledge about land use and land cover has become increasingly important as all nations plan to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands, and loss of fish and wildlife habitats (James R. Anderson, 2001). For proper planning, these cause and effect interrelations need to be understood. This especially important for Ethiopia where the resource base is declining and should be improved in order to feed its growing population.

2.2. Land Use Classification

A land use and land cover classification system which can effectively employ orbital and high altitude remote sensor data should meet the following criteria (Anderson, 1971):

1. The minimum level of interpretation accuracy in the identification of land use and land cover categories from remote sensor data should be at least 85 percent.
2. The accuracy of interpretation for the several categories should be about equal.
3. Repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another.
4. The classification system should be applicable over extensive areas.
5. The categorization should permit vegetation and other types of land cover.
6. The classification system should be suitable for use with remote sensor data obtained at different times of the year.
7. Effective use of subcategories that can be obtained from ground surveys or from the use of larger scale or enhanced remote sensor data should be possible.
8. Aggregation of categories must be possible.
9. Comparison with future land use data should be possible.
10. Multiple uses of land should be recognized when possible.

2.3. Landsat Image

Earth Observation data acquired by the Landsat missions are of immense value to the global community and constitute the world's longest continuous civilian Earth Observation program. The Landsat program is the longest-running enterprise for acquisition of satellite imagery of Earth. On July 23, 1972 the Earth Resources Technology Satellite was launched. There have been seven functional Landsat satellites spanning from 1972 to the current Landsat 8 mission, constituting the longest running civilian enterprise for acquisition (Purss et al, 2015). The instruments on the Landsat satellites have acquired millions of images. The images, archived in the United States and at Landsat receiving stations around the world, are a unique resource for global change research and applications in agriculture, cartography, geology, forestry, regional planning, surveillance and education, and can be viewed through the U.S. Geological Survey (USGS) 'EarthExplorer' website.

Landsat missions 1 through 5 carried the Landsat Multispectral Scanner (MSS), while missions 4 and 5 used the Landsat Thematic Mapper (TM) scanner. There are big and diverse applications of Landsat imagery and satellite date in general, ranging from ecology to geopolitical matters. Land cover determination has become a very common use of Landsat Imagery and remotely sensing generated images all around the world.

2.4. Image Classification

Image classification is perhaps the most important part of digital image analysis. It is very nice to have a "pretty picture" or an image, showing a magnitude of colors illustrating various features of the underlying terrain, but it is quite useless unless to know what the colors mean. Image classification is used to identify and portray, as a unique gray level (or color), the features occurring in an image in terms of the object or type of land cover these features actually represent on the ground. The intent of the image classification process is to categorize all pixels in a digital image into one of several land cover classes, or "themes". This categorized data may then be used to produce thematic maps of the land cover present in an image. Normally, multispectral data are used to perform the classification and, indeed, the spectral pattern present within the data for each pixel is used as the numerical basis for categorization.

Image processing takes a basic understanding of remote sensing and of digital images through the fundamental stages of image processing. It also provides a varied set of cases for application of image processing and introduces a wide range of processing techniques. These form the basis for continued development to advanced level. It is the process of assigning each pixel of an image to a particular group or class. In this case the classes are land cover or crop types, so that the aim is eventually to map the land cover types of the whole image. Usually it needs to acquire ground reference land cover information from a field test site within the image. This site or sites were representative of the range of land cover types that might be found in the area.

There are two main classification methods which are supervised classification and unsupervised Classification.

2.4.1. Supervised Classification

During supervised classification, the classifier/expertise identifies examples of the information classes (i.e., land cover type) of interest in the image which is called "training sites". The image processing software system is then used to develop a statistical characterization of the reflectance for each information class. This stage is often called "signature analysis" and may involve developing a characterization as simple as the mean or the average of reflectance on each bands, or as complex as detailed analyses of the mean, variances and covariance over all bands. Once a statistical characterization has been achieved for each information class, the image is then classified by examining the reflectance for each pixel and making a decision about which of the signatures it resembles most. The objective is to extend, or extrapolate information on land cover types for a known area of the image to the unknown areas of the whole image. The image analyst defines a number of training areas for each land cover category. The computer generates spectral signatures based on this information. Typically, a maximum likelihood descriptor is used to measure the spread of values around the mean of the class. Each pixel of the image is assigned as far as possible to one of the land cover groups, as defined by the signature.

2.4.2. Unsupervised Classification

Unsupervised classification is a method which examines a large number of unknown pixels and divides into a number of classed based on natural groupings present in the image values. Unlike supervised classification, unsupervised classification does not require analyst-specified training data. The basic premise is that values within a given cover type should be close together in the measurement space (i.e. have similar gray levels), whereas data in different classes should be comparatively well separated (i.e. have very different gray levels) (Lillesand and Kiefer, 1994).

Unsupervised classification is the simplest technique. Within the image data for the different wavelengths the computer is asked to determine a user-defined number of clusters. Each cluster represents a land cover class or sub-class. The mean digital value for each input band could be represented as a spectral reflectance profile. The cluster represents the spread of values around the mean for the land cover class. After the classification has been completed each class should be examined and assigned a name. It may also be necessary to merge a number of classes into a single category. The classes that result from unsupervised classification are spectral classed which is based on natural groupings of the image values, the identification of these spectral classes will not be initially known, must compare classified data to some form of reference data (such as larger scale imagery, maps, or site visits) to determine the identity and informational values of the spectral classes (Lillesand and Kiefer, 1994).

An unsupervised approach is useful where no prior ground information exists; is not biased in defining classes; is relatively rapid to compute; and accounts for all cover types in an image. However, the process of identifying and merging classes can be time consuming and the statistical description of the spread of values within the cluster is not as good as the maximum likelihood classifier. Conversely the supervised maximum likelihood approach is time consuming when identifying training areas; relatively slow to compute; and can only produce a class map for which there are training areas (Pembury, 2005).

Unsupervised classification is becoming increasingly popular in agencies involved in long term GIS database maintenance. The reason is that there are now systems that use clustering procedures that are extremely fast and require little in the nature of operational parameters. Thus it is becoming possible to train GIS analysis with only a general familiarity with remote sensing to undertake classifications that meet typical map accuracy standards. With suitable ground truth accuracy assessment procedures, this tool can provide a remarkably rapid means of producing quality land cover data on a continuing basis.

2.4.3. Maximum likelihood Classification

Maximum likelihood Classification is a statistical decision criterion to assist in the classification of overlapping signatures; pixels are assigned to the class of highest probability. The maximum likelihood classifier is considered to give more accurate results than parallelepiped classification however, it is much slower due to extra computations. We put the word `accurate' in quotes because this assumes that classes in the input data have a Gaussian distribution and that signatures were well selected; this is not always a safe assumption.

2.4.4. Ground truth and classification accuracy assessment

Ground truth or field survey is done in order to observe and collect information about the actual condition on the ground at a test site and determine the relationship between remotely sensed data and the object to be observed. It is recommended to have a ground truth at the same time of data acquisition, or at least within the time that the environmental condition does not change. Classification accuracy assessment is a general term for comparing the classification to geographical data that are assumed to be true to determine the accuracy of the classification process. Usually, the assumed true data are derived from ground truth. It is usually not practical to ground truth or otherwise test every pixel of a classified image. Therefore, a set of reference pixels is usually used. Reference pixels are points on the classified image for which actual data are (will be) known. For this study the reference pixel is collected by field survey.

2.4.5. Evaluating the accuracy of image classification

The basic idea is to compare the predicted classification (supervised or unsupervised) of each pixel with the actual classification as discovered by ground truth. Accuracy assessment is a general term for comparing the classification to geographical data that are assumed to be true, in order to determine the accuracy of the classification process. The accuracy of a classification is usually assessed by comparing the classification with some reference data that is believed to accurately reflect the true land cover. Sources of reference data include among other things ground truth, higher resolution satellite images, and maps derived from aerial photo interpretation. Note that virtually all reference data (even ground truth data) are inaccurate to some degree as well. Accuracy assessment is the measurement of the rate and level to which classified image agrees with the reference (ground) data it represents. In statistical terms, accuracy comprises bias and precision and the distinction between the two is sometimes important as one may be traded for the other (Campbell, et al, 1989). In mapping of features from a remotely sensed data, the term accuracy is often used to portray the level of ‘validity’’ and ‘’correctness’’ of a map or classification. ‘‘Valid’’ or ‘’Correct’’ (thematic) maps are those that represent the reality to a significant level of acceptance. That is, a map (thematic) derived from remotely sensed data classification may be considered accurate if it provides an unbiased representation of the actual area of the region it depicts. Therefore, classification accuracy describes the degree to which the derived image classification agrees with reality or conforms to the ‘’truth’’ (Campbell, et al, 1989). A classification error is, thus, some discrepancy between the situation depicted on the thematic map and reality (Foody, 2002). Classification Accuracy Assessment Measures: Accuracy of any image classification may be tested in four different ways;

1. Field checks at selected points: This is usually a non-rigorous statistical technique and it is subjective, that is, it may not be applicable to all classification cases. Selected points of verification are chosen either randomly or along a grid
2. Map overlays: This is a qualitative comparative method which aims to estimate the agreement of theme or class that are identified between a class map and reference maps. The class map and the reference maps are usually superimposed – one on the other
3. Statistical analysis of numerical data: Developed in sampling, measuring, and processing data, using such tests as root mean square, standard error, analysis of variance, correlation coefficients, linear or multiple regression analysis, and Chi square testing, and
4. Confusion matrix calculations: The confusion matrix is a simple cross-tabulation of the mapped class label against the observed in the ground or reference data for a sample set. Several measures of classification accuracy may be derived from a confusion matrix. One of the most popular is the percentage of cases correctly classified. The following are some of the accuracy calculations and indices that can be generated from a confusion matrix;
   A. Overall accuracy: It is obtained by dividing the total number of correct pixels (diagonal) by the total number of pixels in the error matrix.

B. Producer accuracy: Omission error is another term used to mean producer accuracy, it occurs whenever pixels that should have been identified as belonging to a particular class were simply not recognized as present. Producer accuracy is obtained by dividing the total pixels not correctly classified for each class in the reference data (column) by the total pixels for that class in the reference data/image (column total)

C. User accuracy: User accuracy is also referred to as Commission Error. Commission error occurs when pixels associated with a class are incorrectly identified as other classes, or from improperly separating a single class into two or more classes. Commission error is calculated by dividing the number of pixels' not correctly classified for each class in the classification (row) by the total number of pixels for that class in the classification (row total).

D. Mapping accuracy: Mapping accuracy for each class is stated as the number of correctly identified pixels within the total in the displayed area divided by that number plus error pixels of commission and omission.

E. Kappa co-efficient of agreement: Cohen 's kappa coefficient is a chance adjusted measure that was developed and has often been used and adopted as a standard measure of classification accuracy.

2.5. Application of Remote Sensing on LULC Change

Remote Sensing (RS) is defined as the science of obtaining information about an object, area, or phenomenon through the analysis of data acquiring by a device which is not contact with the object, area, or phenomenon under investigation (Bawahidi, 2005). It provides a large amount of data about the earth surface for detailed analysis survey, change detection and map our global environment through use of satellite remote sensing technology. Space based technologies and their applications are playing a key role, to optimize planning, implementation and monitoring of water resource projects. Most of data inputs to the hydrological (SWAT) model is directly or indirectly extracted from remotely sensed data. Some of the important data used in the hydrological modeling that are obtained from remote sensing include digital elevation model (DEM) and land cover maps. Some of the application of remote sensing technology in mapping and studying of the land use and land cover changes are; map and classify the land use and land cover, assess the spatial arrangement of land use and land cover, allow analysis of time-series images used to analyze land scape history, report and analyze results of inventories including inputs to Geographic Information System (GIS), provide a basis for model building. Land use and land cover is changing rapidly in most parts of the world. In this situation, accurate, meaningful and availability of data is highly essential for planning and decision making. Remote sensing is particularly attractive for the land cover data among the different sources. Stefanov, et al (2001) reported that in 1970's satellite remote sensing techniques have started to be used as a modern tool to detect and monitor land cover change at various scales with useful results. William, et al (1991) showed that the information of land use and land cover change which is extracted from remotely sensed data was vital for updating land cover maps and the management of natural resources and monitoring phenomena on the surface. The importance of land cover mapping is to show the land cover changes in the watershed area and to divide the land use and land cover in different classes of land use and land cover. For this purpose, remotely sensed imagery plays a great role to obtaining information on both temporal trends and spatial distribution of watershed areas and changes over the time dimension for projecting land cover changes but also to support changes impact assessment (Atasoy, et al., 2006). To monitor the rapid changes of land cover, to classify the types of land cover, and to obtain timely land cover information, multi temporal remotely sensed images are considered effective data sources. Space based technologies and their applications are playing a key role, to optimize planning, implementation and monitoring of water resource projects.

ERDAS Imagine Software

ERDAS Imagine is a remote sensing application with raster graphics editor abilities designed by ERDAS for geospatial applications. Imagine is aimed mainly at geospatial raster data processing and allows users to prepare, display and enhance digital images for mapping use in geographic information system (GIS) and computer-aided design (CAD) software. It is a toolbox allowing the user to perform numerous operations on an image and generate an answer to specific geographical questions (El-Hattab,2016). By manipulating imagery data values and positions, it is possible to see features that would not normally be visible and to locate geo-positions of features that would otherwise be graphical. The level of brightness, or reflectance of light from the surfaces in the image can be helpful with vegetation analysis, prospecting for minerals etc. Other usage examples include linear feature extraction, generation of processing work flows (spatial models in Imagine), import/export of data for a wide variety of formats, orthorectification, mosaicking of imagery, stereo and automatic feature extraction of map data from imagery.

ERDAS Imagine is an image processing software package that allows users to process the geospatial and other imagery as well as vector data. ERDAS can also handle hyper spectral imagery and LiDAR (Light Detection and Ranging) from various sensors. ERDAS also offers a 3D viewing module (Virtual GIS) and a vector module for modeling. The native programming language is EML (ERDAS Macro Language). ERDAS is integrated within other GIS and remote sensing applications and the storage format for the imagery can be read in many other applications (*.img files). Leica Geo-systems also purchased ER Mapper to add to their mapping software.

2.6. Effect of Land Cover Land Use Change on Hydrology

It is obvious that land cover can affect both the degree of infiltration and runoff following rainfall events, while the degree of land cover can affect rates of evaporation. Land cover has various properties that help to regulate water flows both above and below ground. For example, tree canopy and leaf litter can help reduce the impact of raindrops on the ground, hence reduce soil erosion, while roots hold the soil in place and also absorb water. In the absence of vegetative cover, soil erosion will result and the effects of this phenomenon have been detailed previously.

Ethiopia is the water tower of northeastern Africa. However, land cover change can affect the amount of runoff to the downstream countries of the Nile basin. The effects of land cover are not only contained within the country, but also on the low-lying countries of northeastern Africa as well. That is why agreements are being signed between Ethiopia and these countries so that Ethiopia takes care of its soil erosion. Land cover change does not only affect the neighboring countries but also the Nile basin, within the country, where flooding is a common phenomenon. As a result of this, millions worth of resources are lost nearly every main rainy season. Low level vegetative cover could also affect infiltration and could lead to reduced groundwater levels and therefore the base flow of streams (Dagnachew et al, 2003).

The relationship between land use and hydrology is of greater interest worldwide as it can provide advice for management actions in order to avoid or minimize the negative effects of specific land use activities on the hydrology of a certain region. However, there are still uncertainties on the impact of specific land use practices to different processes of the hydrological cycle due to the complexity and specificity of characteristics of each catchment. Much of the present understanding of land use effects on hydrology is derived from controlled experiments and manipulations of the land surface coupled with observations of hydrological processes, commonly precipitation inputs and stream discharge outputs (De Friesand Eshleman,2004).

The magnitude of changes on the stream flow due to land use changes varies with catchments and other factors such as climate and human activities. Regarding the impact of deforestation and afforestation on the dry season flow in the tropics, there are conflicting statements and findings. Edward et al. (1979) in an experiment conducted in Mbeya, observed that the dry season flow was higher from a catchment with traditional small holder cultivation than with forest cover, even on steep slopes. Similar results were observed after deforestation of Brachy stegia woodland in Zambia and Montane hard wood forest in Taiwan (Taye, 2016).

2.7. Overview on Sediment Transport

2.7.1. Sediment Transport and Discharge Relationships

Sedimentation embodies the processes of erosion, entrainment, transportation, deposition, and the compaction of sediment. These are natural processes that have been active throughout geological times and have shaped the present landscape. Principal external dynamic agents of sedimentation are water, wind, gravity, and ice. When the transporting agent is water, it is called fluvial or marine sediment transport. Aeolian sediment is that moved or deposited by wind. Detachment of sediment particles in the erosion process occurs through the kinetic energy of raindrop impact, or by the force generated by flowing water. Once a particle has been detached, it must be entrained before it can be transported away (VanRijn, 1993). Stream and river control works may have a serious local influence on channel erosion. Channel straightening which increases slope and flow velocity, may initiate channel and bank erosion. If the bed of a main stream is lowered, the beds of tributary streams are also lowered. In many instances, such bed degradation is beneficial because it restores the flood-carrying capacity of channels. The problems associated with sediment deposition are varied. Sediments deposited in stream channels reduce flood-carrying capacity, resulting in more frequent overflows and greater flood water damage to adjacent properties. The deposition of sediments in irrigation and drainage canals, in navigation channels and floodways, in reservoirs and harbors, on streets and highways, and in buildings not only creates a nuisance but inflicts a high public cost in maintenance, removal, or in reduced services. Sedimentation is of vital concern in the conservation, development, and utilization of our soil and water resources (Julien, 2010). Relationships (sediment ratings) were developed between sediment transport and water discharge pairs of data. Scatter plots of logarithms of these data tend to plot as linear patterns with approximately constant variance across the range of discharge. Therefore, relationships were developed using least squares regression analysis on log transformed data using the following model,

$$\text{Log } G = \alpha 0 + \alpha 1 \text{ Log } Q \text{--} 1$$

Where Log G is the predicted logarithm of sediment transport, Log Q is the logarithm of the corresponding water discharge, and $\alpha 0$ and $\alpha 1$ are regression estimates of unknown parameters computed from the collected data. However, other models may also perform well for some of the individual data sets. Sediment ratings (equation 1) were developed for total bed load, bed load by selected size classes, and suspended sediment. At a few sites, the collecting agency reported a bed load transport rate of zero on selected sampling dates. Since the log of zero is undefined, these data were not used in developing the sediment ratings (John, et al, 2004)

2.7.2. Sediment Transport Processes

Sediment transport can be defined as the movement of soil particles downstream caused by gravity and the force of moving fluid imparted. The ability of a particle to move is then related to shear stresses, frictional forces, water depth, and specific weight. These components can be classified into two general categories hydraulics and hydrology, and sediment physics. Sediment transport is a function of slope, velocity, discharge, vegetation, sediment particles size, mean sediment inflow rate and channel morphology. When each of these allows a river to become stable, a river is said to have reached dynamic equilibrium. Basically, erosion of sediment from a watershed begins the process of sediment transport or through human activities, while elements such as wind and chemical reactions can cause erosion. The main proponent of erosion is water; either in a flowing stream or as precipitation falling on earth's surface. Once a particle has been detached, water becomes the "principal vehicle for transport of the eroded material," (Linsley, et al, 1975). The effects of human interference with the sediment transport process have resulted in measureable impacts on water quality.

Soil erosion from hill slopes in hydrological watersheds, one of the most serious problems of today's world, consists of motion of soil particles detached by factors such as rainfall, runoff, wind and transported within flow to finally be deposited either at a downstream section of the river with a lower topo graphical slope or in a downstream river reservoir. The characteristics of a watershed that affect river flows, area, elevation and geology also influence the amount and rate of sediment that can be carried by the river. The sediment load that a river carries is the result of geologic erosion of its watershed. The force of flowing water varies depending on the volume of water in the watershed and the channel slope. Steep gradient rivers have more erosive power than low gradient rivers and may be deeply incised into the surrounding landscape and adjacent floodplain areas. Low gradient rivers are often depositional with large broad floodplains. High volume and high velocity flows can carry heavier sediment farther than slower flows. The changes in flows over time distribute the sediments across the floodplain into layers of sediment shaped into a characteristic geomorphology. Water moves more quickly down a steep canyon than through a relatively flat valley floor. Rivers that flow through wide valleys tend to deposit sediment frequently during normal flows, because the sediment cannot be carried far by slow moving water. As a result, rivers in wide valleys continually build their floodplains. Rivers that flow through steep canyons are more erosive because of their increased velocity. Typically, these rivers form deep and narrow channels and because of the velocity of the water, the sediment is carried by the river flow until the water velocity decreases and sediments fall out of solution. The most important results of the sediment transport process are bank erosion and point-bar formation, which overtime builds floodplains by deposition of sediment. Together, bank erosion, point-bar formation and floodplain building result in the lateral movement of the channel, or channel meander.

2.7.3. Soil Erosion and Sedimentation

soil erosion and its transport out of the drainage basin are complex processes. An intensive program of direct field measurements would be needed to provide the information for a complete understanding of the links between sediment mobilizations on the catchment surface, delivery to the channel network, sediment storage and sediment yield at the catchments outlet. The sediment yield represents only a part of the total erosion within catchment, since a significant portion is deposited before reaching the outlet of a stream network (Fuchs, 2004). Sediment yield is the end product of erosion or wearing away of the land surface by the action of water, wind, ice and gravity. The total amount of onsite sheet, rill, and gully erosion in a watershed is known as the gross erosion. However, not all of this eroded material enters the stream system. Some of the material is deposited as alluvial fans, along river channels, and across flood plains. The portion of the eroded material that is transported through the stream network to some point of interest is referred to as the sediment yield. Most of the empirical approaches for the estimation of erosion rate are based on one of the following methods:

1. Universal Soil Loss Equation (USLE) or its modified versions

2. Sediment yield as a function of drainage area
3. Sediment yield as a function of drainage characteristics

2.7.3.1. Universal Soil Loss Equation

Soil erosion rates on cultivated land can be estimated by the use of universal soil loss equation (Wischmeier and Smith, 1965). This method is based on statistical analysis of data from 47 locations in 24 states in the Central and Eastern United States. The Universal Soil Loss Equation is:

A=R*K*L*S*C*P--2

where A is computed soil loss in tons/acre/year, R is rainfall factor, K is soil-erodibility factor, L is the slope-length factor, S is slope-steepness factor, C is cropping-management factor, and P is erosion-control practice factor. The rainfall factor, R accounts for differences in rainfall intensity, duration and frequency for different locations; that is, the average number of erosion-index units in a year of rain. The soil-erodibility factor, K is a measure of the intrinsic susceptibility of given soil to soil erosion. It is the erosion rate per unit of erosion-index for a specific soil in cultivated, continuous fallow, on a 9-percent slope, 72.6 feet long. The K-factor values range from 0.7 for highly erodible loams and silt loams to less than 0.1 for sandy and gravelly soil with a high infiltration rate (Wischmeier and Smith, 1965). The slope-length factor, L accounts for the increased quantity of runoff that occurs as distance from the top of the slope increases. It is the ratio of the soil loss from a given slope length to that from a 72.6-foot length, with all other conditions the same. The slope-steepness factor, S accounts for the increased velocity of runoff with slope steepness. It is the ratio of soil loss from a given slope steepness to that from a 9-percent slopes. The effects of slope length and steepness are usually combined to one single factor; that is, the LS factor, which can be computed by:

$$LS = \left(\frac{\lambda}{72.6}\right)^{m} * \left(65.41\sin\theta + 4.56\sin\theta + 0.065\right) \quad \text{------------------------------------3}$$

where λ = actual slope length in feet, θ = angles of slope, and m = an exponent with value ranging from 0.5 for slope equal to or greater than 5 percent to 0.2 for slope equal to or less than 1 percent. The cropping-management factor, C accounts for the crop rotation used, tillage method, crop residue treatment, productivity level, and other agricultural practice variables. It is the ratio of soil loss from a field with given cropping and management practices to the loss from the fallow conditions used to evaluate the K-factor. The erosion-control practice factor, P accounts for the effects of conservation practices, such as contouring, strip-cropping, and terracing, on erosion. It is the ratio of soil loss with a given practice to soil loss with straight-row farming parallel to the slope. For example, soil loss may be reduced by 50 percent on a 2 to 7 percent slope as a result of contouring. However, contouring becomes less effective with increasing slope. For steep slopes, terracing is a more effective conservation practice.

2.7.3.2. Modified Universal Soil Loss Equation

(Williams 1975) modified the USLE to estimate sediment yield for a single runoff event. On the basis that runoff is a superior indicator of sediment yield than rainfall i.e., no runoff yields any sediment, and there can be rainfall with little or no runoff. Williams replaced the R (rainfall erosivity) factor with a runoff factor. His analysis revealed that using the product of volume of runoff and peak discharge for an event yielded more accurate sediment yield predictions, especially for large events, than the USLE with the R factor. The Modified USLE, or MUSLE, is given by equation 4.

$$S=95(QPp)^{0.56}K*L*S*C*P \text{--} 4$$

Where S is sediment yield for a single event in tons, Q is total event runoff volume (ft^3), Pp is event peak discharge ($ft^3\ s^{-1}$) and K, L, S, C, and P is USLE parameters as similar to equation 3. The comparison with the USLE was done by estimating the average annual soil loss with the USLE and comparing it to the annual soil loss calculated for each event over the course of the year using the MUSLE. The MUSLE has been tested (Williams, 1981 and; Smith, et al., 1984) and found to perform satisfactorily on grassland and some mixed use watersheds. However, the utility of the MUSLE depends a great deal upon the accuracy of the hydrologic inputs.

2.7.3.3. Extension of Measured Data and Direct Measurement of Sediment Yield

The most accurate method for determining the long term sediment yield from a watershed is by direct measurement of sediment deposition in a reservoir (Blanton, 1982) or by direct measurement of stream flow, suspended sediment concentration and bed load.

The average annual sediment load can then be used to estimate the long-term sediment yield. Long term measurements of suspended sediment concentration are not commonly available and long-term measurements of bed load are rare. A short-term record of suspended sediment concentrations can be extended by correlation with stream flow. A power equation (equation 5) is most commonly used for regression analysis.

$C=aQ^b$---5

where C is the sediment concentration, Q is the rate of stream flow, a and b are regression coefficients. The relationship between stream flow and suspended sediment concentration can change with grain size, from low flows to high flows, from season to season, and from year to year. Therefore, enough measurements of suspended sediment concentration and stream flow are necessary to ensure that the regression equation is applicable over a wide range of stream flow conditions, seasons, and years. A single regression equation may produce an acceptable correlation over a narrow range of conditions. However, separate regression equations may be necessary to achieve satisfactory correlations over a wide range of conditions. For example, the suspended sediment concentrations could be divided into wash load and bed-material load to develop separate regression equations for each. The data could also be sorted by stream flow to develop separate regression equations for low, medium, and high flows. The data may need to be sorted by season to develop separate regression equations for the winter and spring flood seasons. If enough data were available, a portion of the data could be used for the regression analysis, so that the remaining portion could be used for verification. A short-term record of bed load measurements could be extended in the same manner as that described for the suspended sediment concentrations. If no bed load measurements were available, then bed load could be estimated as a percentage of the suspended sand load (typically 2 to 15%) or computed using one of many predictive equations. (Strand and Pemberton, 1982) presented a guide for estimating the ratio of bed load to suspended sediment load on (table 2.1) which presents five conditions that estimate the ratio of bed load to suspended sediment load as a function of the streambed material size, the fraction of the suspended load that is sand and the suspended sediment concentration during floods. A bed load measurement program should be considered if the bed load could be more than 10 percent of the suspended sediment load.

Table 2.1: Bed load adjustment.

Stream bed material	Fraction of suspended sediment load Sand (%)	Suspended sediment concentration (ppm)	Ratio of bed load to suspended sediment load
Sand	20 - 50	< 1000	20 - 150
Sand	20 - 50	1000 – 7500	10-35
Sand	20 – 50	> 7500	5
Compacted clay, gravels, cobbles or boulders	< 25	Any	5-15
Clay and silt	Near 0	Any	< 2

2.8. Hydrological Models

Hydrological models are mathematical descriptions of components of the hydrologic cycle. They have been developed for many different reasons and therefore have many different forms. However, hydrological models are in general designed to meet one of the two primary objectives. The one objective of the watershed hydrologic modelling is to get a better understanding of the hydrologic processes in a watershed and of how changes in the watershed may these phenomena. The other objective is for hydrologic prediction (Tadele, 2007).

On the basis of process description, the hydrological models can be classified in to three main categories (Cunderlik, 2003).

I. **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.

II. **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 behaviour. 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.

III. **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 is more physically-based than the structure of lumped models, and they are less demanding on input data than fully distributed models. SWAT (Arnold, et al., 1993), HEC-HMS (US-ACE,2001), HBV (Bergström, 1995), are considered as semi-distributed models.

Hydrologic Model Selection

There are a range of possible model structures within each class of models. Hence, choosing a particular model structure for a particular application is one of the challenges of the model user community. (Beven, 2000) suggested four criterions for selecting model structures as below.

I. Consider models which are readily available and whose investment of time and money appeared worthwhile.

II. Decide whether the model under consideration will produce the outputs needed to meet the aims of a particular project.

III. Prepare a list of assumptions made by the model and check the assumptions likely to be limiting in terms of what is known about the response of the catchment. This assessment will generally, be a relative one, or at best a screen to reject those models that are obviously based on incorrect representations of the catchment processes.

IV. Make a list of the inputs required by the model and decide whether all the information required by the model can be provided within the time and cost constraints of the project

For this study SWAT model has been selected based on the above criteria's and over the advantages as summarized below;

a. The model was applied for land use and land cover change impact assessment in different parts of the world and Ethiopia.
b. The model simulates the major hydrological process in the watersheds
c. It is less demanding on input data, and
d. It is readily and freely available.

SWAT model were chosen for the compatibility of available data and software and for its complex representation of fine spatial scales. Moreover, SWAT has become popular among environmental managers since it has been adopted as a component of the USA Environmental Protection Agency's Better Assessment Science Integrating Point and Non Point Sources software packages (Gassman, et al., 2007). SWAT has shown to be successful for land-use change assessments and has generated an expanding body of research projects. SWAT has also been extensively validated across the USA for stream-flow and sediment loads (Santhi, at el., 2001). Many researchers have utilized SWAT in their research questions in other countries including Europa, Asia and Africa. Strong emphasis on vegetation and hydrological interactions within SWAT make it a preferable model for this land use based hydrological analysis. A major limitation of SWAT for large area is the spatial detail required to correctly simulate environmental processes. For example, it is difficult to capture the spatial variability associated with precipitation within a watershed. Another limitation is data files can be difficult to manipulate and can contain several missing records. The model simulations can only be as accurate as the input data. The third limitation is that; the SWAT model does not simulate detailed event-based flood and sediment routing (Matjaž and Marina, 2012).

2.9. 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, 2005).

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, 2005). Major hydrologic processes that can be simulated by this model include evapotranspiration, surface runoff, infiltration, percolation, shallow aquifer and deep aquifer flow, and channel routing (Arnold et al., 1998).

2.9.1. Hydrological Component of SWAT

The Simulation of the hydrology of a watershed is done in two separate divisions. One is the land phase of the hydrological cycle that controls the amount of water, sediment, nutrient and pesticide loadings to the main channel in each sub-basin. Hydrological components simulated in land phase of the Hydrological cycle are canopy storage, infiltration, redistribution, evapotranspiration, lateral subsurface flow, surface runoff, ponds, tributary channels and return flow. The second division is routing phase of the hydrologic cycle that can be defined as the movement of water, sediments, nutrients and organic chemicals through the channel network of the watershed to the outlet. In the land phase of hydrological cycle, SWAT simulates the hydrological cycle based on the water balance equation (equation 7).

$$SW_t = SW_0 + \sum_{i=1}^{t}(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}) \quad \text{------------------------------ (6)}$$

In which SW_t is the final soil water content (mm H_2O), SW_0 is the initial soil water content on day i (mm H_2O), t is the time (days), R_{day} is the amount of precipitation on day i (mm H_2O), Q_{surf} is the amount of surface runoff on day i (mm H_2O), E_a is the amount of evapotranspiration on day i (mm H_2O), W_{seep} is the amount of water entering the vadose zone from the soil profile on day i (mm H_2O), and Q_{gw} is the amount of return flow on day i (mm H_2O). More detailed descriptions of the different model components are listed in (Arnold, J.G et al, 1998) and (Neitsch S.L et al, 2005).

Surface runoff occurs whenever the rate of precipitation seep gw exceeds the rate of infiltration. SWAT offers two methods for estimating surface runoff: the SCS curve number procedure (USDA-SCS 1972) and the Green &Ampt infiltration method (Green, W.H. and Ampt, G.A., 1911). Using daily or sub daily rainfall, SWAT simulates surface runoff volumes and peak runoff rates for each HRU. In this study, the SCS curve number method was used to estimate surface runoff because of the unavailability of sub daily data for Green & Ampt method.

The SCS curve number equation is:

$$Q_{surf} = \frac{(R_{day} - 0.2S)^2}{R_{day} + 0.8S} \quad \text{-- (7)}$$

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 8

$$S = 25.4(\frac{100}{CN} - 10) \text{ --- (8)}$$

Where, CN is the curve number for the day and its value is the function of land use practice, soil permeability and soil hydrologic group.

For the definition of hydrological groups, the model uses the U.S. Natural Resource Conservation Service (NRCS) classification. The classification defines a hydrological group as a group of soils having similar runoff potential under similar storm and land cover conditions. Thus, soils are classified in to four hydrologic groups (A, B, C, and D) based on infiltration which represent high, moderate, slow, and very slow infiltration rates, respectively.

2.9.2. Stream Flow Routing

The flow of a stream is directly related to the amount of water moving off the watershed into the stream channel. It is affected by land use, weather, increasing during rainstorms and decreasing during dry periods. It also changes during different seasons of the year, decreasing during the summer months when evaporation rates are high and shoreline vegetation is actively growing and removing water from the ground. The amount of stream flow that comes from the watershed were estimated or simulated by using Arc SWAT and then calibrated and validated with the observed flow. SWAT uses the Muskingum routing method to route flow through the stream network of the watershed. The model incorporates losses in flow from factors such as evaporations and infiltration. The model also has the ability to factor in point sources of flow additions or reductions such as surface water pumping or point source water discharges. SWAT provides the modeler with tools to model flow impacts within the channel throughout the watershed. (Neitsch, et al, 2005)

2.9.3. Sediment Routing

In this study a SWAT model was used for simulation of sediment yield from the Temcha watershed. Soil erosion rates on cultivated land can be estimated by the use of the Universal Soil Loss Equation (Wischmeier, 1965). The Universal Soil Loss Equation is:

A=RKLSCP --- (9)

Where, A is computed soil loss in tons/acre/year, R is rainfall factor, K is soil-erodibility factor, L is slope-length factor, S is slope-steepness factor, C is cropping-management factor and P is erosion-control practice factor.

SWAT routes sediment by simulating both sediment deposition and degradation, Williams (1981) and Bagnold (1977) determined that channel degradation was a function of channel slope and flow depth or channel water velocity. SWAT sets the maximum sediment transport in a reach using William‘s and Bagnold‘s definition of stream power based on the channel peak channel velocity (Neitsch et al, 2005). Erosion and Sediment yield from overland flow is simulated using the modified universal soil loss equation (MUSLE) which simulates sediment deposition proportionally to channel velocity. MUSLE differs from the original universal soil loss equation (USLE) by replacing the energy factor with a runoff factor. SWAT states that this change improves the sediment yield prediction, eliminates the need for delivery ratios, and allows the equation to be applied to individual storm events (Neitsch et al, 2005). Williams (1981) developed the MULSE because it was determined that runoff is a function of antecedent moisture condition as well as rainfall energy. The MUSLE incorporates both of these factors by using both a delivery ratio and a runoff factor to estimate erosion energy. SWAT calculates the soil erosion and sediment yield with the modified universal soil loss equation (MUSLE),

$$Sed = 11.8(Q_{surf} \times q_{peak} \times area_{hru})^{0.56} \times K_{USLE} \times C_{USLE} \times P_{USLE} \times LS_{USLE} \times CFRG \quad \text{------ (10)}$$

In which Sed is the sediment yield on a given day (metric tons), Q_{surf} is the surface runoff volume (mm/ha), q_{peak} is the peak runoff rate (m^3/s), $area_{hru}$ is the area of the HRU (ha),

K_{USLE} is the soil erodibility factor, C_{USLE} is the cover and management factor, P_{USLE} is the support practice factor, LS_{USLE} is the topographic factor and CFRG is the coarse fragment factor (Neitsch et al., 2005).

2.9.4. SWAT 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. (2008) indicated that stream flow and sediment yield simulated with SWAT were reasonable accurate. The same study reported that similar long term data can 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., 2008). This study reported that the model can produce reliable estimates of stream flow and sediment yield from complex watersheds.

In addition to the above, the SWAT model was tested for prediction of sediment yield in Anjeni gauged watershed by Setegn et al., (2008). The study found that the observed values showed a good agreement at Nash-Sutcliff efficiency (ENS) of 80%. In light of this, the study suggested that the SWAT model can be used for further analysis of different management scenarios that could help different stakeholders to plan and implement appropriate soil and water conservation strategies.

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.

2.10. Review Related Previous Studies

Woldeamlak and Geert (2005) analyzed changes in stream flow patterns with reference to dynamics in land cover/use in Chemoga watershed, in northwestern highland Ethiopia. The results show that, between 1960 and 1999, total annual stream flow decreased at a rate of 1.7 mm/ year whereas the annual rainfall decreased only at a rate of 0.29 mm

/year. The decrease in the stream flow was more pronounced during the dry season (October to May), for which a statistically significant decline (0.6 mm /year) was observed while the corresponding rainfall showed no discernible trend. The wet season (June to September) rainfall and stream flow did not show any trends. Extreme low flows analyzed at monthly and daily time steps reconfirmed that low flows declined with time, the changes being highly significant statistically.

Friedrich et al (2012) has assessed the Effects of Land Use Change on Hydrological Responses in the Choke Mountain Range (Ethiopia) using SWAT. The result concludes by Considering the total discharge volumes there is a significant difference observed which accounts for 2.9% of the total flow within the whole period of 30 years.

Asmamew (2013) has assessed the impact of land use land cover change on the hydrology of the Gilgel Abay watershed using SWAT. He has focused on the assessment of the impacts of the land cover changes on the stream flow by changing surface runoff and ground water flow for the wet months and dry months through satellite Remote Sensing (RS) and Geographic Information System (GIS) integrated with the SWAT model. The result of his analysis indicated that the mean monthly stream flow increased by 16.26m3/s for the wet months while for the dry months decreased by 5.41 m3/s.

Setegn (2009) found that in Lake Tana sub basin, sediment yields greater than 30 tons/ha for each of the sub-basin area were 18.4% of the watershed, determined to be high erosion potential area. The MCE results indicated that 12–30.5% of the watershed is high erosion potential area. Both approaches show comparable watershed area with high soil erosion susceptibility.

Gete and Hans (2001) has studied Implications of Land Use and Land Cover Dynamics for Mountain Resource Degradation in the Northwestern Ethiopian Highlands using a geographic Information system (GIS) and a remote sensing approach with field verification the results show that the natural forest cover declined from 27% in 1957 to 2% in 1982 and 0.3% in 1995. The total natural forest cleared between 1957 and 1995 amounts to 7259 ha. This is 99% of the forest cover that existed in 1957. On the other hand, cultivated land increased from 39% in 1957 to 70% in 1982 and 77% in 1995.

Tesfa (2014) has evaluated land use land cover change effects on stream flow and sediment yield, and also assessed best sediment management practices using SWAT model in Gilgel Abay watershed. The result shows an increase of cultivated land by 33.79% over 25 years' period (1986 – 2011) resulted an increase of stream flow and sediment yield by 5.87m3/s and 62.78t/km2 respectively. Three BMPs (best sediment management scenarios) S1 (filter strip), S2 (stone bund) and S3 (reforestation) were considered in this study. The results have showed a decrease of sedimentation by 24.73%, 21.36% and 36.18% sediment yield reductions implementing S1, S2 and S3 respectively.

3. MATERIALS AND METHODS

3.1. Study Area Description

Temcha catchment is situated in the north west part of Ethiopia between 10o 28’ to 10o 44’N latitude and 37o 30’ to 37o 50’E longitudes. This watershed includes 3 woredas’ from West Gojjam and East Gojjam administrative zones of Amhara National Regional State (ANRS). The river originates from small spring located near Choke Mountains Range at an elevation of 3800m a.m.s.l and drains to Abay River. The catchment area of Temcha River from starting point to Out let is around 422 km^2.

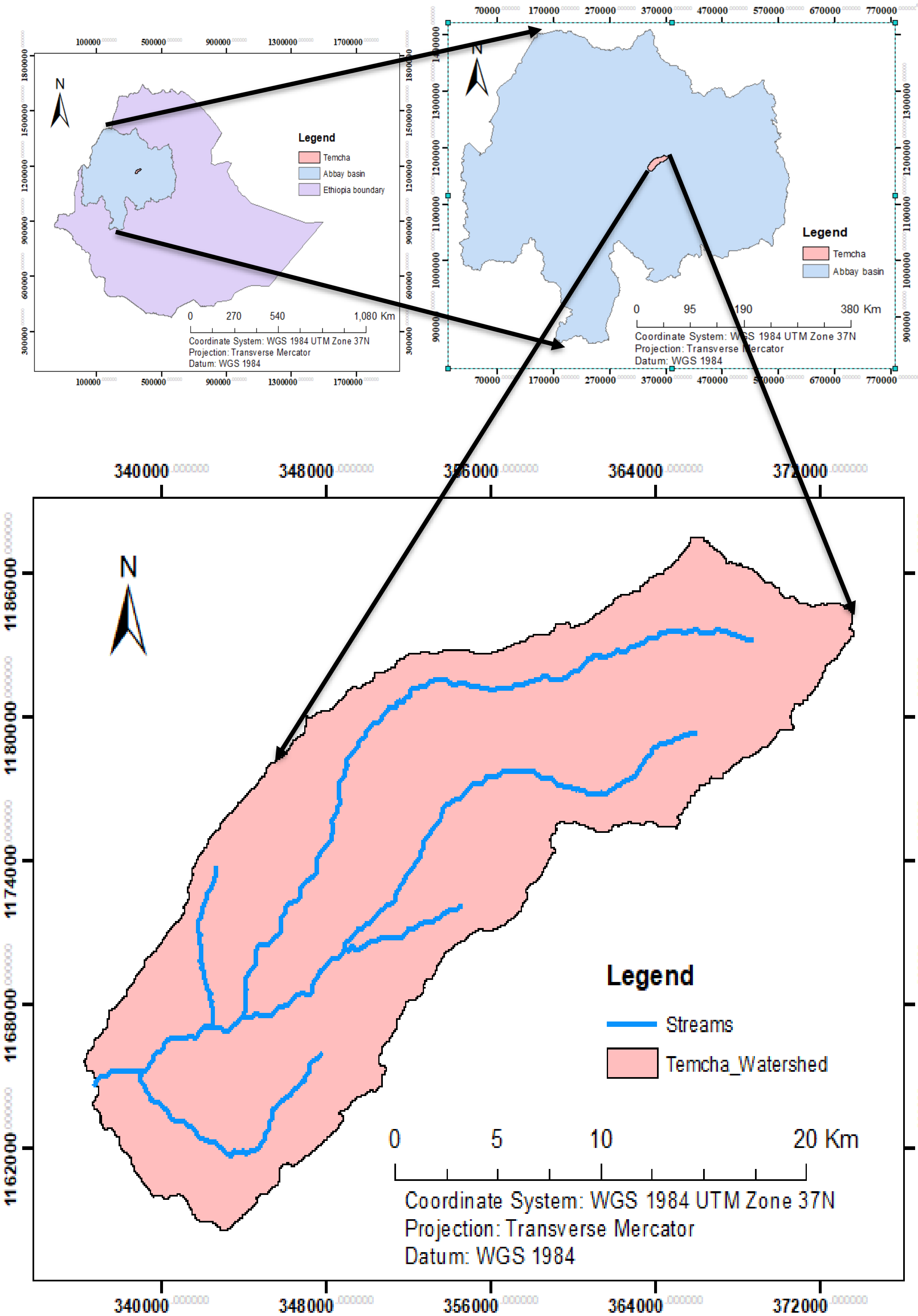

Figure 3.1: Location map of the study area

3.2. Data Type and Method of Collection

SWAT is highly data intensive model that requires specific information about the watershed such as topography, land use and land cover, soil properties, weather data and other land management practices. These data were collected from different sources and databases. The data are analyzed as presented in the next sub-sections.

Table 3.1: Summary of data types, source and their intended use in this study.

No	Data Type	Source	Purpose
1	Meteorological data	Meteorological Agency of Ethiopia	Input for SWAT model
2	Hydrological data (Discharge & Sediment)	MoWIE	SWAT model calibration Validation and Change Study
3	DEM SRTM (30m*30m)	USGS (http://earthexplorer.usgs.gov/)	SWAT watershed Delineation
4	Landsat TM, MSS, ETM+ & OLI_TIRS	USGS (http://earthexplorer.usgs.gov/)	Land use land cover classification for SWAT input
5	Soil (1: 250,000)	MoWIE	SWAT HRU definition

3.2.1. Topography

The elevation of Temcha catchment varies from 1925 to 4048m.a.s.l. The higher elevation ranges are located at the North East corner while the lowest elevation ranges found in South West part of the watershed. From the slope map of the catchment area, about 7.34 % of the watershed is flat (0 to 3% slope steepness), which is mainly under water reservoir and swamp. The gently sloping (3 to 8% slope steepness) area covers about 33.41 %, the sloping (8 to 15% slope steepness) area covers about 30.49 %, the steep (15 to 30% slope steepness) area covers about 25.54 %, the very steep (> 30% slope steepness) covers about 3.23 % of the watershed area.

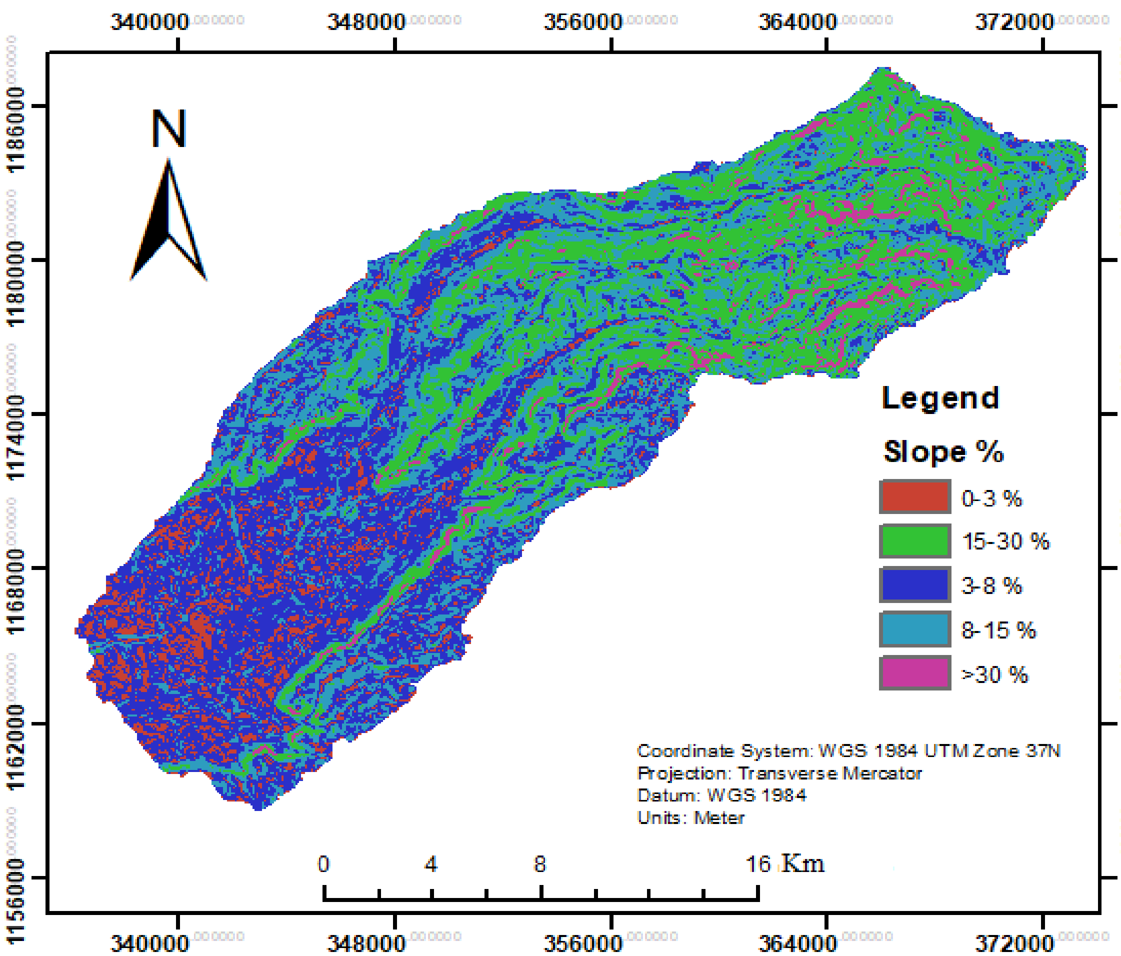

Figure 3.2: Elevation map of the Temcha Watershed

3.2.2. Climate

The majority part of the study area falls in Wurch & Dega (2500-4000 m altitude) climate however, small part of study area that is mainly at the Lower tips of the catchment falls in Weyna Dega Zone with an altitude of 1900-2500m.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. Small rains also occur sporadically during February/March to May.

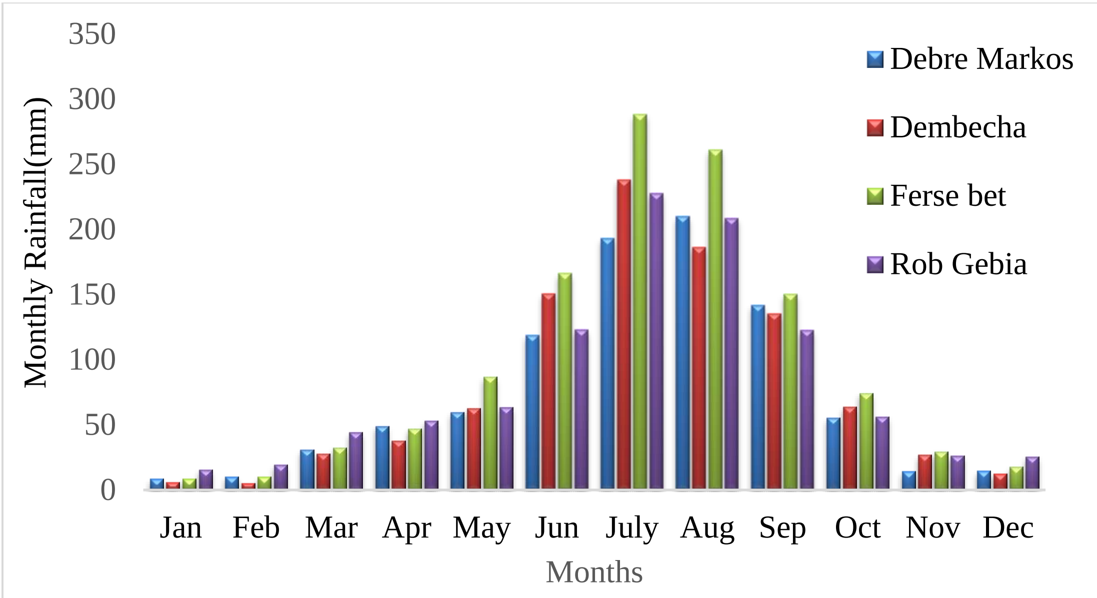

Figure 3.3: Mean monthly rainfall of four stations (1984-2015)

3.2.3. Drainage Network

The source of the Temcha River is a spring that emerges from Choke Mountain near Rob Gebeya town. Locally the name of the stream is Temcha which is enters to the Blue Nile River. On its way downstream, the river receives inflow from several rivers and streams. Many perennial rivers such as Zimble and Ketech are drains to the river before the outlet and Gula drains to the river downstream of outlet that has gage station. The total drainage area of the river is around 422 km^2 and the longest flow path of river from source to the outlet of the catchment is around 48.87 km. There is one main gauging station in the catchment which has continuous records for a long period. It is at the road bridge between Dembecha and Amanuel on the road from Addis Ababa to Bahir Dar.

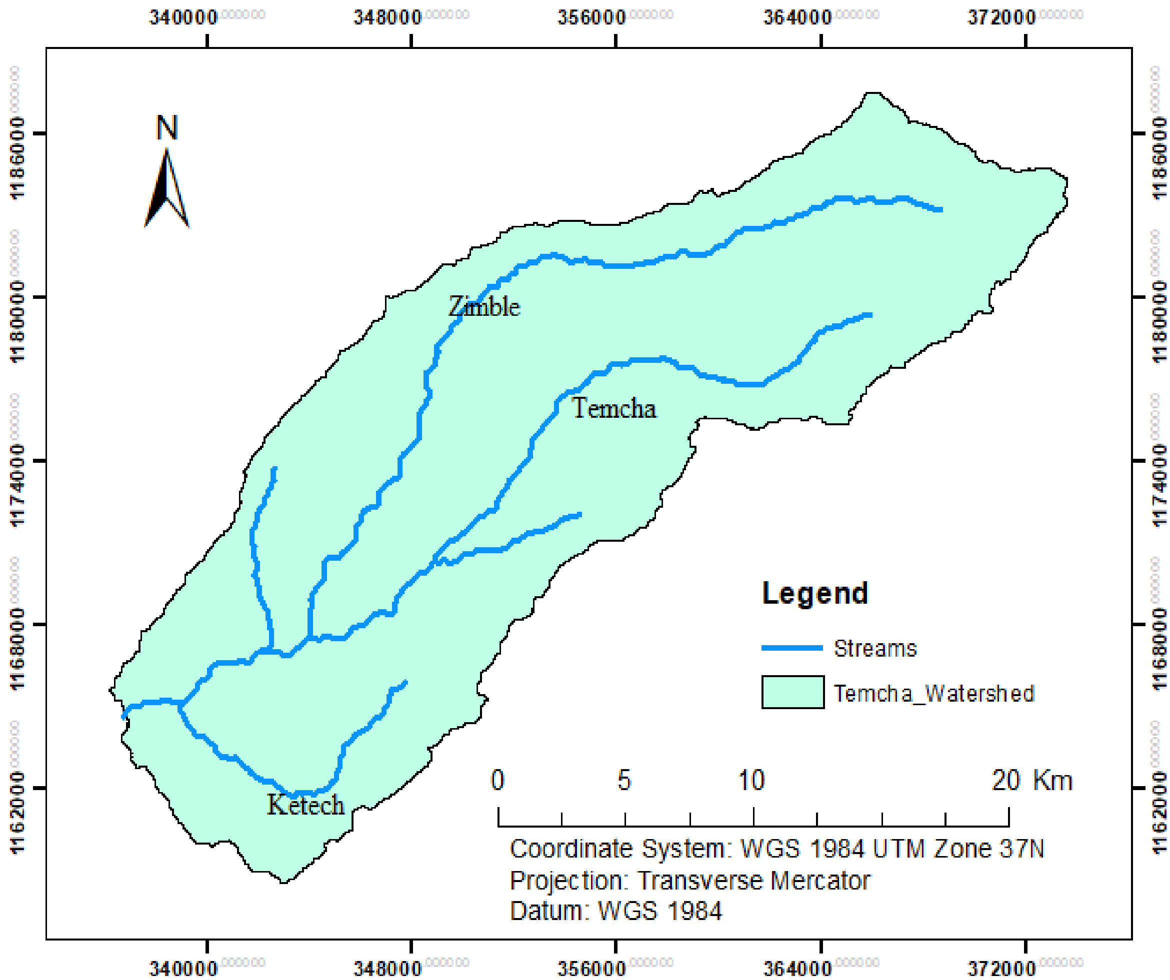

Figure 3.4: Drainage network of Temcha Watershed

3.2.4. Soil Type

The soil map of the study area was also obtained from Ministry of Water, Irrigation and Electricity of Ethiopia. According to FAO/UNESCO – ISRIC classification, in this watershed Four main soil types are found which include, Alisols, Leptosols, Luvisols and Vertisols. Generally, the soil types of this watershed area are characterized with shallow, moderate to deep and very deep in depth and sandy clay to clay texture types. The erodibility of these soils also varies from medium to very erodible characteristics.

Vertisols are deep to very deep, moderately well to poorly drained, very dark grey to dark yellowish brown in the topsoil, and clay textured throughout. The soils have large surface cracks in the dry season. Run-off formation from Vertisols is high and hence it is susceptible to erosion. The shallow and very shallow soils are classified as Leptosols. Leptosols are found in 41.36% areas in the watershed area. These are stony and rocky. The texture of Leptosols varies from sandy clay loam to clay and has excessive drainage characteristics.

Luvisols exist small extent in the watershed area. These soils show textural differentiation with moderate to high clay content. These soils are almost intensively cultivated. The major red clay soils (Alisols) occur mainly on flat to rolling upland plain and flat to undulating land features. These are deep, well drained, permeable and medium textured soils.

Table 3.2: Soils of Temcha Watershed

Type of soil	Area coverage (Ha)	Coverage (%)
Haplic Alisols	21021.81	49.76
Eutric Leptosols	17469.67	41.36
Eutric Vertisols	3412.26	8.08
Haplic Luvisols	338.92	0.80

SWAT model requires different soil textural and physio-chemical properties such as soil texture, available water content, hydraulic conductivity, bulk density and organic content for different layers (up to 4 layers) of each soil type. Major soil types in the watershed were mainly obtained from Ministry of Water, Irrigation and Electricity (MoWIE).

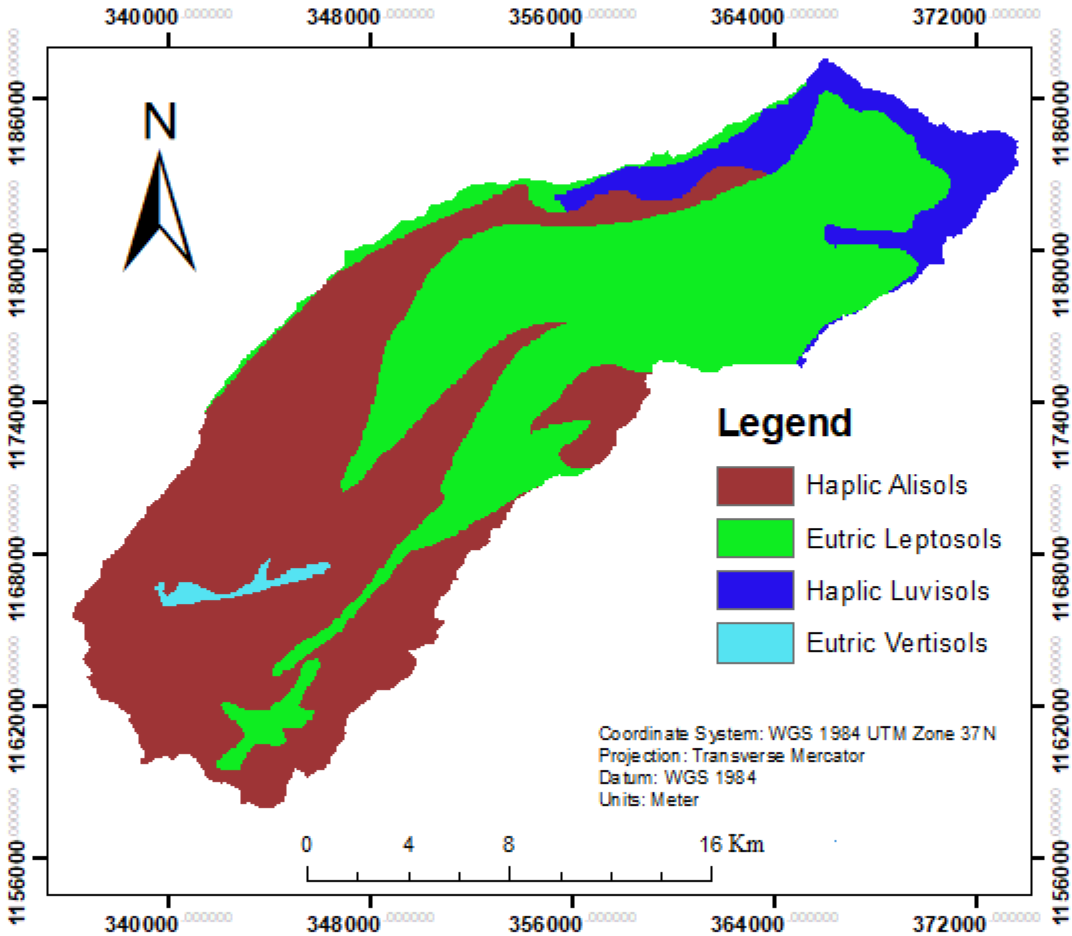

Figure 3.5: Soil Map of Temcha Watershed (Source: MoWIE)

3.2.5. Digital Elevation Model

Digital Elevation Model (DEM) data is required to calculate the flow accumulation, stream networks, and watershed delineation using SWAT watershed delineator tools. A 30 m by 30m resolution SRTM Global Digital Elevation Model was obtained from the NASA website. This data was projected to Transverse Mercator (UTM) on spheroid of WGS84 and it was in raster format to fit in to the model requirement.

3.2.6. Meteorological Data

Meteorological data are among the main demanding input data for the SWAT simulation. The weather input data required for SWAT simulation includes daily data of precipitation, maximum and minimum temperature, relative humidity, wind speed and solar radiation. These were obtained from the Ethiopian National Meteorological Agency. The Meteorological data used were represented from four stations around Temcha watershed, such as Dembecha, Debre Markos, Rob Gebia and Feresbet stations. Debre Markos has daily data of precipitation, maximum and minimum temperature, relative humidity, wind speed and solar radiation, Dembecha has daily data of precipitation, maximum and minimum temperature and the other two stations has only daily data of precipitation. The meteorological data used for this study covers 22 years from January 1984 to December 2005. Based on the class of the stations, the number of weather variables collected varies from stations to stations that are grouped into two. Finally, the weather data were prepared in Text format with lookup tables as required by the model.

Table 3.3: Metrological Stations Location

No	NAME	LAT	LONG	ELEVATION	DATA TYPES
1	Debre Markos	10.35	37.73	2494	RF, Max Temp, Min Temp, RH, WS & SS
2	Rob Gebya	10.55	37.77	2973	RF
3	Feresbet	10.85	37.60	2838	RF
4	Dembecha	10.56	37.49	2098	RF, Max Temp & Min Temp

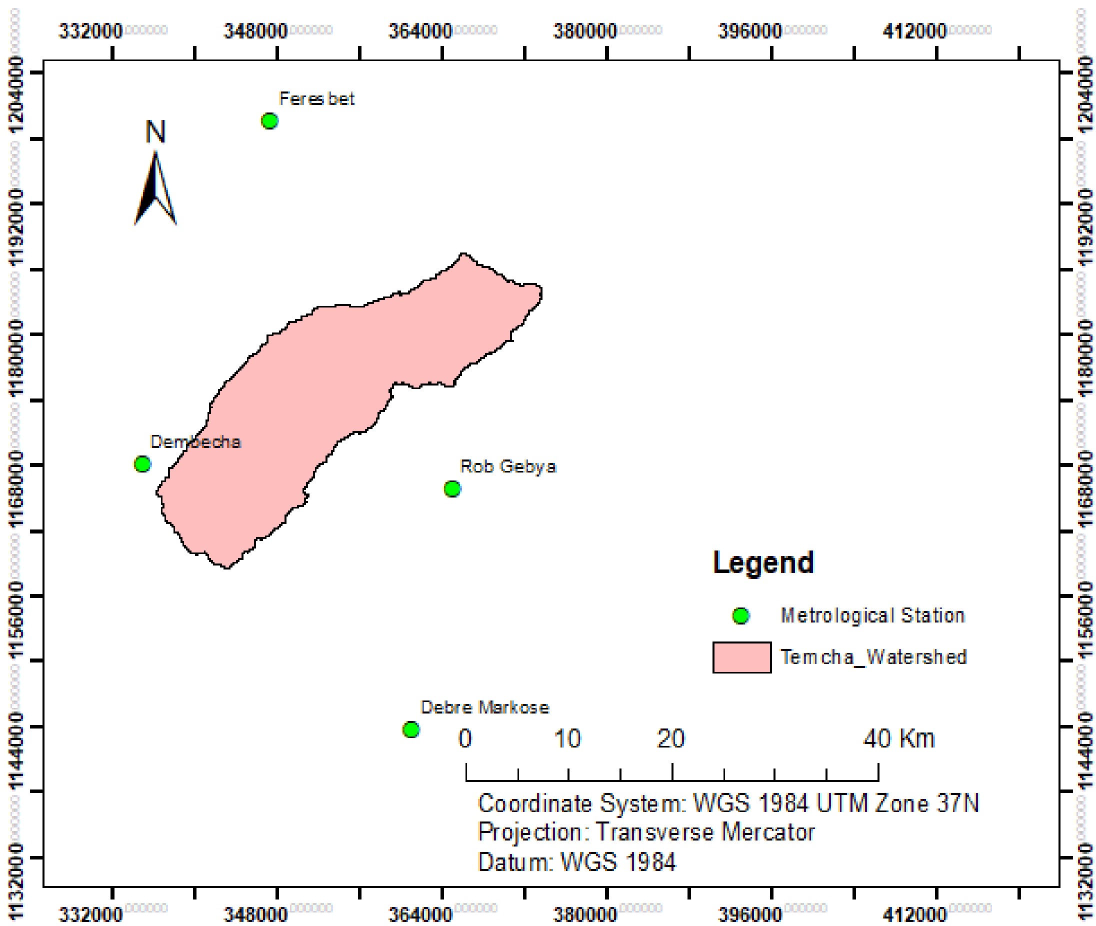

Figure 3.6: Meteorological Stations location of the study

3.2.7. Land use land cover data

Our study focuses on Land use change effect on stream flow and sediment yield. Land use land cover data which is very essential for SWAT input for determining the watershed characteristics, and also used for comparison of impacts on stream flow and sediment yield of the catchment. Land use land cover maps are prepared from Satellite images. To evaluate 28years land use land cover change of Temcha watershed the Land sat 5 & 8 images for the years 1986, 1999 and 2013 were collected from USGS Earth Explore and USGS GLOVIS. The land use map of the area was classified using the Supervised classification system based on the available topographic map (1:50,000), google earth map and field survey. A lookup table that identifies the SWAT land use code for the different categories of LULC was also prepared so as to relate the grid values to SWAT LULC classes.

3.2.8. Ground truth data

The primary data (Current Land use land cover) were collected at the field which was used for further analysis, interpretation, and comparison and expressing of watershed characteristics. The data that were collected at field are GPS data of some selected sites and other relevant data for this study. About 80 Ground Control points are collected by the GPS and others are collected from Google earth and topo map. The collected Ground control points were used as training points for supervised classification and accuracy assessment of the LULC.

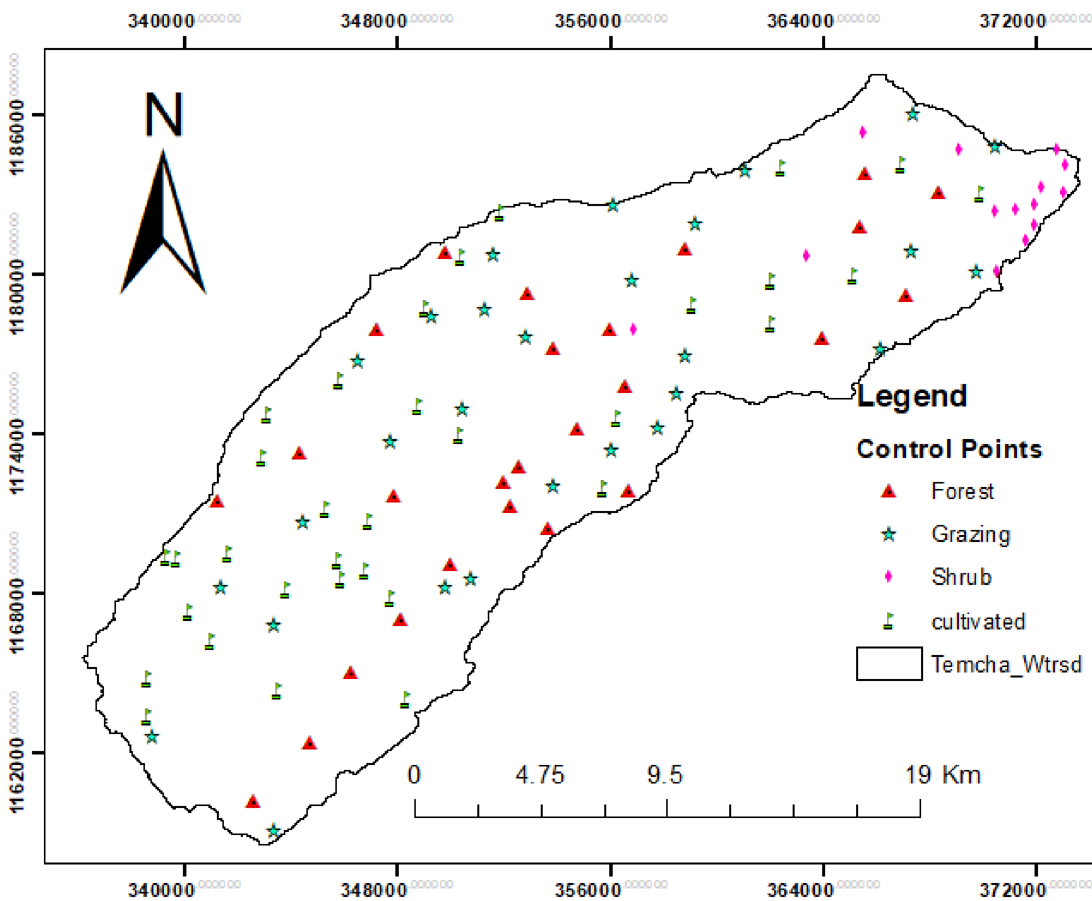

Figure 3.7: Ground control points in study area

3.2.9. Flow and Sediment Data

In order to calibrate and validate a hydrological model for the watershed, hydrological data was essential. Flow and Sediment data are required to calibrate and validate models. This Flow and Sediment data was obtained from MoWIE. Depending on the extent of calibration and validation, stream flow and sediment data was collected and arranged as the requirement of SWAT model. The sediment data collected from MoWIE were in concentration basis. The number of sediment data collected were too small; even though using discharge versus sediment transport relationship a rating curve were developed and the amount of sediment used for calibration at outlet were estimated. The sediment transports relationship with discharge in figure 3.7 was developed for the River and obtained equation 11 from the graph.

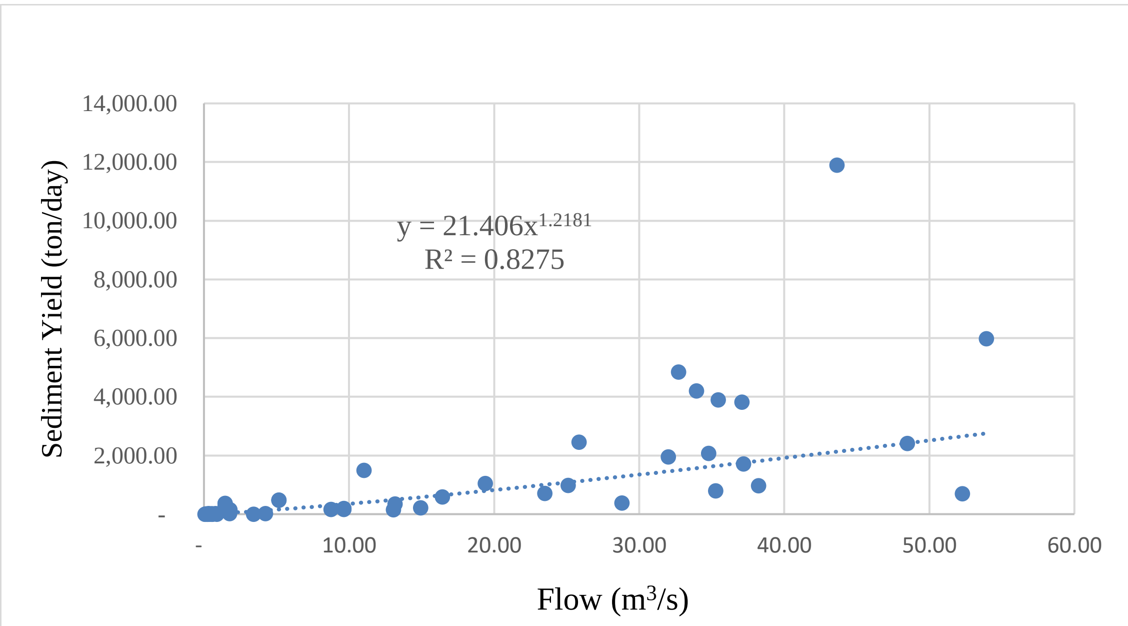

Figure 3.8: Stream flow vs Sediment yield rating curve for Temcha watershed.

$$y = 21.41x^{1.22} \quad \text{--} \quad (11)$$

3.3. Methodology

This study was carried out in four steps. First, a database was established and land use/cover maps 1986, 1999 and 2013 were produced to analyse the land use/cover dynamics. Second, SWAT simulation run was carried out using set of input variables and sensitivity analysis was performed to identify parameters that most influenced the streamflow and sediment yield. Third, the efficiency of the model was assessed by comparing simulated and observed daily streamflow and sediment yield. Fourth, in order to test the assumption that land use/cover change has affected watershed streamflow and sediment yield, further simulations were performed using three maps for the same period. This analysis was performed using different software's like Arc GIS, Arc SWAT, ERDAS Imagine, Microsoft Excel, and SWAT CUP.

Table 3.4: Materials used for this study and their purposes.

No.	Materials	Purpose
1	Arc GIS 10.4	Geo-referencing, rectification and various spatial analysis
2	Arc SWAT 2012	SWAT model development & present result using maps and report
3	ERDAS IMGINE	Image preprocessing, image Classification & Accuracy assessment
4	XLSTAT 2016	For homogeneity test of climate and flow data
5	Garmin GPS 72H	filed survey and ground control point collection
6	Google earth Pro	To collect Ground Control Points
7	SWAT CUP 2012	For Calibration and Validation

3.3.1. Filling Missing Data

Missing data is a common problem for hydrological analysis. To perform hydrological analysis and simulation using data of long time series, filling the missing data was very important. The missing data was filled or completed by using meteorological and hydrological stations located in the nearby stations, provided that the stations are located in a hydro-meteorologically homogenous region. There are different methods for filling the missing data from those methods if mean difference of stations is less than 10% station average and If the mean difference is greater than 10% the normal ratio method was used in this study (Richard H. 1998).

The station average method formula

$$Px = \frac{P1 + P2 + P3 + ... + Pn}{N} \quad \text{--(12)}$$

Where Px is the estimated daily precipitation at station X, P1, P2 and P3 are the adjacent station precipitation value, and N is the number of rain gauge station.

The normal ratio method formula

$$Px = \frac{1}{M} \sum_{i=1}^{m} \left[\frac{Nx}{Ni} \right] Pi \quad \text{--(13)}$$

Where Px is the estimate for the ungauged station, Pi is the rainfall values of rain gauges used for estimation, Nx is the normal annual precipitation of X station, Ni is normal annual precipitation of surrounding stations, and m is number of surrounding stations.

Moreover, to calculate percent of difference to decide whether to use arithmetic mean or normal ratio method, equation 15 has used.

$$\% Difference = \left(\frac{Nx - Ni}{Nx} \right) * 100 \quad \text{--(14)}$$

Where Nx is the normal annual rainfall amount from the missing data station and Ni is the normal annual rainfall amount from the one of the nearby stations.

For this study the average normal annual precipitation of the Dembecha and Rob Gebeya stations is below 10% and Debre Markos and Feres Bet stations is above 10%. Therefore, among the above discussed methods the station-average method has been applied to fill the missing data for Dembecha and Rob Gebeya stations and normal ratio method apply for Debre Markos and Feres Bet stations. For stream flow data I used Gulla and Birr rivers to fill the data. After all meteorological and hydrological input data were filled and their consistency was checked, the data was prepared as the standard format for each type of selected models.

3.3.2. Data quality analysis

In hydrology the data should be stationary, consistent, and homogeneous when it is to be used for frequency analyses and simulate a hydrological modelling (Dahmen and Hall, 1990). To meet these criteria in this study the data quality analysis was carried out using the following Tests.

Test for Absence of trend: - The absence of trend was checked by applying spearman correlation test which is distribution free and power full for both linear and nonlinear trend. Stations having rainfall and stream flow was tested for the absence of trend. All rainfall and stream flow datas are pass the absence of trend test.

Test for stationery of time series: - Stationary of time series data was checked based on stability of the variance by using F-test and the stability of mean by using T-test under 95 % confidence interval. All rainfall and stream flow datas are fit to the F- test and T test.

Consistency and homogeneity: - Double Mass Curve (DMC) was used to check the homogeneity and consistency of rain fall as well for adjustment of inconsistent data. This technique is based on the principle that when each recorded data comes from the same parent population, they are consistent.

The homogeneity of rainfall and flow data were also checked using XLStat (a software package for hydro meteorological frequency analysis and testing the homogeneity of historical datasets).

3.3.3. Image Processing

Historical land cover classification of the Temcha watershed was done to observe the changes that have taken place over time. Landsat satellite imageries were used in the study to identify changes in land cover distribution. Landsat is one of various satellites used to gather data for images of the Earth's land surface and coastal regions. These satellites are equipped with sensors that respond to Earth-reflected sunlight and infrared radiation. Landsat imagery of the study area follows a path 169 and row 053 for Landsat 5 & 8. The image is captured in dry season from January to April, because of phonological difference between wet and dry season vegetation in tropical regions can be marked. This gives an advantage to reduce confusion of pasture and small scale agricultural plot. Landsat Images of 1986,1999 and 2013 were obtained from a website: (http://earthexplorer.usgs.gov/). The acquisition dates, path /Row, Resolution, datum, UTM zone and Source of the image are shown in table 3.5 below.

Table 3.5: Profile of satellite image.

Date of Acquisition	Spacecraft ID	Path and Row	Spatial Resolution (m)	Datum	UTM Zone	Source
01/02/1986	Landsat_5	169/53	30	WGS84	37	USGS
04/08/1999	Landsat_5	169/53	30	WGS84	37	USGS
03/04/2013	Landsat_8	169/53	30	WGS84	37	USGS

The image processing was done using the ERDAS Imagine 2014 software. Once the image downloaded, it was imported into ERDAS Imagine. Since the image was downloaded with proper geographic references from USGS itself, geo referencing was not required. Since the study area is only a small part of this image, the entire image was not required for analysis. Layer stake of the different bands of downloaded satellite images were done for all the data on ERDAS Imagine. Since the area covered by one single satellite image downloaded from the Landsat website was large and most of the image did not fall under the region of interest, the necessary area under focus alone had to be extracted. One of the advantages of performing subset is that, after extracting the area of interest from the larger image, the classification process now will be done only for the required area and the number of pixels for each class will be from the study area alone and not the surrounding portions that is present in the satellite image. The part of the image that has to be extracted using subset can be either specified using the bounding coordinates or can be imported using an inquire box. For this study vector boundaries can also be used as parameters for sub setting an image. The subset step is done using the SUBSET tool which is located in Raster – Subset and Chip – Create subset image. For this study the watershed vector file was used to subset staked images.

3.3.4. Land Use and Land Cover Classes and Classification

The Land use and land cover change studies usually need the development and the definition of homogeneous land use and land cover units before the analysis is started. These have to be differentiated using the available data source such as remote sensing, field assessments, interpretation of satellite images, any other relevant information and the previous local knowledge. Hence, based on the results of satellite image interpretation and field assessments were used to produce the final present land cover map and inclusive report of the study area and identified four different types of land use and land cover for the watershed. The descriptions of these land use and land covers classification are presented the following table.

Table 3.6: Temcha land use and land covers types and descriptions.

Land Cover Type	Description
Cultivated land	Areas used for crop cultivation, both annuals and perennials, and the scattered rural settlement that are closely associated with the cultivated fields. Due to the difficulty encountered to identifying the dispersed rural settlements this kind of land cover was combined with the cultivated land during classification.
Forest land	Land covered with dense trees which includes ever green forest land, mixed forest and plantation forests.

Grazing land	Areas covered with grass used for grazing, as well as bare lands that have little grass or no grass cover. It also includes other small sized plant species.
Bush land	Areas covered with sparse woody plants mixed with shrubs, bushes, and grasses. It is low-density forest forming vegetation. Some of this vegetation is eucalyptus trees.

The main objective of classifying satellite images is to categorize pixel values automatically and transform them directly in to the classes or forms of land use. The supervised classification tools of ERDAS Imagine software were used for the classification of satellite images. Maximum likelihood was selected as the parametric rule while using supervised classification. The Ground control points (GCP's) collected from the field, integrating with Google Earth were taken as a signature for supervised classification. A signature level taken was between 6 and 10 for each of the land cover classes over an image. After supervised classification initial LULC map were edited on the basis of ground verification of doubtful areas and some classes were recorded into their respective classes.

3.3.5. Accuracy Assessment

Accuracy assessment is an important step in the image classification process. The objective of this process is to quantitatively determine how effectively pixels were grouped in to the correct features classes in the area under investigation. It is a process used to estimate the accuracy of image classification by comparing the classified map with a reference map (Caetano et al, 2005). The most widely used classification accuracy is in the form of error matrix which can be used to derive a series of descriptive and analytical statistics (Manandhar et al, 2009). The columns of the matrix depict the number of pixels per class for the reference data, and the rows show the number of pixels per class for the classified image. From this error matrix, a number of accuracy measures such as overall accuracy, user's and producer's accuracy determined. The overall accuracy is used to indicate the accuracy of the whole classification (i.e. number of correctly classified pixels divided by the total number of pixels in the error matrix), whereas the other two measures indicate the accuracy of individual classes. User's accuracy is regarded as the probability that a pixel classified on the map actually represents that class on the ground or reference data, whereas product's accuracy represents the probability that a pixel on reference data has been correctly classified.

In this study, the assessment was carried out using the Ground truth/verification as reference data to generate testing data set on those particular areas for checking the accuracy of classification. For each class i.e. cultivated, forest, shrub land and grassland between 20 and 30 points were marked as a ground control point. A total of 101 testing sample points were selected randomly for the year 1986, 1999 and 2013 respectively.

3.3.6. Change Detection

Change detection is defined as a process used to identify the change that occurred in a specific area over a span of time. By observing the same area at different time intervals using satellites or Aerial photography, the user can identify the change of land use and land cover in that area. Several other analyses can also be done with the help of change detection techniques such as change in the condition of the water or the degrading of a plant species etc.

There are several methods to perform change detection using satellite images such as image differencing, Principal Component Analysis, Image Regression etc. Most methods use statistical calculations to compare the brightness values of the pixels present in the two images and produce results. Since the images used for this study were already classified, the Post classification comparison method was used. This is a simple and more promising method which produces accurate results if the classification is done accurately. Since the images taken at the different times were already independently classified, these classified images can be used to produce change maps that will visualize the pixels that have changed from one class to another. The pixel change count values are recorded in an excel table to make it easier to interpret and see the number of pixels that has changed from one class to another.

3.3.7. SWAT Model Setup

First the watershed is delineated from a DEM. Then stream definition, outlet definition, watershed outlets selection and definition and calculation of sub basin parameters are continuing steps that are done on SWAT model simulation. For the stream definition the threshold based stream definition option were used to define the minimum size of the sub-basins.

In SWAT for simulation hydrological variables a watershed is subdivided into a number of homogenous sub-basins (hydrologic response units or HRUs) having unique soil and land use properties. The input information for each sub-basin is grouped into categories of weather; unique areas of land cover, soil, and management within the sub-basin; ponds/reservoirs; groundwater; and the main channel or reach, draining the sub-basin. The HRU analysis tool in Arc SWAT helps to load land use, soil layers and slope map to the project. The delineated watershed by Arc SWAT and the prepared land use and soil layers were overlapped. HRU analysis in SWAT includes divisions of HRUs by slope classes in addition to land use and soils. The multiple slope option (an option which considers different slope classes for HRU definition) was selected. The LULC, soil and slope map was reclassified in order to correspond with the parameters in the SWAT database. After reclassifying the land use, soil and slope in SWAT database, all these physical properties made to be overlaid for HRU definition. Subdividing the sub watershed into areas having unique land use, soil and slope combinations makes it possible to study the differences in evapotranspiration and other hydrologic conditions for different land covers, soils and slopes. The land use, soil and slope datasets were imported overlaid and linked with the SWAT2012 databases. To define the distributions of HRUs multiple HRU definition options were tested. For multiple HRU definition 10 percent land use, a 10 percent soil and multiple slope threshold were used as an adequate for most applications.

On the other side, climate data was used as another input in SWAT model for simulation of flow. Daily maximum and minimum temperature, daily rainfall, solar radiation, relative humidity and wind speed data were used in climatic input for the model. Then after the process of defining HRUs and importing whether station data, set up of SWAT model was arranged and it had simulated stream flow by default parameters.

3.3.8. Model Sensitivity analysis, Calibration and Validation

3.3.8.1. Sensitivity Analysis

The aim of sensitivity analysis was to estimate the rate of change in the output of a model respect to changes in watersheds that result in a clear difference in hydrologic sensitivity. Sensitivity analysis was conducted for the Temcha watershed hydrology to determine the parameters needed to improve simulation results and better understand behavior of hydrologic system and to evaluate the applicability of the model. Parameters for sensitivity analysis were selected by reviewing previously used calibration parameters and documentation from SWAT manuals. Twenty-four hydrological parameters were tested for sensitivity analysis for the simulation of the stream flow in the study area. Here, the default lower and upper bound parameter values were used. The details of all hydrological parameters are found in the ArcSWAT interface for SWAT user's manual (Winchell et al., 2007). The sensitivity analysis was made by using a SWAT CUP.

3.3.8.2. Model Calibration

Model calibration is a means of adjusting or fine tuning model parameters to match with the observed data as much as possible, with limited range of deviation accepted. It is also the modification of parameter values and comparison of predicted output of interest to measured data until a defined objective function is achieved. Parameters for modification are selected from those identified by sensitivity analysis (White and Chaubey, 2005).

Manual and automatic calibration methods were applied. First the parameters were automatically calibrated for stream flow and sediment yield by using SWAT CUP for the first 14 years (1985-1998) until the model simulation result becomes acceptable as per the model performance measures. Next, the final parameter values that were calibrated using SWAT CUP were used as the initial values for the manual calibration procedure. The graphical and statistical approaches were also being used to evaluate the SWAT model performance a number of times until the acceptable values were obtained for surface runoff and Sediment yield.

3.3.8.3. Validation

Similarly, model validation is testing of calibrated model results with independent data set without any further adjustment at different spatial and temporal scales. 7years (1999-2005) data of were used for validation of Stream flow and sediment.

3.3.9. Model Performance Evaluation

The evaluation of hydrologic model behavior and performance is commonly made and reported through comparisons of simulated and observed variables. The selection and use of specific efficiency criteria and the interpretation of the results can be a challenge for hydrologists since each criterion may place different emphasis on different types of simulated and observed behaviors. In this study coefficient of determination (R^2), Nash-Sutcliffe efficiency (ENS) and Ratio of Root Mean Square Error (RSR) performance evaluation criteria were used.

A. Coefficient of Determination

The determination coefficient (R^2) describes the proportion the variance in measured data by the model. It is the magnitude linear relationship between the observed and the simulated values. R^2 ranges from 0 (which indicates the model is poor) to 1 (which indicates the model is good), with higher values indicating less error variance, and typical values greater than 0.6 are considered acceptable (Santhi et al., 2001). The R^2 is calculated using the following equation:

$$R^2 = \frac{\left[\sum_{i=1}^{N}(O_i - O_{mean})(S_i - S_{mean})\right]^2}{(\sum_{i=1}^{N}(O_i - O_{mean})^2 \sum_{i=1}^{N}(S_i - S_{mean})^2} \quad \text{-------------------------------- (15)}$$

Where S = simulated output; O = observed hydrologic variable; O_{mean} = mean of the observations N = total number of observations and S_{mean} = mean of the model simulations.

B. Nash-Sutcliffe Efficiency

The Nash-Sutcliffe efficiency (NSE) is a normalized statistic that determines the relative magnitude of the residual variance ("noise") compared to the measured data variance ("information"). NSE indicates how well the plot of observed versus simulated data fits the 1:1 line.

$$NSE = 1 - \frac{\sum_{i=1}^{N}((S_i - O_i)^2}{\sum_{i=1}^{N}((O_i - O_{mean})^2)} \quad \text{--- (16)}$$

Where S = simulated output; O = observed hydrologic variable; O_{mean} = mean of the observations that the NSE uses as a benchmark against which performance of the hydrologic model is compared; N = total number of observations and S_{mean} = mean of the model simulations. NSE values range from negative infinity to 1, where 1 shows a perfect model. NSE is zero, implies the observed mean is as good a predictor as the model, and if NSE is less than zero, then the model is worse predictor than Q mean.

C. Ratio of Root Mean Square Error

RMSE-observations standard deviation ratio (RSR): RMSE (Root Mean Square Error) is one of the commonly used error index statistics (Moriasi et al., 2007) RSR standardizes RMSE using the observations standard deviation, and it combines an error index (Moriasi et al., 2007). RSR is calculated as the ratio of the RMSE and standard deviation of measured data, as shown in equation 18.

$$RSR = \frac{RMSE}{STDEV_{obs}} = \frac{\sqrt{\frac{1}{n} * \sum_{i=1}^{n}\left(Q_i^{obs} - Q_i^{sim}\right)^2}}{\sqrt{\sum_{i=1}^{n}\left(Q_i^{obs} - Q_i^{mean}\right)^2}} \quad \text{-------------------------------------- (17)}$$

According to Moriasi, et al. (2007) simulation judged as satisfactory if NSE $\geq$0.5, RSR $\leq$0.70 and $R^2 \geq 0.6$ for flow and sediment.

4. RESULTS AND DISCUSSION

The results of this study are presented based on the following three sub sections including Land use land cover classification, SWAT modeling and LuLc impact evaluation on stream flow and sediment yield. The results for each category have been discussed separately in the following sub section.

4.1. Land cover Classification

In this study three land use land cover maps are prepared; 1986 LuLc is for model calibration and the other two maps are for LuLc change study of the watershed. The land use land cover map has been classified in to four classifications which are forest, bush land, cultivated and grazing land. Spatial analysis was carried out to describe land cover change pattern and overall land use changes with time. This was done after image classification of the three land cover maps (1986, 1999 and 2013) whose result for each time period is presented as follows;

4.1.1. Land cover map of 1986

The land cover map of 1986 presented in Figure 4.1 indicates that 17.70% of the Temcha Catchment was covered by Bush & Shrub, 49.50 % by Cultivated land, 21.83 % by Forest Land and 10.97 % by Grazing area.

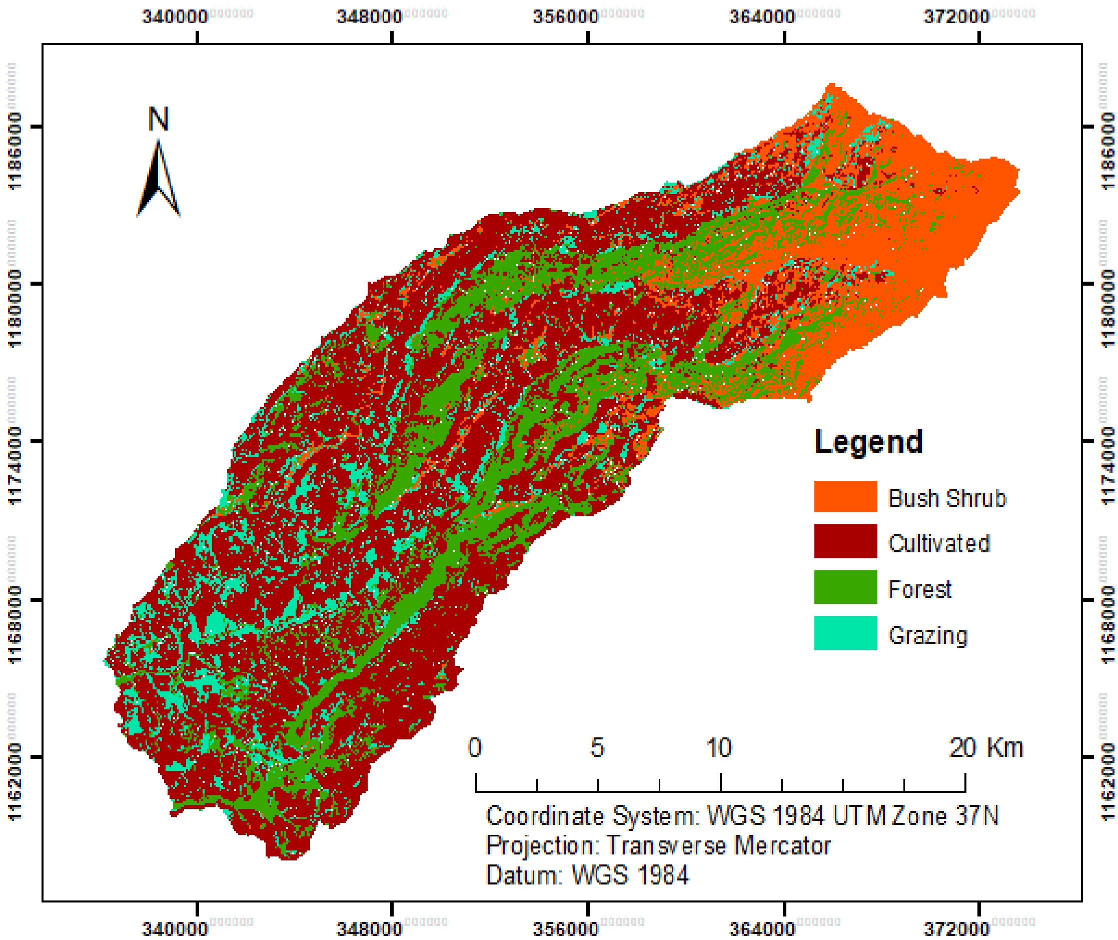

Figure 4.1: Land use Land Cover Map of 1986.

4.1.2. Land cover map of 1999

The land cover map of 1999 presented in Figure 4.2 indicates that 12.43 % of the Temcha Catchment was covered by Bush & Shrub, 66.54 % by Cultivated land, 11.19 % by Forest Land and 9.84 % by Grazing area. The land cover class as it is shown in the figure 4.2, cultivated land increase by 17.04%, Bush& shrub, grazing and forest land decrease by 5.27%, 1.13% and 10.64% respectively relative to 1986 area coverage.

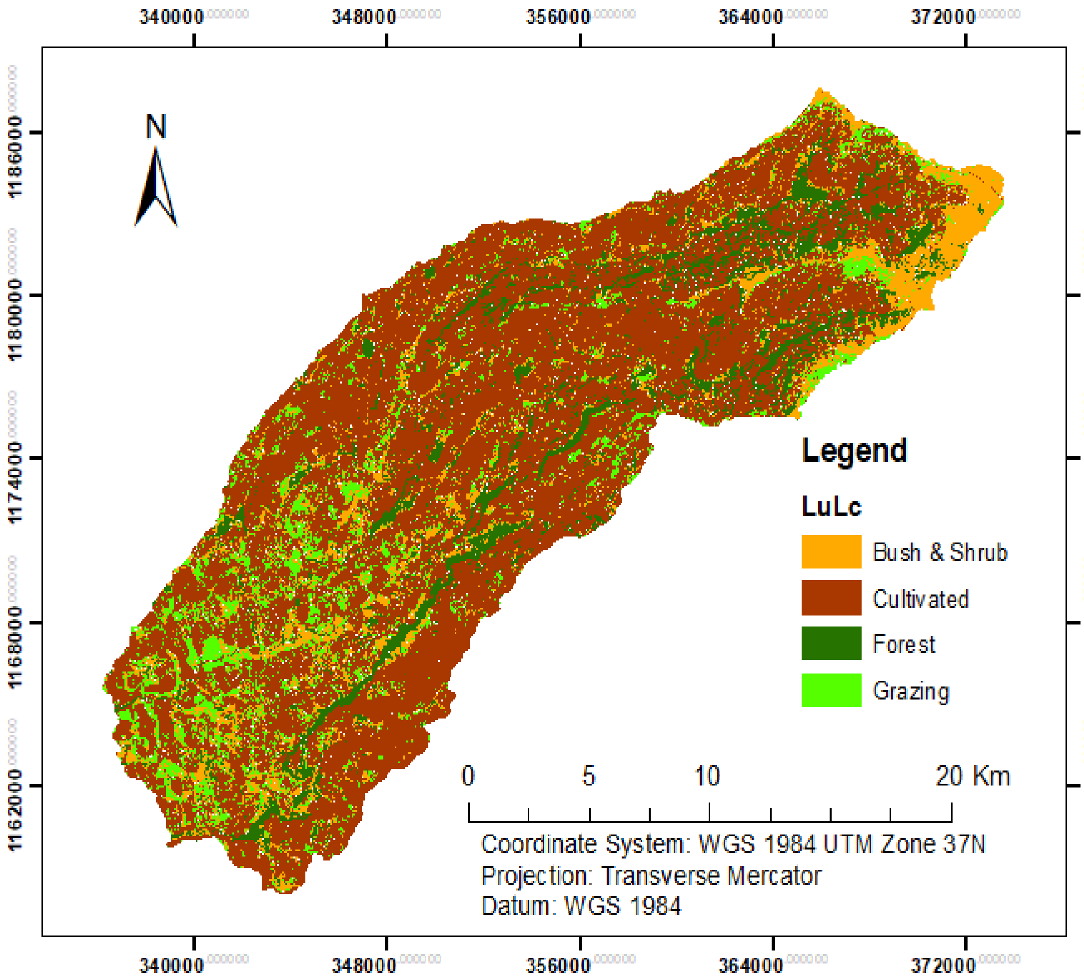

Figure 4.2: Land use Land Cover Map of 1999.

4.1.3. Land cover map of 2013

The land cover map of 2013 presented in Figure 4.3 indicates that 0.31 % of the Temcha Catchment was covered by Bush & Shrub, 87.44 % by Cultivated land, 5.94 % by Forest Land and 6.31 % by Grazing area. The land cover class as it is shown in the figure 4.3 cultivated land increase by 37.94%, Bush & shrub, grazing and forest land decrease by 17.39 %, 4.65 % and 15.90% respectively relative to 1986 area coverage.

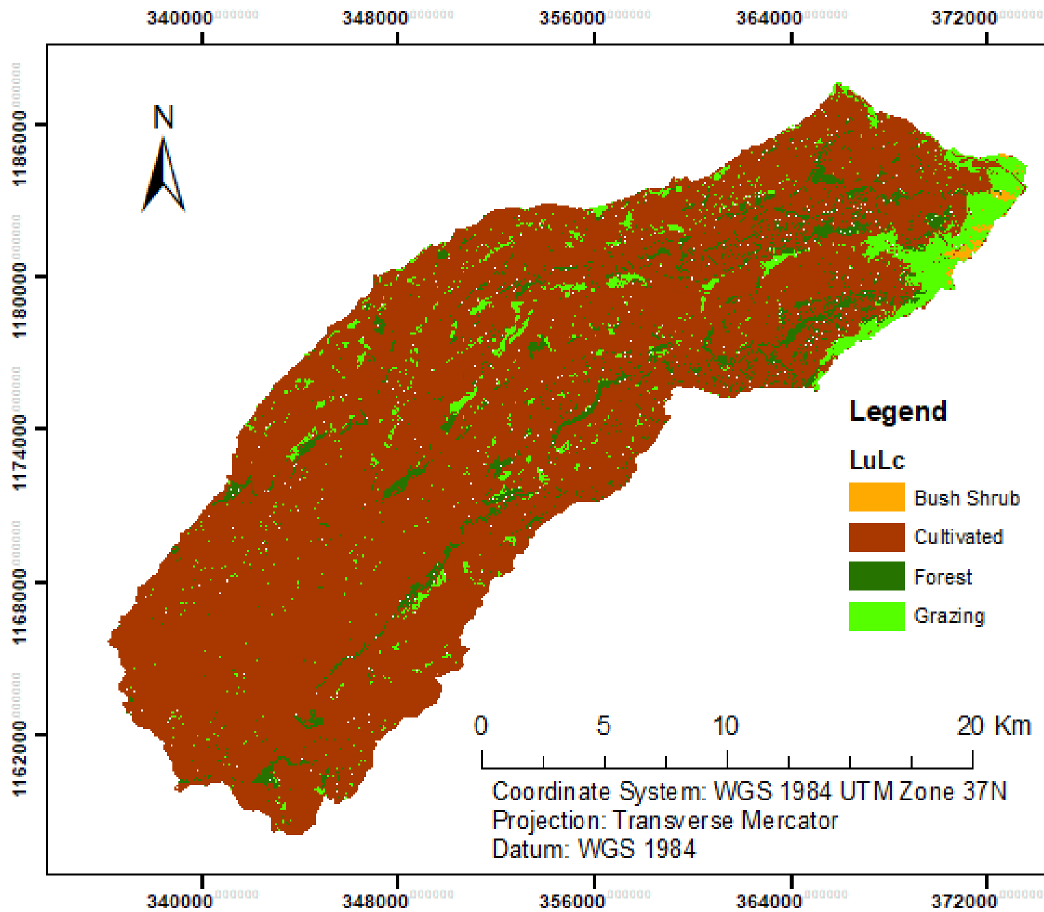

Figure 4.3: Land use Land Cover Map of 2013.

The result of land cover classification maps of Temcha Watershed is arranged in table 4.1 in three different time periods of 1986, 1999 and 2013. land covers change detection in the year 1986 to 2013 is arranged in Table 4.2.

Table 4.1: Summary of land cover class in Temcha catchment (1986 -2013)

Land cover Classes	Areas (hectare)		
	1986	1999	2013
Bush & Shrub	7,476.55	5,249.63	130.38
Cultivated	20,904.70	28,101.80	36,929.70
Grazing	4,632.35	4,153.98	2,666.99
Forest	9,220.52	4,726.83	2,506.97

Table 4.2: Summary of land cover change detection in Temcha catchment (1986 -2013)

Land cover classes	Land Cover change (hectare)	
	1986-1999	1999-2013
Bush & Shrub	-2226.92	-5119.25
Cultivated	7197.10	8827.90
Grazing	-478.37	-1486.99
Forest	-4493.69	-2219.86

The above figures and table showed the significant conversion to agriculture from other classes. It indicates that agricultural expansion is the most factor for the reduction of other classes. It is because of the increment of population and consequently the society had gone to expand the area of cultivation land to maintain the need of food security.

4.1.4. Accuracy Assessment of Land cover classification

After Image Classification an accuracy assessment test was done by using an accuracy matrix with 101 randomly selected points. The accuracy assessment was performed by using land use maps and ground truth points. Great importance was given to the representation of different LULC classes by these randomly chosen points.

Table 4.3: Summary of Accuracy & Kappa values for classified images

Parameters	Year 1986	Year 1999	Year 2013
Overall Kappa Coefficient	0.67	0.74	0.86
Overall Classification Accuracy	0.75	0.81	0.90

The above values in the table indicate the land sat and the methodologies used were good. Suggested statistics Kappa value < 40% is poor, 40 - 55% fair, 55 - 70% good, 70 - 85% very good and greater than 85% as excellent (Monserud, 1992).

4.2. Sensitivity, Calibration & Validation of stream flow

4.2.1. Model Simulation

The default or un calibrated simulation was useful to compare with the observed discharge data and may be used as an indication that the model is capable of simulating the discharge and to what extent the simulation corresponds to or differs from the observed data. Therefore, in this study the model efficiency was not good when the output of the first run or the default run was compared with the observed flow of the catchment. The Nash Sutcliff efficiency and the Ratio of root mean square error of the model were 0.25 and 0.72 respectively. Thus it is difficult to accept and interpret it without calibrating the simulated flow with observed. Therefore, so as to improve the performance of the model, the calibration process was needed to be carried out.

4.2.2. Sensitivity analysis

Table 4.4: Sensitive Parameters identified

No	Parameter Name	Fitted Value	Min value	Max value	Sensitivity Rank
1	CN2.mgt	-0.07825	-0.25	0.25	1
2	ALPHA_BF.gw	0.4355	0	1	7
3	GWQMN.gw	4722.5	0	5000	11
4	CH_K2.rte	0.075	0	150	8
5	CH_N2.rte	0.6095	0	1	6
6	ESCO.hru	0.7285	0	1	3
7	GW_REVAP.gw	0.16689	-0.02	0.2	9
8	SLSUBBSN.hru	-0.13075	-0.25	0.25	5
9	SMFMN.bsn	2.835	0	10	4
10	SOL_AWC(..).sol	0.9115	0	1	2
11	SOL_Z(..).sol	0.03575	-0.25	0.25	10

Sensitivity analysis of simulated stream flow for the watershed was performed using the daily observed flow for identifying the most sensitive parameter and for further calibration of the simulated stream flow. 24 flow parameters were checked for sensitivity and 11 sensitive parameters were identified to have significant influence in controlling the stream flow in the watershed. The sensitive parameters identified were presented in the table above.

4.2.3. Calibration and Validation

The simulation of the model with default value of parameters showed relatively weak matching between simulated and observed stream flow. So the calibration and validation process was carried out automatically by the help of SWAT CUP model using sensitive parameters by Sequential Uncertainty Fitting program (SUFI2). Calibration was performed for 14 years from 1985 to 1998. The result of calibration for daily flow showed that there is a good agreement between the measured and simulated daily flows with Nash-Sutcliffe simulation efficiency (ENS) of 0.74 and coefficient of determination (R^2) of 0.75 and RSR of 0.51 as shown in Table 4.5.

The model validation was also performed for 7 years from 1999 to 2005.The validation simulation also showed good agreement between the simulated and measured daily flow with the ENS value of 0.57, R^2 of 0.60 and RSR of 0.65 as shown in Table 4.5.

Table 4.5: Calibration & Validation results for stream flow

Performance Criteria	Model efficiency		
	R2	NSE	RSR
Calibration	0.75	0.74	0.51
Validation	0.60	0.57	0.65

Similar studies in the nearby watershed also support the results of this study. For example, Ahmed, (2018) reported for the stream flow of Andasa watershed that NSE and R^2 values of 0.765 and 0.77 for calibration and 0.733 and 0.767 for validation periods respectively. Setegn, (2008) also reported the NSE and R^2 values of 0.73 and 0.80 for calibration and 0.71 and 0.80 for validation periods respectively for Gilgel Abay watershed.

The daily calibrated and validated results of stream flow are presented below in figures 4.4 and 4.5 respectively

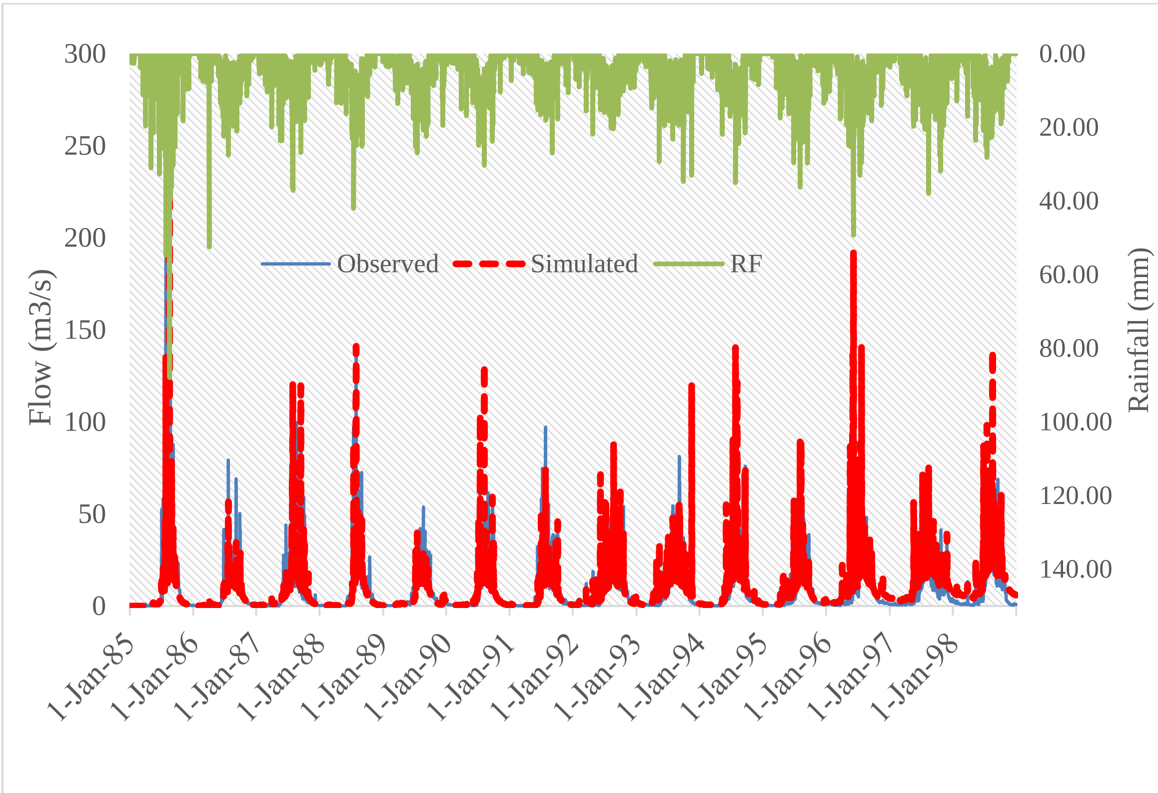

Figure 4.4: Measured and simulated daily flow during calibration (1985-1998).

The peak flow is highly affected by the parameter CN2. Our first sensitive parameter that used in calibration is CN2. And there is a high over land flow in the calibration period. So the Simulated peak flows have an over estimation.

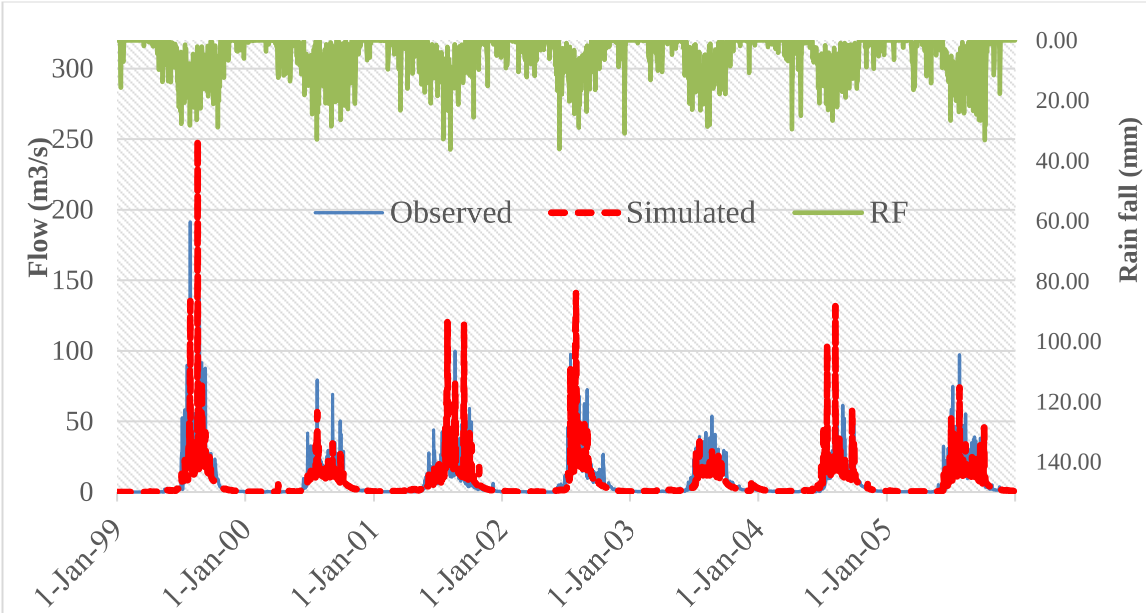

Figure 4.5: Measured and simulated daily flow during Validation (1999-2005).

On the hydrograph of the validation there is a time lag. Time lag is occurred in hydrographs when the watershed has long time concentration, high surface roughness and less slope. Temcha watershed has about 48km longest flow path this may cause for high time of concentration. Over 71% of the watershed slope is less than 15% slope this also cause the time lag.

4.2.4. Evaluation of Stream Flow due to Land Use and land Cover Change

After calibrating and validating of the model using 1986 land use and land cover map SWAT was run using the two land cover maps 1999 and 2013 while putting the other input variables the same for both simulations to quantify the variability of stream flow due to the changes of land use and land cover. This process gave the discharge outputs for three land use and land cover patterns. Then, these outputs were compared and the discharge change during the wettest months of stream flow taken as June, July and August and driest stream flow are considered in the months of December, January and February were calculated and used as indicators to estimate the effect of land use and land cover change on the stream flow. The two tables below present the mean monthly wet and dry month's stream flow for 1986, 1999 and 2013 land use and land cover maps and its variability (1986 -2013).

Table 4.6: Dry and wet Months average stream flow results

Years	1986	1999	2013
Dry Months Average Flow (m^3/s)	1.94	1.42	1.36
Wet Months Average Flow (m^3/s)	21.17	23.21	23.39

Table 4.7: Dry and wet Months average stream flow Change Detection

Years	1986-1999	1999-2013	1986-2013
Dry Months Average Flow (m^3/s)	-0.52	-0.06	-0.58
Wet Months Average Flow (m^3/s)	2.04	0.19	2.23

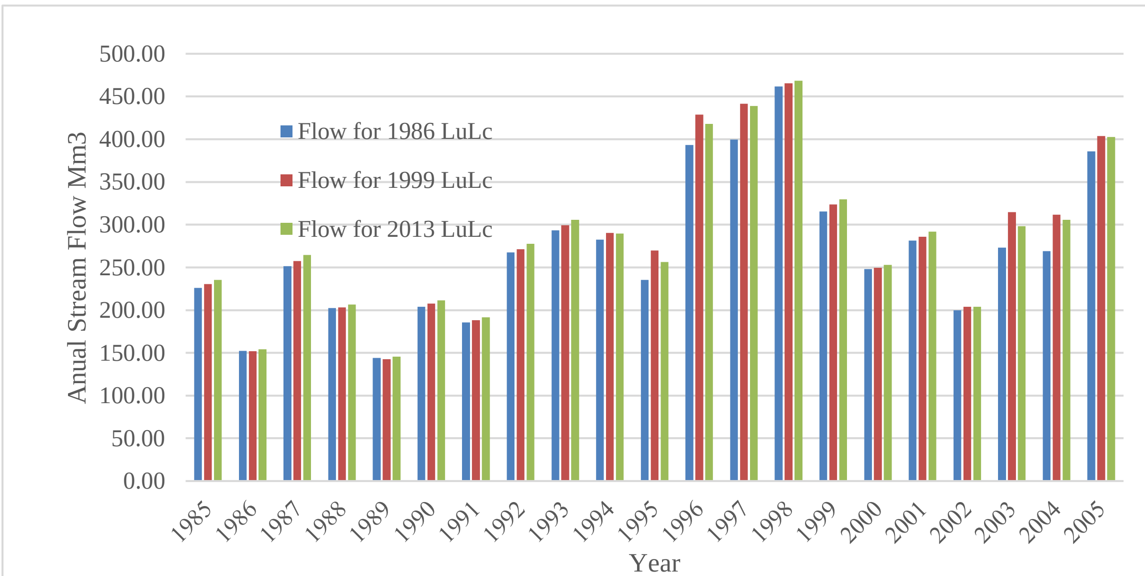

Figure 4.6: Annual stream flow change detection of three LuLc maps

As indicated in the tables above, the mean monthly stream flow for wet months had increased by 2.23m^3/s while the dry season decreased by 0.58m3/s during the 1986-2013 periods due to the land use and land cover change.

Similar studies in the nearby watershed also support the results of this study. For example, Tesfa, (2015) indicated a decrease of 0.65m^3/s and an increase of 17.54 m^3/s for Dry and Wet seasons respectively for Gilgel Abay watershed in 25 years. Asmamaw,

(2013) also indicated a decrease of 5.41m^3/s and an increase of 16.26 m^3/s for Dry and Wet seasons respectively for Gilgel Abay watershed between 1986 and 2001.

4.2.5. Base Flow Separation

A time series of total rainfall-runoff discharges can be splits into its sub flows (such as the overland flow, the subsurface flow or interflow, and the groundwater flow or base flow) using a numerical digital filter technique. For this study Water Engineering Time Series PROcessing tool73 (WETSPRO) excel macro program used. The total runoff simulated for Temcha watershed were comprised of mainly two hydrograph flow components; hence the Total runoff and base flow were decomposed. The Base flow (also called drought flow, low flow, or groundwater recession flow) is the portion of stream flow that comes from the sum of deep subsurface flow and delayed shallow subsurface flow. Sequentially base flow separation was done since it is used to determine the portion of stream flow hydrograph that occurs from base flow and direct runoff or overland flow. I used Recession constant 60 and W - parameter filter 0.62

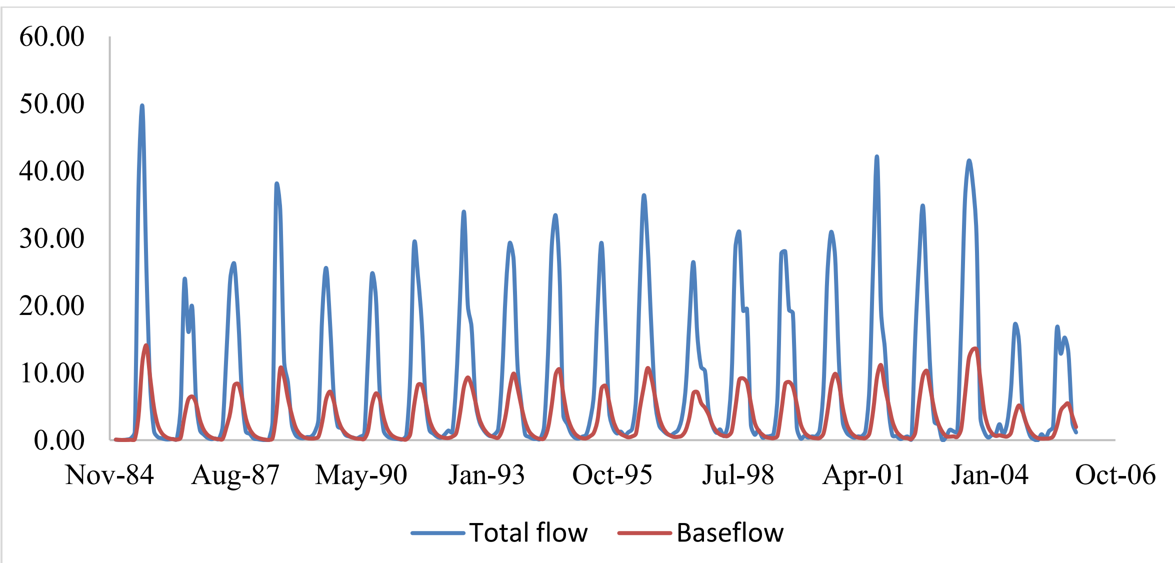

Figure 4.7: Total runoff and base flow hydrograph

The base flows of Temcha were evaluated on daily basis and finally aggregate in monthly basis. From the total stream flow around 62% were direct runoff and 38% were base flow.

4.3. Sediment yield modeling

The amount of sediment yield from Temcha watershed was simulated using SWAT model using land use land cover for the years 1986,1999 and 2013. Sediment yield simulation were also used for further calibration and validation in comparison with the daily observed sediment yield which was estimated by using the sediment concentration versus discharge rating curve developed from 58 measured data by MoWIE.

4.3.1. Calibration and Validation

First the calibration and validation process was carried out automatically by the help of SWAT CUP 2 model using sensitive parameters by Sequential Uncertainty Fitting program (SUFI2). Then manual calibration is performed on the base of auto calibration parameter values. Calibration was performed for 14 years from 1985 to 1998. The result of calibration for daily sediment yield showed that there is a good agreement between the measured and simulated daily flows with Nash-Sutcliffe simulation efficiency (ENS) of 0.59 and coefficient of determination (R^2) of 0.70 and RSR of 0.56 as shown in Table 4.10.

Table 4.8: Calibration & Validation results for sediment yield

Performance Criteria	R2	NSE	RSR
Calibration	0.70	0.59	0.56
Validation	0.60	0.50	0.70

The model validation was also performed for 7 years from 1999 to 2005. The validation simulation also showed good agreement between the simulated and measured sediment yield with the ENS value of 0.50 and R^2 of 0.60 and RSR of 0.70 as shown in Table 4.8.

Similar studies in the nearby watershed also support the results of this study. For example, Ahmed, (2018) reported for the Sediment yield of Andasa watershed NSE 0.667 and R^2 0.685 for calibration and NSE 0.681 and R^2 0.682 for validation periods. Setegn, (2010) also reported the NSE and R^2 values of 0.81 and 0.85 for calibration and 0.79 and 0.80 for validation periods respectively for Gilgel Abay watershed.

The daily calibrated and validated results of sediment yield are presented below in figures 4.8 and 4.9 respectively

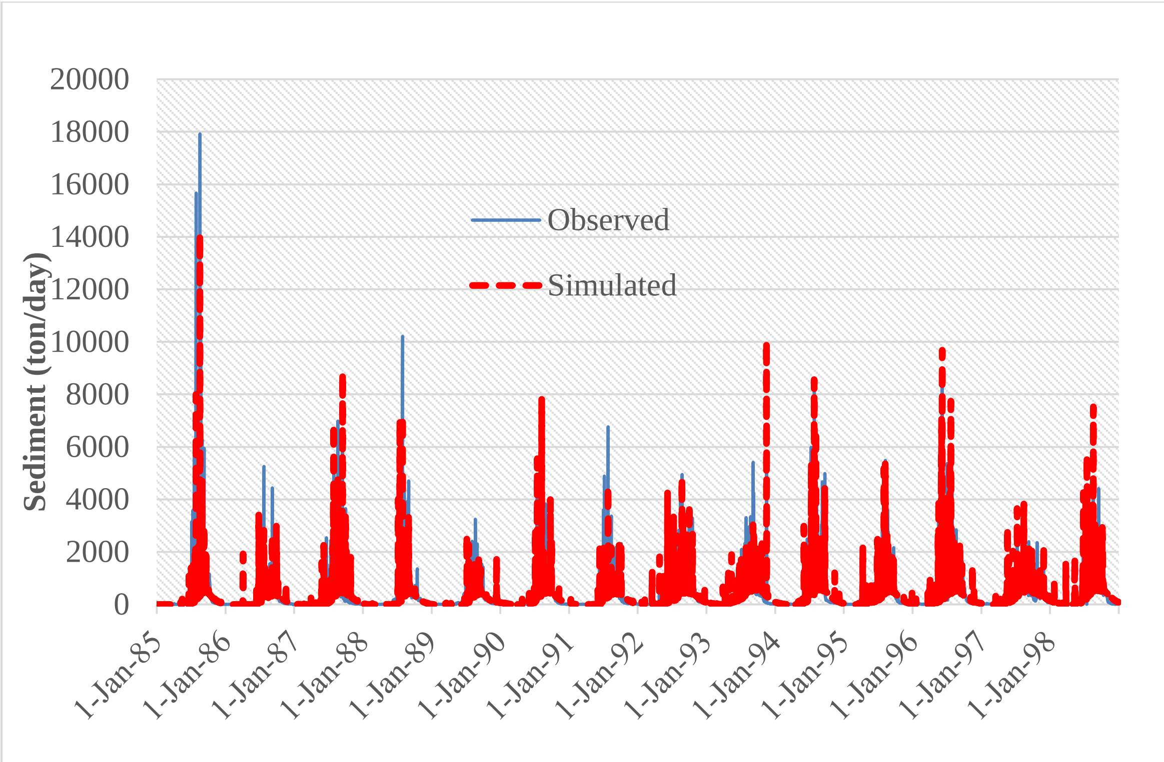

Figure 4.8: Measured and simulated daily Sediment during calibration (1985-1998).

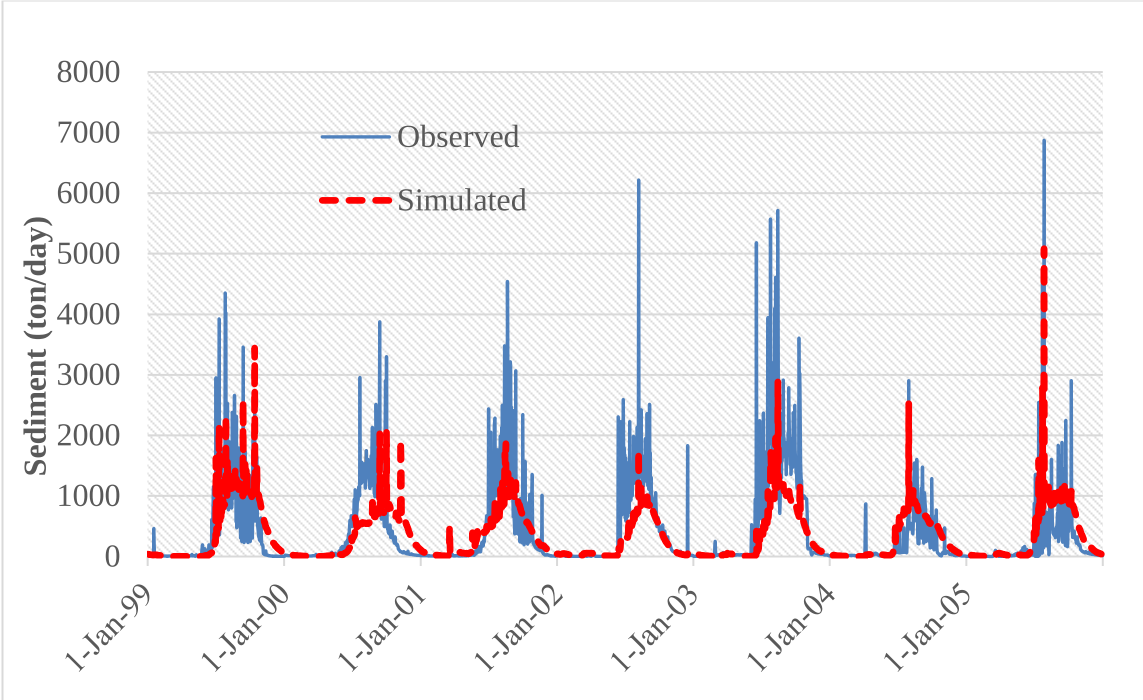

Figure 4.9: Measured and simulated daily sediment during Validation (1999-2005).

4.3.2. Evaluation of Sediment Yield due to Land Use and land Cover Change

After calibrating and validating of the model using 1986 land use and land cover map SWAT was run using the two land cover maps 1999 to 2013 while putting the other input variables the same for both simulations to quantify the variability of sediment yield due to the changes of land use and land cover. Then, these outputs were compared and the sediment yield change during the wettest months taken as June, July and August and driest months are considered as December, January and February and used as indicators to estimate the effect of land use and land cover change on the sediment output. Table 4. presents the mean monthly wet and dry month's sediment yield for 1986, 1999 and 2013 land use and land cover maps.

Table 4.9: Dry and wet Months average Sediment Yield results

Years	1986	1999	2013
Dry Months Sed (ton/day)	46.58	43.78	40.13
Wet Months Sed (ton/day)	709.55	738.89	776.67

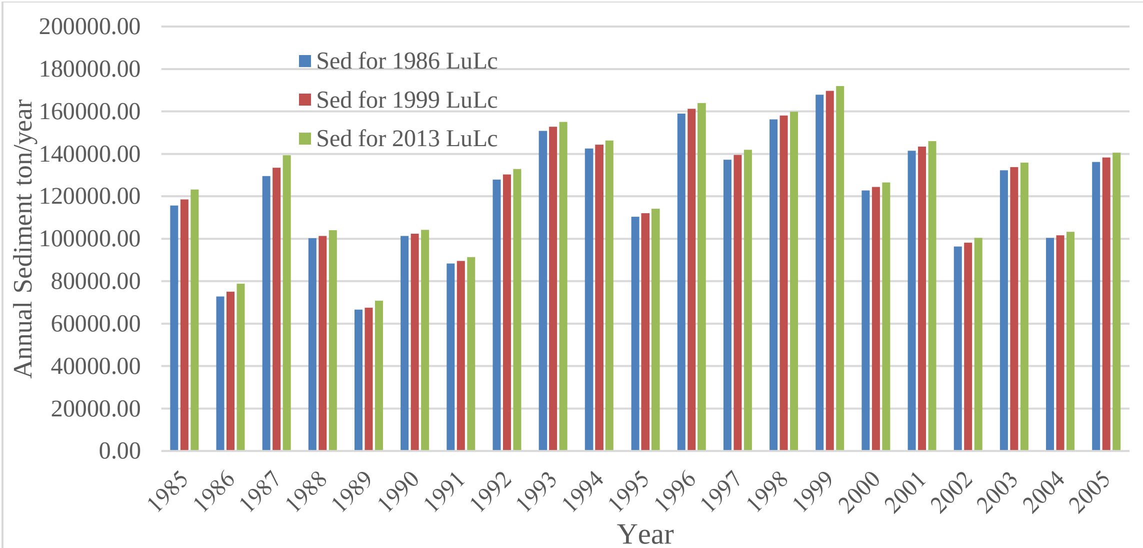

Figure 4.10: Annual Sediment yield change detection of three LuLc maps

Table 4.10: Dry and wet Months average Sediment Yield Change Detection

Years	1986-1999	1999-2013	1986-2013
Dry Months Sed (ton/day)	-2.80	-3.65	-6.45
Wet Months Sed (ton/day)	29.34	37.77	67.11

As indicated in the table 4.10, the mean monthly sediment yield for wet months had increased by 67.11 ton/day while the dry season decreased by 6.45 ton/day during the 1986-2013 periods due to the land use and land cover change.

Similar studies in the nearby watershed also support the results of this study. For example, Tesfa, (2015) indicated an increase of 62.78 ton/km^2 for Gilgel Abay watershed in 25 years. Ahmed, (2018) also indicated an increase of 19.513 t/ha for Andasa watershed in 43 years.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

In this study the impact of land use cover changes on Temcha watershed for over 28 years' period (1986-2013) were detected using Landsat satellite images from USGS earth explorer. The classified land use covers performed on ERDAS Imagine 2014 were integrated with other GIS data as a result stream flow and sediment simulations were done using SWAT model.

In Temcha watershed has a significant change in land use land cover over the past 28 years. It can be recognized that increase of cultivated lands, deforestation and was exhibited by rapid increase of population which changes the Temcha watershed. Forest, Grasslands and shrub lands were significantly changed to cultivated lands showing an identical trend for the two consecutive periods (1986 – 1999, 1999 – 2013). The results revealed the magnitudes of the cultivated land were increased by 37.94% and Bush& shrub, grazing and forest land were decrease by 17.39 %, 4.65 % and 15.90% respectively for 28 years' period. The watershed experienced a significant land use change between the three analyzed periods. It is concluded that the decrease in forest land, bush land and grazing land is accompanied by the increase in agricultural area,

SWAT was simulated successfully by using three LuLc maps to know the impact of the stream flow and sediment yield. The model also calibrated and validated for the temcha watershed. Therefore, SWAT can be utilized very well for hydrological simulations in the selected catchments and it is capable tool for further analysis of the hydrological responses in the watershed also, can be further extended to similar watersheds in the country, particularly in the Blue Nile Basin of Ethiopia.

The changes in land use has resulted an increase of surface runoff, on the other hand, lateral and ground water flow decreases with an expansion of agriculture. The result has also indicated that sediment yield transported through rivers out of the watershed. As a result, the stream flow and sediment yield was increased from year to year during the 28 years' period due to a conversion of grazing lands, bush lands and forest lands to cultivated lands. On 28 years' period (1986 – 2013) an increase of stream flow and sediment yield by 0.41m^3/s and 13.04t/day respectively. The land cover/use variability increase the stream flow and sediments yield during the wet seasons and decrease the base flow and sediment yield during the dry seasons. This is mainly stream flow and sediment yield has showed a direct relationship with cultivated land.

5.2. Recommendations

Based on the results/findings of this study the following recommendations are made;

- As the study has clearly shown that the vegetation coverage of Temcha watershed is degraded because of expansion of agriculture, so afforestation and Soil & Water Conservation practices are required to maintain the ecology of the watershed and protecting the area from human & animal contact to rehabilitate the area.
- Changes of the land use and land cover in the study area and the country in general are mainly caused by increasing population. Therefore, family planning should be given widely and continuously through formal and informal education.
- The other thing which is highly recommended is that the weather stations should be improved both in quality and quantity in order to improve the performance of the model. Hence, it is highly recommended to establish good meteorological and hydrological stations.
- The result of the study could help different stakeholders to plan and implement appropriate soil and water conservation strategies. The model developed could be used in prediction mode to take appropriate measures in advance.

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7. APPENDIX

Appendix 1 Control Points

No.	X	Y	LuLc
1	348112	1167096	Forest
2	344430	1170733	Grazing
3	354750	1174187	Forest
4	351969	1172234	Forest
5	345736	1169230	cultivated
6	346910	1170769	cultivated
7	365553	1183822	Forest
8	338592	1163421	cultivated
9	371985	1182676	Shrub
10	371224	1182436	Shrub
11	369126	1184732	Shrub
12	350340	1173983	cultivated
13	352257	1171312	Forest
14	338801	1162671	Grazing
15	343788	1168178	cultivated
16	343373	1166848	Grazing
17	344719	1162425	Forest
18	342551	1160246	Forest
19	339306	1169398	cultivated
20	352917	1179315	Forest
21	349301	1178498	Grazing
22	345848	1168542	cultivated
23	346797	1168875	cultivated
24	345277	1171192	cultivated
25	339652	1169302	cultivated
26	343077	1174706	cultivated
27	351847	1182328	cultivated
28	351591	1180788	Grazing
29	361052	1183935	Grazing
30	351293	1178749	Grazing
31	352854	1177722	Grazing
32	347857	1171686	Forest
33	358821	1177006	Grazing
34	348307	1164034	cultivated
35	352555	1172769	Forest
36	353832	1177250	Forest
37	355968	1177939	Forest
38	356909	1177965	Shrub
39	369742	1180162	Grazing
40	370460	1184819	Grazing

41	372207	1183282	Shrub
42	370499	1182420	Shrub
43	369918	1183051	cultivated
44	367393	1186047	Grazing
45	356538	1175819	Forest
46	356021	1173453	Grazing
47	356207	1174572	cultivated
48	357774	1174263	Grazing
49	355747	1171932	cultivated
50	353858	1172061	Grazing
51	358485	1175580	Grazing
52	356662	1171897	Forest
53	353654	1170464	Forest
54	338554	1164820	cultivated
55	340952	1166204	cultivated
56	340156	1167334	cultivated
57	341358	1168267	Grazing
58	343474	1164352	cultivated
59	349971	1169125	Forest
60	341224	1171481	Forest
61	344307	1173322	Forest
62	347711	1173774	Grazing
63	348795	1175063	cultivated
64	347241	1177978	Forest
65	349005	1178714	cultivated
66	343325	1159132	Grazing
67	349784	1180825	Forest
68	350391	1180653	cultivated
69	356116	1182685	Grazing
70	359230	1181936	Grazing
71	358787	1180992	Forest
72	362062	1178136	cultivated
73	363995	1177646	Forest
74	366144	1177258	Grazing
75	359102	1178832	cultivated
76	365106	1179960	cultivated
77	367139	1179254	Forest
78	365409	1181830	Forest
79	367336	1180939	Grazing
80	362064	1179753	cultivated
81	362414	1184015	cultivated
82	365493	1185336	Shrub
83	366917	1184142	cultivated
84	356843	1179847	Grazing
85	345825	1176007	cultivated

86	373134	1184120	Shrub
87	368335	1183122	Forest
88	363388	1180699	Shrub
89	346226	1165049	Forest
90	371653	1181286	Shrub
91	370548	1180170	Shrub
92	371937	1181914	Shrub
93	373069	1183123	Shrub
94	372792	1184720	Shrub
95	350466	1174962	Grazing
96	346477	1176784	Grazing
97	349796	1168297	Grazing
98	350746	1168635	Grazing
99	342897	1173102	cultivated
100	347731	1167844	cultivated
101	341589	1169528	cultivated

Appendix 2 List of Meteorological Stations

ID	NAME	LAT	LONG	ELEVATION
1	RFDrMark	10.345	37.73	2494
2	RFRobGby	10.545	37.766	2973
3	RFFrsBet	10.85	37.6	2838
4	RFDemcha	10.5637	37.492	2098

Appendix 3 Total yearly precipitation (mm) data of stations used for this study

Year	Debre Markos	Dembecha	Ferse bet	Rob Gebia
1984	1082.80	1156.42	1482.32	1161.54
1985	1404.20	1499.54	1922.12	1506.15
1986	1079.40	1366.63	1641.01	1272.78
1987	1273.40	1923.92	1140.00	1556.01
1988	1342.80	1262.10	1305.10	1413.13
1989	1445.40	1343.81	1925.60	1472.50
1990	1289.70	1176.37	1478.10	1087.72
1991	1096.63	1074.90	976.50	1010.65
1992	1256.30	1334.70	1028.59	1649.20
1993	1704.76	1614.60	1936.29	1439.40
1994	1201.60	1465.97	1656.18	1331.50

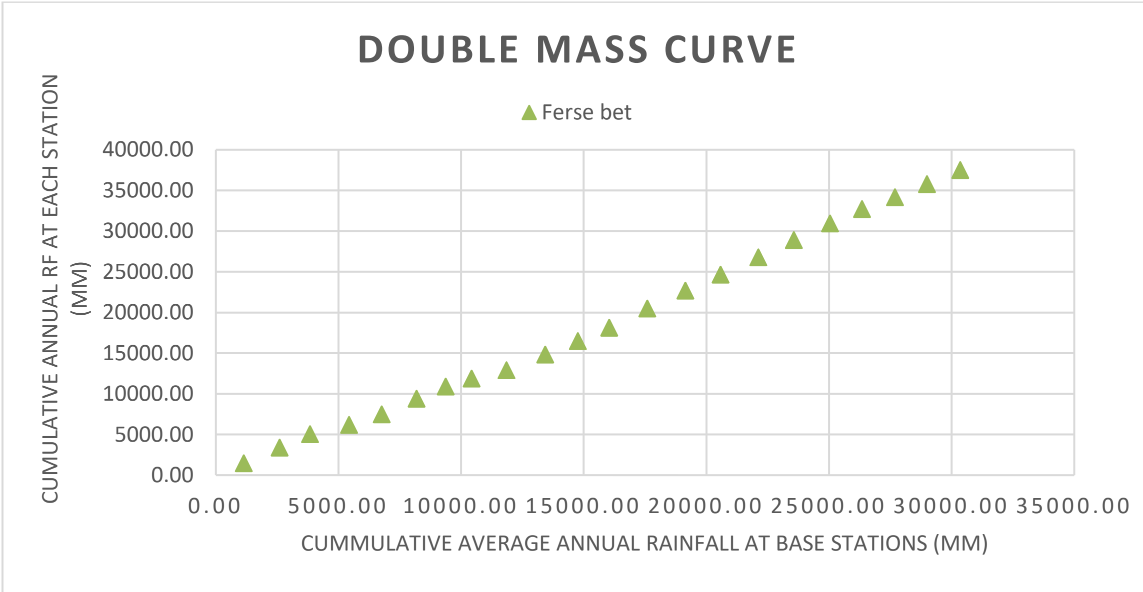
1995	1215.90	1292.40	1658.38	1293.80
1996	1589.20	1564.26	2346.72	1528.80
1997	1529.10	1628.70	2207.55	1501.30
1998	1225.72	1491.12	1942.10	1575.81
1999	1347.40	1586.93	2134.90	1682.20
2000	1439.80	1374.49	2118.50	1548.40
2001	1373.80	1439.40	2045.70	1619.30
2002	1322.80	1062.00	1775.55	1504.61
2003	1212.60	1325.20	1463.46	1488.00
2004	1318.30	1123.80	1606.70	1489.60
2005	1253.30	1404.08	1727.51	1421.88

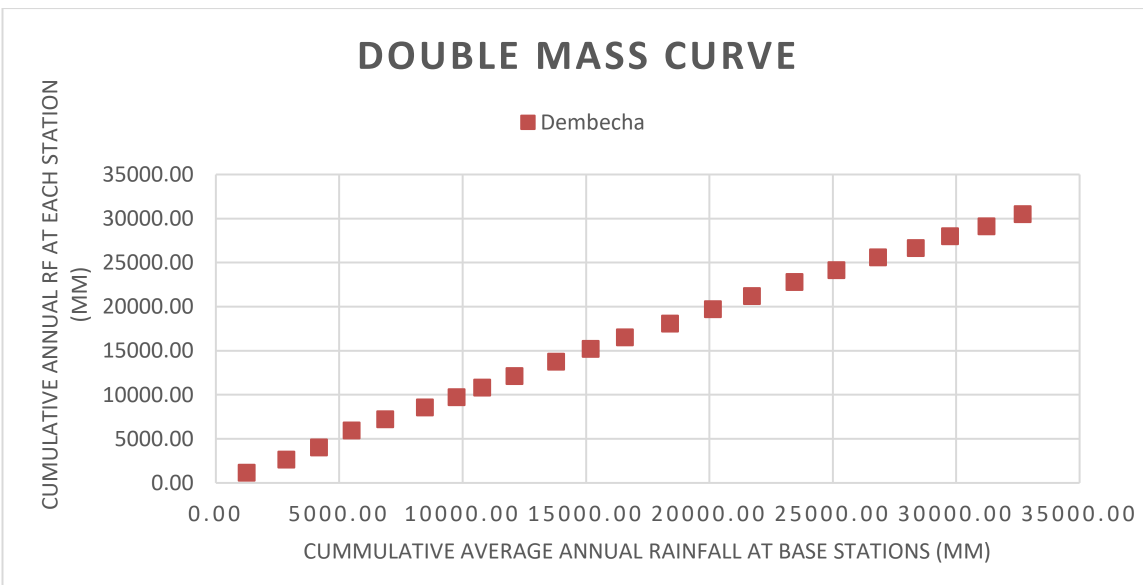
Appendix 4 Sediment concentration data for Temcha river

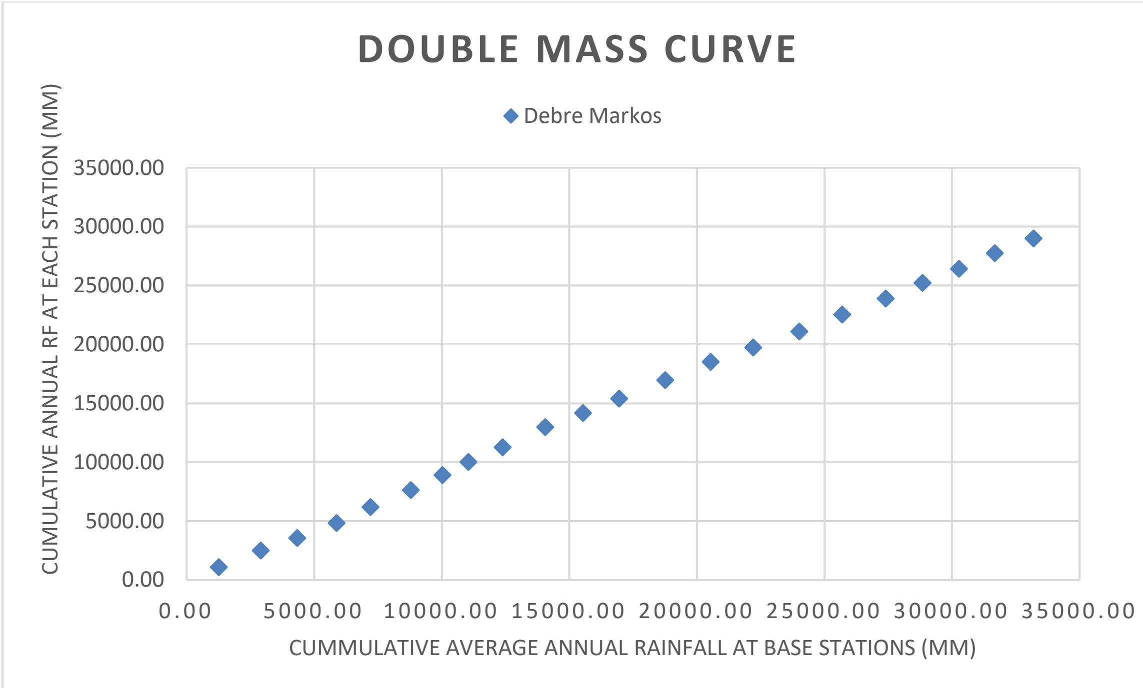
Date	Flow Q (m3/s)	Sedt Cnctr (mg/l)
15-Jul-68	37.090	1191.68
22-Jul-68	25.860	1098.03
12-Aug-68	32.010	705.16
27-Aug-68	37.190	533.75
6-Sep-68	13.180	302.66
20-Sep-68	25.110	451.14
8-Sep-69	23.500	350.00
20-Aug-85	52.290	154.59
22-Aug-85	38.240	292.90
3-Sep-85	28.810	151.15
26-Sep-85	13.070	131.18
8-Oct-85	11.040	1560.91
2-Nov-85	3.430	12.31
9-Jan-86	0.790	276.39
23-Feb-86	0.530	283.05
18-Mar-86	0.110	229.77
26-Apr-86	0.340	469.53
23-May-86	0.128	472.60
22-Jul-86	32.720	1714.53
22-Jul-86	35.450	1273.06
23-Jul-86	53.940	1283.60
6-Sep-86	14.940	165.29
26-Oct-86	4.240	41.33

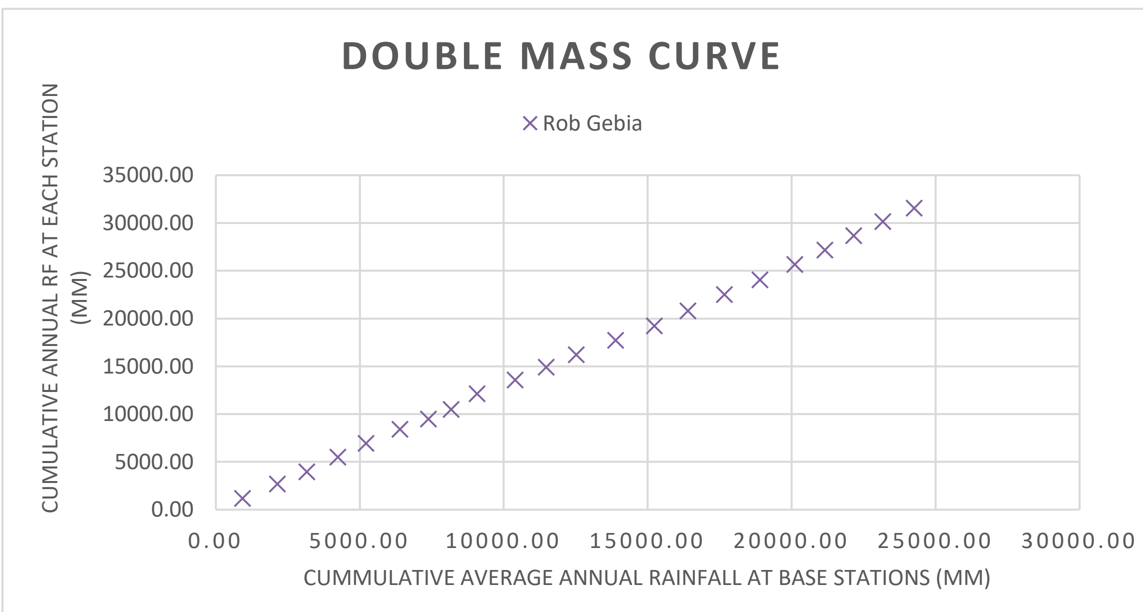
5-Jan-87	0.450	374.66
12-Apr-87	0.179	33.33
1-May-87	0.310	832.50
11-Aug-87	34.790	688.20
14-Aug-87	43.630	3154.62
15-Aug-87	33.960	1430.08
11-Sep-87	48.490	574.98
5-Oct-87	27.030	6142.30
27-Dec-87	0.890	49.95
28-Jan-88	0.560	86.58
27-Feb-88	0.530	243.09
15-Apr-88	0.061	218.45
10-May-88	0.290	146.52
24-Jun-88	4.280	16683.30
28-Jul-88	19.400	625.00
9-Sep-88	16.430	415.30
23-Oct-88	8.770	215.67
14-Jan-89	0.610	89.12
4-Feb-89	0.560	62.85
28-Apr-89	5.160	1083.93
28-Apr-89	0.240	156.43
10-May-89	0.404	107.19
19-Jun-89	1.800	1004.69
12-Jul-89	35.280	259.17
17-Nov-89	1.770	127.19
4-Feb-93	0.560	62.86
28-Apr-93	5.16	1083.93
28-Apr-93	0.240	156.43
12-Oct-93	9.650	218.16
12-Oct-93	9.650	218.71
12-Oct-93	9.650	197.25
12-Oct-93	9.650	238.53
9-Aug-07	1.460	2818.00
9-Aug-07	1.460	2920.88
9-Aug-07	1.460	2268.42

Appendix 5 Double Mass Curve of Four Stations






DOUBLE MASS CURVE
Debre Markos
CUMULATIVE ANNUAL RF AT EACH STATION (MM)
35000.00
30000.00
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
0.00
5000.00
10000.00
15000.00
20000.00
25000.00
30000.00
35000.00
CUMMULATIVE AVERAGE ANNUAL RAINFALL AT BASE STATIONS (MM)


DOUBLE MASS CURVE
Rob Gebia
CUMULATIVE ANNUAL RF AT EACH STATION (MM)
35000.00
30000.00
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
0.00
5000.00
10000.00
15000.00
20000.00
25000.00
30000.00
CUMMULATIVE AVERAGE ANNUAL RAINFALL AT BASE STATIONS (MM)

Appendix 6 Accuracy Assessment result of Land cover classification 1986

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.6677

Conditional Kappa for each Category.

Class Name	Kappa
Unclassified	0.0000
	0.0000
Shrub	0.4195
Grazing	0.9078
	0.0000
	0.0000
Cultivated	0.6387
	0.0000
	0.0000
Forest	0.8829

----- End of Kappa Statistics -----

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	0	0	---	---
	0	0	0	---	---
Shrub	14	26	13	92.86%	50.00%
Grazing	28	15	14	50.00%	93.33%
	0	0	0	---	---
	0	0	0	---	---
Cultivated	33	37	28	84.85%	75.68%
	0	0	0	---	---
	0	0	0	---	---
Forest	26	23	21	80.77%	91.30%
Totals	101	101	76		

Overall Classification Accuracy = 75.25%

----- End of Accuracy Totals -----

1999

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.7432

Conditional Kappa for each Category.

Class Name	Kappa
Unclassified	0.0000
	0.0000
	0.0000
	0.0000
Forest1	0.0000
Forest2	0.8607
Grazing	0.8271
Cultivated	0.6953
Bush	0.5903

----- End of Kappa Statistics -----

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	0	0	---	---
	0	0	0	---	---
	0	0	0	---	---
	0	0	0	---	---
Forest1	0	0	0	---	---
Forest2	26	29	26	100.00%	89.66%
Grazing	28	16	14	50.00%	87.50%
Cultivated	33	39	31	93.94%	79.49%
Bush	14	17	11	78.57%	64.71%
Totals	101	101	82		

Overall Classification Accuracy = 81.19%

----- End of Accuracy Totals -----

2013

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.8622

Conditional Kappa for each Category.

Class Name	Kappa
Unclassified	0.0000
	0.0000
	0.0000
Forest1	0.0000
Forest2	0.9501
Shrub	1.0000
Grazing1	0.0000
Grazing2	0.8518
	0.0000
	0.0000
	0.0000
Cultivated	0.7715

----- End of Kappa Statistics -----

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	0	0	---	---
	0	0	0	---	---
	0	0	0	---	---
Forest1	0	0	0	---	---
Forest2	26	27	26	100.00%	96.30%
Shrub	14	7	7	50.00%	100.00%
Grazing1	0	0	0	---	---
Grazing2	28	28	25	89.29%	89.29%
	0	0	0	---	---
	0	0	0	---	---
	0	0	0	---	---
Cultivated	33	39	33	100.00%	84.62%
Totals	101	101	91		

Overall Classification Accuracy = 90.10%

----- End of Accuracy Totals -----