IMPACT OF LAND USE DYNAMICS ON RESERVIOR SEDIMENTATION IN MEGECH WATERSHED, UPPER BLUE NILE, ETHIOPIA

By

IBRAHIM TEMAM JUHAR

A Thesis Submitted To

The Department of Civil Engineering for the Partial Fulfilment of the Requirements for the Degree of Master of Science in Civil Engineering (Hydraulic Engineering)

ADDIS ABABA SCIENCE AND TECHNOLOGY UNIVERSITY

JUNE 2018

DECLARATION

I hereby declare that this thesis entitled ***"Impact of Land Use Dynamics on Reservoir Sedimentation in Megech Watershed"*** was composed by myself, with the guidance of my advisor, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted, in whole or in part, for any other degree or professional qualification.

Name: Signature, Date:

Ibrahim Temam

CERTIFICATION

This is to certify that the thesis prepared by **Mr. Ibrahim Temam Juhar** entitled ***"Impact of Land Use Dynamics on Reservoir Sedimentation in Megech Watershed"*** and submitted in fulfillment of requirements for the Degree of Master of Science complies with the regulation of the University and meets the accepted standards with respect to originality and quality.

Date of Defense: June 8, 2018

Principal Advisor

1. ______________________ ________ ______

Signature Date

Members of the Examining board:

1. ______________________ ________ ________

External Examiner Signature Date

2. ______________________ ________ ________

Internal Examiner Signature Date

3. ______________________ ________ ________

ERA PG, Programme Coordinator Signature Date

4. ______________________ ________ ________

Head, Civil Eng'g Department Signature Date

5. ______________________ ________ ________

Dean, College of Architecture and Civil Engineering Signature Date

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my thesis advisor, Dr. Fitsum Tesfaye for his advice ,comment, valuable suggestions, encouragement and guidance of my thesis work

I would like to extend my special thanks to Ministry of Water Resource Energy and Irrigation, Ethiopian Construction Work Design and Supervision Corporation, National Metrology Agency, since they were provided the necessary data for my thesis work.

Finally, I would like to thank Ethiopian Road Authority and Addis Ababa Science and Technology for the free scholarship.

ABSTRACT

Reservoir sedimentation is a gradual accumulation of the incoming sediment load from a river. The potential effects of land use/cover change resulting soil erosion and producing over sediment on surface water source of reservoirs, which are losing their capacity due to sedimentation processes, and are therefore seriously threat on their performance. Therefore the main intention of this study is to evaluate the impact of land use dynamics on reservoir sedimentation in Megech watershed. ArcGIS and ERDAS used to generate three land use/cover maps from Landsat TM, ETM+ and ETM+ acquired in 1986 ,2006 and 2015 respectively, The land use maps were generated using the Maximum Likelihood Algorithm of Supervised Classification. The accuracy of the classified maps was assessed using error matrix and kappa statistic. The result of this analysis showed that the cultivated land and built up have expanded during the study period of 1986-2015. Using the three generated land use maps, SWAT model, the same climate data and other input for the period of 1986 to 2015 three independent model were prepared, calibrate and validate with respected period. Then to show the impact of land use dynamics on sediment load the three independent models were runs simulations for the same period from 2003 to 2015. The performance of the SWAT model was evaluated through sensitivity analysis, calibration, and validation using SWAT-CUP software SUFI 2 program. Both the calibration and validation results showed good match between measured and simulated stream flow and sediment load data with acceptable range, coefficient of determination (R^2)(0.68 to 0.88 for Calibration and 0.62 to 0.86 for Validation) and Nash-Sutcliffe efficiency (ENS)(0.64 to 0.88 for Calibration and 0.61 to 0.85 for Validation).The result of this study showed the annual simulated sediment yield 353,835 tons/year (716.26 tons/km^2/year) using land use 1986, 482,319 tons/year (976.36 tons/km^2/year) using land use 2006 and 557,184 tons/year (1127.90 tons/km^2/year) using land use 2015. According to the Empirical Area Reduction method, the Megech reservoir will have useful life of 125, 90 and 78 year using land use 1986, 2006 and 2015 respectively, with trap efficiency 98% and average deposit density 1.12 t/m^3. Generally, the analysis indicated that increasing in sediment load and decrease in useful life of reservoir due to the land cover changes during the study period.

Key words: Megech watershed, Land use dynamics, Stream flow, Sediment yield, Reservoir Sedimentation, GIS, ERDAS, SWAT model, SWAT-CUP, SUFI 2

Table of Contents

LIST OF TABLE

LIST OF FIGURE

LIST OF ABBREVATION

ARS	Agricultural Research Service
DEM	Digital Elevation Model
E	East direction
ERDAS	Earth Resource Development Assessment Tool
ET	Evapotranspiration
ETM+	Enhance Termatic Mapper Plus
GIS	Geographic Information System
GPS	Global Positioning System
Km	Kilometer
Km^2	Square kilometer
HRU	Hydrological Response Unit
HEC-HMS	Hydraulic Engineering Center-Hydrologic Model Center
MoWIE	Minster of Water, Irrigation and Electricity.
MUSLE	Modified Universal Soil Losses
m.a.s.l	mean above sea level
N	North direction
NMSA	National Metrological Service
PET	Potiential Evapotranspiration
RS	Remote Sensing
S	South direction
SCS	Soil Conservation Service
SUFI 2	Sequential Uncertainty Fitting Version Two
SWAT	Soil and Water Assessment Tool
SWAT-CUP	Soil and Water Assessment Tool-Calibration and Uncertainty
TM	Termatic Mapper
USDA	United States of department of Agriculture
W	West direction
USLE	Universal Soil Loss Equation
WWDSE	Water Works Design and Supervision Enterprise

CHAPTER ONE

1. INTRODUCTION

1.1 Background

Reservoir sedimentation is a gradual accumulation of the incoming sediment load from a river. This accumulation is a serious problem in many parts of the world and has severe consequences on water management, flood control and production of energy. In the present situation, the worldwide loss of storage capacity in surface water reservoirs due to sedimentation is higher than the increase in storage volume achieved through construction of new reservoirs (White, 2010). The worldwide loss in reservoir storage capacity is estimated to be between 0.5% and 1% per annum (Mahmood, 1987; White, 2010).

Inappropriate use of land and poor ecosystem management have accelerated land degradation and reduced the storage capacity of reservoirs. (Gebiaw et al., 2017). The potential effects of land use/cover change resulting soil erosion and producing over sediment on surface water source of reservoirs, which are losing their capacity due to sedimentation processes, and are therefore seriously threat on their performance. Soil erosion is among the serious problems affecting the quality of water resources; soil and land upon which man depends for their sustenance and proper management of those resources is important to satisfy the current demand as well as to maintain sustainability. The most essential natural resources of water for living species are limited in amount, scarce, and not spatially distributed in relation to the population needs. Deforestation, agricultural activities, construction, mining, urban and industrial development, and similar activities can have significant impact on the quantity and rate of surface runoff. (Tadele, 2007).

Land use/cover are highly changed especially in the developing countries which have agriculture based economics and rapidly increasing populations. Most studies in Ethiopia indicate that sheet and rill erosion by water and burning of cow dung and crop residue are the major drivers of land degradation that affect land productivity (Hurni, 1993). Demands for land are increasing as population increases because of the need land for their farming and housing activities, and affect the natural resource coverage of the earth. Land use planning and management are closely related to the sustainability of water resources as changes of land use are linked with amount of water through relevant hydrological processes (Guo et al, 2008).

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).

Appropriate tools are needed for better assessment of long-term hydrology and soil erosion processes and as decision support for planning and implementing appropriate measures. The tools include various hydrological and soil erosion models, as well as geographical information system (GIS). Due to technological developments in recent years, distributed catchment models are increasingly being used to implement alternative management strategies in the area of water resource allocation and flood control. Many hydrological and soil erosion models are designed to describe hydrology, erosion and sedimentation processes. Hydrological models describe the physical processes controlling the transformation of precipitation to runoff, while soil erosion modeling is based on understanding the physical laws of processes that occur in the natural landscape (Setegn et al, 2009).

Among several factors that affect sedimentation, land use/ cover is one and one of the primary factors. So the knowledge how land use/cover change influence watershed hydrology and reservoir sedimentation 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.

The purpose of this study is therefore applying the integration of Geographical Information System (GIS), Remote sensing and physically based semi distributed model i.e. Soil and water assessment tool (SWAT), to evaluate the impact of land use dynamics on reservoir sedimentation in Megech watershed.

1.2 Problem of statement

The silting of reservoirs is the most challenging problem in Ethiopia. Sedimentation adversely affects the reservoir capacity. The consequences are very complex, because dams usually serve multiple purposes. The loss of storage capacity is particularly felt in connection with energy production, water supply for domestic use, industry and agriculture, recreation and in flood control. Sedimentation also have consequences on increasing in maintenance cost, operation cost and shortening lifespan of water resources infrastructure.

The problems in the study area were overgrazing, human settlements, poor land management, highly increasing deforestation and agricultural expansion which are directly related to land use change. This change will cause an effect on the hydrology and sediment yield of the watershed. For example when forest is lost and agricultural land is expanded base flow will be reduced and increase in surface runoff and cause soil erosion.

Therefore analyzing the impacts of different variables which cause/accelerate the problem is essential. Specifically, on land use/cover change impact on soil erosion potential, which is the main cause of reservoir sedimentation. This study with little effort and cost can evaluate the impact of land use dynamics on reservoir sedimentation and predict sediment yield in the basin continuously.

1.3 Objective of the study

1.3.1 General objective

The main objective of this study was to evaluate the impacts of land use dynamics on reservoir sedimentation in Megech watershed, Upper Blue Nile, Using Remote Sensing, GIS Techniques and Soil and Water Assessment (SWAT model) Tool.

1.3.2 Specific objectives

- To examine land use/ cover change in Megech watershed.
- To predict sediment yield at Megech reservoir catchments with current land use
- To estimate the useful life of the Megech reservoir, under different land use/ land cover.
- To forward recommendations to any measures that can be taken in order to reduce the amount of sediment inflow.

1.4 Research questions

To address the research objective for this study the following questions should be answered

- How is the land cover in the area being changed?
- How much is sediment yield at Megech Reservoir watershed with current land use?
- How long the useful life of the reservoir under different land uses /covers?
- What possible measures can be implemented to reduce sediment inflow?

1.5 Significance of the study

Now a day our country Ethiopia is straggling against poverty. Implementing irrigation by constructing water storage dams is one and the main way of poverty reduction by increasing productivity. Beside this our dams are in a serious problem of sedimentation. It is obvious that sedimentation is influenced by land use/cover and the adopted management practice. This implies having a good land use and management practice significantly reduce the sedimentation problem in the reservoir. Hence studying the impact of land use dynamics on the reservoir sedimentation have a great significance in decision making on both in designing the storage reservoir and land use management. It will also help to develop available information for researchers, technology institution and the local government for the purpose of integrated water resource management activities.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Concept and definition of land use and land cover change

Land cover is the physical and biophysical cover over the surface of earth, including distribution of vegetation, water, bare soil and artificial structures. Land use refers to the intended use or management of the land cover type by human beings such as agriculture, forestry and building construction. Land use land cover change is commonly grouped in to two broad categories: conversion (a change from one cover or use category to another e.g. from forest to grassland) and modification (a change within one land use or land cover category (e.g. from rain fed cultivated area to irrigated cultivated area) due to changes in its physical or functional attributes (Meyer and Turner, 1994).

These changes in land use and land cover systems have important environmental consequences through their impacts on soil and water, biodiversity, and microclimate. Land cover changes have been influenced by both the increase and decrease of a given population (Turner and Skole, 1994). In most developing countries like Ethiopia population growth has been a dominant cause of land use and land cover change than other forces.

2.2 Soil erosion and sedimentation

Soil erosion and sedimentation by water involves the processes of detachment, transportation, and deposition of sediment by raindrop impact and flowing water (Julien, 1998). Soil erosion is the process whereby the earth or rock material is loosened or dissolved and removed from any part of the earth's surface (Morris and Fan, 1998). Gross erosion is the sum of all types of erosion rill, gully, channel erosion, and mass wasting. The relative importance of each type of erosion varies from area to area. Sheet and rill erosion occurs particularly in grazing and cultivated areas of mild slope where runoff is not concentrated in well-defined channel (Morris and Fan, 1998; Vanoni, 2006).

The detached sediment is transported down slope primarily by flowing water, although there is a small amount of down slope transport by raindrop splash also (Walling, 1988). Once runoff starts over the surface areas and in the streams, the quantity and size of material transported depends on transport capacity of runoff water. However, if transport capacity is less than the amount of eroded soil material available, then the amount of sediment exceeding the transport capacity gets deposited (Meyer &Wishmeier, 1969; Haan et al., 1994). A basin sediment yield refers to the amount of sediment exported by a basin over a period of time which is also the amount that will enter a reservoir located at the downstream limit of the basin (Morris and Fan, 2009).

Several factors affect soil erosion: which include climate, soil, topography, land use land cover and management practice. Among those land use land cover and management practice have direct link to soil erosion. Cover includes plant canopy, mulches, plant residue etc. it has a greater impact on erosion than any other single factor. The canopy intercepts rain drops, and if it is close to the ground, water dripping from the leaves has much less energy than unhindered rain drops (wischmeir and smith, 1978). Materials in contact with the ground surface reduce the erosion more effective than a canopy. No detachment occurs by raindrop impact where the soil is covered because there is no fall distance for rain drops to regain energy. Beside such materials slow the runoff, which increase the flow depth

According to Altunkaynak (2009), estimation of sediment load is required in practical studies for the planning, design, operation and maintenance of water resources structures. The sediment transportation monitoring requires a good sample techniques which is very lengthy and costly (Pavanelli and Palgliarani, 2002). Therefore, it is important to develop a model that can estimate accurately the suspended sediment yield from the basin.

2.3 Impact of land use on erosion and sediment load

Forests are checkers of soil erosion. Protection is largely because of under stores vegetation and litter, and the stabilizing effect of the root network. On steep slopes, the net stabilizing effect of trees is usually positive. Vegetation cover can prevent the occurrence of shallow landslides (Bruijnzeel, 1990). However, large landslides on steep terrain are not influenced appreciably by vegetation cover. These large slides may contribute the bulk of the sediment, as for example in the middle hills of the Himalayas (Bruijnzeel and Bremmer, 1989).

Deforestation may increase erosion. The actual soil loss, however, depends largely on the use to which the land is put after the trees have been cleared. Surface erosion from well-kept grassland, moderately grazed forests and soil-conserving agriculture are low to moderate (Bruijnzeel, 1990). Road construction may be a major cause for erosion during timber harvesting operations. In the USA, forest roads are estimated to account for 90 percent of the erosion caused by logging activities.

Effects of erosion control measures on sediment yield will be most readily felt on-site. There is an inverse relation between basin size and sediment delivery ratio. In basins of several hundred km^2 improvements may only be noticeable after a considerable time lag (Decades), due to storage effects (Bruijnzeel, 1990).

2.4 Remote sense and GIS for land cover classification

Remote sensing is broadly defined as the art and science of obtaining information about an object without being in direct physical contact with the object (Colwell, 1983; Lillesand et al., 2004).The modern usage of the term 'Remote Sensing' has more to do with the technical ways of collecting airborne and space borne information. It was the launch of the first civilian remote sensing satellite in the late July 1972 that paved the way for the modern remote sensing applications in many fields including natural resources management (Tucker et al. 1983).The multispectral data provided by the on- board sensors led to an improved understanding of crops, forests, soils, urban growth, land degradation and many other earth features and processes.

GIS is important to use the benefit of collateral information, such as digital elevation models, hydrology and soil maps (Jensen, 2005), which can be provided with the extracted information from remotely sensed images into GIS platforms. Thus, the integration of remotely sensed data with GIS data has the potential to improve the accuracy of results. The main advantage of GIS is that changes can be detected more clearly than with other techniques using multi-source data

In recent years, remote sensing and GIS have been commonly integrated for analyzing and mapping land use and land cover changes (Murayama, 2009). Driving land use and land cover change maps into GIS applications has been done using supervised classification algorithms through remotely sensed software (Tripathi and Kumar, 2012). Remote sensing analysts have become avid consumers of GIS data as a means to add value to remotely sensed data and analysis (Franklin, 2003).

Currently widespread use of the technologies for spatial data acquisition such as remote sensing (RS) and geographic information system (GIS) provide extraordinary ways to achieve significant progress in modeling. Remote sensing provided better way to detecting patterns at ground surface and obtaining data for processes at different spatial scales range. GIS create multistate representation by incorporate and linking digital maps at different scale and assessing the impact of scale in modeling. Digital elevation models (DEM) are one of the most popular application in GIS. DEM should use for extract and delineate basin geometry. the spatial distribution of meteorological data on one way and vegetation , soil characteristics, land use on other way are important in hydrological modeling . Both of them influence runoff contribution and soil moisture content. That factor can be observed using RS(wigmosta et al.1994).Satellite image use for mapping and for classification of land use and land cover(Baker et al.1991).The digital satellite images involve the three image processing which are pre-processing, classification and post – Classification. Two general types of image classification techniques have been developed: supervised and unsupervised techniques. In supervised classification, the analyst's role is to specify in advance the multispectral reflectance and admittance values typical of each land cover class. Case of unsupervised classification does not define training fields for each land cover class in advance.

2.5 Hydrological model

Modeling is defined by as the process of organizing, synthesizing, and integrating component parts into a realistic representation of the prototype. USDA (1980) lists the following benefits of modeling: Models help sharpen the definition of hypotheses, define and categorize the state of knowledge, provide an analytical mechanism for studying the system of interest, and can be used to simulate experiments instead of conducting the experiments on the watershed itself.

Hydrological modeling is a great method of understanding hydrologic systems for the planning and development of integrated water resources management. On the basis of process description, the hydrological models can be classified in to three main categories (Cunderlik, 2003).

Lumped models. Parameters of lumped hydrologic models do not vary spatially within the basin and thus, basin response is evaluated only at the outlet, without explicitly accounting for the response of individual sub-basins. The parameters often do not represent physical features of hydrologic processes and usually involve certain degree of empiricism. These models are not usually applicable to event-scale processes. If the interest is primarily in the discharge prediction only, then these models can provide just as good simulations as complex physically based models

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

Semi-distributed models. Parameters of semi-distributed (simplified distributed) models are partially allowed to vary in space by dividing the basin 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.

Among the above mentioned hydrological models, for this study SWAT model were selected. The physically based semi-distributed watershed model SWAT (Soil and Water Assessment Tool) watershed model is one of the most recent models developed at the USDA-ARS (Arnold et al., 1998) during the early 1970's. SWAT model is semi-distributed physically based simulation model and can predict the impacts of land use change and management practices on hydrological regimes in watersheds with varying soils, land use and management conditions over long periods and primarily as a strategic planning tool (Neitsch, et al, 2011). It is widely applied in many parts of United States and many other countries like Ethiopia

The interface of SWAT model is compatible with ArcGIS that can integrate numerous available geospatial data to accurately represent the characteristics of the watershed. In SWAT model, the impacts of spatial heterogeneity in topography, land use, soil and other watershed characteristics on hydrology are described in subdivisions. There are two scale levels of subdivisions; the first is that the watershed is divided into a number of sub-watersheds based upon drainage areas of the attributes, and the other one is that each sub-watershed is further divided in to a number of Hydrologic Response Units (HRUs) based on land use and land cover, soil and slope characteristics.

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

The model allows users to model watersheds with less monitoring data and to assess predictive scenarios using alternative input data such as climate, land-use practices, and land cover on water movement, nutrient cycling, water quality, and other outputs. Several model components have been previously validated for a variety of watersheds.

The SWAT Model is one of the most widely used and scientifically accepted tool for assessing water quality, sediment transport and stream flow in a watershed; as evidenced by worldwide conferences and publications of SWAT related reports and articles. The use of the model is primary driven by the demand of various environmental agencies for direct and exploratory assessments of the impact of anthropogenic activities, climate change, and other wide range of land management issues on water and soil resources (Gassman et al, 2007). Since many watersheds globally are already experiencing degradation and calls for sound management of resources, SWAT has been increasingly used even outside of the United States of America. According to (Arnold et al, 2011), the SWAT model has also been used in countries such as China, Iran, Japan, Korea, Philippines, as well as countries in Europe and in Africa.

In the Upper Nile Basin in Africa, SWAT has been used for hydrology/water balance, erosion, water quality, and climate change assessments, calibration uncertainty, land use change studies, and SWAT development (vanGriensven et al, 2012). Additionally, (Gassman et al, 2007) showed that the global application of SWAT included calibration and/or sensitivity analysis, climate change impacts, GIS interface descriptions, hydrologic assessments, variation in configuration or data input effects, comparison with other models or techniques, interfaces with other models, and pollutant assessments. The SWAT model application was calibrated and validated in some parts of Ethiopia (Chekol, 2006; Setegn et al, 2009; Tibebe and Bewket, 2010; vanGriensven et al,2012; Tesfahunegn et al., 2012) have already shown that SWAT model was evaluated with adequate level of accuracy in gauged catchments in some parts of Ethiopia.

2.6 Hydrological model selection criteria

There are various criteria which can be used for choosing the right hydrological model for a specific problem. These criteria are always project dependant, since every project has its own specific requirements and needs. Further, some criteria are also user-depended (and therefore subjective). Among the various project-dependent selection criteria, there are four common, fundamental ones that must be always answered (Cunderlik, 2003):-

I. Required model outputs important to the project and therefore to be estimated by the model (Does the model predict the variables required by the project such as long-term sequence of flow?)
II. Hydrologic processes that need to be modelled to estimate the desired outputs adequately (Is the model capable of simulating single-event or continuous processes?)
III. Availability of input data (Can all the inputs required by the model be provided within the time and cost constraints of the project?)
IV. Price (Does the investment appear to be worthwhile for the objectives of the project?).

Among various hydrological model, SWAT model was fulfiled the hydrological model selection crietera and it’s suitable to achive the objective of the study. SWAT was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time.

2.7 Reasons for selecting SWAT model

The reasons behind for selecting SWAT model for this study are:-

I. Is physically based: rather than incorporating regression equations to describe the relationship between input and output variables, SWAT requires specific information about weather, soil properties, topography, vegetation, and land management practices occurring in the watershed. The physical processes associated with water movement, sediment movement, crop growth, nutrient cycling, etc. are directly modeled by SWAT using this input data.

II. Uses readily available inputs: while SWAT can be used to study more specialized processes such as sediment transport, the minimum data required to make a run are commonly available from government agencies.

III. Is computationally efficient: simulation of very large basins or a variety of management strategies can be performed without excessive investment of time or money.

IV. Enables users to study long-term impacts: many of the problems currently addressed by users involve the gradual build-up of pollutants and the impact on downstream water bodies. To study these types of problems, results are needed from runs with output spanning several decades.

V. Applied in a wide variety of Ethiopian situations (applicable and gave good results)

VI. It is readily and freely available

2.8 Previous studies in Ethiopia

Various researches were done in the Ethiopia using GIS and SWAT models. The areas of research include land cover changes, sedimentation, and stream flow and conditions relating these parameters.

Setegn (2008) have studied on Hydrological and Sediment yield modeling in Lake Tana. The main objective of this study was to identify the most erosion sensitive areas. Two decision support models, SWAT and MCE (multi- criteria evaluation), were used. SWAT calculates the soil erosion and sediment yield within each hydrological response units (HRU's) within each sub basin. The GIS tool combines the slope, Land cover, soil and river layers as a major factor which contributes to soil erosion. The output of the SWAT model has shown that 18.5 % of the watershed area has high potential .The annual average simulated sediment yield was 27.8 and 29.5 tones/ha for calibration and validation periods, respectively

Kassa (2007) have studied impact of land use/cover change on stream flow: the case of Hara watershed. The objective of this study was to detect the land use/cover change and to evaluate the impact of land use on stream flow. The results of the land use/cover change analysis indicated that farmlands and settlements class has expanded which is mostly associated with the decrease in forest class. farmland and settlement land use class grows from 28.3% cover in 1975 to 52.0% cover in 2004 with a rate of change of +136.9 ha/year. On the other hand forest cover reduced from 28.4% in 1975 to 16.2% in 2004 with a rate of change of -70 ha/year. The upper watershed and the border zone in between the uplands and lowland were the most affected parts of the watershed. The measured and predicted stream flow was calibrated and validated on monthly and annual time steps. The results of these tests illustrated that the monthly coefficient of determination values range from 0.72 to 0.92, with the highest value (0.92) during the calibration of the model for the 2004 land use/cover condition. Likewise, the Nash- Sutcliffe coefficient varies from 0.41-0.92 for annual and 0.43-0.82 for monthly calibrations and validations that verified the model had predicted quite satisfactory annual and monthly flows.

Nurelegn and Amare (2014) have studied on Land use/cover dynamics in rib land watershed, upper Blue Nile. The main objectives of the study was to determine the land cover/use status of Ribb River watershed in the years 1973, 1987, 1995, and 2011 by using Landsat images. The overall results of the analysis have shown that between the last 38 years in the Ribb Watershed, about 57.4% of forest, 52.3 % of bush lands 63.5 % of areas of water bodies were converted to cultivated and settlement lands, grazing lands and wetlands, whereas the cultivated and settlement lands, grazing lands and wetlands were increased in area by 36.2%, 50.9% and 66.3% respectively. Population pressure and, land tenure policy were identified as causes for changes in land use/cover. The results of this study were significant indicators for planners and other stakeholders in the watershed to take measures that can help to bring long term solutions for resource conservation and bringing sustainable development and livelihood attaining mechanisms in the watershed.

Gebiaw et al. (2017) have studied on Stream flow and Sediment Yield Prediction for Watershed Prioritization in the Upper Blue Nile River Basin, Ethiopia .The objectives of this study were to: assess the spatial variability of sediment yield, quantify the amount of sediment delivered into the reservoir; and prioritize sub-catchments for watershed management using the Soil and Water Assessment Tool (SWAT). Sediment yield estimated with the SWAT model was found to correlate reasonably well with land use, and topography for each HRU. The long-term (19-year) mean annual catchment discharge soil, land use, and topography for each HRU. The long-term (19-year) mean annual catchment was 604 mm/yr and the model sediment yield prediction indicated an annual average catchment discharge was 604 mm/yr and the model sediment yield prediction indicated an annual average suspended sediment yield of 24.3 t /ha/yr. As with unimodal rainfall distribution in the individual sub-catchment sediment yield and stream flow varied with the maximum value during the heavy rainfall season of the year, July to September.

Fetene et al. (2008) have studied on Relationship between rainfall, runoff and sedimentation of the Blue Nile. The main objective of this thesis was to determine sediment yield in the different sub basin of Blue Nile in Ethiopia, sediment load and sediment concentration in the main rivers of the tributaries and in the Abbay River using SWAT model. In addition to this, the aim is to look spatial and temporal variation of sediment yield/ concentration in the basin. The SWAT was successfully calibrated and validated for measured streamflow at Bahir Dar near Kessie and at the border of Sudan for flow gauging stations, and for measured sediment yield at Gilgel Abbay, Addis Zemen and near Kessie gauging stations in the Blue Nile Basin. The model performance evaluation statistics (Nash–Sutcliffe model efficiency (ENS) and coefficient of determination (r^2)) are in the acceptable range (r^2 in the range 0.71 to 0.91 and ENS in the range 0.65 to 0.90). It was found that the Guder, N. Gojam and Jemma sub basins are the severely eroded areas with 34% of sediment yield of the Blue Nile coming from these sub basins. Similarly, the Dinder, Beshilo and Rahad sub basins only cover 7% of sediment yield of the basin. The annual average sediment yield is 4.26 t/ha/yr and the total is 91.3 million tones for the whole Blue Nile Basin in Ethiopia.

CHAPTER THREE

3 MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Location

The Megech River originates near the semian mountains National park where located in the Northwestern plateau of North Gondar zone Amhara National Region, which is about 75 km long, The catchment area at the dam site is 424 km^2 with a mean annual flow of 11 m^3/s and mean annual inflow 335 MCM. The river, which flows generally in a southern direction and empties into Lake Tana, is one of the main streams flowing into Lake Tana from the North.

Megech Dam is located on the Megech River, on the northern side of Lake Tana Sub-Basin, in North Gondar Zone of Amhara National Regional State. The dam axis is located in between the geographic grid ref. UTM E 332995, N1382164 and E332492, N1382864. Megech Watershed covers parts of three Woredas in the Zone, including Gondar Zuria, Lay Gayint, Wegera and Gondar town. Megech watershed lies approximately between 12°48' and 12° 75' N Latitude ,37° 36' and 37°61'E Longitude. The Megech Dam project consists of: An earth-rock fill dam 864 m long, 76.5 m high above the riverbed level (84.5 m above general foundation level);A reservoir impounding about 182 MCM of water; A side channel spillway and chute, required for the safe passage of a 2-day ½ PMF flood discharge of 662 m^3/s and the passage of 1 PMF without dam overtopping; and Outlet pipes to release water from the Outlet Tower of the reservoir for Gondar water supply, for downstream environmental releases, and for the 20,000 ha irrigable area. (WWDSE, 2006)

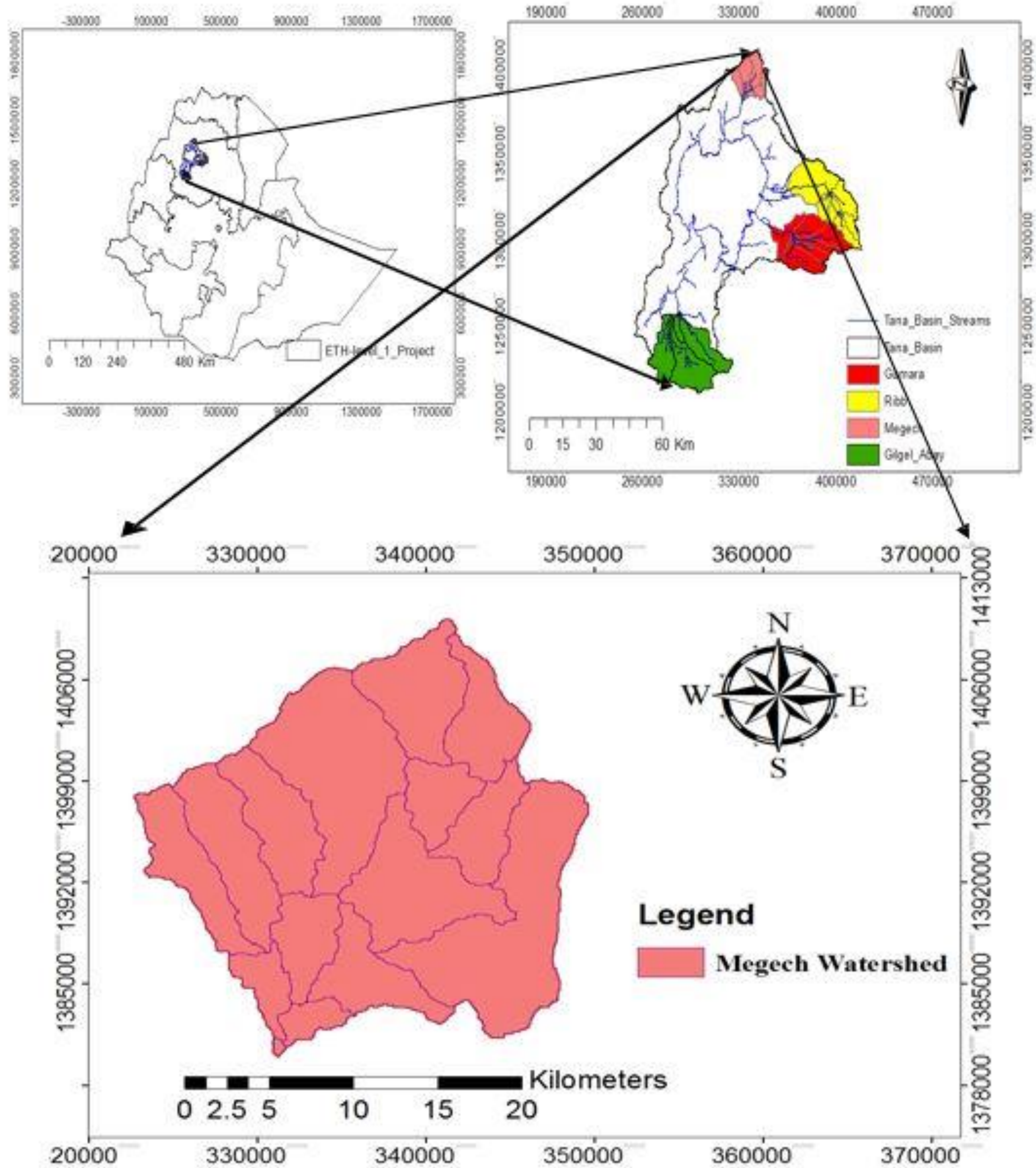


Figure 3.1: Location of Megech watershed

3.1.2 Climate

The climate of the Megech catchment is marked by a rainy season from May to October, with monthly rainfall varying from 67 mm in October to 306 mm in July. Mean annual precipitation is about 1,100 mm in the upper part and about 1,000 mm in the lower part. Rainfall over the Megech watershed is mono-modal with nearly 79 % of the annual rainfall occurring in the period June – September. The dry season, from November to April, has a total rainfall of about 8% of the mean annual rainfall. Dependable rainfall (85%) varies from less than 1.2 mm during the dry season to 88–225 mm/month during the period of June to July/August, equivalent to 55–75% of the average values. Temperature variations throughout the year are minor. Maximum temperatures vary from 23 ºC in July to 30 ºC in March, whereas minimum temperatures range from 11.5 ºC in January to 15.6 ºC in April & May. Humidity varies between 39% in March and 79% in August. Wind speed is low, thus minimizing potential evapotranspiration values between 101 mm/month in July and 149 mm/month in March. Sunshine duration is reduced to 4.2 – 4.9 hours during July and June, respectively.

3.1.3 Topography

The Megech watershed is characterized as a mountainous, wedge shaped and steep sloped (3.2%) watershed. The highest elevation of the watershed is 2,956 m above mean sea level, in its north eastern part and lowest topography land is at the outlet, which is at an altitude of 1854 m above sea level. The land escape the area is highly rugged with high mountain range on the south and closely dispersed and their escarpments in the central and northern parts of the watershed, which are dissected deep and widen bedded gorges and valleys as well as plains on the top of the hills.

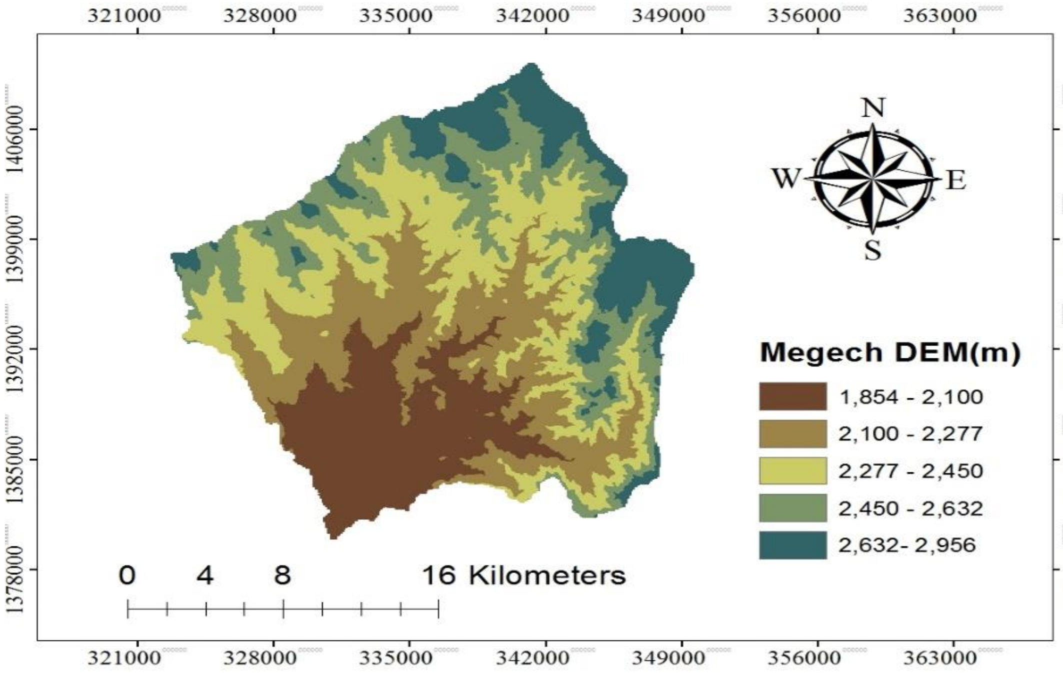


Figure 3.2: Elevation map of Megech watershed

3.1.4 Land cover

Based on MoWIE (2001) The land cover map (Figure 3.3) showed that 65.95 % of the watersheds area was covered by Agriculture, 20.43% by forest land ,11.7% by grass and shrub land, and 1.86 % by built up area.

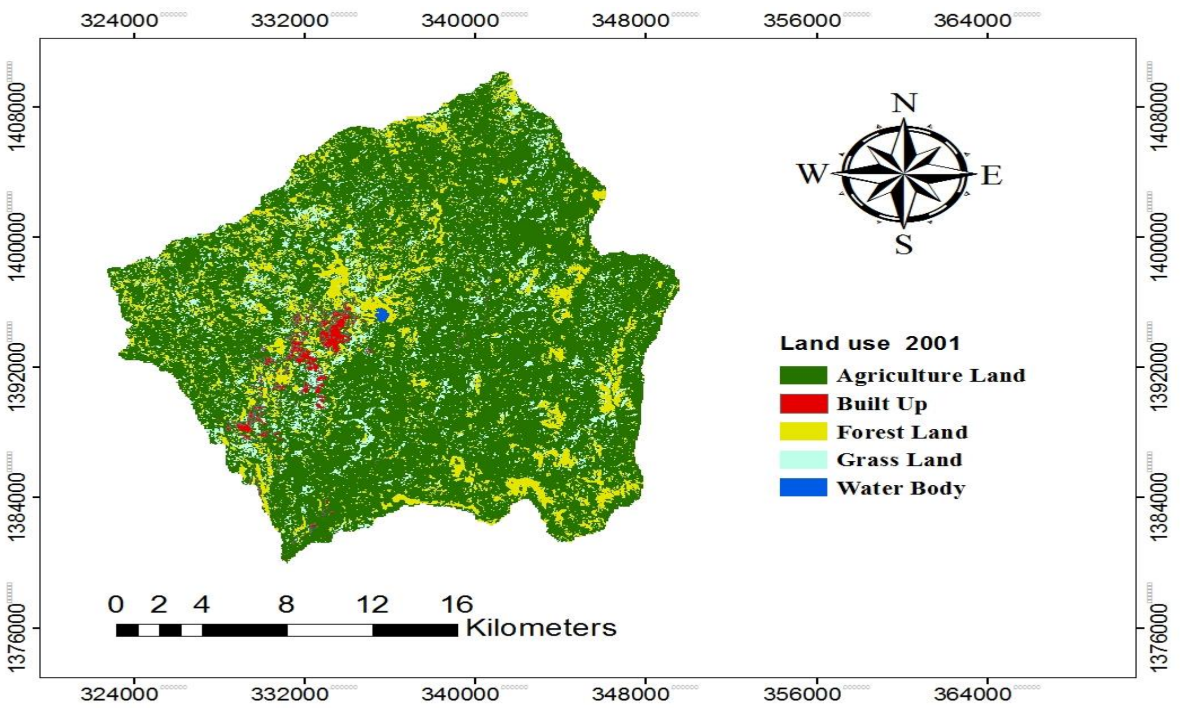


Figure 3.3: Land use/cover map of Megech watershed

3.1.5 General work flow of the study

The following framework illustrates the general workflow of the study can be

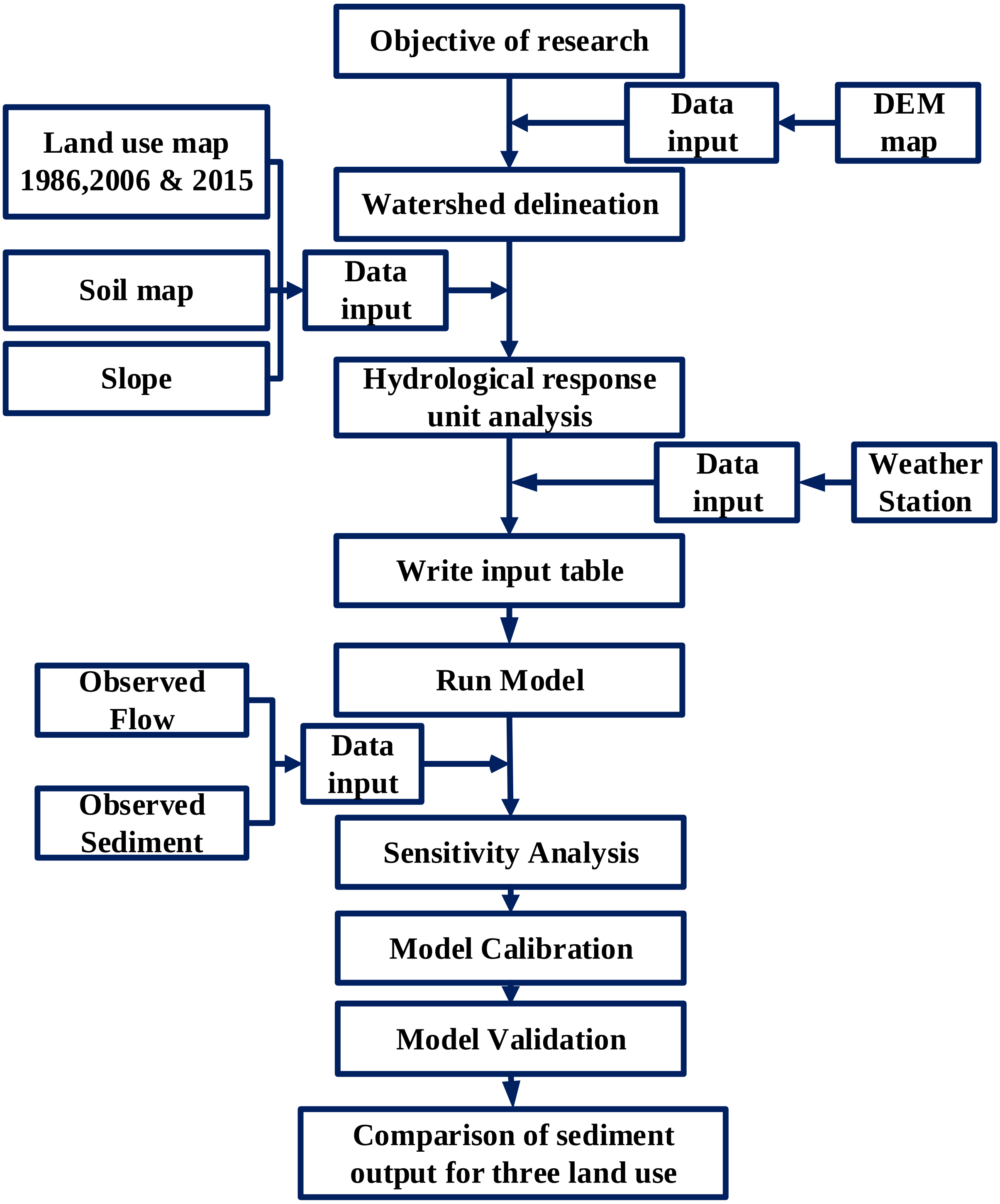


Figure 3.4: General flow chart used for this study

3.2 Data collection and analysis

For this study, various data are required that includes topographic data (DEM), Land use and land cover data, soil data, daily data of climatic variables (daily data of precipitation, maximum and minimum temperature, relative humidity, wind speed and solar radiation). Land cove/use satellite data were obtained from the United State Geological survey (USGS) website. DEM (30mx30m), Soil, Land cover and hydrological data were collected from the the Ministry of Water, Irrigation and Electricity of Ethiopia (MoWIE). The climatic data were obtained from the National Meteorological Agency of Ethiopia.

3.2.1 Hydro-meteorological data screening

A time series of hydrological data for hydrological model should have to existing primary data screening such as sationarity, inconsistency. The basic data-screening procedure used here is based upon split- record tests for stability of the variance (F-test) and stability of mean (t-test) of such a time series. A time series of hydrological data may exhibit jumps and trends owing to what Yevjevich and Jeng (1969) call inconsistency and non-homogeneity. Inconsistency is a change in the amount of systematic error associated with the recording of data. It can arise from the use of different instruments and methods of observation. Non-homogeneity is a change in the statistical properties of the time series. It can be because of either natural or man-made. These include alterations to land use, relocation of the observation station, and implementation of flow diversion. The data screening procedure passed through the following principal steps in order to check the absolute and relative consistency, homogeneity and sationarity of the data, for the selected stations.

1. Rough screening of the data and compute or verify the totals for the hydrological year or season.
2. Plot these totals according to the chosen time step (yearly for this study) and note any trends or discontinuities (visual examination).
3. Test the time series for absence of trend with Spearman’s rank-correlation method.
4. Apply the F-test for stability of variance and the t-test for stability of mean to the split, non- overlapping, sub-sets of the time series at the 5-percent level of significance;
5. Test the time series for absence of persistence by computing the first serial- correlation Coefficient (Used only for flow data);

6. Test the time series for relative consistency and homogeneity with double-mass analysis. Five metrological stations for the study area which are absolutely consistence and Homogenous are selected.

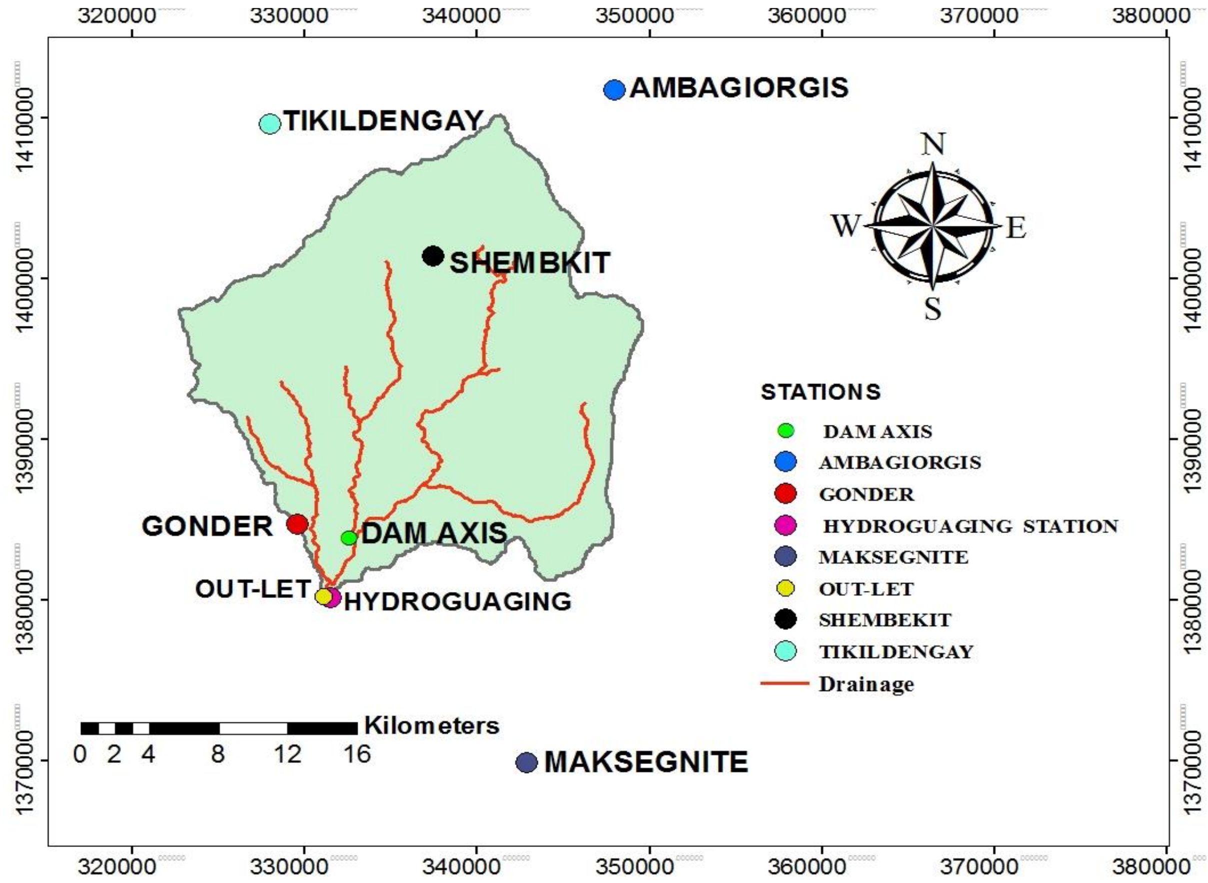


Figure 3.5: Location of meteological station in and around the stations

3.2.2 Filling the missed rainfall data

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

There are different methods to fill in missing data. These are: arithmetic mean method, normal ratio method and inverse distance weighing method. Arithmetic mean method can be used to fill in missing data when normal annual precipitation is within 10% of the gauge/station for which data are being reconstructed. The normal ratio method is used when the normal annual precipitation at any of the index station differs from that of the precipitation station by more than10%.

In the absence of normal annual rainfall for the stations inverse distance weighing method can be used to fill the missing data. So for this specific study the normal ratio method (Eqn. 3.1) were used to fill the missed data.

$$P_x = \frac{N_x}{M}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \ldots + \frac{P_m}{N_m}\right] \quad \text{--------------} \quad \text{(Eqn. 3.1)}$$

Where: P_X=Missed value of precipitation to be computed,

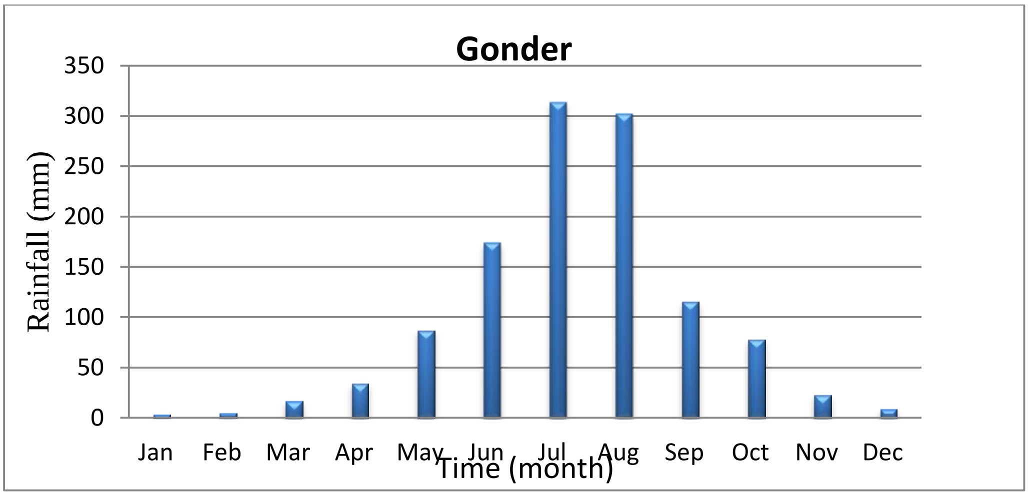
N_X = average value of rainfall for the station in question for recording period,

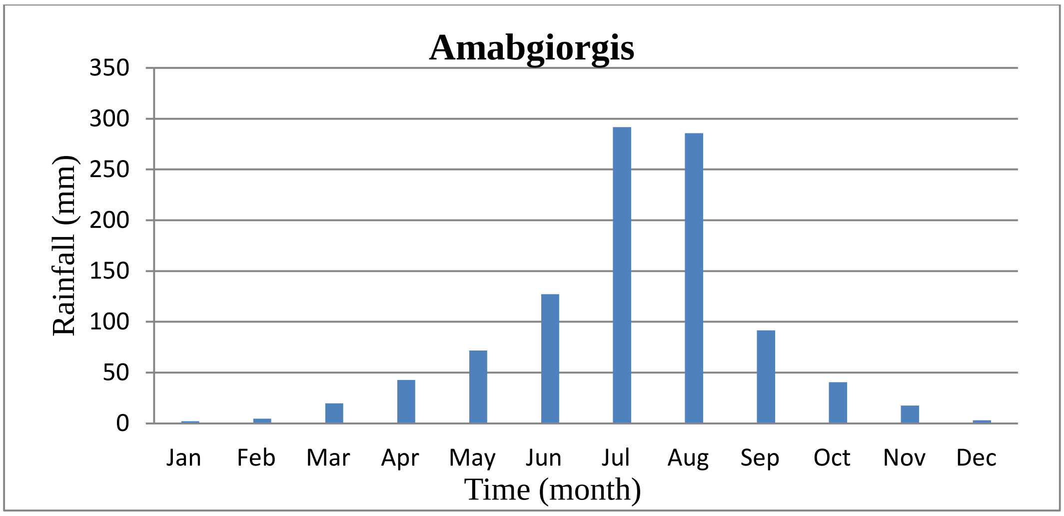
N_1 = average value of rainfall for the neighboring station,

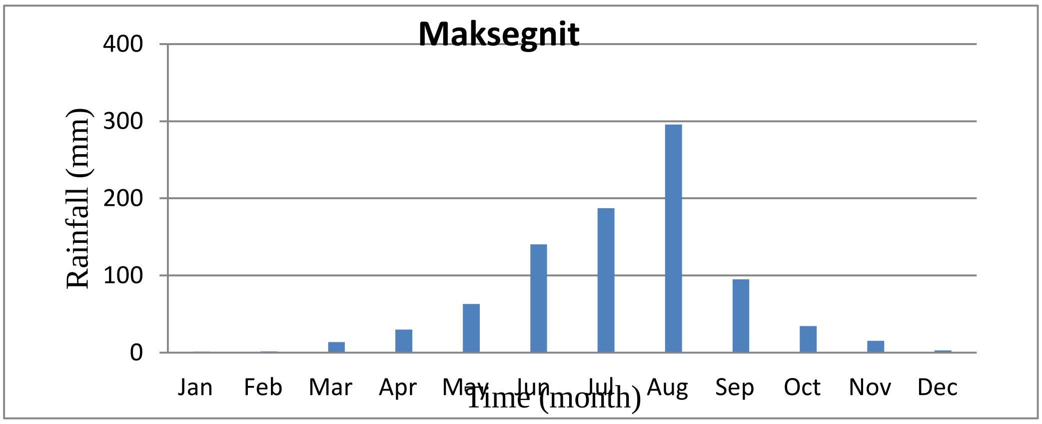
P_1, P_2 … P_m = rainfall of neighboring station during missing period and

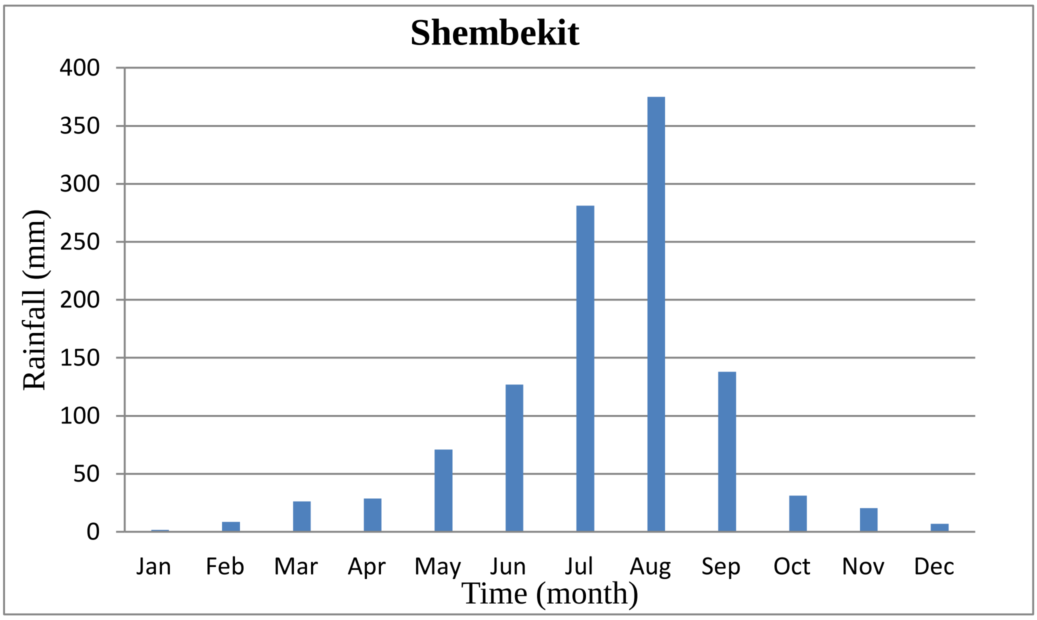
M= number of stations used in the computation

The mean monthly rainfall of the Gonder, Ambagiorgis, Maksegnit, Tikildengay and Shembekit stations for the period of 1986-2015 is shown in Figure 3.6 below.




Amabgiorgis
Rainfall (mm)
350
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Time (month)


Maksegnit
Rainfall (mm)
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Time (month)


Shembekit
Rainfall (mm)
400
350
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Time (month)

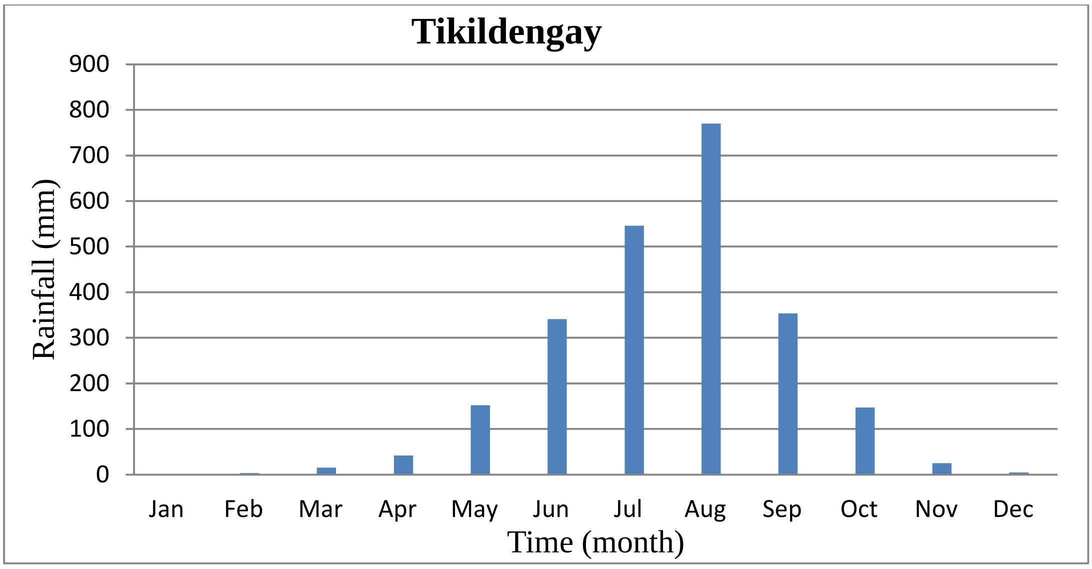


Figure 3.6: Mean monthly rainfall distribution of selected meterological stations for the period from 1986 to 2015.

Data of Megech river flow was collected from the MoWIE from 1990-2014 near Azezo gage station. The minimum average monthly discharge 2.81 m^3/s in Feburary and maximum average monthely discharge 47.41 m^3/s in Auguest (Figure 3.7)

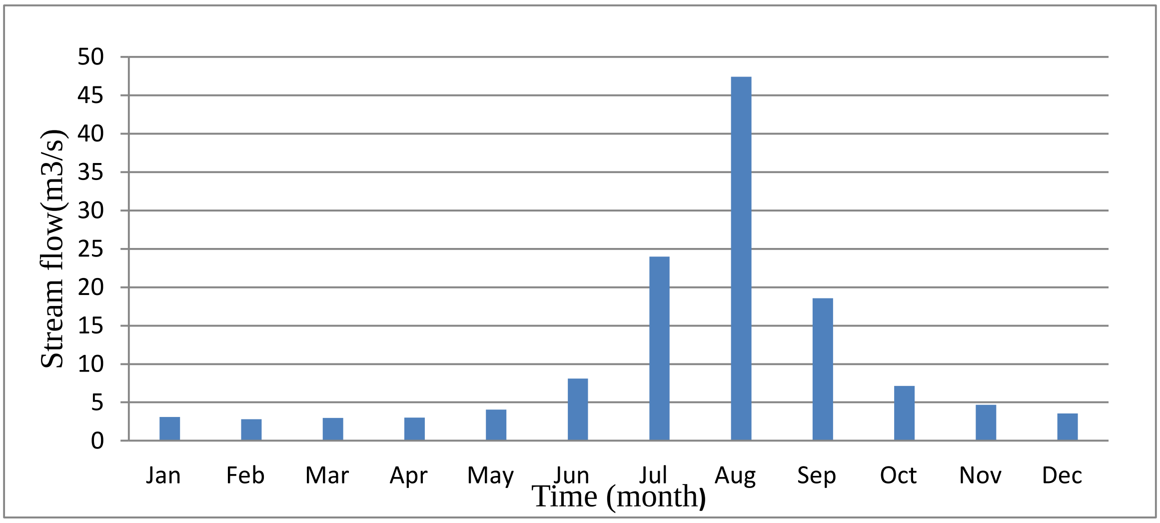


Figure 3.7: Discharge record of Megech River at Azezo station (1990-2014)

3.2.3 Test for consistency of the record

Rainfall data analysis from the station may not be consistent always. Many factors could affect the consistency of the record at studies station.To check and correct the consistency of a record Double Mass Curve (DMC) have been used .This method uses the accumulated annual rainfall of study site station versus the cumulative rainfall of all station surrounding base stations. If rainfall record in a given station is consistent then the double mass curve will have a constant slope otherwise there is inconsistency in the measured value. (Peng et al, 2017). Based on double mass curve result all station was found consistent

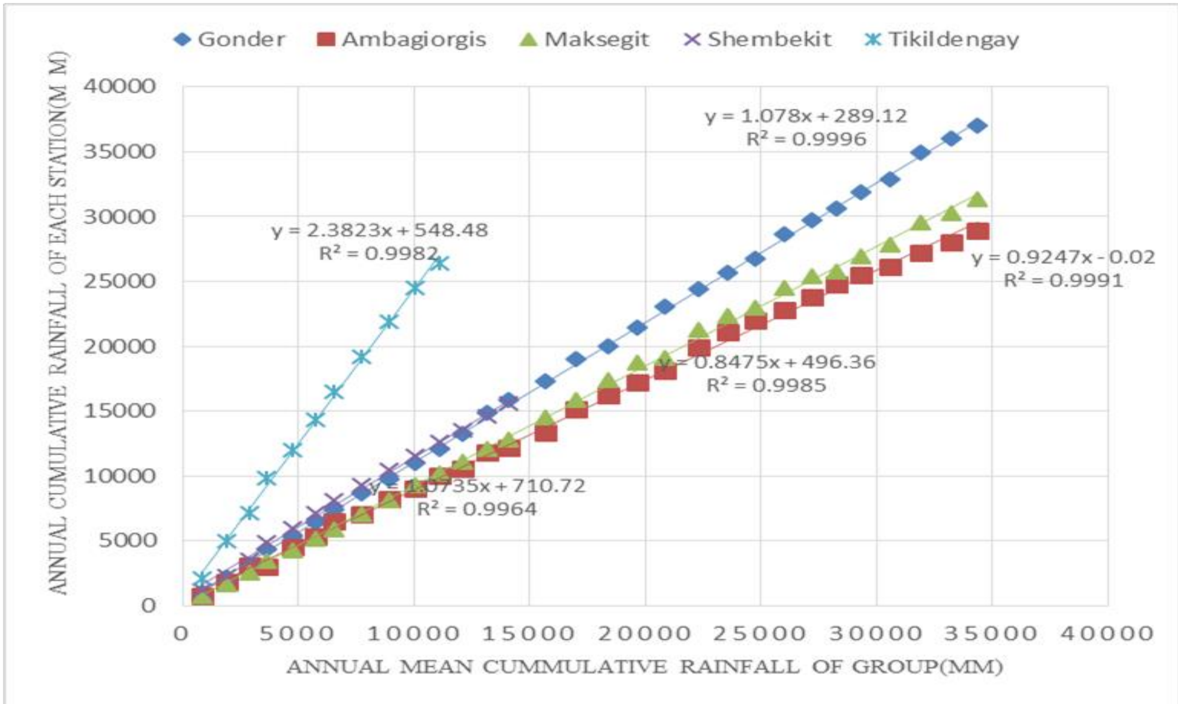


Figure 3.8: Duble mass curve for selected stations

Table 3.1: Thissen weight for selected stations in Megech watershed stations

No	Rainfall (Station Name)	Longitude(Deg.)	Latitude(Deg.)	Elevation(m)	Weight (%)
1	Gonder	37.43	12.52	1973	32.7
2	Ambagiorgis	37.6	12.77	2900	1.53
3	Tikildengay	37.42	12.75	2035	0.77
4	Maksegnit	37.56	12.39	1912	3.4
5	Shembekit	37.5	12.67	2403	61.6

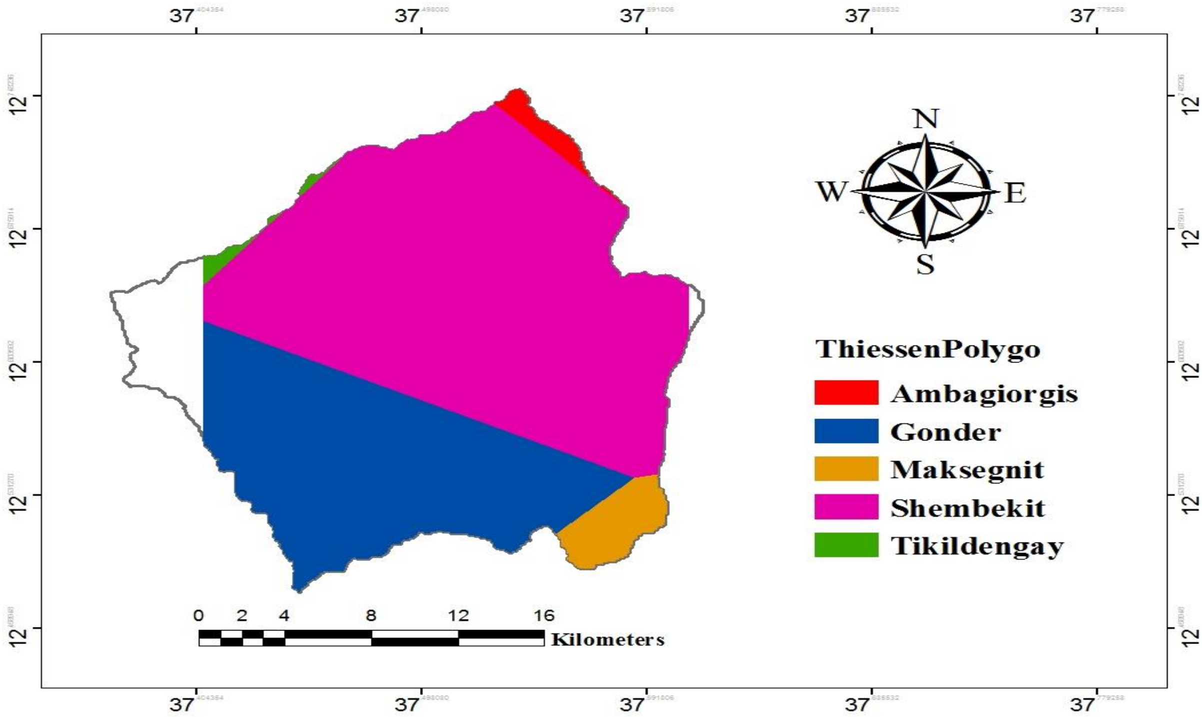


Figure 3.9: Thiessen polygo for Megech watershed

3.3 Image processing

This study was done using Landsat image of seven bands to identify changes in land use /cover distribution in the Megech watershed over 30 years period from 1986 to 2015. Landsat TM, ETM+ and ETM+ were selected for the period of 1986, 2006 and 2015 respectively. To avoid a seasonal variation in vegetation pattern and distribution throughout a year, the selection of dates of the acquired data were made as much as possible in the same annual season of the acquired years. The images used in this study area were orthorectified to a Universal Transverse Mercator projection using datum WGS (World Geodetic System) 84 zone 37N. In order to view and discriminate the surface features clearly, all the input satellite images were composed using the RGB color composition The prepared band and color combination of Landsat image of band 7,5and, 3 for (2015), band 4,3,2 for (2006) and band 7, 4, 2 for (1986) interpretation of the image in their true color.

The image data files were downloaded in zipped files from the United State Geological survey (USGS) website and extracted to Tagged Image File Format (Tiff) format files. The acquisition dates, sensor, path/row, resolution and the producers of the satellite images used in this study are summarized in the Table 3.2 below.

Table 3.2: The Acquisition dates, path/row, resolution of the images

Sensor	Satellite Name	Path	Row	Acquisition	Resolution(m)
TM	Landsat 5	170	51	5-Jan-86	30
ETM+	Landsat 7	170	51	5-Jan-06	30
ETM+	Landsat 8	170	51	5-Jan-15	30

3.3.1 Land use/cover image classification

For the purpose of classifying the land cover during image analysis the land cover types were defined (Table 3.3). During field observation five different types of land cover have been identified for the Megech watershed as described in Table 3.3

Table 3.3: Land use/cover description for Megech watershed (based on field observation)

Land use/cover	Description of land use/covers
Forest Land	High density of trees which include deciduous forest land, ever green forest land, mixed forest land and plantation forests that mainly are eucalyptus, junipers and conifers
Agriculture Land	Areas used for both annual and perennial crop cultivation, and the large sized cultivated fields.
Grass Land	Areas covered with shrubs, bushes and small trees, with little wood, mixed with some grass .Area covered with grass that is used for grazing
water area	Area which remains open water area throughout the year, the man made water harvesting ponds, the rivers and its main tributaries
Built-up	This type of land cover of rural settlements area and Urban area, Transportation, Institution

Image classification is the process of assigning of pixels of continuous raster image to the predefined land cover classes. In remote sensing, there are various image classification methods. Their appropriateness depends on the purpose of land cover maps produced for and the analyst’s knowledge of the algorithms is using. However, in most cases the researchers categorized them in to three major categories: Supervised, unsupervised and hybrid.

For this study, the supervised classification type was applied. It is the most common type of classification technique in which all pixels with similar spectral value are automatically categorized in to land cover classes or themes. Supervised classification which relies on the prior knowledge of pattern recognition of the study area was used.

It requires the manual identification of point of interest areas as reference or Ground Truth within the images, to determine the spectral signature of identified features. For the supervised classification, the ground control points collected in the field were also used as the training sample set. In general, a total of five major land cover classes were selected during the field observation .the five different types of land cover are: agricultural land, grass and shrubs land, forest, water and urban.

For supervised classification method 200 Ground Control points were collected in the field as the training samples set on all land cover types (Appendix H:Table 13).Supporting information collected during field observation in watershed and interview with local elder people. Which were used for image classification of the pixels into similar groups based on sample signature specific.

The classification was done by using ERDAS 2014. & ArcGIS 10.2 and performed by Maximum Likelihood Algorithm of Supervised Classification. Finally post classification comparison technique has been used to determine the changes detection in land use/cover over 30 years (1986-2015). The advantage of post classification comparison was it simplifies the difficulties associated with the analysis of the images acquired at different times of the year, or by different sensors and quite high change detection accuracy (Alphan, 2003). This the most common approach to change detection and the methods comparison uses separate classifications of the images that occurred at different moment in time to produce different maps from which “from-to” change information can be generated (Jensen, 2005)

3.3.2 Accuracy assessment

Accuracy assessment is part of the image classification process and its objective was to evaluate the total number of correctly classified pixels divided by the total number of ground truth pixels. 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).

User's accuracy and producer accuracy measured the correctness of each category with respect to errors matrix. The users' accuracy is defined as the probability that a reference pixel has been correctly classified as well as the producer accuracy is defined as the probability that a pixel classified on the map represents that class on the ground.

The accuracy of thematic maps was determined by the constructed matrices along kappa statistics in order to test whether any difference exists in the interpretation. Kappa statistics (Eqn. 3.2) considers a measure of overall accuracy of image classification and individual category accuracy as a means of actual agreement between classification and observation. Monserud et al. (1992) suggested the use of subjective kappa value as < 40 % as poor, 40-55 % fair, 55-70 % good, 70-85 % very good and > 85 % as excellent. The generally the estimate of Kappa was computed as follows

$$\mathbf{K} = \frac{p_0 - p_c}{1 - p_c} \quad \text{-------------------------- (Eqn. 3.2)}$$

Where, Po= proportion of observed agreements

Pc= proportion of agreement expected by chance

3.3.3 Flow chart for landuse classification

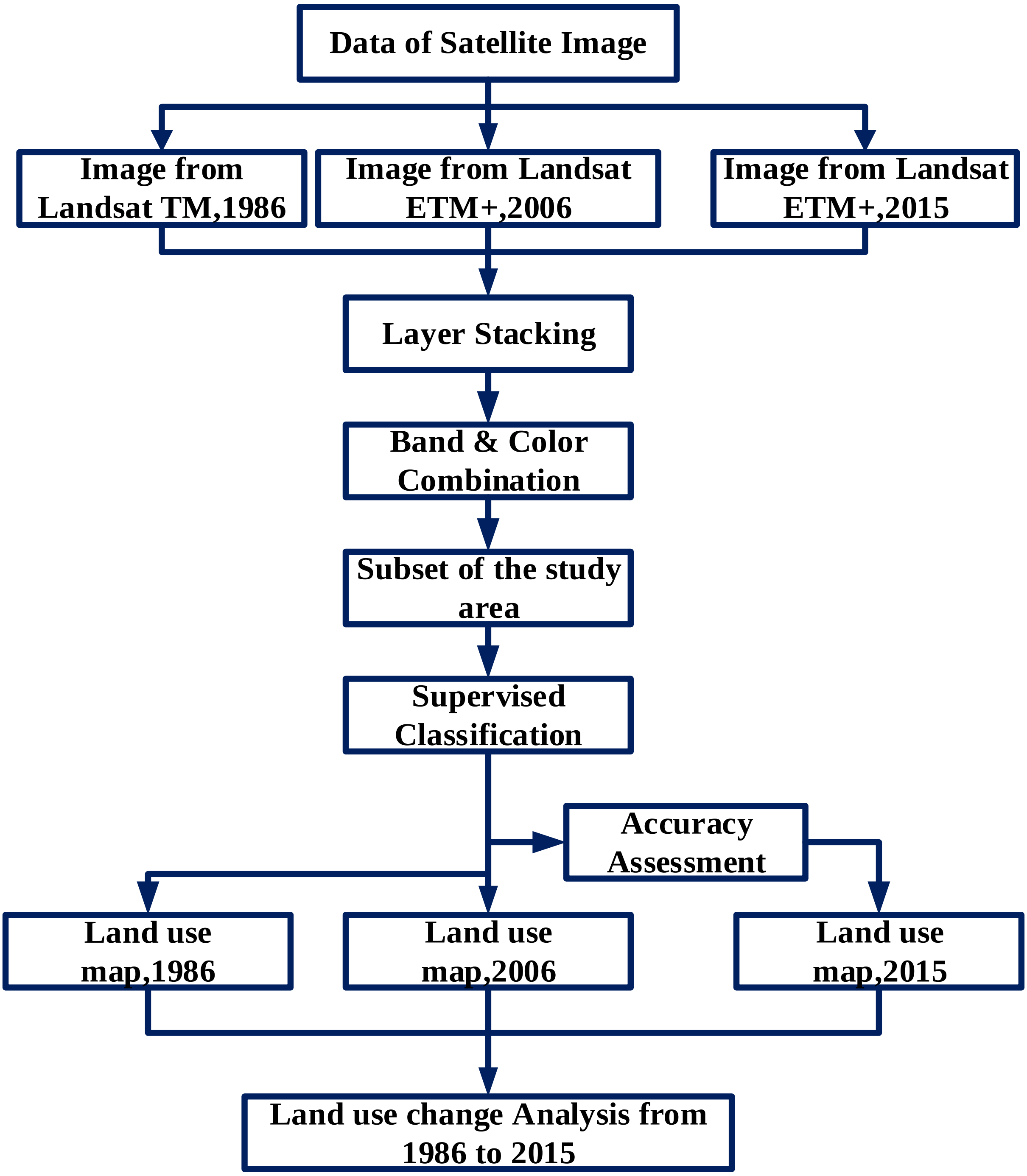


Figure 3.10: Flow chart for land use classification used for this study

3.4 Model input

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.

3.4.1 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 DEM was obtained from the MoWIE. (Figure 3.11)

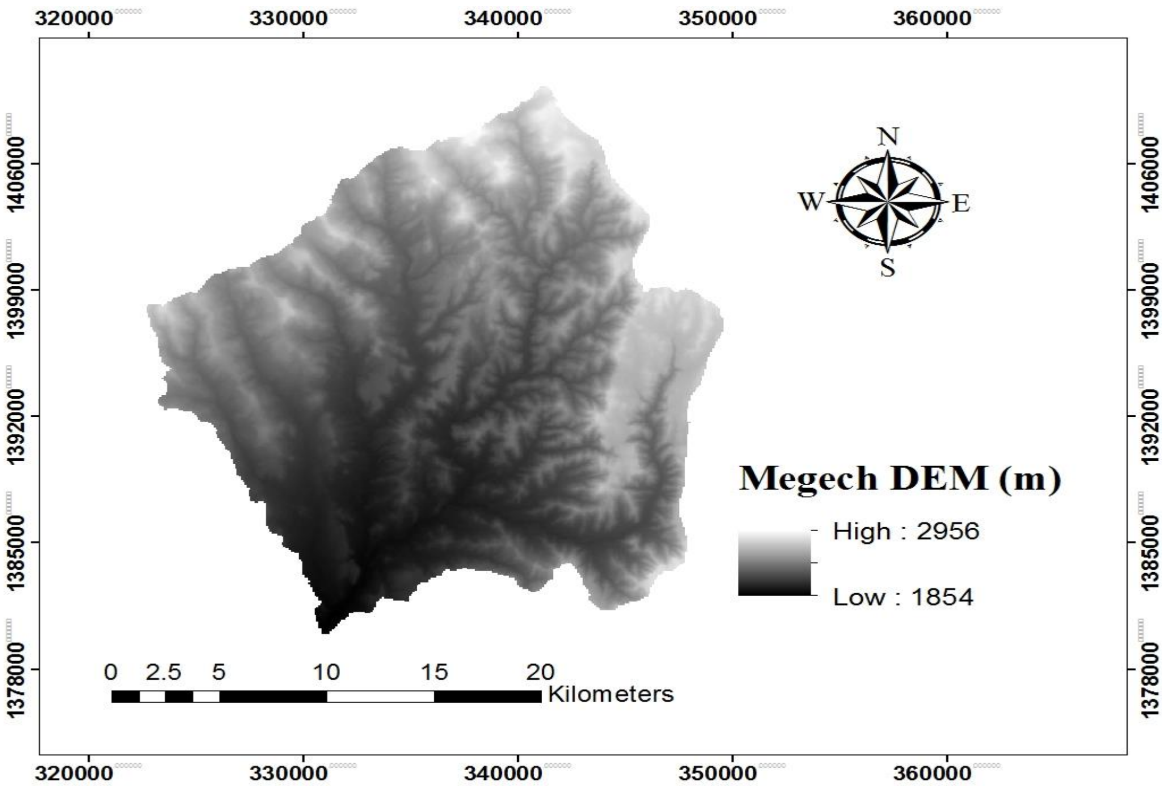


Figure 3.11: Digital elevation model of Megech watershed

3.4.2 Weather data

Weather data are among the main 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 weather data used were represented from five stations in and around Megech watershed, such as Gonder, Shembekit, Maksegit, Ambagiorgis and Tikeldengay, as shown in Figure 3.11. Gonder station is the first classes and has records on all climatic variables, whereas the rest are third and fourth class stations (Table 3.4). The climatic data used for this study covers 30 years from January 1986 to December 2015.

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

Finally, the weather data were prepared in text format with lookup tables as required by the model.

Table 3.4: Meterological station names, location and variables

Station Name	Data Year	Lat.(deg.)	long.(deg.)	R.F	M.Temp	M.Temp	R.H	Wind S.	Sun. H.
Gonder	1986-2015	12.52	37.43	√	√	√	√	√	√
Maksegnit	1986-2015	11.61	38.05	√	√	√			
Ambagiorgis	1986-2015	12.77	37.05	√	√	√			
Shembekit	2002-2015	12.67	38.05	√					
Tkildengay	2005-2015	12.75	37.42	√					

3.4.3 Soil data

Soil data is one of the major input data for the SWAT model with physical and chemical properties. According to FAO/UNESCO – ISRIC classification, five major soil groups were identified in the watershed of Megech (Figure 3.12).

SWAT model requires soil physical and chemical properties such as soil texture, available water content, hydraulic conductivity, bulk density and organic carbon content for different layers of each soil type. These data were obtained from Ethiopian construction work design and Supervision Corporation.

To integrate the soil map with SWAT model, a user soil database which contains textural and chemical properties of soils was prepared for each soil layers and added to the SWAT user soil databases using the data management append tool in ArcGIS. The symbol and areal coverage of the soil types are presented in Table 3.5.

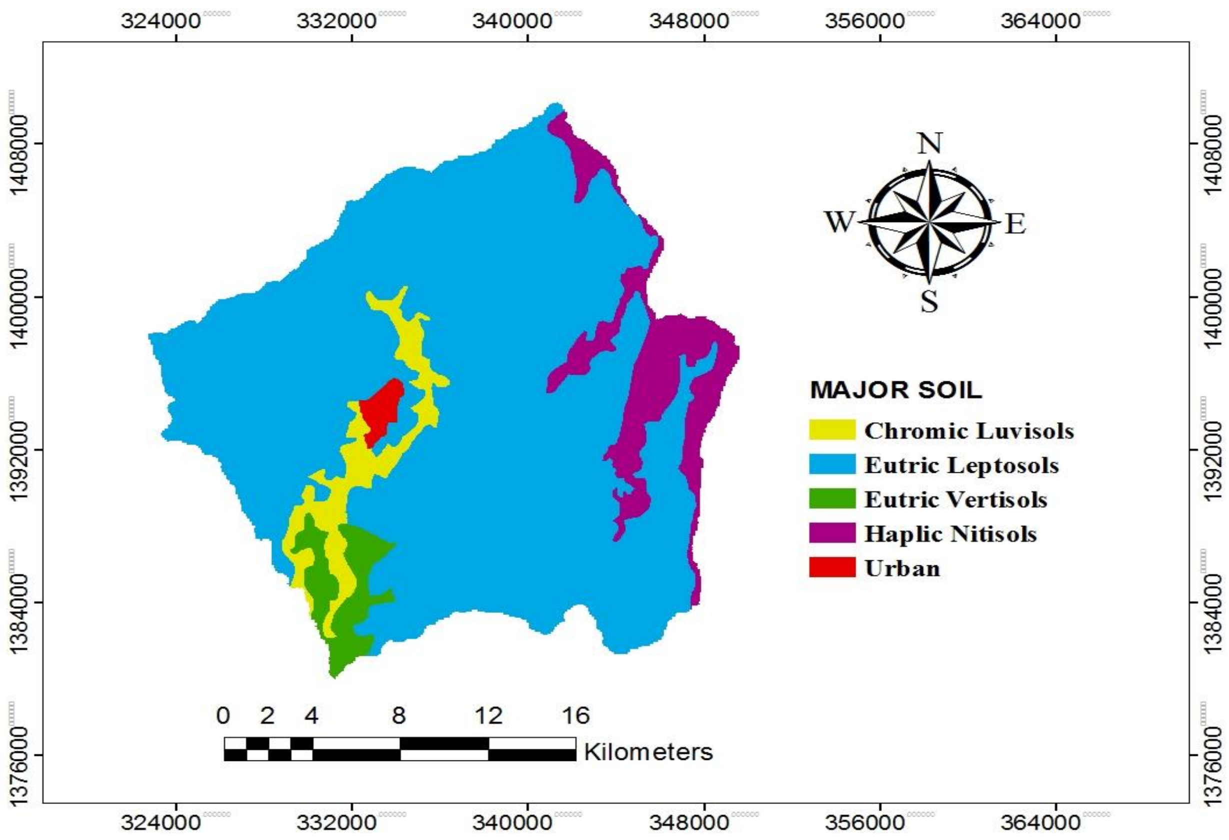


Figure 3.12: Map of the soil types of Megech watershed

Table 3.5: Soil types of Megech watershed with their symbols and areal coverage

No	Soil type	Symbol	Area(KM2)	%Of Total area
1	Chromic Luvisols	LVx	25	5
2	Eutric Leptosols	LPe	407.8	81.6
3	Eutric Vertisols	VRe	16.98	3.4
4	Haplic Nitisols	NTh	46.13	9.2
5	Urban Land	URBN	16.98	0.8

3.4.4 Land use/cover

Land use is one of the highly influencing the hydrological properties of the watersheds. It is one of the main input data of the SWAT model to describe the Hydrological Response Units (HRUs) of the watersheds.

The SWAT model has predefined four letter codes for each land use category (Table 3.6). These codes were used to link or associate the land use map of the study area to SWAT land use databases. Hence, while preparing the lookup-table, the land use types were made compatible with the input needs of the model.

Table 3.6: Soil types of Megech watershed with their symbols and areal coverage

Land use / Land cover	Land use according to SWAT database	SWAT code
Cultivated land	Agricultural land close to grown	AGRC
Forest	Forest mixed	FRST
Urban	Urban	URBN
Grass land	Pasture land	PAST
Water body	Water	WATR

3.4.5 Hydrological data

The stream flow and sediment data of the Megech watershed is needed for the calibration and validation of the model. The daily stream flow data (1990-2014) were collected from the Ministry of Water, Irrigation and Electricity of Ethiopia. And the sediment data measured by Minister of Energy and Water Resources of Ethiopia is quite insufficient so using this data to estimate monthly suspended sediment I developed sediment rating curve for Megech river at the gauging site near to Azezo (494.16 Km^2).

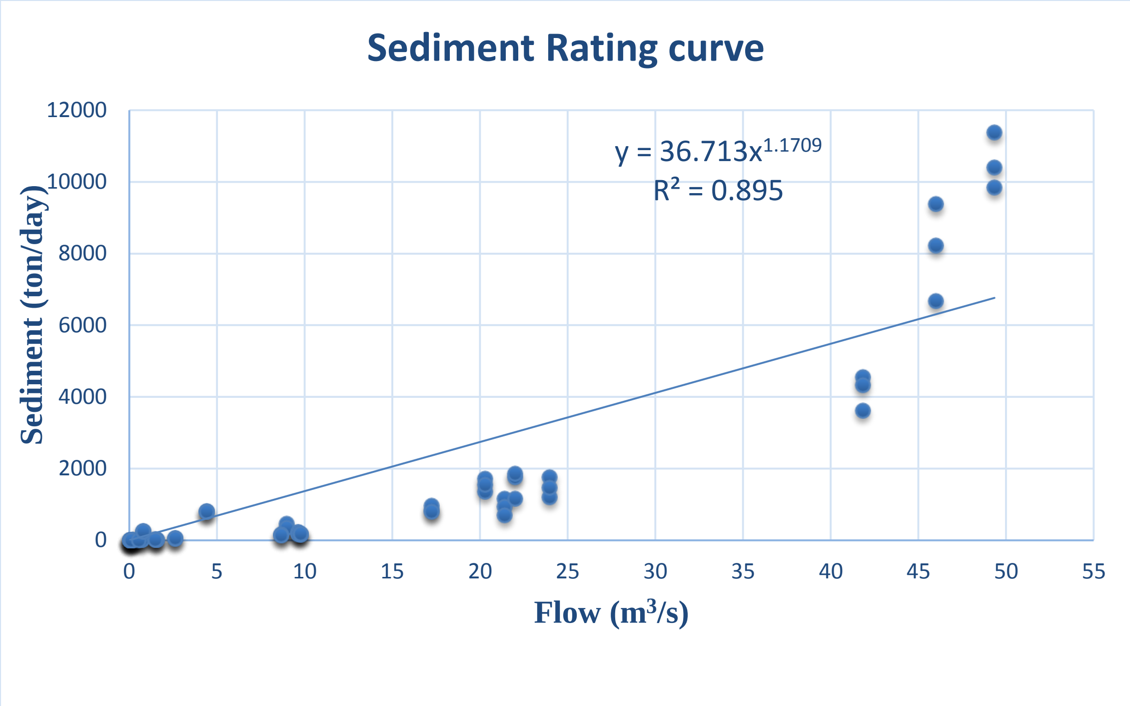


Figure 3.13: Sediment rating curve

$$Q_s = 36.713Q^{1.1709} \quad \text{--} \quad \text{(Eqn. 3.3)}$$

Where:- Q_s = Suspended sediment mass transport rate (ton/day)

Q = discharge (m^3/s)

Based on the above rating equation and historical monthly flows at the gauging site near to Azezo monthly suspended sediment load were estimated and used for calibration and validation.

3.5 Model setup

3.5.1 Watershed delineation

The watershed and sub watershed delineation was performed using 30 m resolution DEM data using Arc SWAT model watershed delineation function. First, the SWAT project set up was created. The watershed delineation process consists of five major steps, DEM setup, stream definition, outlet and inlet definition, watershed outlets selection and definition and calculation of sub basin parameters. Once, the DEM setup was completed and the location of outlet was specified on the DEM, the model automatically calculates the flow direction and flow accumulation. Subsequently, stream networks, sub watersheds and topographic parameters were calculated using the respective tools.

The stream definition and the size of sub basins were carefully determined by selecting threshold area or minimum drainage area required to form the origin of the streams. Using a threshold value suggested by the Arc SWAT interface (2000 hectares), the Megech watershed was delineated in to 15 sub watersheds having an estimate total area of 494.16km2 (Figure 3.14)

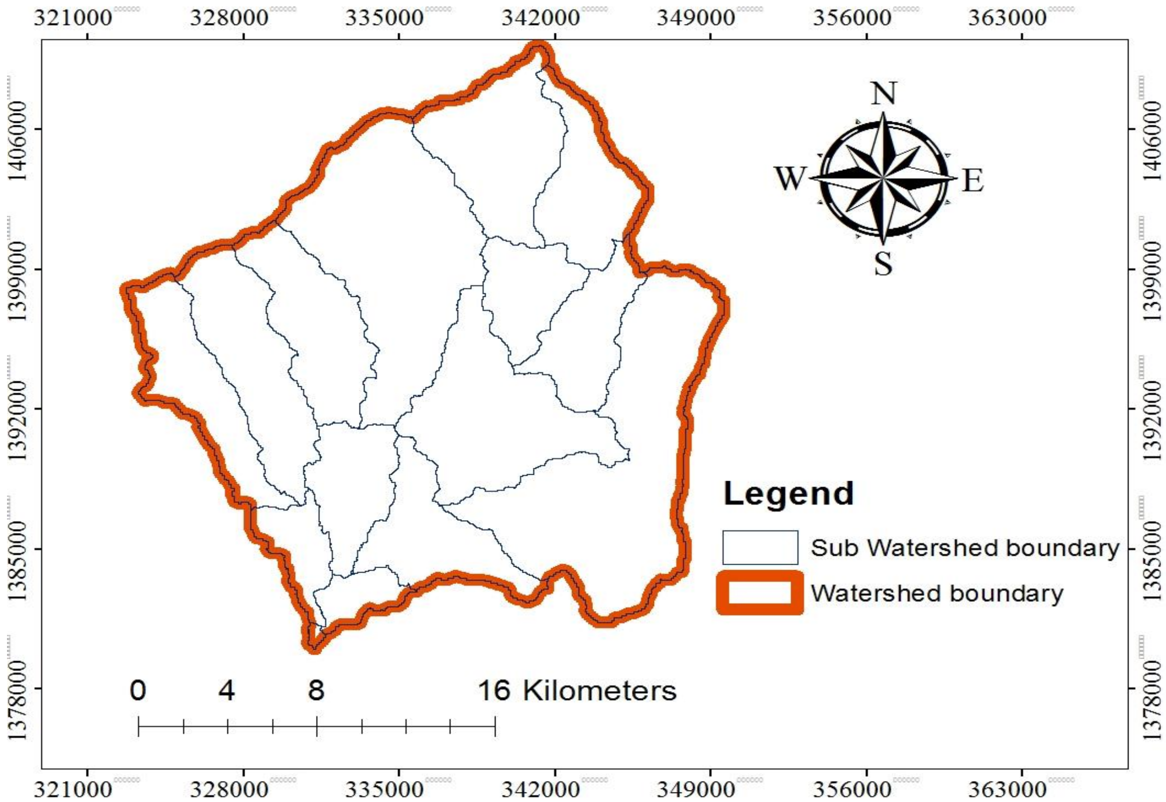


Figure 3.14: Sub watershed map of Megech watershed

During the watershed delineation process, the topographic parameters (elevation, slope) of the watershed and its sub watershed were also generated from the DEM data. Accordingly the elevation of the watershed ranges from 1854 to 2956 above mean sea level, Slope classification was carried out based on the height range of the DEM used during watershed delineation. The slope values of the watershed were reclassified in percent. It reclassified in to five classes (Figure 3.15).

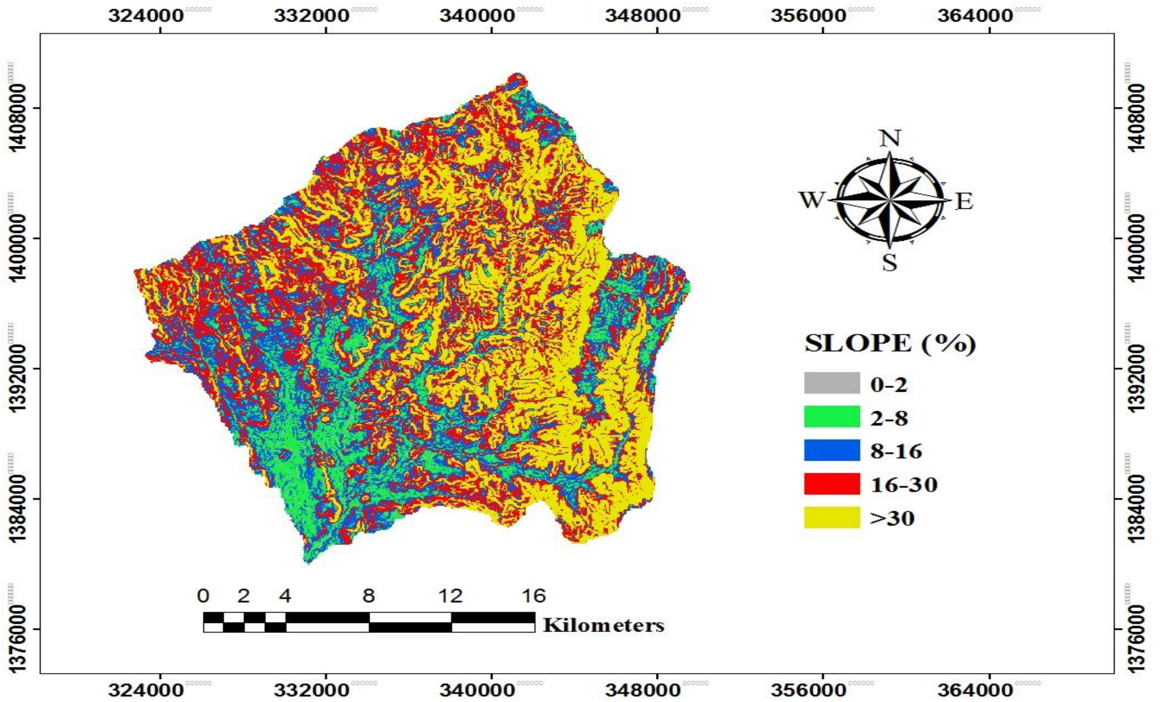


Figure 3.15: The slope class map of Megech Watershed

3.5.2 Hydrologic response units analysis

The sub watersheds were divided into HRUs by assigning the threshold values of land use and land cover, soil and slope percentage. In general the threshold level used to eliminate minor land use and land covers in sub basin, minor soil with in a land use and land cover area and minor slope classes with in a soil on specific land use and land cover area. Following minor elimination, the area of remaining land use/land covers, soils and slope class are reapportioned, so that 100 % of their respective areas are modelled by SWAT. Land use, soil and slope characterization for the Megech watershed was performed using commands from the HRU analysis menu on the Arc SWAT Toolbar. These tools allowed loading land use and soil maps which are in raster format in to the current project, evaluates slope characteristics and determining the land use/soil/slope class combinations in the delineated sub watershed

In the model, there are two options in defining HRU distribution: assign a single HRU to each sub watershed or assign multiple HRUs to each sub watershed based on a certain threshold values. The SWAT user's manual suggests that a 20% land use threshold, 10% soil threshold and 20% slope threshold are adequate for most modeling application. However, Setegn et al, 2008, suggested that HRU definition with multiple options that account for 10% land use, 20% soil and 10% slope threshold combination gives a better estimation of runoff and sediment components.

Therefore, for this study, HRU definition with multiple options that accounts for 10% land use, 20% soil and 10% slope threshold combination was used. These threshold values indicate that land uses which form at least 10% of the sub watershed area and soils which form at least 20% of the area within each of the selected land uses will be considered in HRU.

Hence, the Megech watershed was divided in to 187 HRUs for land use 1986 model, 127 HRUs for land use 2006 model and 73 HRUs for land use 2015 model.each HRU has a unique land use,slope and soil combinations. The number of the HRUs varies with in the sub watersheds.

3.5.3 Weather station

In developing countries, there is a lack of full and realistic long period of climatic data. Therefore, the weather generator solves this problem by generating data from the observed one (Schuol & Abbaspour, 2007). The Model requires the daily values of all climatic variables from measured data or generated from values using monthly average data over a number of years. This study used measured data for all climatic variables. However, the weather data obtained for the stations in and around Megech watershed had missed records in some of the variables. Therefore, these missed values were filled with the weather generator utility in the Arc SWAT Model from the values of weather generator parameters. Weather data of Gonder station with continuous records were used as an input to determine the values of the weather generator parameters. Hence, for weather generator data definition, the weather generator data file WGEN_User was selected first. Subsequently, rain fall data, temperature data, relative humidity data, solar radiation data and wind speed data were selected and added to the model.

The SWAT Model contains weather generator model called WXGEN (Schuol & Abbaspour, 2007). It is used in SWAT model to generate climatic data or to fill missing data using monthly statistics which is calculated from existing daily data. From the values of weather generator parameters, the weather generator first separately generates precipitation for the day. Maximum temperature, minimum temperature, solar radiation and relative humidity are then generated. Lastly, the wind speed is generated independently.

To generate the data, weather parameters were developed by using the weather parameter calculator SWAT Weather database, which were downloaded from the SWAT website. The SWAT Weather database Program calculates the monthly daily average and standard deviation as well as probability of wet and dry days, skew coefficient, dew point and average number of precipitation days in the month by reading of the daily values of the variables from the Gonder station.Moreover, daily solar radiation was calculated from the daily available sunshine hour's data.

3.6 Description of SWAT model

Soil and Water Assessment Tool (SWAT) was applied in the Megech watershed to assess the impacts of land use/cover changes on hydrological components. The criterion used to select this model is based on benefits it provides to meet the objectives of the study area. The SWAT model is embodied in ArcGIS that can integrate various readily available geospatial data to accurately represent the characteristics of the watershed.

The SWAT watershed model is one of the most recent models developed by the USDA-ARS to predict the impacts of land management practices on water, sediment and agricultural chemicals yields in watersheds with varying soils, land use and management practices over long periods of time (Neitsch, *et al*, 2011).

The model is a physical based, semi-distributed, continuous time, and operating on daily time step (Neitsch, *et al*, 2011). As a physical based model, SWAT uses Hydrological Response Units (HRUs) to describe spatial heterogeneity in terms of land use, soil types and slope with in a watershed.

In order to simulate hydrological processes in a watershed, SWAT divides the watershed in to sub watersheds based upon drainage areas of the tributaries. The sub watersheds are further divided in to smaller spatial modelling units known as HRUs, depending on land use and land cover, soil and slope characteristics.

One of the main advantages of SWAT is that it can be used to model watersheds with less monitoring data. For simulation, SWAT needs digital elevation model, land use and land cover map, soil data and climate data of the study area. These data are used as an input for the analysis of hydrological simulation of surface runoff and groundwater recharge.

SWAT splits hydrological simulations of a watershed in to two major phases: the land phase and the routing phase. The land phase of the hydrological cycle controls the amount of water, sediment, nutrient, and pesticide loadings to the main channel in each sub watershed. While the routing phase considers the movement of water, sediment and agricultural chemicals through the channel network to the watershed outlet.

The land phase of the hydrologic cycle is modelled in SWAT based on the water balance equation (Neitsch, *et al*, 2011):

$$SW_t = SW_o + \sum_{i=1}^{t}(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}) \text{ --------- (Eqn. 3.4)}$$

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

SW_o is the initial water content (mm)

t is the time (days)

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

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

E_a is the amount of evapotranspiration on day i (mm)

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

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

The model has eight major components: hydrology, weather, sedimentation, soil temperature, crop growth, nutrients, pesticides, and agricultural management (Neitsch, *et al*, 2011). However, brief description of some of the SWAT computation procedures which are considered in this study are presented under the following subsections. For complete model description, one may refer to SWAT Theoretical Documentation (Neitsch, *et al*, 2011)

3.6.1 Surface runoff

Surface runoff refers to the portion of rainwater that is not lost to interception, infiltration, and evapotranspiration. Surface runoff occurs whenever the rate of precipitation exceeds the rate of infiltration. SWAT offers two methods for estimating the surface runoff: the Soil Conservation Service (SCS) curve number method (USDA-SCS, 1972) or the Green & Ampt infiltration method (Green and Ampt, 1911). The Green and Ampt method needs sub-daily time step rainfall which made it difficult to be used for this study due to unavailability of sub-daily rainfall data. Therefore, the SCS curve number method was adopted for this study.

The general equation for the SCS curve number method is expressed by eqn. 3.5:

$$Q_{surf} = \frac{(R_{day} - I_A)^2}{(R_{day} - I_A + S)} \quad \text{---------------------------} \; (3.5)$$

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

R_{day} is the rainfall depth for the day (mm water),

I_A is initial abstraction which includes surface storage, interception and infiltration prior to runoff (mm water),

S is retention parameter (mm water).

The retention parameter varies spatially due to changes with land surface features such as soils, land use, slope and management practices. This parameter can also be affected temporally due to changes in soil water content. It is mathematically expressed as:

$$S = 25.4 * \left(\frac{1000}{CN} - 10 \right) \quad \text{-----------------------------} \; (\text{Eqn. } 3.6)$$

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.

The initial abstraction, I_a, is commonly approximated as $0.2S$ and equation 3.5 becomes:

$$Q_{surf} = \frac{(R_{day} - 0.2S)^2}{(R_{day} - 0.8\,S)} \quad \text{-----------------------------} \; (\text{Eqn. } 3.7)$$

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.

3.6.2 Potential evapotranspiration

Potential Evapotranspiration is a collective term that includes evaporation from the plant (transpiration) and evaporation from the water bodies and soil. Evaporation is the primary mechanism by which water is removed from a watershed. An accurate estimation of evapotranspiration is critical in the assessment of water resources and the impact of land use change on these resources.

There are many methods that are developed to estimate potential evapotranspiration (PET). SWAT provides three options for PET calculation: Penman-Monteith (Monteith, 1965), Priestley-Taylor (Priestley and Taylor, 1972), and Hargreaves (Hargreaves *et al.,* 1985) methods. The methods have various data needs of climate variables. Penman- Monteith method requires solar radiation, air temperature, relative humidity and wind sped; Priestley-Taylor method requires solar radiation, air temperature and relative humidity; whereas Hargreaves method requires air temperature only. For this study Penman-Monteith used.

3.6.3 Ground water flow

To simulate the ground water, SWAT partitions groundwater into two aquifer systems: a shallow, unconfined aquifer which contributes return flow to streams within the watershed and a deep, confined aquifer which contributes return flow to streams outside the watershed (Arnold *et al.,* 1993). In SWAT the water balance for a shallow aquifer is calculated with equation 5.

$$Aq_{sh,i} = aq_{sh,i-1} + W_{rchrg} - Q_{GW} - W_{revap} - W_{deep} - W_{pump,sh} \quad \text{------------------ (Eqn. 3.8)}$$

Where, $aq_{sh,i}$ is the amount of water stored in the shallow aquifer on day i (mm),

$Aq_{sh,i-1}$ is the amount of water stored in the shallow aquifer on day i-1 (mm),

W_{rchrg} is the amount of recharge entering the aquifer on day i (mm),

Q_{gw} is the ground water flow, or base flow, or return flow, into the main channel on day i (mm),

W_{revap} is the amount of water moving in to the soil zone in response to water deficiencies on day i (mm),

W_{deep} is the amount of water percolating from the shallow aquifer in to the deep aquifer on day i (mm), and

$W_{pump,sh}$ is the amount of water removed from the shallow aquifer by pumping on day i (mm).

3.6.4 Flow routing phase

The second component of the simulation of the hydrology of a watershed is the routing phase of the hydrologic cycle. It consists of the movement of water, sediment and other constituents (e.g. nutrients, pesticides) in the stream network.

Two options are available to route the flow in the channel network: the variable storage and Muskingum methods. The variable storage method uses a simple continuity equation in routing the storage volume, whereas the Muskingum routing method models the storage volume in a channel length as a combination of wedge and prism storages. In Muskingum routing method, when a flood wave advances into a reach segment, inflow exceeds outflow and a wedge of storage is produced. As the flood wave recedes or retreat, outflow exceeds inflow in the reach segment and a negative wedge is produced.

In addition to the wedge storage, the reach segment contains a prism of storage formed by a volume of constant cross-section along the reach length. The variable storage method was used for this study. The method was developed by (Williams, 1969). The equation of the variable storage routing is given by:

$$\Delta V_{stored} = V_{IN} - V_{out} \quad \text{--------------------------- (Eqn. 3.9)}$$

Where, ΔV_{stored} is the change in volume of storage during the time step (m^3 water)

V_{IN} is the volume of inflow during the time step (m^3 water), and

V_{out} is the volume of outflow during the time step (m^3 water).

3.6.5 SWAT sediment simulation

Erosion and sediment yield are estimated for each sub-basin with the Modified Universal Soil Loss Equation (MUSLE)

$$Sed=11.8(Q_{surf} \cdot Q_{peak} \cdot Area_{hru})^{0.56} \cdot K_{USLE} \cdot C_{USLE} \cdot P_{USLE} \cdot LS_{USLE} \cdot CFRG \quad \text{------- (Eqn. 3.10)}$$

Where: sed- is the sediment yield on a given day (metric tons),

Q_{surf} is the surface runoff volume (mm H2O/ha),

Q_{peak} is the peak runoff rate (m3/s),

$Area_{hru}$ is the area of the HRU (ha),

K_{USLE} is the USLE soil erodibility factor

P_{USLE} is the USLE support practice factor;

C_{USLE} is the USLE cover and management factor

LS_{USLE} is the USLE topographic factor and

CFRG is the coarse fragment factor

Channel routing consists of flood and sediment routing. The flood routing model uses a variable storage coefficient method developed by Williams. Channel inputs include the reach length, channel slope, bank full width and depth, channel side slope, flood plain slope, and Manning's n for channel and floodplain. Flow rate and average velocity are calculated using Manning's equation and travel time is computed by dividing channel length by velocity. Outflow from a channel is also adjusted for transmission losses, evaporation, diversions, and return flow. The channel sediment routing equation uses a modification of Bagnold's sediment transport equation that estimates the transport concentration capacity as a function of velocity:

$$CY_u = SPCON * V^{SPEXP} \quad \text{-------------------------------- (Eqn. 3.11)}$$

Where, *CYu* is sediment transport concentration capacity in g/m3; SPCON is the concentration capacity in g/m3 at a velocity of 1 m/s; V is flow velocity in m/s; and SPEXP is a constant in Bagnold's equation. The SWAT model either deposits excess sediment or restrains sediments through channel erosion depending on the sediment load entering the channel.

3.6.6 Sensitivity, Calibration and Validation analysis

A computer based watershed models can save time and money because of their ability to perform long term simulation of the effect of watershed processes and management activities on water quality and quantity and soil quality (Moriasi et al, 2007). But, obviously these hydrological models under estimate or overestimate the long term simulation of the hydrological processes activities within the watersheds. To increase the applicability of the any hydrological model, it need to check there performance before to use for simulation of the hydrological processes using Graphical or statistical methods.

SWAT 2012 version provides the algorithmic techniques for calibration, validation and sensitivity analysis interrelated with SWAT-CUP program. SWAT-CUP (Calibration and Uncertainty Procedures) is a standalone program developed for calibration, validation and sensitivity analysis of SWAT models. (Abbaspour et al., 2017) The program contains five different calibration procedures and includes functionalities for validation and sensitivity analysis, SUFI-2, PARASOL, GLUE, McMc and PSO.

In this study, we used the program SUFI-2 for model calibration, validation and sensitivity analysis. SUFI-2 is a tool for sensitivity analysis, multisite calibration, and uncertainty analysis. It lends itself easily to parallelization and is capable of analyzing a large number of parameters and measured data from many gauging stations (outlets) simultaneously. SUFI-2 is linked to SWAT in the SWAT-CUP software [Abbaspour, 2015]. Yang et al. [2008] found that SUFI-2 needed the smallest number of model runs to achieve a similarly good calibration and prediction uncertainty results in comparison with four other techniques.This efficiency is of great importance when dealing with computationally intensive, complex large-scale models.

3.6.6.1 Sensitivity analysis

Calibration is necessary to optimize the values of the model parameters which help to reduce the uncertainty in the model outputs. However, such type of model with a multiple parameters, the difficult task is to determine which parameters are to be calibrated. In this case, sensitivity analysis is important to identify and rank parameters that have significant impact on the specific model outputs of interest (Van Griensven *et al.*, 2006). Therefore, for this study, sensitivity analysis was done prior to the calibration process in order to identify important parameters for model calibration. Two types of sensitivity analysis are used, Global sensitivity and one at-a-time sensitivity analysis.

Global sensitivity analysis:-a multiple regression analysis is used to get the statistics of parameter sensitivity. The t-stat is the coefficient of parameter divided by its standard error. It is a measure of the precision with which the regression coefficient is measured. If a coefficient is “large “compered to its standard error, then it is probably different from 0 and the parameter is sensitive.

In Global sensitivity analysis t-stat provides a measure of sensitivity and hence larger in absolute values are more sensitive. On the other hand, P-value indicates the significance of the sensitivity and hence a value close to zero has more significance. Therefore, ranking in both cases (t-stat or P-value) give the same result i.e. a parameter will have the same rank whether it is ranked based on the t- stat or P-value.

One-at-a-time sensitivity analysis: - The local sensitivity analysis was carried out using the Latin-Hypercube One-Factor-at-a-Time (LH-OAT) sensitivity analysis method.
This parameters are fixed at a value of the best iteration. Then the parameter was varied the model output independently method should be performed for one parameter at a time only while the other and its effect on was evaluated.

Based on the above two sensitivity analysis method more sensitive parameters were selected for calibration and validation process.

3.6.6.2 Model calibration and validation

Model calibration is the processes of estimating model parameters by comparing model prediction (output) for a given set of assumed conditions with observed data for the same conditions. The calibration of the model has been done based on the assumption of there is a linear relation between the observed and the simulated one. That mean all of the error variance is contained in the simulated values and the measured data are free of error. But in reality the measured data are not free of error (Moriasi et al, 2007). The goal of calibration is to find those set of parameter values for the model that gives a simulated hydrological series adequately matches with the observed series. SWAT provides three options for calibration: auto-calibration, manual calibration and combination of these two methods. For this study, auto calibration procedure was used. The calibration was done on monthly time steps using the average measured stream flow data of the Megech watershed for the three independent model with respected time .i.e for land use 2015 model (2008-2011), for land use 2006 model (2000-2004) and for land use 1986 model (1990-1995). Three years were used for each model before calibration period to warm up the model.The models were calibrated by using the values of parameters that were identified as highly sensitive to flow parameters .after the auto calibration runs completed, the model was run using the best parameter output values and the simulations were compared with observed stream flow data using Nash and Sutcliffe coefficient of efficiency (ENS) and coefficient of determination (R^2). After calibration of flow, calibration of sediment was carried out in the same way.

Validation was also done to compare the model outputs with an independent data set without making further adjustment of the parameter values.

Model validation is comparison of the model outputs with an independent data set without making further adjustment which may adjust during calibration process. The measured data of average monthly stream flow were used for the model validation process. The Validation was done on monthly time steps using the average measured stream flow data of the Megech watershed for the three independent model with respected time .i.e for land use 2015 model (2012-2014), for land use 2006 model (2005-2007) and for land use 1986 model (1996-1999) without any further adjustment of calibrated parameters. Validation of sediment was carried out in the same way.

3.6.6.3 Model performance evaluation

To evaluate the model simulation outputs in relative to the observed data, model performance evaluation is necessary. There are various methods to evaluate the model performance during the calibration and validation periods. For this study, two methods were used: coefficient of determination (R^2) and Nash and Sutcliffe simulation efficiency (ENS).

The coefficient of determination (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:

$$R^2 = \frac{\Sigma [Xi - Xav] [Yi - Yav]}{\sqrt{\Sigma[Xi - Xav]^2} \sqrt{\Sigma[Yi - Yav]^2}} \text{ ---------------- (Eqn. 3.12)}$$

Where, Xi – measured value (m^3/s)

Xav – average measured value (m^3/s) Yi – simulated value (m^3/s) and

Yav – average sim**u**lated value (m^3/s)

The Nash – Sutcliffe simulation efficiency (ENS) indicates that how well the plots of observed versus simulated data fits the 1:1 line. ENS is computed using the following equation:

$$ENS = 1 - \frac{\Sigma (Xi - Yi)^2}{\Sigma (Xi - Xav)^2} \quad \text{--------------- (Eqn. 3.13)}$$

Where, Xi – measured value

Yi – simulated value and

Xav – average observed value

The value of ENS ranges from negative infinity to 1 (best) i.e, $(-\infty, 1]$. ENS value ≤ 0 indicates the mean observed value is better predictor than the simulated value, which indicates unacceptable performance. While ENS values greater than 0.5, the simulated value is better predictor than mean measured value and generally viewed as acceptable performance (Santhi *et al*., 2001).

3.6.6.4 Uncertainity analysis

Prediction uncertainty arises from the uncertainty in the parameters, the model, and the inputs. In the concept of SUFI-2, all these uncertainties are assigned to the parameter distributions. The increasing of the uncertainties in the parameters leads to uncertainties in the model output variables, which are expressed as the 95% probability distributions. These are calculated at the 2.5% and 97.5% levels of the cumulative distribution of an output variable generated by the propagation of the parameter uncertainties using Latin hypercube sampling. This is referred to as the 95% prediction uncertainty or 95PPU (Abbaspour, 2015).

In SUFI2, the model result (95PPU) envelops most of the observations. To quantify the fit between simulation results, expressed as 95PPU, and observation, SUFI-2 uses two statistics p-factor and r-factor, p-factor is the percentage of observed data enveloped by our modeling result (the 95PPU), r-factor is the thickness of the 95PPU envelop. For p-factor value of >70% for discharge and r-factor of around 1 is acceptable. For sediment, a smaller p-factor and a larger r-factor could be acceptable (Abbaspour, 2015).

3.7 Evaluation of land use dynamics on reservoir sedimentation

This study was carried out to evaluate the impact of land use dynamics on reservoir sedimentation, so three independent model were prepared using Land use 1986, land use 2006 and Land use 2015 and the same Climate data and other input for the period of 1986 – 2015 then calibrate and validate each model with respected period i.e for land use 1986 model from 1990-1999, for land use 2006 model from 2000-2007 and for land use 2015 model from 2008-2014. After calibration and validation of each model to show the variability of sediment load the three independent models i.e. 1986 land use model, 2006 land use model & 2015 land use model runs simulation for the period of 2003-2015 keeping other input parameter the same and comparison were made on the three model simulation out-put.

3.8 Sedimentation rate

The problem of reservoir sedimentation on its useful life is complex. Several methods based on empirical, physical and arithmetic models have been formulated and applied to simulate sediment deposition processes in lakes and reservoirs. For this specific study Empirical area reduction method was selected because it requires little input data, it is usually more accurate in predicting bed elevation change near the dam, is simple to apply and has been very widely used.

3.8.1 Empirical area reduction method

The most common empirical method is called area reduction method. This method was developed by Borland and Miller (1958) based on survey of 30 reservoirs in USA to establish volume-surface area-depth relationship of reservoirs after deposition of sediment (Morris and Fan, 1998). This method includes four main steps as outlined in Morris and Fan, 1998:

1. Determine the amount of sediment to be distributed.
2. On the basis of the site characteristics, select the appropriate empirical curve for sediment distribution.
3. Determine the height of sediment accumulation at the dam, termed the new zero-capacity elevation.
4. Use the selected empirical curve to distribute sediment as a function of depth above the new zero-capacity elevation. These values are then subtracted from the original stage-area and stage-capacity curves to produce the adjusted curves.

CHAPTER FOUR

4 RESULT AND DISCUSSION

4.1 Land cover classification

4.1.1 Accuracy assessment

Accuracy assessment of image classification was done based on the observed ground truth data to minimize error caused during land cover classification. A total of 200 ground control point were used to validate the classified image. The accuracy was performed for the 2015 image. This is because filed data was available only for 2015 site. The overall accuracy of the classification was 86% with kappa coefficient of 60%. The kappa statistic was calculated from the result of the land cover classification, with five classes shown at the bottom of the error matrix table.

Table 4.1: Base error matrix of 2015 land use/cover map

Classification	**Reference data or ground truth classes**					
	Open water	Build up	Agriculture	Forest	Grass	Row Total
Open water	12	0	0	0	0	12
Built up	0	30	0	0	0	30
Agriculture	0	6	100	6	0	112
Forest land	0	0	12	20	0	32
Grass Land	4	0	0	0	10	14

Table 4.2: Accuracy assessment of 2015 land use/cover class

Class Name	Reference Total	Classified Total	Number Correct	Producer's Accuracy %	User's Accuracy %
Open water	16	12	12	75	75
Built up	36	30	30	83.3	83.3
Agriculture	112	112	100	100	89.3
Forest	26	32	20	81.3	76.9
Grass Land	10	14	10	71.4	100
Totals	200	200	172		

For the average the user's accuracy is 84.6% and the average producer's accuracy is 84.9%. The overall accuracy of the classification was 86 % with Kappa coefficient of 60%. The kappa value of 60% represents a probable 60% percent better accuracy. The result of classification for this study could be considered as good agreement.

4.1.2 Land use/cover classes

4.1.2.1 Land use/cover class of 1986

The land use/ cover map of 1986 (Figures 4.1) and (Figures 4.2) shows 38.56 % of the Megech sub basin was covered by forest land , 29.57 % of agriculture land , 31.42 % by grassland and 0.45 % was built up area . The 1986 Landsat 5 image land use/cover map (Figure 4.2) show that the Megech watershed was dominantly covered by Forest and grass land cover type

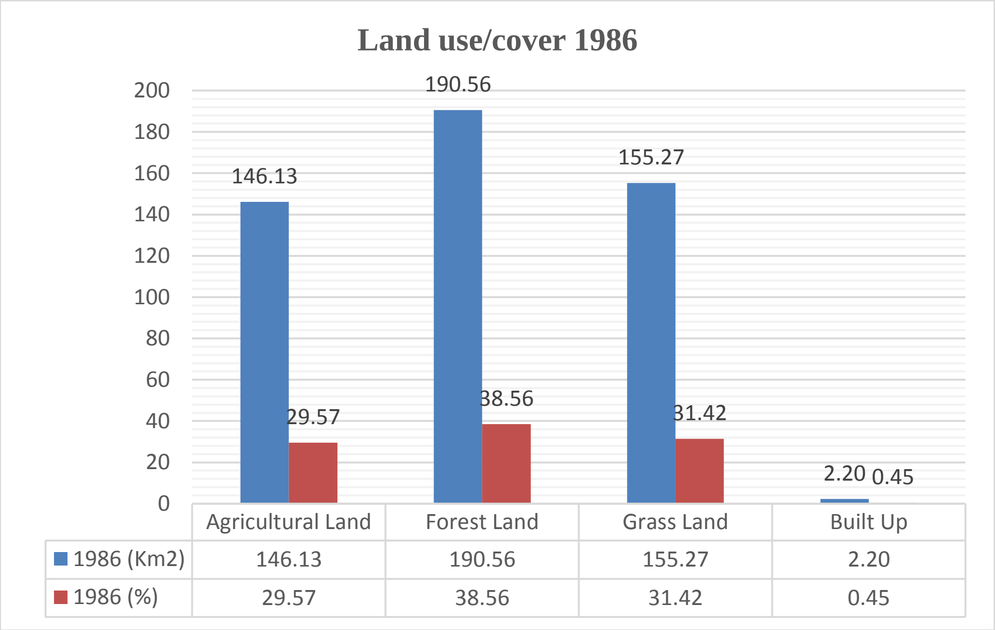


Figure 4.1: 1986 Land use/cover relative coverage

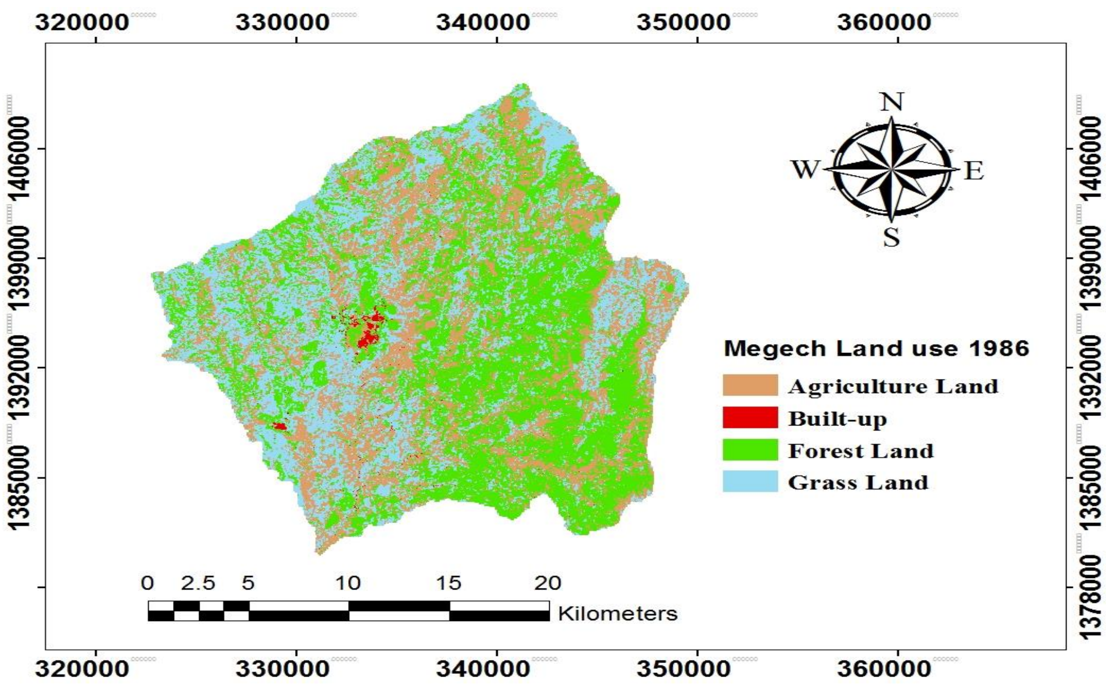


Figure 4.2: 1986 Land use/cover relative coverage

4.1.2.2 Land use/ cover class of 2006

The land use/ cover map of 2006 (Figures 4.4) and (Figures 4.3) shows 13.38 % of the Megech sub basin was covered by forest land , 75.67 % of agriculture land , 8.80 % by grassland , 2.06 % was built up area and 0.08 was water body

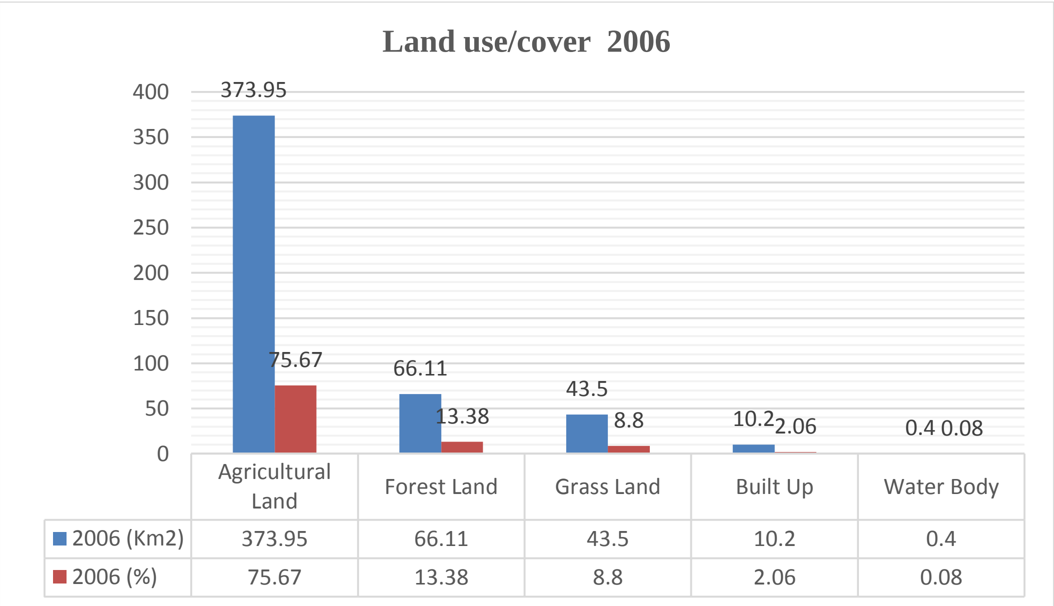


Figure 4.3: 2006 Land use/cover relative coverage

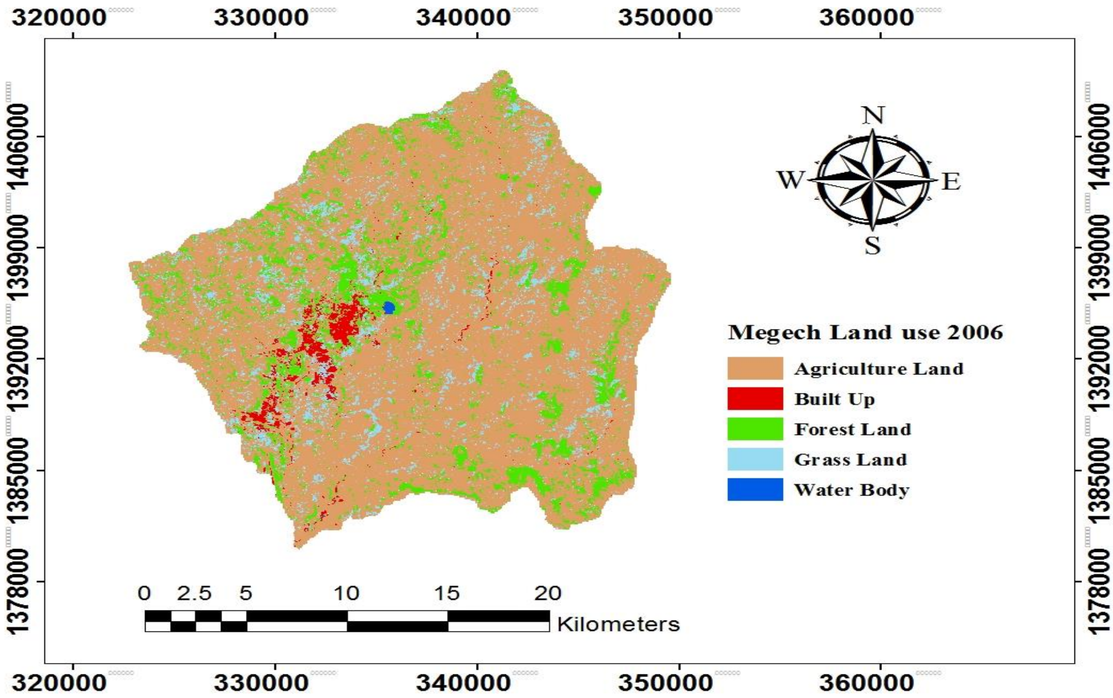


Figure 4.4: 2006 Land use map of Megech watershed

4.1.2.3 Land use/ cover class of 2015

The land use/ cover map of 2015 (Figures 4.6) and (Figures 4.5) shows 6.38 % of the Megech sub basin was covered by forest land , 83.36 % of agriculture land , 1.82 % by grassland and 3.32 % was built up area and 0.13 was water body. The 2015 Landsat 8 image land cover class (Figure 4.6) show that Megech watershed was dominantly covered by Agricultural land cover type

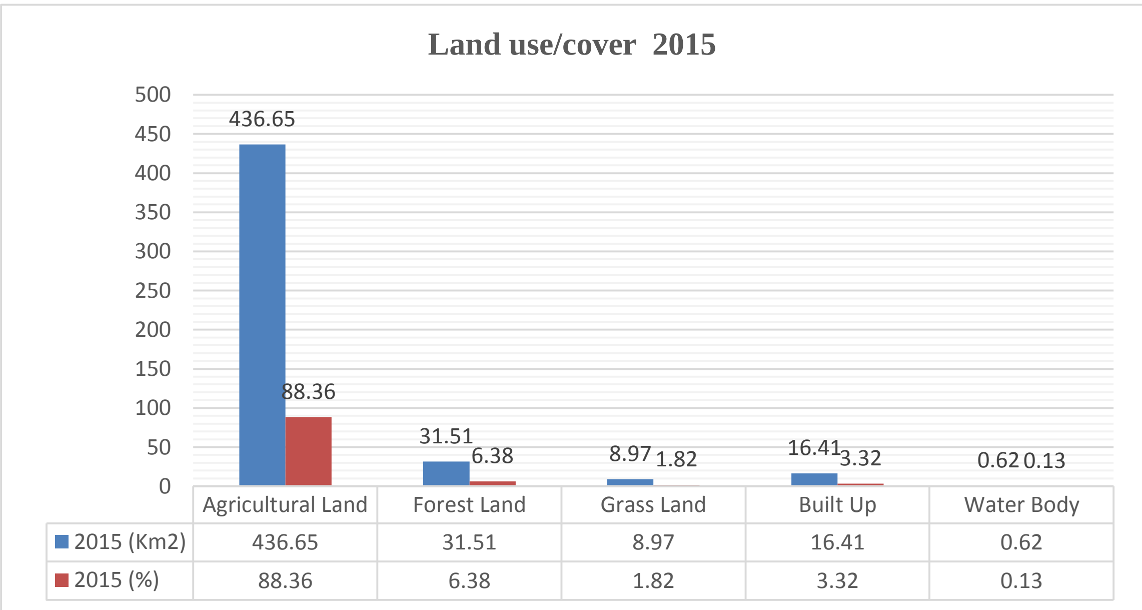


Figure 4.5: 2015 Land use/cover relative coverage

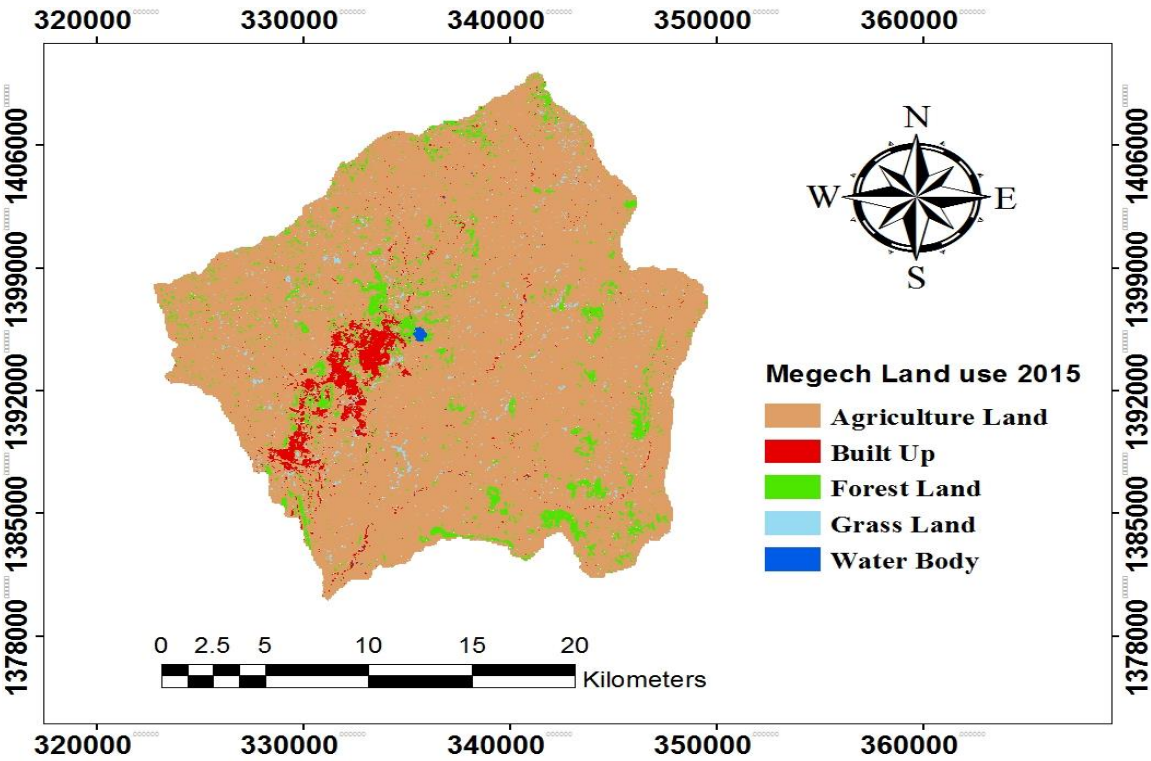


Figure 4.6: 2015 Land use map of Megech watershed

4.1.3 Trends in land use/cover classes (1986-2015)

Figure 4.2, 4.4 and 4.6 shows the three land use /cover maps 1986, 2006 and 2015 that have been generated using the Maximum Likelihood Algorithm of Supervised Classification from Landsat TM , ETM+ and ETM+ imagery classification respectively. It is easily shown that the increase of cultivation land and build up and decrease of forest area, grass land over the last 30 years. The land use /cover map of 1986 in the Figure 4.2 shows that the total cultivated land coverage class was about 29.57% of the total area of the watershed. It increased rapidly and became 75.67 % of the watershed in 2006 and 88.36 in 2015 land use/cover map (Figure 4.4) and (Figure 4.6) respectively. This is mainly because of the population growth that caused the increase in demand for new cultivation land and settlement which in turn resulted shrinking on other types of land use and land cover of the area. On the land use/cover map of the year 1986 the total forest coverage was about 38.56 % of the total area of the watershed. On the land use/ cover map of the year 2006 and 2015 it reduced to almost 13.38 % and 6.38 % of the total area respectively. This is most probably because of the deforestation activities that have taken place for the purpose of agriculture. The grass land in1986 land use/ cover map cover 31.42% of total area of the watershed and it reduced to almost 8.8% and 1.82% of total area in 2006 and 2015 land use/cover map respectively .The individual class areas and change statistics for the three periods are summarized in Table 4.3.

Table 4.3: Area of land use/cover types and change statistics of Megech watershed

Land use type	1986		2006		2015		2015-1986	
	(Km2)	(%)	Km2	(%)	(Km2)	(%)	(Km2)	(%)
Agricultural Land	146.13	29.57	373.95	75.67	436.65	88.36	290.52	58.79
Forest Land	190.56	38.56	66.11	13.38	31.51	6.38	-159.05	-32.19
Grass Land	155.27	31.42	43.5	8.8	8.97	1.82	-146.3	-29.61
Built Up	2.20	0.45	10.2	2.06	16.41	3.32	14.21	2.88
Water Body	_	_	0.4	0.08	0.62	0.13	0.61	0.13

In Table 4.3 the negative and positive sign indicates the decrease and increase of land use/cover class for the specified time period respectively. In general, during the 30 years period the cultivated land and build up increased almost 58.79 % (290.52 km^2) and 2.88 % (14.21 km^2) whereas the forest land and grass land decreased by 32.19. % (159.05 km^2) and 29.61% (146.30 km^2) respectively.

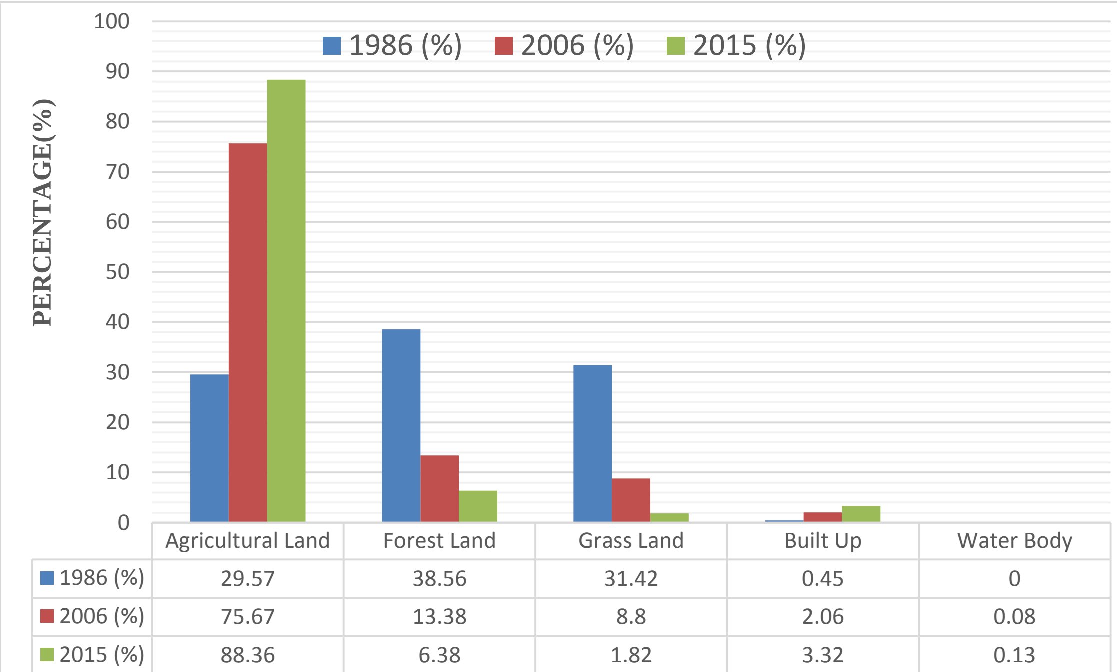


Figure 4.7: Land use/cover class from 1986, 2006 and 2015

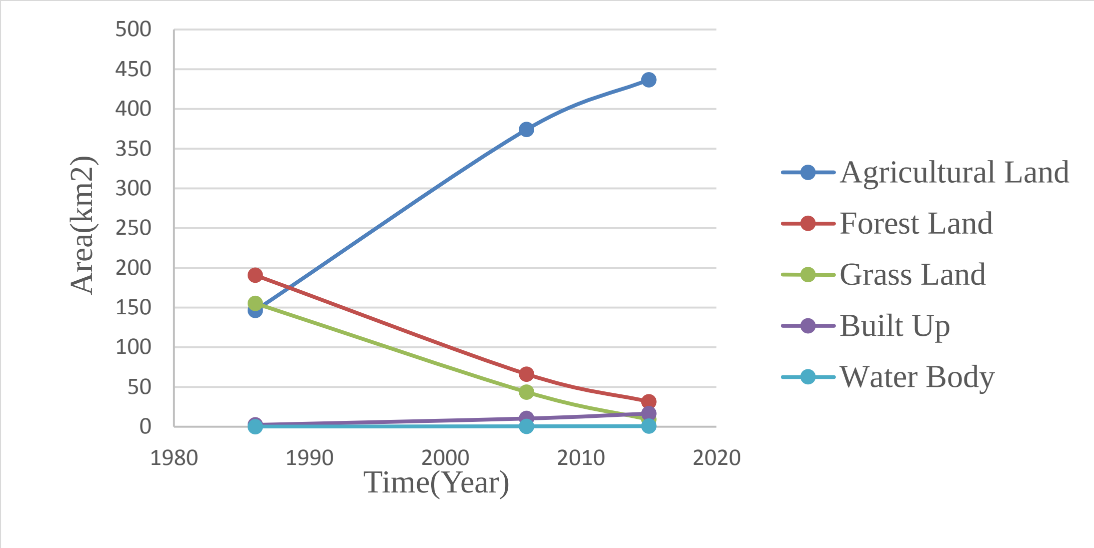


Figure 4.8: Land use/cover class trend analysis from 1986 to 2015

4.2 Sensitive parameters

The sensitivity analysis was done for flow and sediment separately since some parameters are sensitive to both flow and sediment, some sensitive to flow only and others sensitive to sediment only (Abbaspour et al., 2007). Therefore, it is wise to test the sensitivity of the parameters for flow and sediment separately. Sensitivity analysis was carried out before calibrating the model to save time during calibration. Identifying sensitive parameters enables us to focus only on those parameters which affect most the model output during calibration since SWAT model has a number of parameters to deal with. Some parameters do not have any influence on the model output while some may have little effect. Sensitivity analysis was performed on flow and sediment parameters of SWAT on monthly time steps with observed data at megech river gauge station for the three independent model with respected period, i.e for land use 1986 model from 1990-1999, for land use 2006 model from 2000-2007 and for land use 2015 model from 2008-2014. For this analysis 18 flow parameter and 7 sediment parameter were considered and only 10 flow parameter and 7 sediment parameter were identified as most sensitive and used for calibration.

4.2.1 Parameters sensitive to flow

The flow parameters used for sensitivity analysis were selected based on previous SWAT modeling studies including Santhi et al. (2001), Van Liew et al., (2007) and Yihun et al. (2015). The 18 parameters listed in Table 4.4, Table 4.5 and 4.6 were used in sensitivity analysis for the three model .The parameter identification was done by using the monthly flow data from 1990 to 1999 for land use 1986,from 2000 to 2007 for land use 2006 and from 2008 to 2014 for land use 2015. According to the result from the global sensitivity analysis, the curve number (CN2) was found to be the most sensitive parameter followed by Base flow alpha factor (ALPHA_BF), Ground water delay (GW_ Delay) and all others as shown in Table 4.4,Table 4.5 and Table 4.6

Table 4.4: Parameter rank based on p-value and t-value for Land use 2015 model

Parameter Name	Description of parameters	t-Stat	P-Value	Rank
V CN2.mgt	SCS runoff curve number	-14.9	1.00E-24	1
V ALPHA_BF.gw	Base flow alpha factor	8.181	4.00E-12	2
V GW_DELAY.gw	Groundwater delay	-6.08	2.00E-09	3
V GWQMN.gw	Threshold depth of water in the shallow aquifer for return	5.942	7.00E-08	4
V GW_REVAP.gw	Groundwater revap coefficient	-4.26	6.00E-05	5
V ESCO.hru	Soil evaporation compensation	2.437	0.0171	6
V CH_N2.rte	Manning’s “n” value for the	0.783	0.436	7
V CH_K2.rte	Effective hydraulic conductivity in the main	0.665	0.5079	8
V REVAPMN.gw	Threshold depth of water in	-0.62	0.5376	9
R SOL_AWC (...).sol	Available water content of soil	0.554	0.581	10
V RCHRG_DP.gw	Deep aquifer percolation	0.502	0.6173	11
V HRU_SLP.hru	Average slope steepness	-0.45	0.6551	12
V OV_N.hru	Manning’s “n” value for Overland flow	0.344	0.7315	13
V SURLAG.bsn	Surface runoff lag time	-0.32	0.7485	14
V EPCO.bsn	Plant uptake compensation factor	0.238	0.8123	15
R SOL_BD (...).sol	Moist bulk density	0.183	0.8195	16
R SOL_K (...).sol	Saturated hydraulic conductivity (mm/hr)	0.183	0.8556	17
R SOL_Z (...).sol	Soil depth (for each layer)	0.017	0.9867	18

Table 4.5: Parameter rank based on p-value and t-value for Land use 2006 model

Parameter Name	Description of parameters	t-Stat	P-Value	Rank
V CN2.mgt	SCS runoff curve number	-12.6	9.60E-07	1
V ALPHA_BF.gw	Baseflow alpha factor	11.01	6.60E-06	2
V GW_DELAY.gw	Groundwater delay	-8.28	7.84E-06	3
V ESCO.hru	Soil evaporation compensation factor	6.742	5.24E-05	4
V GW_REVAP.gw	Groundwater revap coefficient	5.523	3.60E-04	5
V GWQMN.gw	Threshold depth of water in the shallow aquifer for return flow	5.437	0.0172	6
V CH_N2.rte	Manning's "n" value for the	4.933	0.536	7
V CH_K2.rte	Effective hydraulic conductivity in the main	2.076	0.5879	8
V REVAPMN.gw	Threshold depth of water in the	1.62	0.673	9
R SOL_AWC (...).sol	Available water content of soil	1.574	0.681	10
R SOL_K (...).sol	Saturated hydraulic conductivity (mm/hr.)	0.902	0.6973	11
V HRU_SLP.hru	Average slope steepness	-0.675	0.7601	12
V OV_N.hru	Manning's "n" value for Overland flow	0.544	0.7615	13
V RCHRG_DP.gw	Deep aquifer percolation fraction	-0.522	0.7909	14
V EPCO.bsn	Plant uptake compensation factor	0.443	0.7923	15
R SOL_Z (...).sol	Soil depth (for each layer)	0.283	0.864	16
V SURLAG.bsn	Surface runoff lag time	0.083	0.875	17
R SOL_BD (...).sol	Moist bulk density	0.015	0.885	18

Table 4.6: Parameter rank based on p-value and t-value for Land use 1986 model

Parameter Name	Description of parameters	t-Stat	P-Value	Rank
V CN2.mgt	SCS runoff curve number	4.7	3.60E-06	1
V ALPHA_BF.gw	Baseflow alpha factor	3.81	5.25E-04	2
V GW_DELAY.gw	Groundwater delay	-3.08	6.32E-04	3
V ESCO.hru	Soil evaporation compensation factor	2.94	3.22E-02	4
V GW_REVAP.gw	Groundwater revap coefficient	-2.26	3.25E-02	5
V GWQMN.gw	Threshold depth of water in the shallow aquifer for return flow	1.47	0.2171	6
R SOL_AWC (...).sol	Available water content of soil	1.03	0.4126	7
V CH_K2.rte	Effective hydraulic conductivity in the main channal	1.015	0.4279	8
V REVAPMN.gw	Threshold depth of water in the shallow	-0.62	0.4376	9
V CH_N2.rte	Manning’s “n” value for the main	0.54	0.5001	10
V RCHRG_DP.gw	Deep aquifer percolation fraction	0.52	0.5163	11
V HRU_SLP.hru	Average slope steepness	-0.45	0.5251	12
V OV_N.hru	Manning’s “n” value for Overland flow	0.143	0.5316	13
V SURLAG.bsn	Surface runoff lag time	-0.232	0.5485	14
V EPCO.bsn	Plant uptake compensation factor	0.123	0.6123	15
R SOL_BD (...).sol	Moist bulk density	0.113	0.6195	16
R SOL_K (...).sol	Saturated hydraulic conductivity (mm/hr.)	0.103	0.6556	17
R SOL_Z (...).sol	Soil depth (for each layer)	0.005	0.7857	18

4.2.1.1 Global sensitivity analysis

Global sensitivity analysis was done for the parameters shown in Table 4.4, Table 4.5 and Table 4.6. According to the result from the global sensitivity analysis, the Curve number (CN2) was found to be the most sensitive parameter followed by Base flow alpha factor (ALPHA_BF), Ground water delay (GW_ Delay) Threshold depth of water in the shallow aquifer for return flow (GWQMN), Groundwater revap coefficient (GW_REVAP), oil evaporation compensation factor (ESCO), and others were found to be most sensitive parameters in the order appearance. Ranking position as shown in Table 4.4, Table 4.5 and Table 4.6 above.

Here, t-stat provides a measure of sensitivity and hence larger in absolute values are more sensitive. On the other hand, P-value indicates the significance of the sensitivity and hence a value close to zero has more significance. Therefore, ranking in both cases (t-stat or P-value) give the same result i.e. a parameter will have the same rank whether it is ranked based on the t- stat or P-value.

4.2.1.2 One-at-a-time sensitivity analysis

The local sensitivity analysis was carried out using the Latin-Hypercube One-Factor-at-a-Time (LH-OAT) sensitivity analysis method. As described in earlier section this method should be performed for one parameter at a time only while the other parameters are fixed at a value of the best iteration. Then the parameter was varied independently and its effect on the model output was evaluated. Based on the analysis result groundwater delay (GW_DELAY), groundwater revap coefficient (GW_REVAP),oil evaporation compensation factor (ESCO), Base flow alpha factor (ALPHA_BF), runoff curve number (CN) and saturated hydraulic conductivity of soil layers were found to be most sensitive parameters in the order appearance. On the other hand parameters such as Manning’s “n” value for the main channel (CH_N2), available water content the soil (SOL_AWC), Threshold depth of water in the shallow aquifer (REVAPMN), threshold depth of water in the shallow aquifer required for return flow to occur (GWQMN) and threshold depth of water in the shallow aquifer for revap to occur (REVAPMN) were found to be least sensitive. The remaining parameters have moderate effect on the model output. In general, the global sensitivity analysis and the local sensitivity analysis produce different result. Therefore, attention was given to most sensitive parameters during model calibration process.

4.2.2 Parameters sensitive to sediment

Once it is shown that the flow was accurately represented by the model the focus is shifted to the calibration of the model for sediments. This involves changing parameter values that control sediment generation within the model. The sediment parameters used for calibration were selected based on previous SWAT modeling studies including Santhi et al. (2001), Van Liew et al., (2007) and Yihun et al. (2015)

The most sensitive parameters for erosion simulations were: USLE Soil erodibility factor (USLE_K), USLE support practice factor (USLE_P),Channel re-entrainment exponent parameter (SPEXP), channel cover factor (CH_COV2) and Channel erodibility factor (CH_COV1). These sediment parameters are used to compute the amount of sediment from a catchment (from upland) and from the channel (in stream sediment).The parameters that were used to evaluate the sensitivity to sediment are shown in Table 4.7, Table 4.8 and Table 4.9

Table 4.7: Parameters highly sensitive to sediment for Land use 2015 model

Parameter Name	Description of parameters	t-Stat	P-Value	Rank
V_ USLE_K .sol	USLE soil erodibility factor	20.35	9E-54	1
V _ USLE_P.mgt	USLE support practice factor	16.85	7.00E-55	2
V_ SPEXP.bsn	Exponential re-entrainment parameter	10.67	3.00E-35	3
V _CH_COV2.rte	Channel cover factor	1.331	0.1865	4
V_ CH_COV1.rte	Channel erodibility factor	1.255	0.2128	5
R _ RSDIN.hru	Initial residue cover [kg/ha]	-0.14	0.8855	6
V_SPCON.bsn	Linear re-entrainment parameter for channel sediment routing	0.071	0.9437	7

Table 4.8: Parameters highly sensitive to sediment for Land use 2006 model

Parameter Name	Description of parameters	t-Stat	P-Value	Rank
V_ USLE_K .sol	USLE soil erodibility factor	21.24	0.17175	1
V _ USLE_P.mgt	USLE support practice factor	-20.8	2.98E-01	2
V_ SPEXP.bsn	Exponential re-entrainment parameter	1.369	5.09E-01	3
V_SPCON.bsn	Linear re-entrainment parameter for channel sediment routing	1.042	0.52236	4
V_ CH_COV1.rte	Channel erodibility factor	0.661	0.5416	5
R _ RSDIN.hru	Initial residue cover [kg/ha]	0.64	0.655	6
V _CH_COV2.rte	Channel cover factor	-0.61	0.741	7

Table 4.9: Parameters highly sensitive to sediment for Land use 1986 model

Parameter Name	Description of parameters	t-Stat	P-Value	Rank
V_ USLE_K .sol	USLE soil erodibility factor	21.19	0.00216	1
V _ USLE_P.mgt	USLE support practice factor	6.205	3.52E-02	2
R _ RSDIN.hru	Initial residue cover [kg/ha]	3.083	6.70E-02	3
V _CH_COV2.rte	Channel cover factor	2.112	0.41494	4
V_ SPEXP.bsn	Exponential re-entrainment parameter	1.836	0.44179	5
V_ CH_COV1.rte	Channel erodibility factor	0.816	0.44488	6
V_SPCON.bsn	Linear re-entrainment parameter for channel sediment routing	0.071	0.81389	7

4.3 Model calibration and validation

4.3.1 Model calibration for flow

The objective of calibration and validation was to maximazing the model efficiencies and finally using the parameter obtained through those calibration techniques. The calibration of SWAT model for flow was done by using the Monthly observed flow data at the outlet of the study watershed (Megech watershed). By using the values of parameters that were identified as highly sensitive to flow as it was described under sensitivity analysis section by SWAT-CUP software SUFI 2 program for the years 2008- 2011 for land use 2015 model ,2005-2007 for land use 2006 model and 1990-1995 for land use 1986 model .As shown on Table: 4.10, Table 4.11 and Table 4.12 the value of coefficient of determination (R^2) and the Nash-Sutcliffe efficiency (NS) for land use 2015 model were 0.88 and 0.88 respectively, for land use 2006 model were 0.78 and 0.78 respectively and land use 1986 model were 0.85 and 0.85 respectively .The result indicates the performance of the model in predicting is well and the observed flow and the dispersion of simulated flow are very close to each other. For land use 2015 p-factor was 0.94 which means 94% of the observed data is captured by the 95PPU with r-factor of 0.81 which is acceptable, for land use 2006 p-factor was 0.70 which means 70% of the observed data is captured by the 95PPU with r-factor of 0.78 which is acceptable and for land use 1986 p-factor was 0.94 which means 94% of the observed data is captured by the 95PPU with r-factor of 1.29 which is acceptable. The simulated and observed monthly flow at the outlet of the watershed were plotted for visual comparison in Figure 4.9, 4.10 and 4.11 below.

Table 4.10: Summary of stat txt for flow calibration period for land use 2015 model

Variable	p-factor	r-factor	R2	NS	bR2	MSE	SSQR	PBIAS	KGE	RSR	MNS	VOL_FR	Mean_sim(Mean_obs)
FLOW_OUT_15	0.94	0.81	0.88	0.88	0.7	6.80E+01	2.50E+01	-5.7	0.87	0.4	0.7	0.95	21.71(20.53)

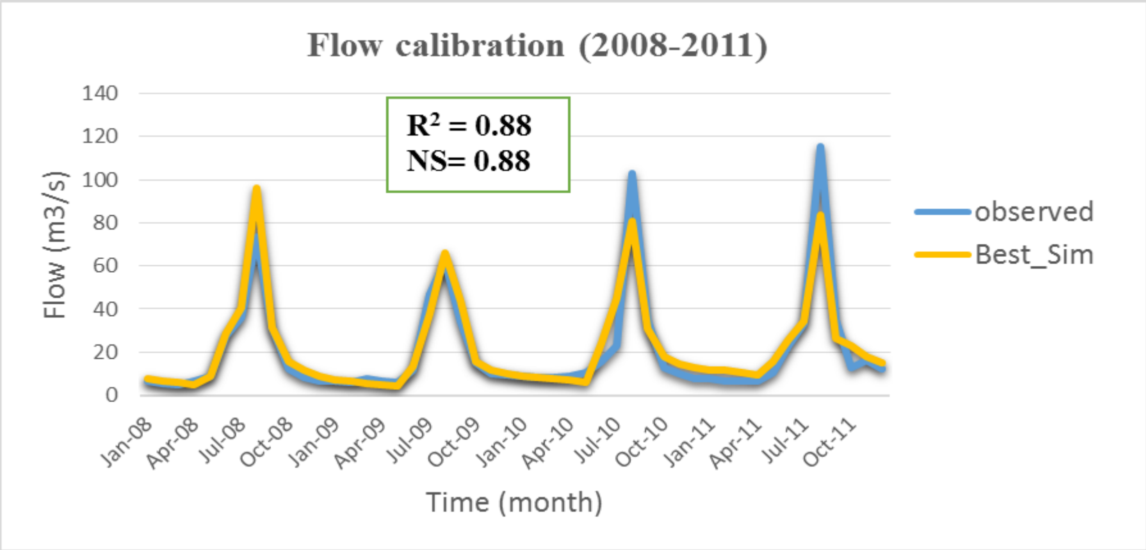


Figure 4.9: Comparison of observed and simulated monthly flow at the outlet of Megech watershed for calibration period 2008-2011 for land use 2015 model

Table 4.11: Summery of stat txt for flow calibration period for land use 2006 model

Variable	p-factor	r-factor	R2	NS	bR2	MSE	SSQR	PBIAS	KGE	RSR	MNS	VOL_FR	Mean_sim(Mean_obs)
FLOW_OUT_15	0.70	0.78	0.78	0.78	0.5942	2.00E+01	3.20E+00	-3.5	0.82	0.47	0.54	0.97	7.34(7.09)

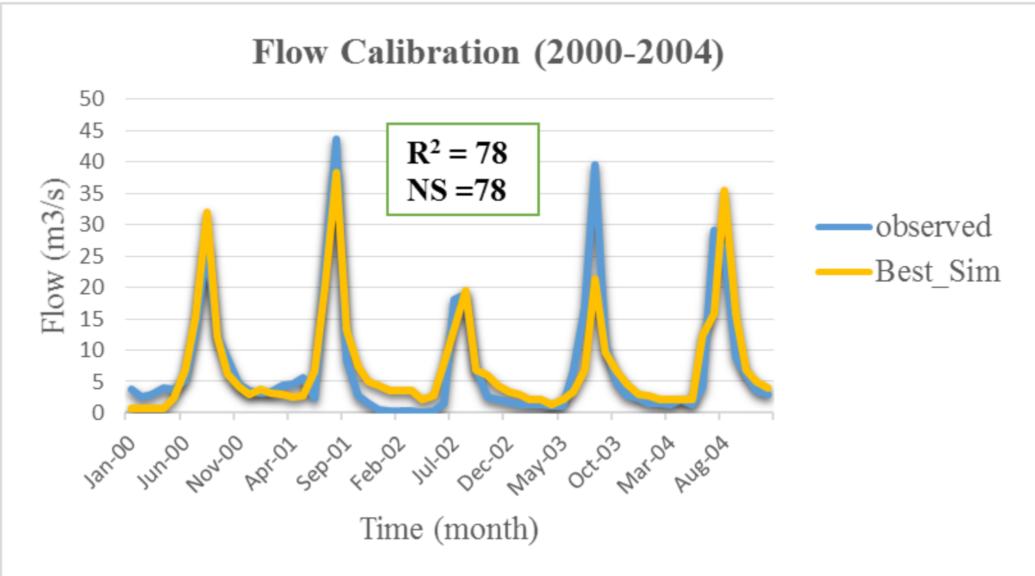


Figure 4.10: Comparison of observed and simulated monthly flow at the outlet of Megech watershed for calibration period 2000-2004 for land use 2006 model.

Table 4.12: Summery stat txt for flow calibration period for land use 1986 model

Variable	p-factor	r-factor	R2	NS	bR2	MSE	SSQR	PBIAS	KGE	RSR	MNS	VOL_FR	Mean_sim(Mean_obs)
FLOW_OUT_15	0.94	1.29	0.85	0.85	0.735	9.70E+00	3.20E+00	-13.4	0.83	0.39	0.62	0.88	4.86(4.29)

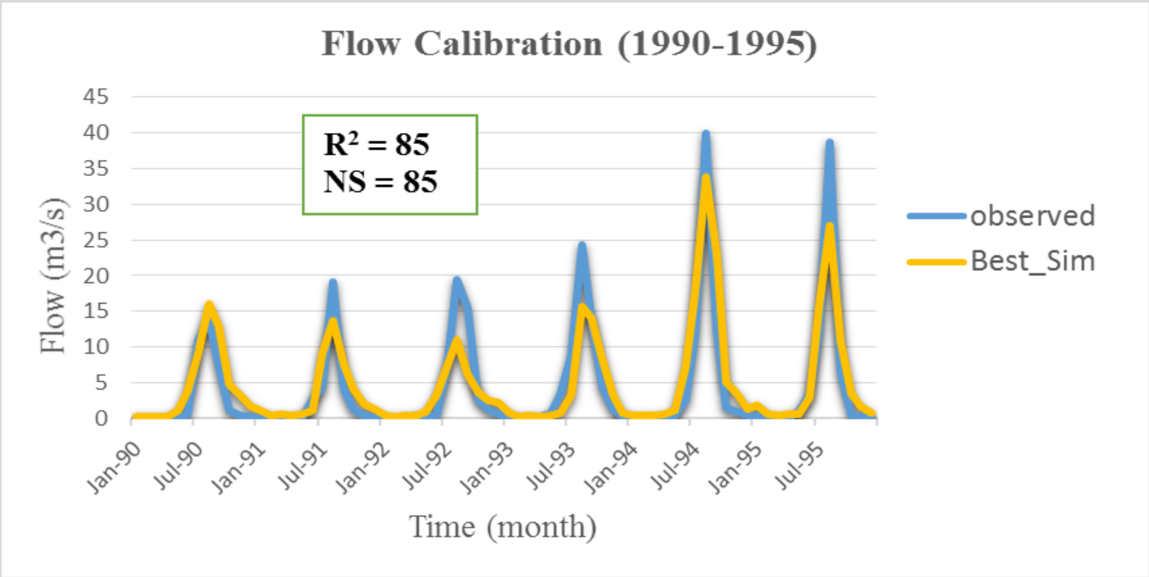


Figure 4.11: Comparison of observed and simulated monthly flow at the outlet of Megech watershed for calibration period 1990-1995 for land use 1986 model

4.3.2 Model validation for flow

Validation is a process of proving the performance of model. Validation is carried out for time periods different from calibration period, but without any further adjustment of calibrated parameters. The validation was carried out for Monthly flow for land use 2015 model from 2012 to 2014, for land use 2006 model from 2005 to 2007 and for land use 1986 model from 1996 to 1999. As shown on Table: 4.13, Table 4.14 and Table 15 the value of coefficient of determination (R^2) and the Nash-Sutcliffe efficiency (NS) for land use 2015 model were 0.79 and 0.79 respectively, for land use 2006 model were 0.73 and 0.71 respectively and for land use 1986 model were 0.86 and 0.85 respectively. The result indicates the performance of the model in predicting is good and the observed flow and the dispersion of simulated flow are very close to each other. For land use 2015 p-factor was 0.81 which means 81% of the observed data is captured by the 95PPU with r-factor of 0.84 which is acceptable, for land use 2006 p-factor was 0.72 which means 72% of the observed data is captured by the 95PPU with r-factor of 0.91 which is acceptable and for land use 1986 p-factor was 0.83 which means 83% of the observed data is captured by the 95PPU with r-factor of 0.82 which is acceptable.

The simulated and observed monthly flow at the outlet of the watershed were plotted for visual comparison in Figure 4.12, 4.13 and 4.14 below

Table 4.13: Summery stat txt for flow validation period for land use 2015 model

Variable	p-factor	r-factor	R2	NS	bR2	MSE	SSQR	PBIAS	KGE	RSR	MNS	VOL_FR	Mean_sim(Mean_obs)
FLOW_OUT_15	0.81	0.84	0.79	0.79	0.67	9.20E+01	2.60E+01	-2.8	0.87	0.5	0.6	0.97	20.97(20.39)

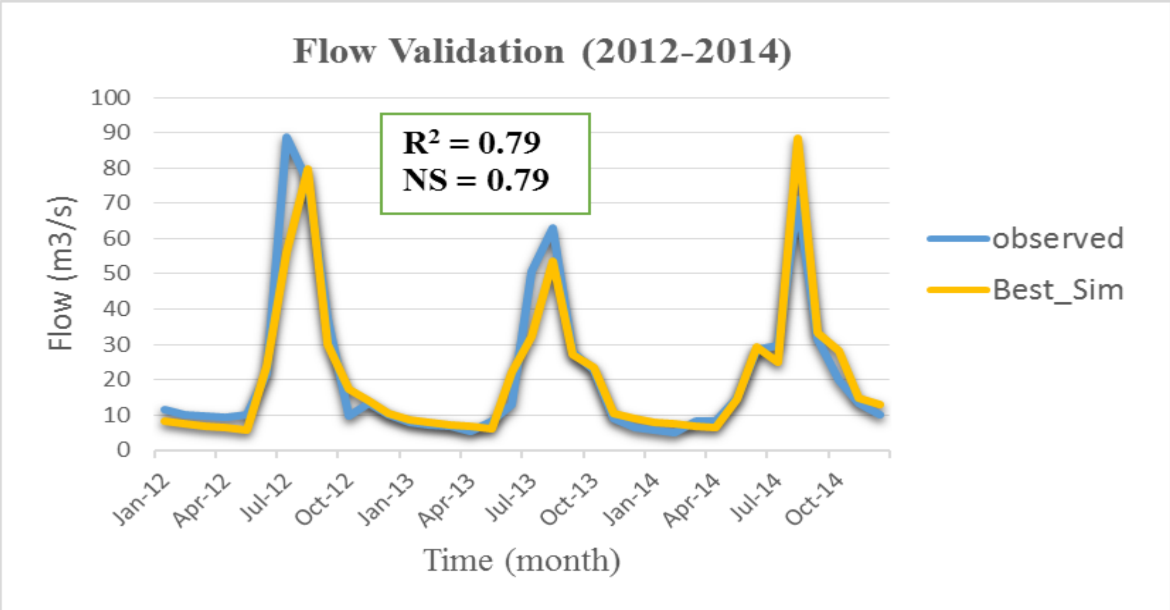


Figure 4.12: Comparison of observed and simulated monthly flow at the outlet of Megech watershed for validation period 2012-2014 for land use 2015

Table 4.14: Summery stat txt for flow validation period for land use 2006 model

Variable	p-factor	r-factor	R2	NS	bR2	MSE	SSQR	PBIAS	KGE	RSR	MNS	VOL_FR	Mean_sim(Mean_obs)
FLOW_OUT_15	0.72	0.91	0.73	0.71	0.47	3.00E+02	9.80E+01	-11.1	0.76	0.62	0.48	0.9	22.09(19.89)

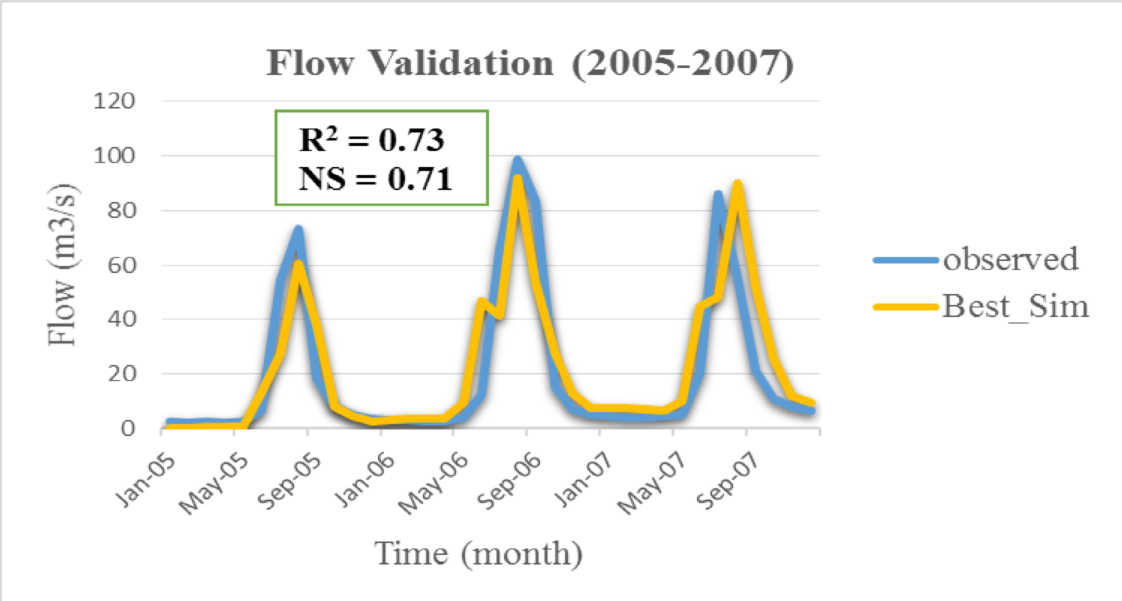


Figure 4.13: Comparison of observed and simulated monthly flow at the out let of Megech watershed for validation period 2005-2007 for land use 2006 model

Table 4.15: Summery stat txt for flow validation period for land use 1986 model

Variable	p-factor	r-factor	R2	NS	bR2	MSE	SSQR	PBIAS	KGE	RSR	MNS	VOL_FR	Mean_sim(Mean_obs)
FLOW_OUT_15	0.83	0.82	0.86	0.85	0.6876	1.60E+01	5.40E+00	7.1	0.83	0.38	0.69	1.08	6.40(6.89)

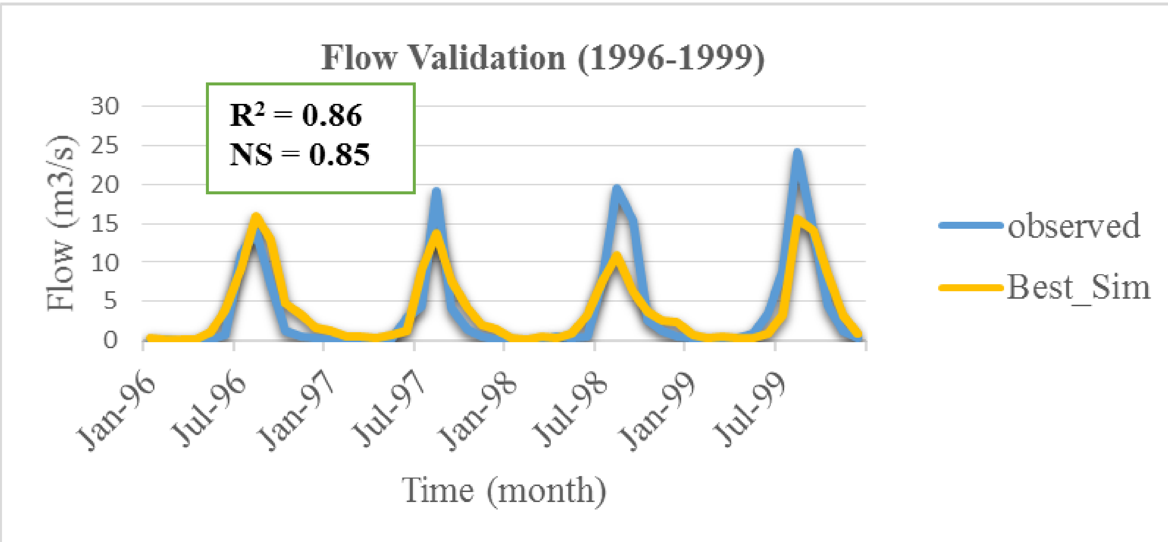


Figure 4.14: Comparison of observed and simulated monthly flow at the outlet of Megech watershed for validation period 1993-1999 for land use 1986 model

4.3.3 Model calibration for sediment

SWAT model was first calibrated and validated to flows, then to sediment. The model was calibrated for sediment by comparing monthly model simulated sediment load against monthly measured sediment load data at the outlet of the study watershed (Megech watershed) by using the values of parameters that were identified as highly sensitive to flow as it was described under sensitivity analysis section by SWAT-CUP software SUFI 2 program for the years 2008- 2011 for land use 2015 model ,2005-2007 for land use 2006 model and 1990-1995 for land use 1986 model. As shown on Table: 4.16, Table 4.17 and Table 4.18. the value of coefficient of determination (R^2) and the Nash-Sutcliffe efficiency (NS) for land use 2015 model were 0.68 and 0.67 respectively, for land use 2006 model were 0.70 and 0.66 respectively and for land use 1986 model were 0.69 and 0.64 respectively. The result indicates the performance of the model in predicting is good and the observed sediment load and the dispersion of simulated sediment load are close to each other. For land use 2015 p-factor was 0.73 which means 0.73% of the observed data is captured by the 95PPU with r-factor of 1.98 which is acceptable, for land use 2006 p-factor was 0.78 which means 0.78% of the observed data is captured by the 95PPU with r-factor of 0.90 which is acceptable and for land use 1986 p-factor was 0.83 which means 83% of the observed data is captured by the 95PPU with r-factor of 1.40 which is acceptable.The simulated and observed monthly flow at the outlet of the watershed were plotted for visual comparison in Figure 4.16, 4.17 and 4.18 below.

Table 4.16: Summery stat txt for sediment calibration period for land use 2015 model

Variable	p-factor	r-factor	R2	NS	bR2	MSE	SSQR	PBIAS	KGE	RSR	MNS	VOL_FR	Mean_sim(Mean_obs)
SED_OUT_15	0.73	1.98	0.68	0.67	0.47	1.20E+09	3.90E+08	6.1	0.75	0.6	0.58	1.06	31369.51(33391.43)

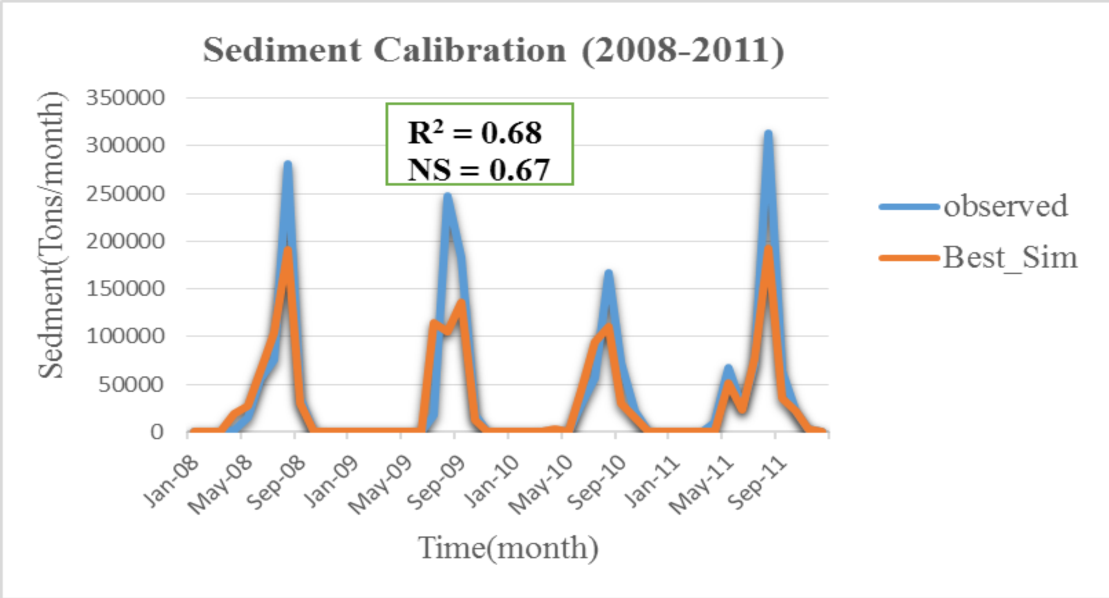


Figure 4.15: Comparison of observed and simulated monthly sediment load at the outlet of Megech watershed for calibration period 2008-2011 for land use 2015

Table 4.17: Summery stat txt for sediment calibration period for land use 2006 model

Variable	p-factor	r-factor	R2	NS	bR2	MSE	SSQR	PBIAS	KGE	RSR	MNS	VOL_FR	Mean_sim(Mean_obs)
SED_OUT_15	0.78	0.90	0.7	0.66	0.6661	6.60E+07	1.10E+07	4.6	0.87	0.45	0.7	1.05	7191.42(7535.61)

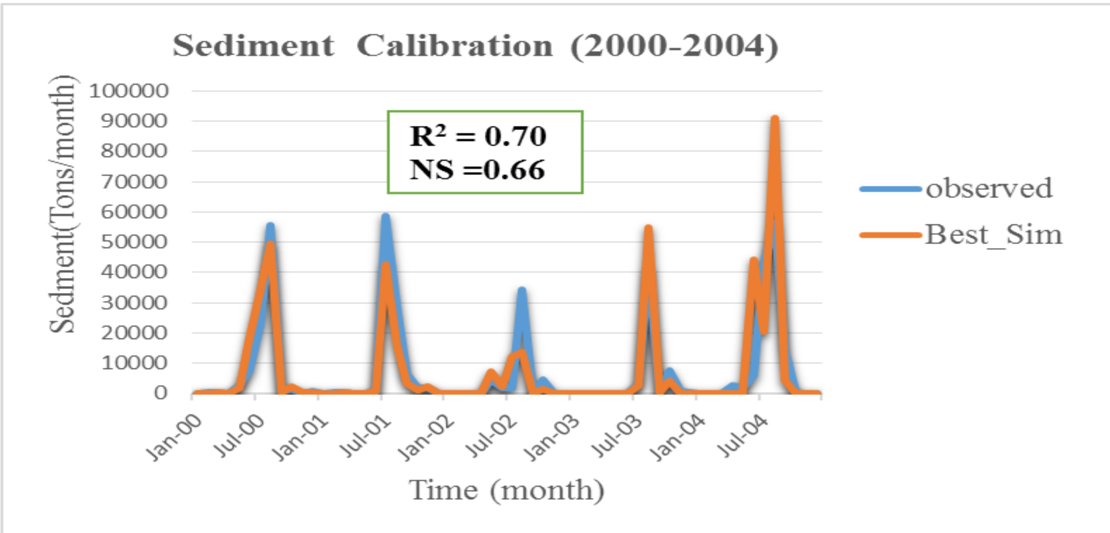


Figure 4.16: Comparison of observed and simulated monthly sediment load at the out let of Megech watershed for calibration period 2000-2004 for land use 2006 model

Table 4.18: Summery of stat txt for sediment calibration period for land use 1986 model

Variable	p-factor	r-factor	R2	NS	bR2	MSE	SSQR	PBIAS	KGE	RSR	MNS	VOL_FR	Mean_sim(Mean_obs)
SED_OUT_15	0.83	1.40	0.69	0.64	0.6675	4.30E+07	5.90E+06	1.8	0.87	0.45	0.67	1.02	5901.30(6009.16)

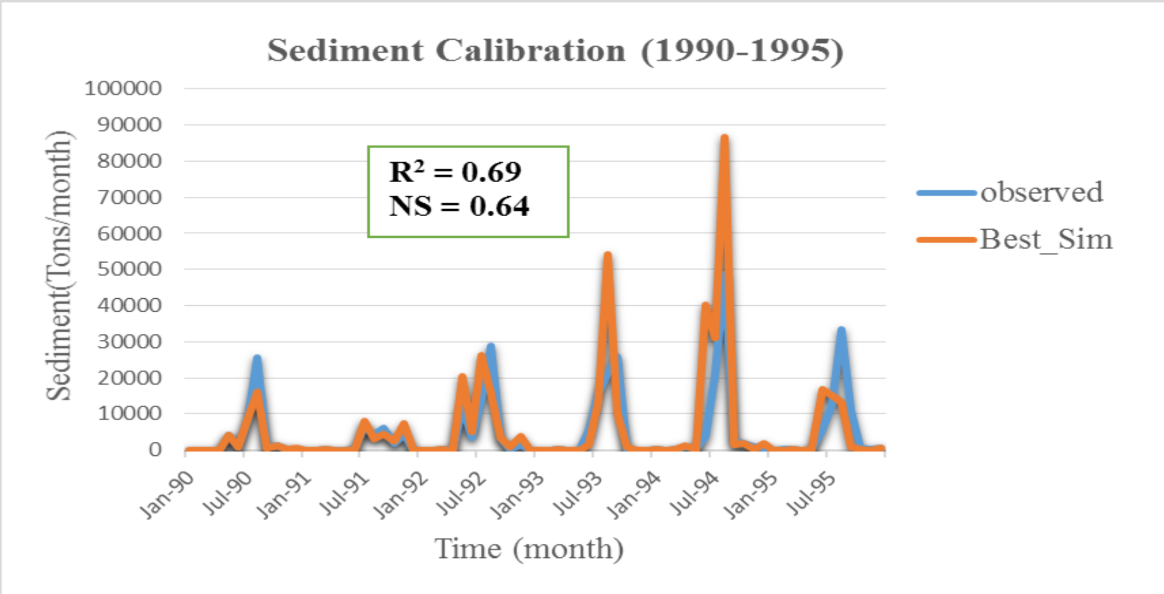


Figure 4.17: Comparison of observed and simulated monthly sediment yield at the outlet of Megech watershed for calibration period 1990-1995 for land use 1986 model

4.3.4 Model validation for sediment

The validation was carried out for Monthly Sediment load for land use 2015 model from 2012 to 2014, for land use 2006 model from 2005 to 2007 and for land use 1986 model from 1996 to 1999. As shown on Table 4.19, Table 4.20 and Table 4.21 the value of coefficient of determination (R^2) and the Nash-Sutcliffe efficiency (NS) for land use 2015 model were 0.65 and 0.65 respectively, for land use 2006 model were 0.64 and 0.63 respectively and land use 1986 model were 0.62 and 0.61 respectively. The result indicates the performance of the model in predicting is good and the observed sediment load and the dispersion of simulated sediment load are close to each other. For land use 2015 p-factor was 0.77 which means 0.77% of the observed data is captured by the 95PPU with r-factor of 1.37 which is acceptable, for land use 2006 p-factor was 0.83 which means 0.83% of the observed data is captured by the 95PPU with r-factor of 1.29 which is acceptable and for land use 1986 p-factor was 0.69 which means 69% of the observed data is captured by the 95PPU with r-factor of 0.77 which is acceptable. The simulated and observed monthly flow at the outlet of the watershed were plotted for visual comparison in Figure 4.19, 4.20 and 4.21 below.

Table 4.19: Summery of stat txt for sediment validation period for land use 2015 model

Variable	p-factor	r-factor	R2	NS	bR2	MSE	SSQR	PBIAS	KGE	RSR	MNS	VOL_FR	Mean_sim(Mean_obs)
SED_OUT_15	0.77	1.37	0.65	0.65	0.453	1.10E+09	1.10E+08	11	0.74	0.6	0.63	1.12	33461.20(37609.44)

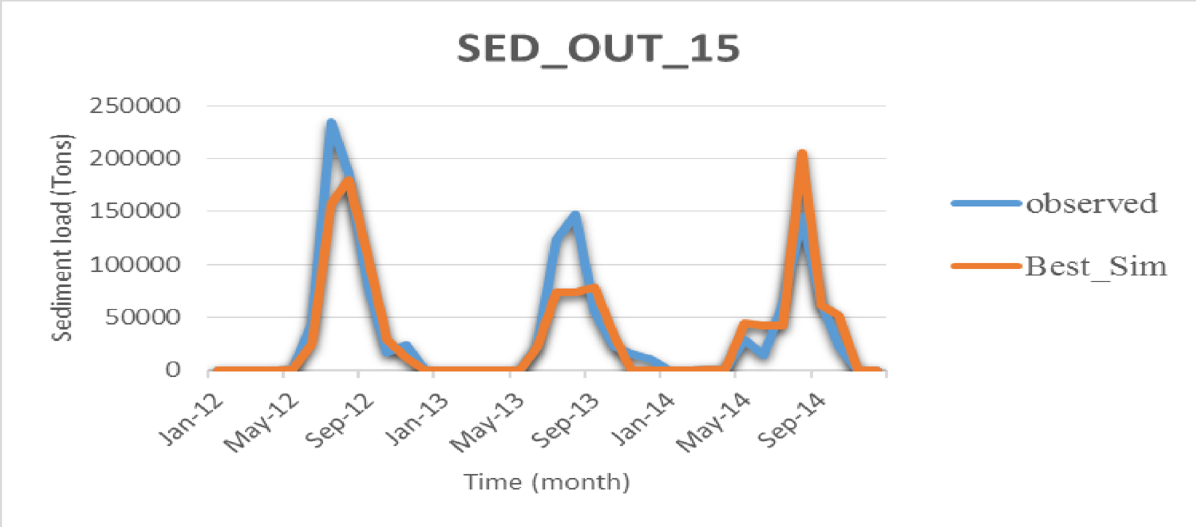


Figure 4.18: Comparison of observed and simulated monthly sediment load at the outlet of Megech watershed for validation period 2012-2014 for land use 2015 model

Table 4.20: Summery of stat txt for sediment validation for land use 2006 model

Variable	p-factor	r-factor	R2	NS	bR2	MSE	SSQR	PBIAS	KGE	RSR	MNS	VOL_FR	Mean_sim(Mean_obs)
SED_OUT_15	0.83	1.29	0.64	0.63	0.453	5.30E+08	2.80E+08	12.1	0.74	0.61	0.67	1.14	17657.69(20094.41)

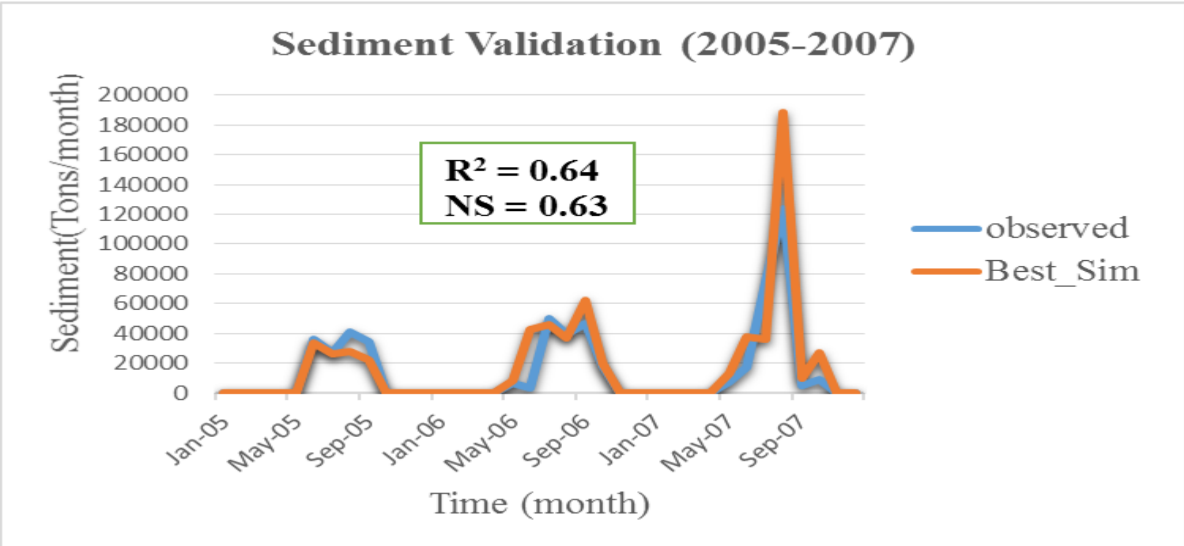


Figure 4.19: Comparison of observed and simulated monthly sediment at the outlet of Megech watershed for calibration period 2005-2007 for land use 2006 model

Table 4.21: Summary of stat txt for sediment validation period for land use 1986 model

Variable	p-factor	r-factor	R2	NS	bR2	MSE	SSQR	PBIAS	KGE	RSR	MNS	VOL_FR	Mean_sim(Mean_obs)
SED_OUT_15	0.69	0.77	0.62	0.61	0.4211	1.90E+08	1.70E+07	13.2	0.71	0.63	0.5	1.15	10344.94(11915.50)

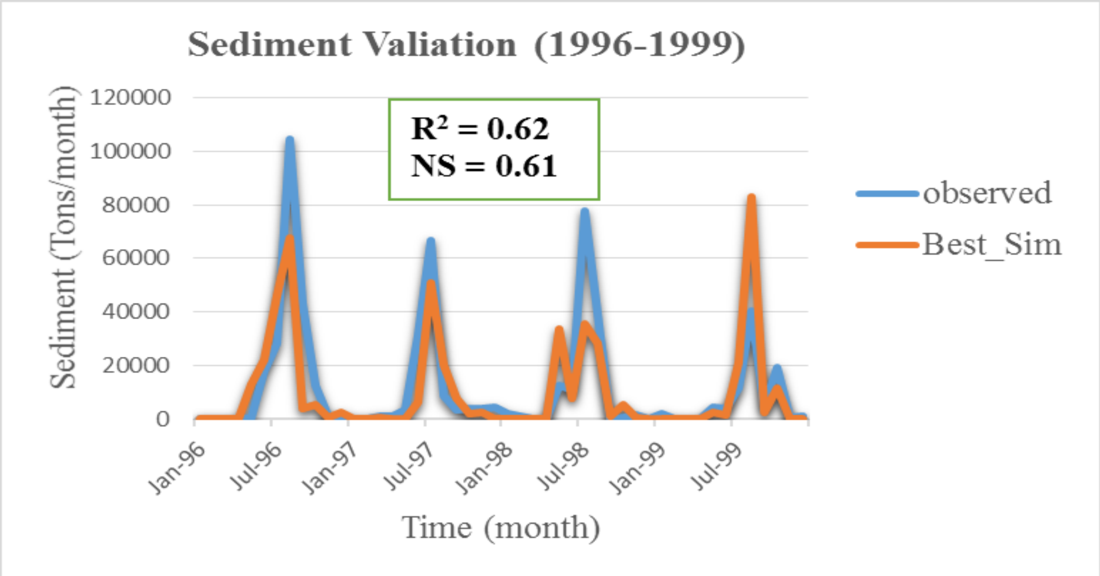


Figure 4.20: Comparison of observed and simulated monthly sediment load at the outlet of Megech watershed for calibration period 1996-1999 for land use 1986 model

4.4 Impact of land use dynamics on sediment yield

The impacts of land-use change were assessed by running the calibrated and validated models for the period from 2003 to 2015 for the three independent models i.e. 1986 land use model, 2006 land use model & 2015 land use model keeping other input parameter the same. It was found that the greatest impact was observed on the amount of sediment yield. Table 4.22 shows that using land use 1986 the watershed was contributed the total annual sediment yield 353,835 tons/year (716.26 tons/km2/year),using land use 2006 the watershed contributed the total annual sediment yield 482,319 tons/year (976.36 tons/km2/year) and using land use 2015 the annual sediment yield became 557,184 tons/year (1127.90 tons/km2/year). This is because of the high expansion of cultivation land over forest and grassland that results in the increase of surface runoff and sediment yield following rainfall events.

Table 4.22: Average annual sediment yield for the period 2003 to 2015

Years	1986 Land use	2006 Land use	2015 Land use
2003	224,933	294,901	372,065
2004	255,321	487,987	543,197
2005	188,664	288,535	347,203
2006	196,971	391,469	454,152
2007	440,998	511,456	682,432
2008	486,281	541,408	599,436
2009	458,589	642,594	741,431
2010	371,639	607,910	763,597
2011	417,277	430,195	451,924
2012	513,375	693,012	752,310
2013	295,198	485,056	542,370
2014	458,763	498,846	574,762
2015	291,839	396,782	418,517
Total	4,599,851	6,270,153	7,243,396
Tons/year	353,835	482,319	557,184
Tons/km2/year	716.26	976.36	1127.90

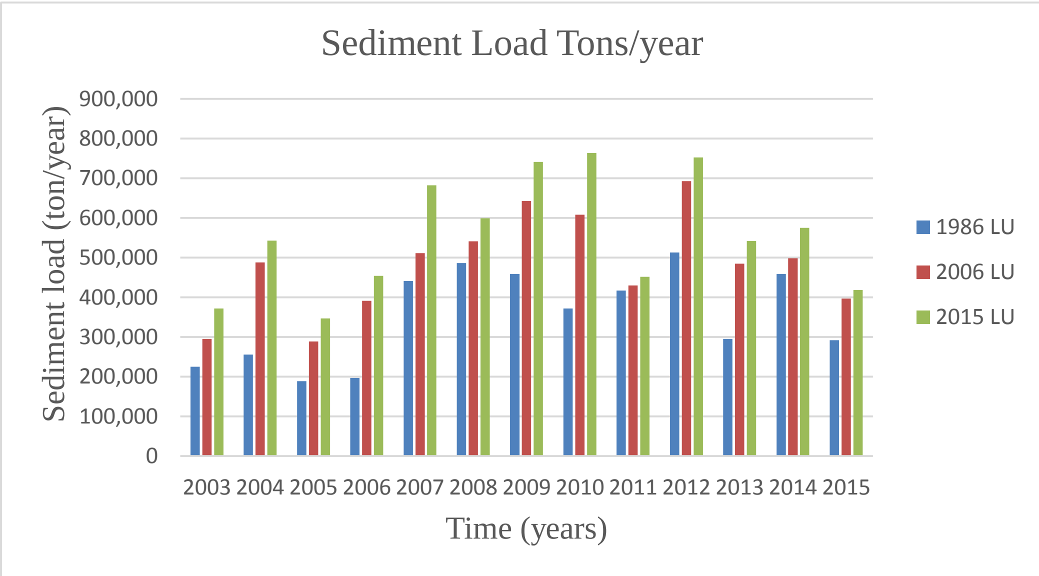


Figure 4.21: Impact of land use/cover on sediment yield for the year from 2003-2015

4.5 Comparison with sediment yield estimates from other reservoirs

The mean annual sediment load estimates by USBR (1964) and BCEOM (1999) for the Megech dam site were 70,000 ton (151 ton/km^2/year) and 240,000 ton (576 ton/km^2/year), respectively. Hydrology Department of the MoWRIE conducted bathymetric survey on Angerb reservoir (a tributary of Megech River with watershed area 48 km^2) found that a mean annual sediment deposition of 0.14 Mm^3 estimated over ten years (1995-2004), taking the density of sediment as 1.2 gm/cc, the sediment yield is 3500 ton/km^2/year, which is very high. Studio Pietrangeli (2005) gave a comparison of total sediment load estimate for five hydropower reservoirs (Table 4.23).

The present estimate of Megech reservoir sediment load using current land use (2015) is 1,126.90 ton/km^2/year for over ten year (2003-2015) is within the sediment yield estimate given in Table 4.23. However, as compared to the Angerb reservoir sediment yield, it is about one third. The very high sediment yield rate partly attributed to the size of the watersheds, the smaller the watershed the higher sediment yield.

Table 4.23 : Sediment yield estimate for hydropower reserviors in Ethiopia

Hydropower reservoirs	Tons/km2/year
Gibe 1	1,300.00
Gojeb	218.00
Halele-Weabesa	1,200.00
Chemoga Yeda	1,600.00
Tekeze	1,283.00

4.6 Sedimentation rate of Megech reservior

The problem of reservoir sedimentation on its useful life is complex. Sedimentation rate influenced by Trap efficiency, Specific weight of sediment deposit and sediment distribution.

4.6.1 Trap efficiency

The abilty of a reservoir to trap and retain incoming sediment is known as trap efficiency and is usually expressed as a percent of sediment yield of the catchment retained in the reservoir. Reservoir trap efficiency is defined as a ratio of deposited sediment to the total sediment inflow for a given period. Trap efficiency is influenced by many factors of which primary factors are:

the sediment fall velocity, velocity field through the reservoir and reservoir operation rules (Ahmed, 2008).

Brune’s and Churchil’s empirical relationships have been widely used and found to provide reasonable estimates for long term release and trapping efficiency (Morris and Fan, 1998). Both methods are based on reservoir capacity to inflow ratio referred to as capacity inflow ratio (CIR) and neither method specifically considers effect of sediment characteristics. For this study BRUNE’S CURVE method is used. Brune’s curve which equates capacity to inflow ratio requires little input data, is simple to apply and has been very widely used to estimate reservoir trap efficiency.

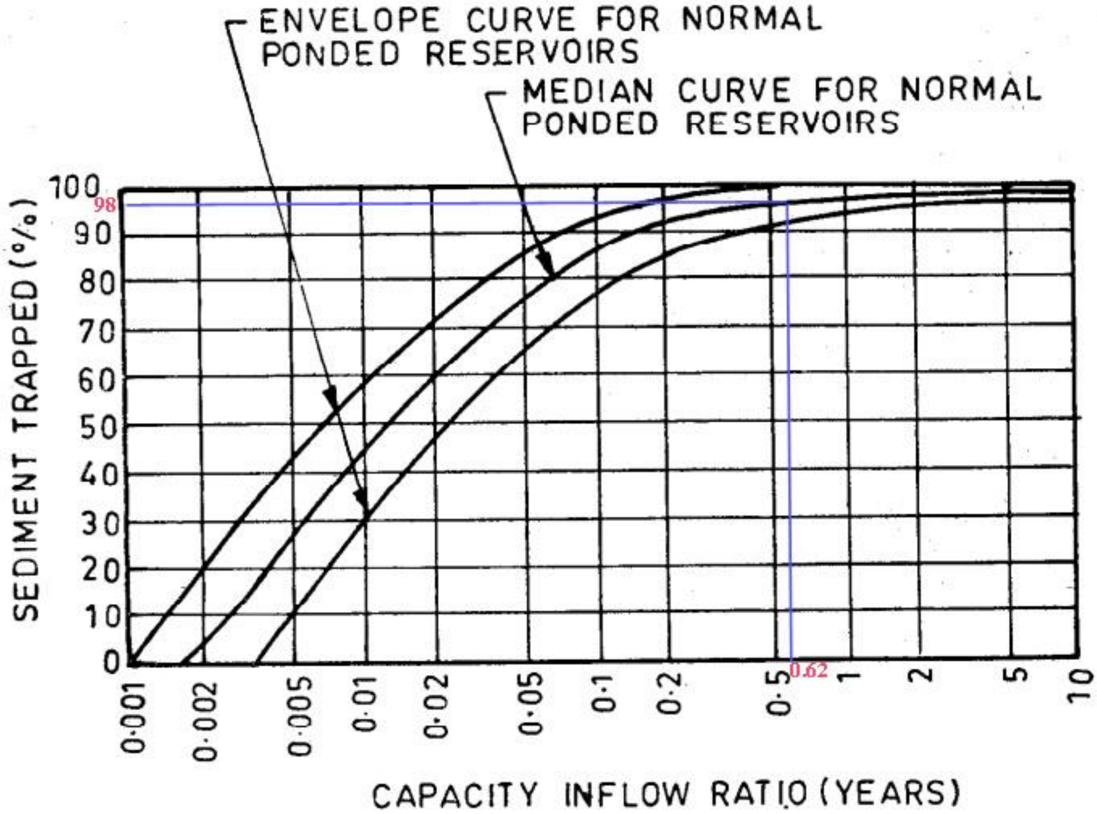


Figure 4.22: Brune's curve (redrawn from brune, 1953)

Full supply level = 1950.46 masl

Average annual runoff volume at Megech = 335 million m3

Storage capacity of the reservoir at FSL = 206 million m3

With these information trap efficiency of Megech was estimated to be 98% (Figure 4.22) based on Brune’s method.

4.6.2 Specific weight of sediment deposit

Sediment load usually expressed in terms of its dry weight basis, however, to estimate the volume occupied by a given weight of sediment, it is necessary to know the specific weight of deposited sediment. The specific weight is expressed as the ratio of dry weght of the sediment (tonnes) in unit volume (m^3) of sediment deposit in the reservoir. The specific weight or sediment deposits depends upon the composition, reservoir operation and consolidation undergone by the deposit time.

Lara and Pemberton (1963) developed an empirical method for estimating the initial specific weight of sediment deposits based on the analysis of some 1300 sample from reservoirs.
Lara- Pamberton equation is given as:

$$W = WcPc + WmPm + WsPs \text{ .... Eqn. (4.1)}$$

Where, W is the deposit specific weight in kg/m^3; W_C, Wm and Ws are initial weights for clay, silt and sand respectively; Pc, Pm andPs are percentages of clay, silt and sand respectively

Table 4.24: Cofficent B and intial weight values for consolidation calculation

Reservoir operation	Clay		Silt		Sand	
	Wc(kg/m^3)	B	Wm(kg/m^3)	B	Ws(kg/m^3)	B
Continuously submerged	416	256	1120	91	1150	0
Peridic drawdown	516	135	1140	29	1150	0
Resrevoir normally empty	641	0	1150	0	1150	0

The average density of all sediment deposited during t years of consolidation may be Computed using the equation presented by Milller (1953) (Morris and Fan, 1997).

$$W_t = W + 0.04343B\left(\frac{t}{t-1}(\ln t) - 1\right) \text{ ---------------- (Eqn. 4.2)}$$

Where, W_t is average specific weight of deposit with an age of t years, W is initial specific weight and B is constant which depends on particle size and reservoir operation

For the composition of sediment in the Blue Nile; Sand (0.02-0.2 mm) ~22%, Silt (0.002-0.02 mm) ~ 38% and Clay (< 0.002 mm) ~ 40 %.(Tufa, 2013) and continuously submerged reservoir, initial specific weight can be estimated as 0.846 t/m3. The average deposit density of sediment deposit in Megech equals 1.12 t/m^3 in about 250 years according to Miller, 1953

4.6.3 Sediment distribution in Megech reservoir

In order to evaluate the sediment distribution within the reservoir, the Empirical Area Reduction method, developed by Borland and Miller (1958) with revisions by Lara (1962) and Pamberton (1978), was used. This method as briefly described in the previous section predicts deposition by taking into account the reservoir shape, the total amount of deposited sediment, on the size and texture of sediment particles as well as on the type of reservoir operation.

The shape of the reservoir characterized by the depth to capacity relationship is considered the major factor in determining the sediment distribution within the reservoir. The adopted classification of reservoir shape depends on m-values which is the reciprocal of the slope of the depth (as ordinate) versus the reservoir capacity (as abscissa) curve on log-log plot. The m-value for Megech reservoir was found to be 2.19 which according to this method categorize the reservoir as type III (Hill).

The Elevation-Area-Storage relationship data for minimum water level and full supply level obtained from WWDS design report. The Elevation-Area-Storage data for 1 m elevation interval is given in Appendix F, Table 7.10.

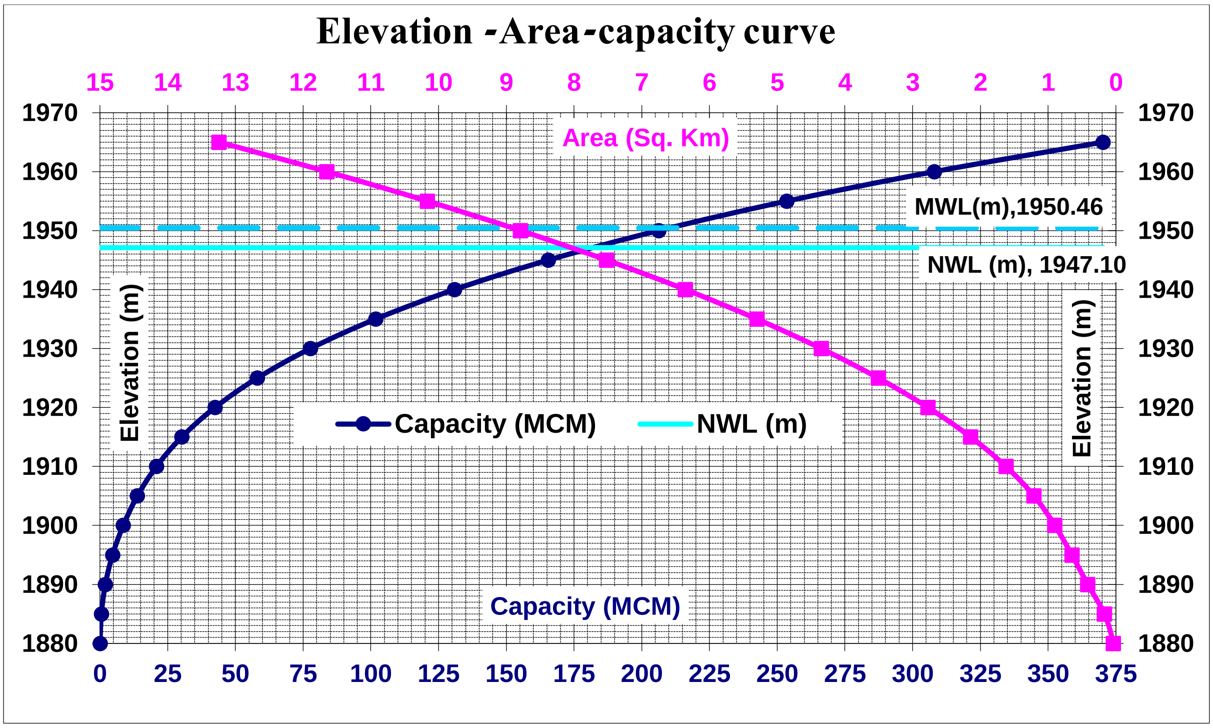


Figure 4.23 : Elevation - Area -Capacity relationship curve before sedimentation

Due to deposition of sediments in the reservoir, the water-spread area at an elevation keeps on decreasing. Using the Empirical Area Reduction method, the water-spread area and storage capacity at different reservoir levels was determined. By comparing the original and revised elevation-capacity curves, the amount of capacity lost to sedimentation was assessed

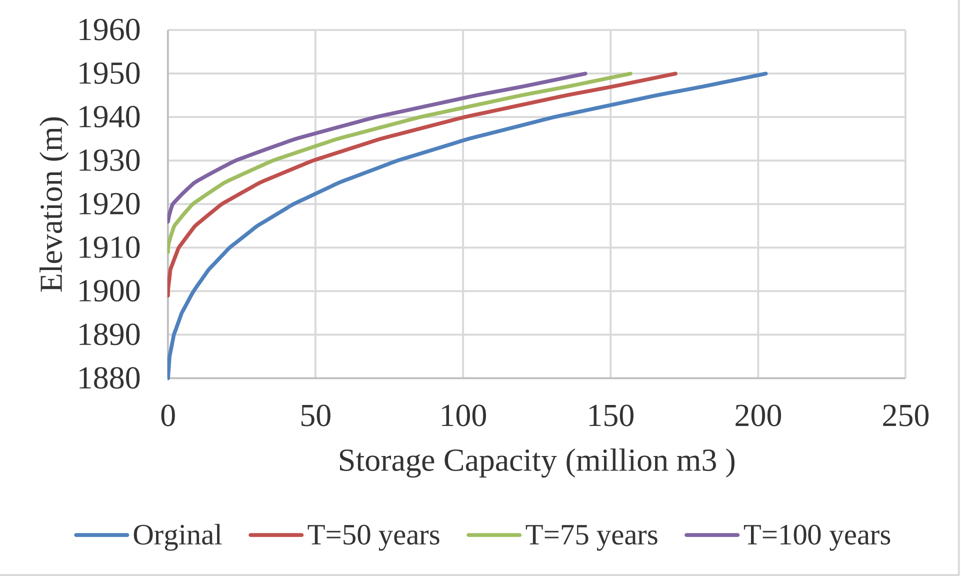


Figure 4.24: The original and adjusted Elevation-Capacity-Curves for Megech reservoir (using 2015 land use)

With the gradual deposition of sediment both in live and dead storage, the reservoir operates with reduced water supply until the dead storage is completely filled with sediment. According to the Empirical Area Reduction method, (Figure 4.24) the Megech reservoir will have useful life of **78** years for the estimate average annual sediment load of 557 thousand tones which is output from Swat model using land use 2015 simulation from 2003 to 2015, trap efficiency of 98% and average deposit density 1.12 t/m^3. The reservoir storage capacity will be lost at an average rate of 0.33 % per year.

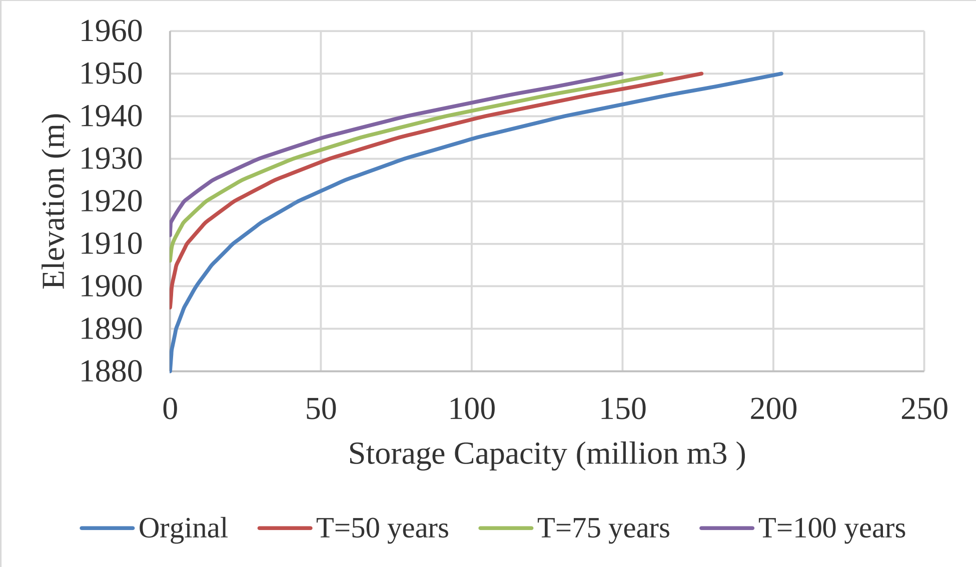


Figure 4.25: The original and adjusted Elevation -Capacity Curves for Megech reservior (using 2006 land use)

With the gradual deposition of sediment both in live and dead storage, the reservoir operates with reduced water supply until the dead storage is completely filled with sediment. According to the Empirical Area Reduction method, (Figure 4.25) the Megech reservoir will have useful life of **90** years for the estimate average annual sediment load of 482 thousand tones which is output from Swat model using land use 2006 simulation from 2003 to 2015, trap efficiency of 98% and average deposit density 1.12 t/m^3. The reservoir storage capacity will be lost at an average rate of 0.29 % per year

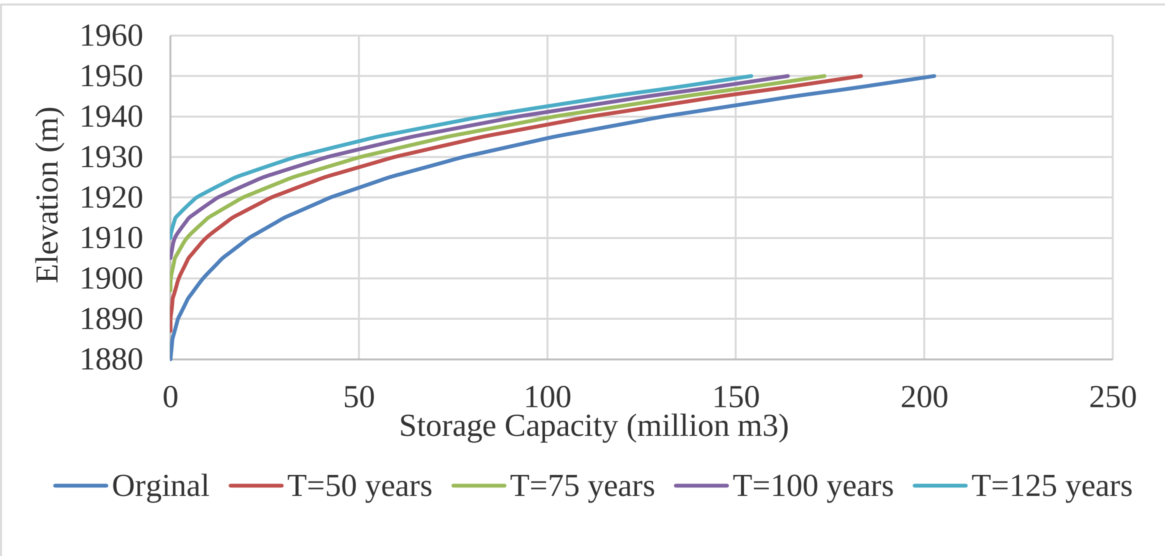


Figure 4.26: The original and adjusted Elevation-Capacity Curves for Megech reservoir (using Land use 1986)

With the gradual deposition of sediment both in live and dead storage, the reservoir operates with reduced water supply until the dead storage is completely filled with sediment. According to the Empirical Area Reduction method, (Figure 4.26) the Megech reservoir will have useful life of **125** years for the estimate average annual sediment load of 354 thousand tones which is output from Arc Swat 2012 using land use 1986 simulation from 2003 to 2015, trap efficiency of 98% and average deposit density 1.12 t/m^3. The reservoir storage capacity will be lost at an average rate of 0.21 % per year.

4.7 Reducing sediment inflow to reservoir

In the upstream watershed of a reservoir implementing watershed management and soil conservation measures substantially reduce erosion and thereby decrease the sediment inflow to the stream system. These measures include practices such as contour farming and terracing; strip cropping, crop rotation, no-till farming, bank protection works, filter strips, stone bunds and reforestation However, any implementation of watershed management measures to reduce sediment yields involves the use of resources and willingness of decision makers

Betrie et al.(2011) evaluate sediment yield simulations in the Upper Blue Nile under different Best Management Practice scenarios The results showed that applying filter strips, stone bunds and reforestation scenarios reduced the current sediment yields both at the sub basins and the basin outlets The simulation of filter strips scenario reduced the total sediment yield by 44% .The simulation of stone bunds scenario reduced the total sediment yield by 41% and the simulation of reforestation scenario showed the least reduction of total sediment loads, which is 11% reduction. The effectiveness of each Best Management Practice, however, depends upon the percentage of land available, and local topographical conditions in the basin. The potential effect of the Best Management Practices could be obtained by implementing reforestation in steep areas, and filter strips and stone bunds in low slope areas of the catchment. These results indicate that applying Best Management Practice could be effective in reducing sediment transport for sustainable water resources management in the basin.

According to the swat model output result in megech watershed the sediment inflow is very high.by implementing the above watershed management measures can reduced sediment inflow, sedimentation and increase the use full life of the reservoir

CHAPETER FIVE

5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In this study, satellite data ERDAS 2014 and ArcGIS 10.2 were integrated with a hydrological model to evaluate the impacts of land use and land cover dynamics on the reservoir sedimentation of the Megech watershed of Lake Tana basin. An integrated approach of ArcGIS and remote sensing are excellent tools to map different land cover classes and to detect and analyses spatiotemporal land use dynamics.These techniques were applied to enable and asses of the land use dynamic effects on the sedimentation of the watershed. The impacts of the land cover change on reservoir sedimentation was analyzed statistically using the hydrological model, SWAT 2012. To do this analysis, first land use and land cover change during the past 30 years (1986 – 2015) was analyzed; then SWAT model were tested for its performance at the Megech watershed in order to examining the sediment response of the watershed to changes in land use and land cover.

The study shows that land use/cover changes in Megech watershed from 1986, 2006 and 2015 were identified from TM, ETM+ and ETM+ satellite images, respectively. ArcGIS and ERDAS used to generate the land use/ cover maps of the year 1986, 2006 and 2015 and the accuracy assessments of the three maps were checked using the error Matrix and kappa statistic.

From the land use/ cover change analysis, it can be concluded that the land use/cover of the Megech watershed for the period of 1986 to 2015 showed significantly changed. In land use / cover map of 1986 the total cultivated land coverage was about 29.57% of the total area of the watershed. It increased rapidly and became 75.67 % of the watershed in 2006 and 88.36 in 2015 land use /cover map respectively. This is mainly because of the population growth that caused the increase in demand for new cultivation land and settlement which in turn resulted shrinking on other types of land use / cover of the area. On the land use and land cover map of the year 1986 the total forest coverage was about 38.56 % of the total area of the watershed. On the land use/ cover map of the year 2006 and 2015 forest coverage reduced to almost 13.38 % and 6.38 % of the total area respectively. This is most probably because of the deforestation activities that have taken place for the purpose of agriculture. The grass land in 1986 land use and land cover map cover 31.42% of total area of the watershed and it reduced to almost 8.8% and 1.82% of total area in 2006 and 2015 land use land cover map respectively. the cultivated land includes areas for crop cultivation and the scatter rural settlement that are closely associated with the cultivated fields dynamically increased in the period of the last 30 years (1986-2015). This might be due to the population pressure has caused a high demand for additional land as a result shortage of cultivated land is the major problem for farmers in the study area.

The SWAT model were used to evaluate the impact of land use dynamics on reservoir sedimentation .Using the three generated land use maps, the same Climate data and other input for the period of 1986 – 2015 three independent model were prepared and then calibrate and validate each model with respected period i.e. for land use 1986 model from 1990-1999, for land use 2006 model from 2000-2007 and for land use 2015 model from 2008-2014. After calibration and validation of each model to show the impact of land use dynamics on sediment load the three independent models runs simulations for the period of 2003-2015.

The performance of the SWAT model was evaluated through sensitivity analysis, calibration, and validation using SWAT-CUP software SUFI 2 program. The most sensitive parameters were identified to be sensitive for the stream flow and sediment yield of the study area and used for model calibration and validation. For stream flow calibration the value of coefficient of determination (R^2) and the Nash-Sutcliffe efficiency (NS) for land use 2015 model were 0.88 and 0.88 respectively, for land use 2006 model were 0.78 and 0.78 respectively and land use 1986 model were 0.85 and 0.85 respectively. For stream flow Validation the value of coefficient of determination (R^2) and the Nash-Sutcliffe efficiency (NS) for land use 2015 model were 0.79 and 0.79 respectively, for land use 2006 model were 0.73 and 0.71 respectively and land use 1986 model were 0.86 and 0.85 respectively, For Sediment load calibration the value of coefficient of determination (R^2) and the Nash-Sutcliffe efficiency (NS) for land use 2015 model were 0.68 and 0.67 respectively, for land use 2006 model were 0.70 and 0.66 respectively and land use 1986 model were 0.69 and 0.64 respectively, For sediment Validation the value of coefficient of determination (R^2) and the Nash-Sutcliffe efficiency (NS) for land use 2015 model were 0.65 and 0.65 respectively, for land use 2006 model were 0.64 and 0.63 respectively and land use 1986 model were 0.62 and 0.61 respectively.

Both the calibration and validation results showed good match between measured and simulated stream flow and sediment load data with acceptable coefficient of determination (R^2) and Nash-Sutcliffe efficiency (ENS)

the result of this study show the annual simulated sediment yield 353,835 tons/year (716.26 tons/km^2/year) using land use 1986, 482,319 tons/year (976.36 tons/km^2/year) using land use 2006 and 557,184 tons/year (1127.90 tons/km^2/year) using land use 2015. This is because of the high expansion of cultivation land over forest and grassland that results in the increase of surface runoff and sediment yield following rainfall events. According to the Empirical Area Reduction method, the Megech reservoir will have life of 78, 90 and 125 year using land use 1986, 2006 and 2015 with sedimentation rate 0.20 %,0.27 % and 0.31 % per year respectively, with trap efficiency 98% and average deposit density 1.12 t/m^3. Generally, the analysis indicated that increasing of sediment load and decrease in useful life of reservoir due to the land cover changes during the study period. By implementing the different watershed management measures (strip cropping, crop rotation, no-till farming, bank protection works, filter strips, stone bunds and reforestation) can reduced sediment inflow, sedimentation and increase the use full life of the reservoir

5.2 Recommendation

Watershed management and conservation practices are recommended to be applied for these severe parts of the watershed area; several measures can be suggested comprising contour farming, terracing, bank protection works ,filter strips, stone bunds and reforestation. Further studies need to examine the effect of different types of best management practices scenario using swat and other model in mitigating the problems of soil erosion and sedimentation.

The other thing which is highly recommended is that the weather stations and hydrological station 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.

Creating awareness among farmers about short-term and long-term impacts of land use/cover change, soil erosion land degradation and designing appropriate strategies that participate farmers in soil and water conservations practices.

Similar studies in other watershed can use this methodology and can improve study by using higher resolution of land sat images, future land use scenario and more meteorological stations for improving model performance.

6 REFERENCE

Abbaspour, K.C. (2007). User manual for SWAT-CUP, SWAT calibration and uncertainty analysis programs. Swiss Federal Institute of Aquatic Science and Technology, Eawag, Duebendorf, Switzerland.

Abbaspour K.C., M. Vejdani, S.Haghighat, (2007), Calibration and Uncertainty Program for SWAT. Swiss Federal Institute of Aquatic science and Technology, Switzerland.

Abbaspour, K. C. (2015). 'SWAT-CUP 2012: SWAT calibration and uncertainty programs- A user manual.' Swiss Federal Institute of Aquatic Science and Technology, Switzerland.

Abbaspour, K.C., Saied A., Vaghefi & Raghuan S. (2017). A guideline for successful calibration &uncertainty analysis for soil and water assessment. A review of papers from the 2016 international SWAT conference. Swiss Federal Institute of Aquatic Science and Technology, Eawag, Duebendorf, Switzerland.

Ahmed, A. A. (2008). Sediment in the Nile River System, UNESCO, Khartoum, Sudan.

Alphan, H. (2003).Land-use change and urbanization of Adana, Turkey.Land Degrad. Dev.14, 575. Analyses for regional hydrological modeling in the drainage basin. Hydrology WRP, and gumara WRP, and gumara catchments

Altunkaynak A. (2009) Sediment load prediction by genetic algorithms. Advances in Engineering Software.

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

Arnold, J.G., R. Sirinivasan, R.S. Muttiah, and J.R. Williams. (1998). Large AreaHydrologic Modeling and Assessment – Part I: Model Development. Journal of the American Water Resources Association (JAWRA) 34(1): 73-89

Arnold, J. G., Kiniry, J. R., Srinivasan, R., Williams, J. R., & Neitsch, S. L. (2011). Soil and water assessment tool: Input/output file documentation version 2009. Texas Water Resources Institute Technical Report No. 365. Texas A&M University System College Station, Texas 77843-2118.

Arnold, J. G., Haney, E.B., Kiniry, J. R., Neitsch, S.L., Srinivasan, R., Neitsch, S. L., & Williams, J. R. (2012). Soil and water assessment tool theoretical documentation version 2012. Texas Water Resources Institute.

Asemamaw Adamu (2013), assessing the impacts of land use land cover change on hydrology of watershed: case study on Gilgel Abbay Watershed, Lake Tana basin, Ethiopia. Baker, J.R., Bgiggs, S.A., Gordon, V., Jones, A.R., Settle, J.J., Townshend, J.R.G., and Wyatt, B.K., 1991.

BCEOM, 1999: Abbay River Basin Integrated Development Master Plan Project: phase 2 data Collection-site Investigation Survey and Analysis for soil, Addis Ababa, Ministry of Water Resources.

Bergstrom, S. (1995). The HBV model. In: Sing, V.P. (Ed), Computer models of watershedhydrology. Water Resources Publications, Colorado. 443-476.

Betrie, G. D., Mohamed, Y. A., Griensven, A. V., & Srinivasan, R. (2011). Sediment management modelling in the Blue Nile Basin using SWAT model. Hydrology and Earth System Sciences.

Borland W.M and Miller C.R. (1958), Distribution of Sediment in Large Reservoir

Bruijnzeel, L. A. and Bremmer, C. N. (1989). Highland-lowland interactions in the Ganges Brahniaputra river basin: A review of published literature. ICIMOD Occasional Paper.

Bruijnzeel, L. (1990). Hydrology of moist tropical forests and effects of conversion: A state of- knowledge review. Paris: UNESCO International Hydrological Program.

Chekol, A. (2006). Modeling of hydrology and soil erosion of upper Awash River basin, Ethiopia. Pub. PhD Thesis. University of Bonn, Germany.

Colwell, R. (1983). Manual of Remote Sensing. American Society of Photogrammetric and Remote Sensing, 2ndedition. Falls Church, VA Advance in classification for and cover mapping using spot HRV images.

Cunderlik. M. (2003).Hydrologic model selection for the CFCAS project: Assessment of Water Resources risk and vulnerability to changing climatic conditions, project report

FAO. (2002). Land-Water Linkages in Rural Watersheds Case Study Series. Food and Agriculture Organization of the United Nations, Rome, Italy.

Fetene, F., Awulachew, S. B., Teklie, N., (2008): Development of Rainfall-Runoff-Sediment discharge relationship in the Blue Nile Basin.

Foster, G. R. and Meyer, L. D. (1977). Soil erosion and sedimentation by water-an Over view" Procs National Symposium on Soil Erosion and Sedimentation by Water, Am. So4c. Of Agric. Eng., St. Joseph, Michigan.

Franklin, S.E., 2003, On Canadian leadership in remote sensing, Canadian Journal of Remote sensing.Green, W.H. and Ampt, G.A. (1911). Studies in Soil Physics, I: The Flow of Air and Water through Soils. Journal of Agricultural Sciences.

Gassman, P. W., Reyes. M. R., Green. C. H., Arnold. J. G. (2007). The Soil and Water Assessment Tool: Historical Development, Applications, and Future Research Direction. American Society of Agricultural and Biological Engineers ISSN.

Gebiaw T., Engidasew Z., Bofu Y., LAN D. and Jae H. (2017), Stream flow and Sediment yield prediction for watershed prioritization in the upper Blue Nile basin, Ethiopia.

Guo, H., Hu, Q., Jiang, T., (2008). Annual and seasonal stream flow responses to climate and land-cover changes in the Poyang Lake basin, China. Journal of Hydrology, vol. 355, 106-122.

Hargreaves, G.L., Hargreaves, G.H., Riley, J.P. (1985). Agricultural benefits for Senegal River basin. Journal of irrigation and Drainage Engineering. 111(2): 113-124

Hurni, H., (1983). Soil erosion and soil formation in agricultural ecosystems in Ethiopia and Northern Thailand. Mountain research and development 1983; 3(2):131-142.

Jensen J. R., (2005). "Introductory Digital Image Processing: A Remote Sensing Perspective," In: K. C. Clarke, Ed., 3rd Edition, Prentice Hall, the United States of America.

Julien, P. Y. (1998). "Erosion and sedimentation" Cambridge University Press, Cambridge, New York.

Lara J.M. (1962), Revision of the procedure of sediment distribution in large reservoirs, US Bureau of Reclamation, Denver, Colorado.

Lillesand, T. and R. Kiefer. (2004). Remote Sensing and Image Interpretation.Fifth Edition. John Wiley & Sons, Inc, New York.

Manandhar, R., Odeh, I., and Ancev, T. (2009). Improving the Accuracy of Land use and land cover classification of Landsat Data using Post-Classification Enhancement.

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

Meyer. L. D. and W. H. Wischmeier. 1969. Mathematical simulation of process of soil Erosion by water. Transaction of the ASAE, 12.

Monserud, Robert A, & Leemans, Rik. (1992). Comparing global vegetation maps with the Kappa statistic.Ecological Modelling.

Monteith, J. (1965). Evaporation and the environment. In The state and movement of water in living organisms, Sixth Symposium. Soc. For Exp. Biol. Swansea, Cam- bridge University Press.

Moriasi, D.N., Arnold, J.G., Van Liew, M.W., Binger, R.L., Harmel, R.D., Veith, T. (2007). Model evaluation guidelines for systematic quantification of accuracy in watershed simulations.Transactions of the American Society of Agricultural and Biological Engineers.

Morris, G. L., & Fan, J. (1998). Reservoir sedimentation handbook: design and management of dams, reservoirs, and watersheds for sustainable use (Vol. 9). New York: McGraw-Hill.

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

Monserud, Robert A, & Leemans, Rik. (1992). Comparing global vegetation maps with the Kappa statistic.Ecological Modelling.

Neitsch, S. L., Arnold, J. G., Kiniry, J. R., & Williams, J. R. (2011). Soil and water assessment tool theoretical documentation version 2009. Texas Water Resources Institute.

Nurelegn M. and Amare S. (2014), Land use/cover Dynamics in Ribb watershed, north western Ethiopia, Bahir Dar University, Ethiopia.

Pavanelli. D. and Palgliarani A. (2002), Monitoring water flow, turbidity and suspended Sediment load, from an Apennine catchment basin, Italy. Bio systems engineering.

Pemberton E.L. (1978), Reservoir Sedimentation, Proceeding of the US- Japan Seminar on Sedimentation and Erosion, Honolulu, Hawaii.

Peng G.,pengteici, Baili Z, Guangio Z.,Wenyi S.,Xingmin M.(2017) ,Use of Double Mass Curves in Hydrological Benefit Evaluations.

Priestley, C.H.B. and R.J. Taylor. (1972). On the Assessment of Surface Heat Flux and Evaporation Using Large Scale Parameters. Mon. Weath. Rev. 100:8192. Project: A comparison on USDA-ARS experimental watersheds.

Thapaand R. B. and Murayama Y. (2009). Urban Mapping, Accuracy, & Image Classification: A Comparison Multiple Approaches in Tsukuba City, Japan," Applied Geography.

Tadele Kassa, K., (2007). Impact of Land use/cover change on stream flow: the case of Hare River Watershed, Ethiopia. Arba Minch Water Technology Institute, Arbaminch University, Ethiopia.

Tadesse Tufa (2013), Sedimentation and Sustainability of Hydropower Reservoirs: cases of Grand Ethiopian Renaissance Dam on the Blue Nile River, Ethiopia, Norwegian University of science and technology, Norwegian.

Tesfahunegn, G.B., Vlek, P.L.G., Tamene, L., (2012). Management strategies for reducing soil degradation through modeling in a GIS environment in northern Ethiopia catchment. Nutrient Cycling in Agroecosystems.

Tibebe, D. and Bewket W. (n.d.). Surface runoff and soil erosion estimation using the SWAT model in the Keleta Watershed, Ethiopia. Land Degradation and Development. http://dx.doi.org/10.1002/1dr.1034.

Tripathi D. and M. Kumar, (2012). Remote Sensing Based Ana- lysis of Land Use/Land Dynamics in Takula Block, Almora District (Uttarakhand), Journal of Human Ecology.

Turner Bl. And Dl. Skole (1994), Global land use/Cover change toward on integrated program of study.

Santhi, C., Arnold, J.G., Williams, J.R., Dugas, W.A., Srinivasan, R. and Hauck, L.M., (2001). Validation of the SWAT model on a large river basin with point and nonpoint sources, Journal of the American Water Resources Association.

Schuol J. and K.C. Abbaspour (2007), Using monthly weather statistics to generate daily data in a SWAT model application to West Africa, Swiss Federal institute of aquatic science and technology, Switzerland.

Setegn S.G. (2008) Hydrological and Sediment Yield Modelling in Lake Tana.

Setegn S.G., R. Srinivasan, B. Dargahi and A.M. Melessa. (2009). Spatial delineation of soil vulnerability in the Lake Tana Basin, Ethiopia. Hydrological Processes. 23, 3738-3750.

Studio Pietrangeli (2005) Gibe III hydropower project. EEPCO.

Tesfahunegn, G.B., Vlek, P.L.G., Tamene, L. (2012). Management strategies for reducing soil degradation through modeling in a GIS environment in northern Ethiopia catchment. Nutrient Cycling in Agroecosystems, 92, pp.255-272.

Tucker C., C. Vanparet, and A. Gaston. (1983). Satellite remote sensing of total dry matter production in the Senegalese Sahel. Remote Sensing Environment.

USBR (1964): Land and Water Resources of the Blue Nile Basin – Ethiopia.

USDA, Soil Conservation Service. (1980). National Engineering Handbook, Section 4: Hydrology. U.S. Government Printing Office, Washington, DC.

USDA-SCS (U.S. Department of Agriculture-Soil Conservation Service), (1972), National Engineering Handbook. Part 630 Hydrology, Section 4, U.S. Government Printing Office, Washington, D.C.

Van Liew, M.W., T.L. Veith, D.D. Bosch, and J.G. Arnold. 2007. Suitability of SWAT for the Conservation Effects Assessment Project: A comparison on USDA ARS watersheds. J. Hydrol. Engr. 12(2): 173-189.

Vanoni, Vito A., 2006: Sedimentation Engineering. American Society of Civil Engineers, Virginia.

VanGriensven, A., Ndomba, P., Yalew, S., & Kilonzo, F. (2012). Critical review of SWAT Applications in the Upper Nile Basin countries. Hydrology and Earth System Sciences.

Van Griensven, A., Meixner, T., Grunwald, S., Bishop, T., Diluzio, M. and Srinivasan, R. (2006). A global sensitivity analysis tool for the parameters of multi-variable catchment models. Journal of Hydrology.

Yevjovich V. and R.I.Jeng (1969), Properties of non- homogenous hydrologic series, Colorado state university, Colorado.

Walling, D. E., (1988).Erosion and sediment yield research – some recent perspectives. Journal of Hydrology.

Water work Design and Supervision Enterprise (2006), Megech Dam Feasibility Study Report, Ethiopia, Addis Ababa.

White W. R., 2010. A Review of Current Knowledge, World Water: Resources, Usage and the Role of Man Made Reservoirs. Foundation of Water Research, Malrow, UK.

Wigmosta, M.S., Vail, L.M., and Lettenmaier.D.P. 1994. Adistributed hydrology vegetation Model for complex terrain Water.

Williams J.R. (1969). Flood routing with variable travel time or variable storage coefficient. Transactions of the ASAE 12(1).

Wischmeier, W.H. and Smith, D.D. (1978) "Predicting rainfall erosion losses –A guide to Conservation planning." U.S. Department of Agriculture handbook No. 537.

Yang J.,Peter R.,Abbaspour K.C, Junxia & Hang Y. (2008) .Comparing uncertainty analysis techniques for swat application to the chaohe basin in china. Institute of Geographical sciences and natural resources research, bejing china.

Yihun T., Louise K., Prasod D., Raghavan S., David W.,Johan R.(2015),Assessing the implications of water harvesting intensification on upper stream – downstream services: a case study in the lake Tana basin, Texas A&M university, USA.

7 APPENDIX

Appendix A: Megech inflow

Table 7.1: Monthly inflow (Mm3) at Megech dam site.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1990	0.325	0.139	0.09	0.07	0.3	1.6	29.6	37	19.1	3.14	1.1	0.69	93.1
1991	0.361	0.227	0.31	0.57	0.3	7.4	12	51	10.9	3.61	1.1	0.96	88.6
1992	0.275	0.156	0.26	1.09	0.7	1.1	20.6	52.2	40.1	6.77	3.4	0.82	128
1993	0.828	0.611	0.68	0.76	2.2	8.9	23.9	64.9	35.9	11.8	3.2	0.81	154
1994	0.866	0.373	0.25	0.22	1	6.5	31.4	107	32.5	4.1	2.3	1.26	188
1995	0.673	0.414	0.42	0.38	2.5	9.1	32.2	117	17	1.25	0.4	0.25	182
1996	0.076	0.036	0.03	0.5	4	30	40.9	89	20.3	5.51	2.6	1.29	194
1997	0.796	0.472	0.51	0.5	2.9	16	61.1	51.8	11.1	7.72	4.1	1.36	158
1998	0.549	0.403	0.58	0.52	1	5.6	66.6	90.8	41.5	15.5	2.9	5.46	231
1999	4.747	3.506	3.72	3.89	8.1	7.4	32.1	95.9	47.2	28.9	16	12.4	264
2000	10.17	6.725	7.58	10.4	10	13	34	71.4	32.2	23.5	12	9.77	242
2001	8.273	7.858	11.9	11.8	15	6.7	59.1	115	24.8	7.33	3.8	1.49	273
2002	0.996	0.526	0.59	0.37	0.8	3.4	48	50.7	19	7.12	5.4	4.45	141
2003	3.539	3.162	3.35	2.91	2.9	17	44.9	104	30.5	13	7.4	6.3	239
2004	4.263	3.805	3.77	5.43	3.8	10	55.7	90.9	23.6	16.2	9.5	7.94	235
2006	6.801	5.671	7.38	6.18	6.5	42	39	87.9	48.8	21.4	13	9.71	294
2007	8.366	7.088	7.52	7.41	11	5.6	63.8	157	62.3	28.1	18	14.2	391
2008	16.98	13.39	13.7	15.8	25	70	91.5	199	82.6	33.1	21	15.3	597
2009	17.34	14.99	20.5	17	16	30	125	166	88.5	40.5	26	24.9	587
2010	23.69	20.29	21.9	22.7	29	41	62.1	275	90.8	33.8	26	21.3	666
2011	19.88	16.03	17.8	16.7	28	59	89.1	309	90.7	33.7	42	33.4	756
2012	30.47	25.51	26	23.7	27	56	238	203	96.4	26.2	35	26.6	814
2013	20.69	17.52	17.7	13.4	22	34	135	169	72.1	34.5	24	17.2	577
2014	15.84	12.44	22.8	21.8	40	22	79.4	164	81.3	32.6	26	15.4	534
Avg.	8.199	6.722	7.89	7.67	11	21	63.1	122	46.6	18.3	13	9.72	334

Appendix B1: Soils parameters and legend used in SWAT model
Table 7.2: Soil Parameter Legend

NLAYERS	Number of layers in the soil (min 1 and max 10)
HYDGRP	Soil hydrographic group (A, B, C, D)
SOL_ZMX	Maximum root depth of the soil profile (mm)
TEXTURE	Texture of the layer
SOIL_Z	Minimum depth from soil surface to bottom of layer (mm)
SOL_BD	Moist bulk density (g/cm$_3$)
SOL_AWC	Available water capacity of soil surface to bottom of the layer(mm/mm)
SOL_K	Saturated hydraulic conductivity (mm/hr.)
SOL_CBN	Organic carbon content (%)
CLAY	Clay content (%)
SILT	Silt content (%)
SAND	Sand content (%)
USLE_K	Soil erodibility (K factor)

Appendix B2: Soil Parameters of the study area used in Swat Model
Table 7.2: Soil Parameters

SNAM	Symbol	NLAYERS	HYDGRP	SOL_ZMX	TEXTURE	SOL_Z	SOL_BD	SOL_AWC	SOL_K	SOL_CBN	CLAY	SILT	SAND	ROCK	SOL_ALB	USLE_K
Chromic Luvisols	LVx	7	B	1800	SiL	210	1.45	0.22	38.4	1.2	11	67	22	0	0.13	0.3
						260	1.46	0.21	37.2	0.3	14	66	20	0	0.13	0.3
						460	1.45	0.2	34.8	0.21	19	59	22	0	0.13	0.3
						650	1.49	0.2	33.6	0.2	22	56	22	0	0.13	0.3
						950	1.48	0.2	36	0.2	17	57	26	0	0.13	0.3
						1350	1.49	0.2	36	0.12	17	57	26	0	0.13	0.3
						1800	1.47	0.21	36	0.1	16	59	25	0	0.13	0.3
Eutric Vertisols	VRe	7	C	2422.4	C	181.68	1.1	0.11	4.34	1.47	60.6	23.3	16.1	0	0.09	0.2
						363.4	1.27	0.11	4.54	1.37	60.6	18.6	20.8	0	0.09	0.2
						847.85	1.28	0.11	5.16	1.41	62.6	17	20.4	0	0.09	0.3
						1029.5	1.22	0.11	4.24	0.88	62.8	8.4	28.8	0	0.09	0.3
						1392.9	1.13	0.11	4.34	1.17	62.6	9.4	28	0	0.09	0.3
						1635.2	1.1	0.11	4.24	1.24	60	12.7	27.3	0	0.09	0.2
						2422.4	1.1	0.09	4.04	0.34	63.6	16.6	19.8	0	0.09	0.3
Haplic Nitisols	NTh	4	D	2000	C-SiL	200	1.1	0.11	4.34	2	50	33	17	5	0.13	0.22
						900	1.27	0.11	4.54	1.5	23	50	27	0	0.13	0.22
						1000	1.28	0.11	5.16	1.3	60	25	15	0	0.13	0.22
						1000	1.22	0.11	4.24	0.5	71	20	9	0	0.13	0.22
Eutric Leptosols	LPe	2	C	650	CL	200	1.1	0.11	25	2	50	34	17	5	0.13	0.22
						650	1.23	0.1	13	1.1	66	14	20	0.01	0.13	0.22

Appendex C: Parameter initial and final value

Table 7.3: For 2015 land use model flow calibration

Parameter Name	Description of parameters	Final Fitted Value	Initial Range of Value
R CN2.mgt	SCS runoff curve number	-0.11	±25
V ALPHA_BF.gw	Baseflow alpha factor	0.02	0-1
V GW_DELAY.gw	Groundwater delay	155.13	0-500
V GWQMN.gw	Threshold depth of water in the shallow aquifer for return flow	3032.86	0-5000
V GW_REVAP.gw	Groundwater revap coefficient	0.26	0-0.2
V ESCO.hru	Soil evaporation compensation factor	0.89	0-1
V CH_N2.rte	Manning's "n" value for the main cha	0.02	0.01-0.3
V CH_K2.rte	Effective hydraulic conductivity in	77.83	0.01-500
V REVAPMN.gw	Threshold depth of water in the	0.38	0-1000
R SOL_AWC (...).sol	Available water content of soil	131.04	0-1

Table 7.4: For 2006 land use model flow calibration

Parameter Name	Description of parameters	Final Fitted Value	Initial Range of Value
R CN2.mgt	SCS runoff curve number	-0.27	±25
V ALPHA_BF.gw	Baseflow alpha factor	0.44	0-1
V GW_DELAY.gw	Groundwater delay	455.00	0-500
V ESCO.hru	Soil evaporation compensation factor	1224.50	0-1
V GW_REVAP.gw	Groundwater revap coefficient	0.30	0-0.2
V GWQMN.gw	Threshold depth of water in the shallow aquifer for return flow	0.94	0-5000
R SOL_AWC (...).sol	Available water content of soil	0.15	0-1
V CH_K2.rte	Effective hydraulic conductivity in the main channal	119.38	0.01-500
V REVAPMN.gw	Threshold depth of water in the shallow	0.42	0-1000
V CH_N2.rte	Manning's "n" value for the main cha	57.07	0.01-0.3

Table 7.5: For 1986 land use model flow calibration

Parameter Name	Description of parameters	Final Fitted Value	Initial Range of Value
V CN2.mgt	SCS runoff curve number	-0.44	±25
V ALPHA_BF.gw	Baseflow alpha factor	0.19	0-1
V GW_DELAY.gw	Groundwater delay	178.09	0-500
V ESCO.hru	Soil evaporation compensation factor	4032.86	0-5000
V GW_REVAP.gw	Groundwater revap coefficient	0.05	0-0.2
V GWQMN.gw	Threshold depth of water in the shallow aquifer for return flow	0.96	0-1
R SOL_AWC (...).sol	Available water content of soil	0.16	0.01-0.3
V CH_K2.rte	Effective hydraulic conductivity in the	195.23	0.01-500
V REVAPMN.gw	Threshold depth of water in the	457.81	0-1000
V CH_N2.rte	Manning's "n" value for the main cha	0.33	0-1

Table 7.6: For 2015 land use model Sediment calibration

Parameter Name	Description of parameters	Final Fitted Value	Initial Range of Value
V_ USLE_K .sol	USLE soil erodibility factor	0.2697	0-0.65
V _ USLE_P.mgt	USLE support practice factor	1.39E-01	0-1
V_ SPEXP.bsn	Exponential re-entrainment parameter	1.33E+00	1-1.5
V _CH_COV2.rte	Channel cover factor	1.407	0.001-1
V_ CH_COV1.rte	Channel erodibility factor	0.219	0.05-0.6
R _ RSDIN.hru	Initial residue cover [kg/ha]	479	0-10000
V_SPCON.bsn	Linear re-entrainment parameter for channel sediment routing	0.002611	0.0001-0.01

Table 7.8: For 2006 land use model Sediment calibration

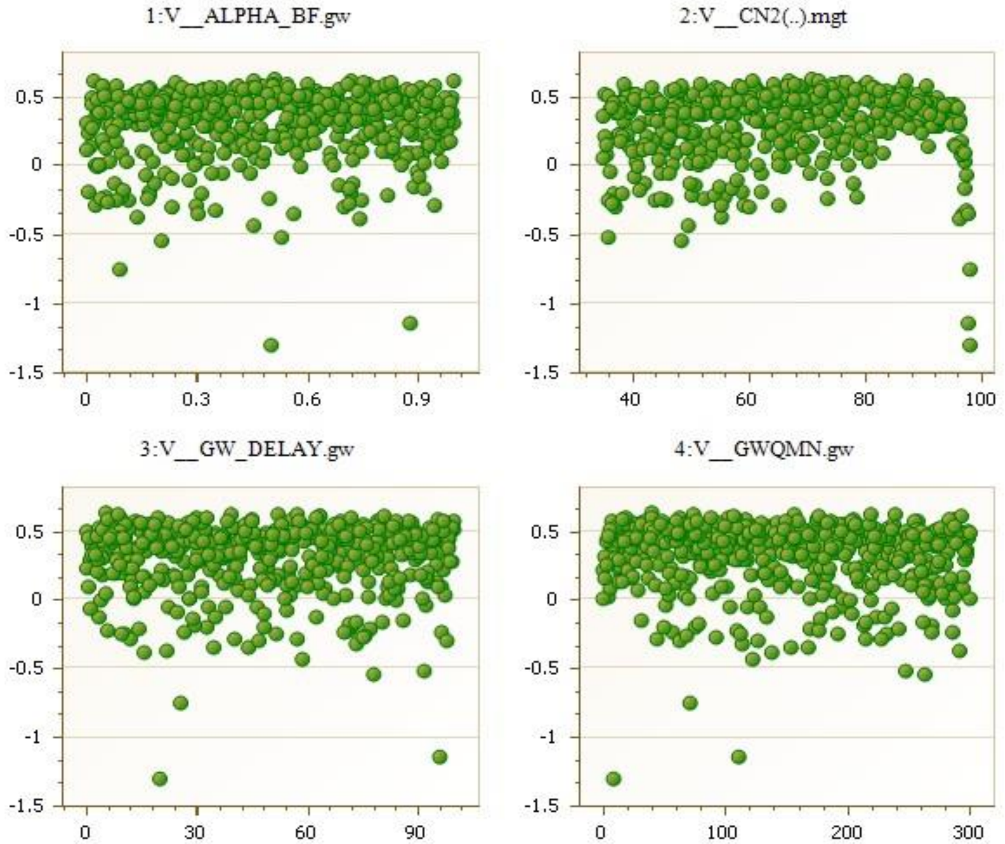
Parameter Name	Description of parameters	Final Fitted Value	Initial Range of Value
V_ USLE_K .sol	USLE soil erodibility factor	0.59	0-0.65
V _ USLE_P.mgt	USLE support practice factor	7.20E-01	0-1
V_ SPEXP.bsn	Exponential re-entrainment parameter	1.39E+00	1-1.5
V_SPCON.bsn	Linear re-entrainment parameter for channel sediment routing	0.009437	0.0001-0.01
V_ CH_COV1.rte	Channel erodibility factor	0.280255	0.05-0.6
R _ RSDIN.hru	Initial residue cover [kg/ha]	620.55	0-10000
V _CH_COV2.rte	Channel cover factor	0.413	0.001-1

Table 7.9: For 1986 land use model Sediment calibration

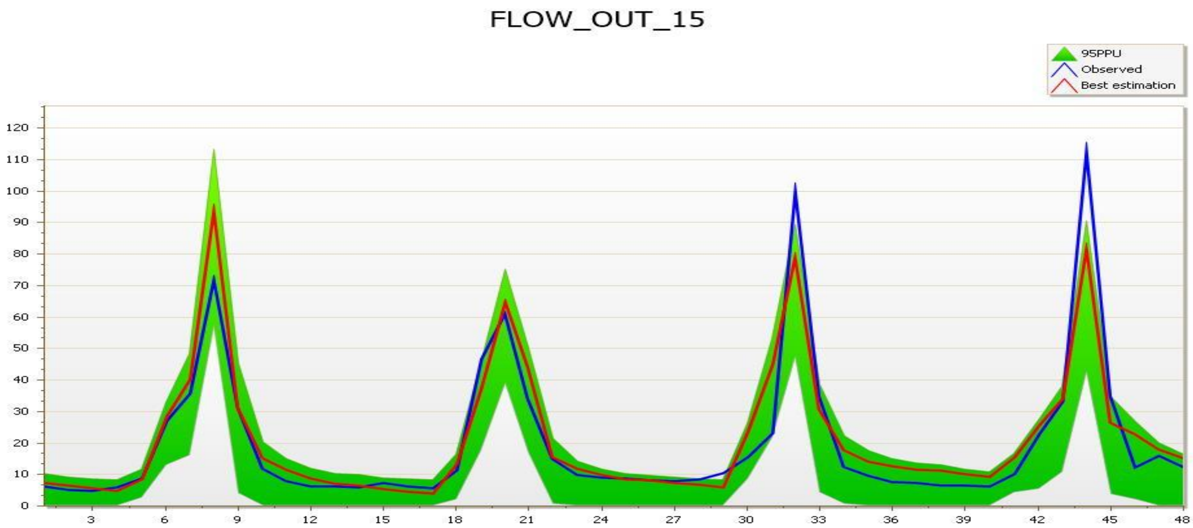
Parameter Name	Description of parameters	Final Fitted Value	Initial Range of Value
V_ USLE_K .sol	USLE soil erodibility factor	0.13	0-0.65
V _ USLE_P.mgt	USLE support practice factor	1.75E-01	0-1
R _ RSDIN.hru	Initial residue cover [kg/ha]	894.6	0-10000
V _CH_COV2.rte	Channel cover factor	0.188	0.001-1
V_ SPEXP.bsn	Exponential re-entrainment parameter	1.27319	1-1.5
V_ CH_COV1.rte	Channel erodibility factor	0.314	0.05-0.6
V_SPCON.bsn	Linear re-entrainment parameter for channel sediment routing	0.0027	0.0001-0.01

Appendex C2: Parameter sensitivity

Dotty plots



95PPU plot



Appendix D: Sedment Concentraton at megech gauge station

Table 7.8: Sediment concentration data

River	Station	Date of Sampling	Time Taken (Sec)	G/height (m)	Flow (m^3/s)	Depth (m)	Width (m)	Sediment Conc.(mg/l)
Megech	Azezo	21-Feb-90	59	0.74	0.044	0.10	0.700	186.76
Megech	Azezo	21-Feb-90	61	0.74	0.044	0.09	1.700	177.06
Megech	Azezo	21-Feb-90	60	0.74	0.044	0.04	2.500	229.99
Megech	Azezo	10-Aug-90	25	1.29	8.960	0.660	12.000	594.06
Megech	Azezo	10-Aug-90	25	1.29	8.960	0.35	18.000	451.56
Megech	Azezo	27-May-92	35	0.75	0.046	0.03	0.400	368.00
Megech	Azezo	27-May-92	31	0.75	0.046	0.10	0.800	368.00
Megech	Azezo	27-May-92	27	0.75	0.046	0.17	1.200	315.00
Megech	Azezo	14-May-93	68	0.83	0.192	0.33	1.100	454.52
Megech	Azezo	14-May-93	20	0.83	0.192	0.36	2.300	628.70
Megech	Azezo	14-May-93	6	0.83	0.192	0.21	2.500	528.90
Megech	Azezo	6-Oct-94	37	1.00	2.610	0.57	2.200	253.24
Megech	Azezo	6-Oct-94	38	1.00	2.610	0.58	4.200	188.67
Megech	Azezo	6-Oct-94	40	1.00	2.610	0.36	6.200	245.37
Megech	Azezo	11-Mar-05	70	1.09	0.108	0.30	1.00	300.00
Megech	Azezo	11-Mar-05	45	1.09	0.108	0.35	2.00	289.43
Megech	Azezo	2-Sep-05	11	1.60	9.614	0.74	6.00	277.68
Megech	Azezo	2-Sep-05	13	1.60	9.614	0.54	12.00	280.75
Megech	Azezo	2-Sep-05	22	1.60	9.614	0.32	18.00	204.87
Megech	Azezo	3-Sep-05	11	1.57	9.782	0.74	6.00	191.58
Megech	Azezo	3-Sep-05	10	1.57	9.782	0.52	12.00	210.99
Megech	Azezo	3-Sep-05	12	1.57	9.782	0.24	18.00	213.42
Megech	Azezo	4-Sep-05	10	1.54	8.665	0.70	6.00	189.43
Megech	Azezo	4-Sep-05	9	1.54	8.665	0.49	12.00	223.06
Megech	Azezo	4-Sep-05	9	1.54	8.665	0.34	18.00	204.35
Megech	Azezo	15-Aug-07	8	1.86	17.236	1.95	3.00	564.06
Megech	Azezo	15-Aug-07	9	1.86	17.236	1.46	6.00	650.00
Megech	Azezo	15-Aug-07	15	1.86	17.236	0.91	9.00	529.19
Megech	Azezo	16-Aug-07	9	2.22	45.996	2.44	4.00	2361.52
Megech	Azezo	16-Aug-07	9	2.22	45.996	1.49	8.00	2070.91
Megech	Azezo	16-Aug-07	14	2.22	45.996	0.85	12.00	1681.16
Megech	Azezo	18-Aug-07	7	2.25	49.332	2.50	4.00	2441.94
Megech	Azezo	18-Aug-07	8	2.25	49.332	1.52	7.50	2671.01
Megech	Azezo	18-Aug-07	13	2.25	49.332	0.91	11.50	2310.27
Megech	Azezo	19-Aug-07	18	1.90	21.405	0.85	3.00	628.62
Megech	Azezo	19-Aug-07	10	1.90	21.405	1.46	6.00	504.74

Megech	Azezo	19-Aug-07	10	1.90	21.405	1.46	6.00	504.74
Megech	Azezo	19-Aug-07	7	1.90	21.405	0.88	9.00	382.29
Megech	Azezo	20-Aug-07	10	1.90	23.985	6.60	4.00	581.00
Megech	Azezo	20-Aug-07	17	1.90	23.985	3.80	8.00	852.05
Megech	Azezo	20-Aug-07	29	1.90	23.985	2.00	12.00	709.87
Megech	Azezo	21-Aug-07	7	2.16	41.816	7.40	4.00	1004.72
Megech	Azezo	21-Aug-07	8	2.16	41.816	4.90	8.00	1261.43
Megech	Azezo	21-Aug-07	7	2.16	41.816	2.80	12.00	1198.84
Megech	Azezo	22-Nov-07	35	1.32	0.701	0.30	3.00	301.43
Megech	Azezo	22-Nov-07	34	1.32	0.701	0.46	6.00	262.86
Megech	Azezo	22-Nov-07	45	1.32	0.701	0.42	9.00	255.00
Megech	Azezo	17-Aug-10	15	2.060	21.991	2.16	4.000	609.75
Megech	Azezo	17-Aug-10	20	2.060	21.991	1.25	8.000	930.00
Megech	Azezo	17-Aug-10	23	2.060	21.991	0.79	12.000	978.00
Megech	Azezo	18-Aug-10	14	2.000	20.277	2.01	3.500	983.21
Megech	Azezo	18-Aug-10	18	2.000	20.277	1.40	7.000	776.10
Megech	Azezo	18-Aug-10	37	2.000	20.277	0.73	10.500	886.25
Megech	Azezo	14-Oct-11	57	1.600	1.559	0.32	2.400	133.01
Megech	Azezo	14-Oct-11	42	1.600	1.559	0.52	4.950	148.68
Megech	Azezo	14-Oct-11	_	1.600	1.559	0.54	7.450	113.08
Megech	Azezo	15-Oct-11	60	1.580	1.480	0.34	2.400	258.29
Megech	Azezo	15-Oct-11	38	1.580	1.480	0.60	5.400	130.37
Megech	Azezo	15-Oct-11	48	1.580	1.480	0.54	7.900	183.49
Megech	Azezo	24-May-14	20	1.60	4.404	0.44	8.850	2115.44
Megech	Azezo	24-May-14	25	1.60	4.404	0.34	16.850	2119.04
Megech	Azezo	24-May-14	25	1.60	4.404	0.48	23.850	2073.58
Megech	Azezo	26-Jun-14	40	1.32	0.782	0.28	6.000	3730.77
Megech	Azezo	26-Jun-14	46	1.32	0.782	0.18	12.500	3597.21
Megech	Azezo	26-Jun-14	32	1.32	0.782	0.25	17.500	3780.86

Appendix E: Sedment Rating Curve at megech gauge station

Table 7.9: Sediment Rating Curve

River	Station	Date	Flow (m^3/s)	Sediment Conc.(mg/l)	Sediment tone/day
Megech	Azezo	21-Feb-90	0.04	186.76	0.71
Megech	Azezo	21-Feb-90	0.04	177.06	0.67
Megech	Azezo	21-Feb-90	0.04	229.99	0.87
Megech	Azezo	10-Aug-90	8.96	594.06	459.89
Megech	Azezo	10-Aug-90	8.96	451.56	349.57
Megech	Azezo	27-May-92	0.05	368.00	1.46
Megech	Azezo	27-May-92	0.05	368.00	1.46
Megech	Azezo	27-May-92	0.05	315.00	1.25
Megech	Azezo	14-May-93	0.19	454.52	7.54
Megech	Azezo	14-May-93	0.19	628.70	10.43
Megech	Azezo	14-May-93	0.19	528.90	8.77
Megech	Azezo	6-Oct-94	2.61	253.24	57.11
Megech	Azezo	6-Oct-94	2.61	188.67	42.55
Megech	Azezo	6-Oct-94	2.61	245.37	55.33
Megech	Azezo	11-Mar-05	0.11	300.00	2.80
Megech	Azezo	11-Mar-05	0.11	289.43	2.70
Megech	Azezo	2-Sep-05	9.61	277.68	230.65
Megech	Azezo	2-Sep-05	9.61	280.75	233.20
Megech	Azezo	2-Sep-05	9.61	204.87	170.18
Megech	Azezo	3-Sep-05	9.78	191.58	161.92
Megech	Azezo	3-Sep-05	9.78	210.99	178.32
Megech	Azezo	3-Sep-05	9.78	213.42	180.38
Megech	Azezo	4-Sep-05	8.67	189.43	141.82
Megech	Azezo	4-Sep-05	8.67	223.06	167.00
Megech	Azezo	4-Sep-05	8.67	204.35	152.99
Megech	Azezo	15-Aug-07	17.24	564.06	839.99
Megech	Azezo	15-Aug-07	17.24	650.00	967.97
Megech	Azezo	15-Aug-07	17.24	529.19	788.06
Megech	Azezo	16-Aug-07	46.00	2361.52	9384.81
Megech	Azezo	16-Aug-07	46.00	2070.91	8229.91
Megech	Azezo	16-Aug-07	46.00	1681.16	6681.02
Megech	Azezo	18-Aug-07	49.33	2441.94	10408.24
Megech	Azezo	18-Aug-07	49.33	2671.01	11384.61
Megech	Azezo	18-Aug-07	49.33	2310.27	9847.03
Megech	Azezo	19-Aug-07	21.41	628.62	1162.56
Megech	Azezo	19-Aug-07	21.41	504.74	933.46

Megech	Azezo	19-Aug-07	21.41	382.29	707.00
Megech	Azezo	20-Aug-07	23.99	581.00	1204.01
Megech	Azezo	20-Aug-07	23.99	852.05	1765.71
Megech	Azezo	20-Aug-07	23.99	709.87	1471.07
Megech	Azezo	21-Aug-07	41.82	1004.72	3629.96
Megech	Azezo	21-Aug-07	41.82	1261.43	4557.42
Megech	Azezo	21-Aug-07	41.82	1198.84	4331.29
Megech	Azezo	22-Nov-07	0.70	301.43	18.26
Megech	Azezo	22-Nov-07	0.70	262.86	15.92
Megech	Azezo	22-Nov-07	0.70	255.00	15.44
Megech	Azezo	17-Aug-10	21.99	609.75	1158.54
Megech	Azezo	17-Aug-10	21.99	930.00	1767.02
Megech	Azezo	17-Aug-10	21.99	978.00	1858.22
Megech	Azezo	18-Aug-10	20.28	983.21	1722.52
Megech	Azezo	18-Aug-10	20.28	776.10	1359.68
Megech	Azezo	18-Aug-10	20.28	886.25	1552.65
Megech	Azezo	14-Oct-11	1.56	133.01	17.92
Megech	Azezo	14-Oct-11	1.56	148.68	20.03
Megech	Azezo	14-Oct-11	1.56	113.08	15.23
Megech	Azezo	15-Oct-11	1.48	258.29	33.03
Megech	Azezo	15-Oct-11	1.48	130.37	16.67
Megech	Azezo	15-Oct-11	0.54	183.49	8.56
Megech	Azezo	24-May-14	4.40	2115.44	804.94
Megech	Azezo	24-May-14	4.40	2119.04	806.31
Megech	Azezo	24-May-14	4.40	2073.58	789.01
Megech	Azezo	26-Jun-14	0.78	3730.77	252.07
Megech	Azezo	26-Jun-14	0.78	3597.21	243.04
Megech	Azezo	26-Jun-14	0.78	3780.86	255.45

Appendix F: Elevation –Area- Storage Capacity Relation

Table 7. 10: Elevation –Area-Storage Capacity relation

Elevation masl	Height (m)	Area (km2)	Volume(mill.m3)	Remark
1880	0	0.04	0	Bed level at dam
1881	1	0.066	0.106	
1882	2	0.092	0.212	
1883	3	0.118	0.318	
1884	4	0.144	0.424	
1885	5	0.17	0.530	
1886	6	0.218	0.822	
1887	7	0.266	1.114	
1888	8	0.314	1.406	
1889	9	0.362	1.710	
1890	10	0.41	2.040	
1891	11	0.458	2.522	
1892	12	0.506	3.054	
1893	13	0.554	3.586	
1894	14	0.602	4.118	
1895	15	0.65	4.650	
1896	16	0.7	5.440	
1897	17	0.75	6.230	
1898	18	0.8	7.020	
1899	19	0.85	7.810	
1900	20	0.9	8.670	
1901	21	0.962	9.644	
1902	22	1.024	10.688	
1903	23	1.086	11.732	
1904	24	1.148	12.776	
1905	25	1.21	13.820	
1906	26	1.292	15.226	
1907	27	1.374	16.632	
1908	28	1.456	18.038	
1909	29	1.538	19.444	
1910	30	1.62	20.980	Dead Storage Level
1911	31	1.724	22.724	
1912	32	1.828	24.598	
1913	33	1.932	26.472	
1914	34	2.036	28.346	
1915	35	2.14	30.220	
1916	36	2.266	32.668	
1917	37	2.392	35.116	
1918	38	2.518	37.564	
1919	39	2.644	40.012	
1920	40	2.77	42.460	
1921	41	2.918	45.592	
1922	42	3.066	48.724	
1923	43	3.214	51.856	
1924	44	3.362	54.988	
1925	45	3.51	58.120	
1926	46	3.678	62.038	
1927	47	3.846	65.956	
1928	48	4.014	69.874	
1929	49	4.182	73.792	
1930	50	4.35	77.710	
1931	51	4.54	82.526	
1932	52	4.73	87.342	
1933	53	4.92	92.158	
1934	54	5.11	96.974	
1935	55	5.3	101.790	
1936	56	5.512	107.592	
1937	57	5.724	113.394	
1938	58	5.936	119.196	
1939	59	6.148	124.998	
1940	60	6.36	130.800	
1941	61	6.592	137.744	
1942	62	6.824	144.688	
1943	63	7.056	151.632	
1944	64	7.288	158.576	
1945	65	7.52	165.520	
1946	66	7.774	173.296	
1947	67	8.028	181.072	
1948	68	8.282	188.306	
1949	69	8.536	195.480	
1950	70	8.79	202.654	Full Supply Level

Appendix G: Deposition Pattern

Table 7.11: Depositin pattern for annual sediment load 557 thousend tonnes (land use 2015)

	50yr		75yr		100yr	
Elevation masl	Area Km2	Volume mill.m3	Area Km2	Volume mill.m3	Area Km2	Volume mill.m3
1950	8.790	172.051	8.790	156.787	8.790	141.488
1949	8.536	164.878	8.535	149.614	8.535	134.315
1948	8.280	157.705	8.278	142.442	8.276	127.145
1947	8.023	150.475	8.019	135.215	8.012	119.922
1946	7.764	142.706	7.756	127.452	7.743	112.170
1945	7.504	134.942	7.490	119.700	7.469	104.435
1944	7.264	128.018	7.244	112.793	7.211	97.554
1943	7.023	121.103	6.994	105.902	6.948	90.702
1942	6.779	114.198	6.741	99.031	6.680	83.884
1941	6.534	107.305	6.485	92.182	6.406	77.105
1940	6.288	100.426	6.225	85.359	6.127	70.370
1939	6.059	94.705	5.983	79.707	5.863	64.827
1938	5.830	89.000	5.738	74.086	5.595	59.338
1937	5.599	83.314	5.491	68.499	5.321	53.908
1936	5.366	77.647	5.241	62.950	5.043	48.542
1935	5.132	72.002	4.988	57.439	4.761	43.244
1934	4.919	67.365	4.755	52.957	4.497	39.004
1933	4.705	62.752	4.520	48.518	4.229	34.840
1932	4.490	58.164	4.284	44.125	3.959	30.755
1931	4.274	53.601	4.045	39.780	3.685	26.752
1930	4.057	49.064	3.805	35.483	3.408	22.835
1929	3.861	45.453	3.586	32.136	3.152	19.903
1928	3.665	41.870	3.365	28.840	2.893	17.060
1927	3.469	38.315	3.144	25.598	2.633	14.309
1926	3.272	34.788	2.922	22.408	2.372	11.650
1925	3.074	31.291	2.700	19.273	2.110	9.085
1924	2.897	28.610	2.497	16.979	1.868	7.400
1923	2.720	25.957	2.295	14.739	1.626	5.810
1922	2.543	23.334	2.093	12.553	1.384	4.313
1921	2.366	20.739	1.891	10.421	1.143	2.909
1920	2.189	18.174	1.690	8.343	0.904	1.598
1919	2.035	16.320	1.512	7.001	0.688	1.061
1918	1.882	14.495	1.335	5.710	0.474	0.613
1917	1.730	12.696	1.160	4.469	0.264	0.251
1916	1.578	10.922	0.987	3.276	0	0
1915	1.428	9.174	0.816	2.130	0	0
1914	1.301	8.024	0.668	1.602	0	0
1913	1.175	6.896	0.524	1.116	0	0
1912	1.051	5.789	0.382	0.669	0	0
1911	0.928	4.702	0.243	0.258	0	0
1910	0.807	3.762	0.108	0.011	0	0
1909	0.710	3.047	0	0	0	0
1908	0.615	2.475	0	0	0	0
1907	0.522	1.916	0	0	0	0
1906	0.432	1.366	0	0	0	0
1905	0.344	0.823	0	0	0	0
1904	0.278	0.647	0	0	0	0
1903	0.215	0.473	0	0	0	0
1902	0.155	0.299	0	0	0	0
1901	0.098	0.121	0	0	0	0
1900	0.044	0.007	0	0	0	0
1899	0	0	0	0	0	0
1898	0	0	0	0	0	0

Table 7.12: Depositin pattern for annual sediment load 482 thousend tonnes (land use 2006)

	50yr		75yr		100yr	
Elevation masl	Area Km2	Volume mill.m3	Area Km2	Volume mill.m3	Area Km2	Volume mill.m3
1950	8.790	176.183	8.790	162.949	8.790	149.719
1949	8.536	169.009	8.535	155.776	8.535	142.545
1948	8.280	161.836	8.279	148.604	8.277	135.374
1947	8.024	154.605	8.021	141.375	8.016	128.149
1946	7.766	146.835	7.760	133.609	7.751	120.390
1945	7.507	139.070	7.497	125.852	7.482	112.645
1944	7.268	132.142	7.253	118.937	7.231	105.748
1943	7.028	125.222	7.007	112.034	6.976	98.873
1942	6.786	118.311	6.759	105.148	6.716	92.023
1941	6.544	111.410	6.508	98.278	6.453	85.202
1940	6.299	104.521	6.254	91.430	6.186	78.415
1939	6.074	98.786	6.019	85.745	5.935	72.806
1938	5.847	93.066	5.781	80.085	5.681	67.238
1937	5.619	87.361	5.541	74.453	5.423	61.715
1936	5.390	81.672	5.299	68.849	5.161	56.239
1935	5.159	76.002	5.055	63.276	4.897	50.814
1934	4.950	71.336	4.831	58.722	4.651	46.429
1933	4.740	66.690	4.606	54.202	4.403	42.100
1932	4.529	62.065	4.379	49.718	4.153	37.831
1931	4.317	57.461	4.151	45.272	3.900	33.624
1930	4.104	52.879	3.922	40.864	3.646	29.480
1929	3.913	49.218	3.714	37.394	3.411	26.299
1928	3.722	45.581	3.505	33.965	3.176	23.186
1927	3.530	41.967	3.295	30.578	2.939	20.141
1926	3.337	38.377	3.084	27.232	2.701	17.165
1925	3.145	34.812	2.874	23.929	2.463	14.259
1924	2.972	32.057	2.683	21.455	2.244	12.209
1923	2.800	29.327	2.492	19.023	2.026	10.230
1922	2.627	26.622	2.301	16.635	1.808	8.322
1921	2.455	23.940	2.111	14.288	1.590	6.482
1920	2.283	21.283	1.922	11.984	1.374	4.712
1919	2.134	19.333	1.755	10.405	1.181	3.694
1918	1.985	17.407	1.589	8.865	0.989	2.742
1917	1.837	15.503	1.425	7.366	0.800	1.854
1916	1.690	13.620	1.261	5.904	0.613	1.029
1915	1.543	11.759	1.100	4.478	0.428	0.264
1914	1.420	10.492	0.962	3.662	0.268	0.130
1913	1.297	9.243	0.826	2.878	0.112	0.050
1912	1.176	8.012	0.692	2.125	0.000	0.000
1911	1.057	6.797	0.561	1.400	0.000	0.000
1910	0.939	5.728	0.432	0.831	0.000	0.000
1909	0.844	4.879	0.328	0.494	0.000	0.000
1908	0.751	4.173	0.227	0.307	0.000	0.000
1907	0.660	3.476	0.130	0.138	0.000	0.000
1906	0.571	2.788	0	0	0	0
1905	0.484	2.105	0	0	0	0
1904	0.419	1.789	0	0	0	0
1903	0.356	1.474	0	0	0	0
1902	0.296	1.159	0	0	0	0
1901	0.238	0.841	0	0	0	0
1900	0.183	0.588	0	0	0	0
1899	0.142	0.440	0	0	0	0
1898	0.104	0.352	0	0	0	0
1897	0.069	0.251	0	0	0	0
1896	0.037	0.133	0	0	0	0
1895	0	0	0	0	0	0
1894	0	0	0	0	0	0

Table 7.13: Depositin pattern for annual sediment load 353 thousend tonnes (land use 1986)

	50yr		75yr		100yr		125yr	
Elevation masl	Area Km2	Volume mill.m3	Area Km2	Volume mill.m3	Area Km2	Volume mill.m3	Area Km2	Volume mill.m3
1950	8.790	183.234	8.790	173.527	8.790	163.818	8.790	154.109
1949	8.536	176.060	8.536	166.354	8.535	156.645	8.535	146.935
1948	8.281	168.887	8.280	159.181	8.279	149.473	8.278	139.764
1947	8.025	161.655	8.023	151.950	8.021	142.244	8.018	132.537
1946	7.768	153.883	7.765	144.181	7.760	134.478	7.754	124.776
1945	7.511	146.114	7.505	136.417	7.497	126.720	7.487	117.026
1944	7.274	139.182	7.266	129.491	7.254	119.804	7.239	110.123
1943	7.036	132.255	7.025	122.574	7.008	112.901	6.987	103.238
1942	6.798	125.334	6.782	115.667	6.760	106.012	6.732	96.375
1941	6.558	118.420	6.538	108.771	6.510	99.141	6.473	89.536
1940	6.317	111.515	6.292	101.888	6.257	92.290	6.211	82.727
1939	6.096	105.760	6.065	96.161	6.022	86.602	5.965	77.090
1938	5.873	100.015	5.836	90.450	5.785	80.938	5.717	71.489
1937	5.650	94.282	5.607	84.757	5.546	75.301	5.466	65.926
1936	5.426	88.560	5.375	79.082	5.305	69.692	5.211	60.403
1935	5.201	82.850	5.143	73.427	5.062	64.113	4.954	54.925
1934	4.997	78.140	4.931	68.779	4.839	59.552	4.717	50.478
1933	4.793	73.444	4.719	64.152	4.615	55.024	4.477	46.080
1932	4.588	68.762	4.505	59.550	4.389	50.531	4.235	41.733
1931	4.383	64.096	4.291	54.971	4.162	46.075	3.991	37.439
1930	4.177	59.445	4.076	50.416	3.934	41.656	3.746	33.199
1929	3.993	55.708	3.882	46.786	3.726	38.174	3.521	29.913
1928	3.808	51.987	3.687	43.181	3.518	34.732	3.295	26.685
1927	3.623	48.284	3.493	39.603	3.310	31.330	3.068	23.515
1926	3.438	44.597	3.297	36.052	3.100	27.969	2.840	20.405
1925	3.253	40.927	3.102	32.529	2.891	24.649	2.612	17.355
1924	3.088	38.061	2.927	29.818	2.701	22.157	2.404	15.151
1923	2.922	35.212	2.751	27.135	2.512	19.707	2.195	13.007
1922	2.757	32.381	2.576	24.480	2.322	17.298	1.987	10.924
1921	2.592	29.566	2.401	21.852	2.133	14.930	1.780	8.901
1920	2.427	26.768	2.226	19.250	1.945	12.603	1.573	6.936
1919	2.285	24.671	2.074	17.359	1.779	11.000	1.390	5.714
1918	2.143	22.591	1.922	15.494	1.614	9.437	1.207	4.548
1917	2.001	20.526	1.772	13.654	1.451	7.911	1.027	3.438
1916	1.860	18.476	1.622	11.838	1.288	6.423	0.848	2.382
1915	1.720	16.441	1.473	10.046	1.128	4.970	0.672	1.376
1914	1.602	14.995	1.347	8.850	0.991	4.124	0.520	0.994
1913	1.485	13.561	1.223	7.674	0.856	3.311	0.371	0.658
1912	1.369	12.140	1.100	6.519	0.723	2.527	0.226	0.366
1911	1.254	10.730	0.978	5.382	0.592	1.772	0.083	0.113
1910	1.140	9.461	0.858	4.392	0.464	1.171	0	0
1909	1.049	8.410	0.762	3.624	0.361	0.802	0	0
1908	0.960	7.496	0.668	3.000	0.261	0.582	0	0
1907	0.871	6.590	0.576	2.387	0.163	0.379	0	0
1906	0.784	5.689	0.486	1.782	0.069	0.190	0	0
1905	0.699	4.793	0.398	1.185	0	0	0	0
1904	0.634	4.261	0.333	0.954	0	0	0	0
1903	0.572	3.731	0.270	0.725	0	0	0	0
1902	0.511	3.201	0.210	0.496	0	0	0	0
1901	0.452	2.668	0.153	0.264	0	0	0	0
1900	0.395	2.202	0.098	0.095	0	0	0	0
1899	0.351	1.844	0.059	0.031	0	0	0	0
1898	0.310	1.548	0.022	0.026	0	0	0	0
1897	0.270	1.243	0	0	0	0	0	0
1896	0.233	0.927	0	0	0	0	0	0
1895	0.197	0.597	0	0	0	0	0	0
1894	0.166	0.509	0	0	0	0	0	0
1893	0.137	0.404	0	0	0	0	0	0
1892	0.110	0.278	0	0	0	0	0	0
1891	0.085	0.131	0	0	0	0	0	0
1890	0.062	0.009	0	0	0	0	0	0
1889	0.042	0.013	0	0	0	0	0	0
1888	0.024	0.014	0	0	0	0	0	0
1887	0	0	0	0	0	0	0	0

Appendix H: Location of Ground control point in study area

Table 7.13: Ground control point

No	X	Y	Land use	No	X	Y	Land use
1	331319.57	1382535.59	Grass Land	101	342229.73	1405003.72	Agriculture Land
2	331256.06	1382789.59	Grass Land	102	338610.22	1405178.34	Agriculture Land
3	331883.13	1383051.53	Grass Land	103	344662.58	1403838.34	Agriculture Land
4	332073.63	1383107.09	Grass Land	104	341884.45	1404020.24	Agriculture Land
5	332351.44	1384400.91	Grass Land	105	334932.69	1404378.09	Agriculture Land
6	331906.94	1384218.34	Grass Land	106	335991.02	1404517.00	Agriculture Land
7	335122.46	1387455.36	Grass Land	107	344292.34	1399688.34	Agriculture Land
8	334917.41	1388407.86	Grass Land	108	348394.82	1396081.29	Agriculture Land
9	331631.08	1399383.59	Grass Land	109	348490.07	1395795.54	Agriculture Land
10	342317.18	1396902.58	Grass Land	110	348638.24	1396536.37	Agriculture Land
11	335392.89	1395211.71	Water body	111	344732.98	1396663.37	Agriculture Land
12	335646.89	1394894.21	Water body	112	344754.15	1396028.37	Agriculture Land
13	335920.73	1395251.40	Water body	113	227561.35	1397106.82	Agriculture Land
14	335722.29	1395560.97	Water body	114	337789.95	1396929.02	Agriculture Land
15	332923.47	1383149.34	Water body	115	338488.45	1396630.57	Agriculture Land
16	332385.26	1382122.56	Water body	116	339212.35	1396960.77	Agriculture Land
17	337676.94	1387176.80	Water body	117	326565.38	1398852.28	Agriculture Land
18	335621.12	1395354.69	Water body	118	326427.79	1398249.03	Agriculture Land
19	335549.68	1395108.63	Water body	119	327676.63	1397741.02	Agriculture Land
20	335368.44	1395415.54	Water body	120	329031.30	1397868.02	Agriculture Land
21	335461.04	1395435.39	Water body	121	332322.72	1397550.52	Agriculture Land
22	341202.41	1404621.34	Water body	122	332788.39	1396979.02	Agriculture Land
23	340296.74	1404013.07	Water body	123	323893.08	1397471.15	Agriculture Land
24	341971.55	1403675.73	Water body	124	325724.00	1397243.61	Agriculture Land
25	335361.44	1394603.53	Water body	125	327316.79	1397053.11	Agriculture Land
26	332161.74	1382160.14	Water body	126	324274.08	1396497.48	Agriculture Land
27	333545.56	1397970.40	Forest Land	127	330181.71	1395945.38	Agriculture Land
28	333605.09	1398711.24	Forest Land	128	330679.13	1395617.30	Agriculture Land
29	333300.82	13964668.9	Forest Land	129	323175.53	1397961.51	Agriculture Land
30	335053.69	1395721.44	Forest Land	130	323866.09	1397453.51	Agriculture Land
31	336006.97	1394858.33	Forest Land	131	325755.22	1397207.45	Agriculture Land
32	336337.70	1395933.19	Forest Land	132	323397.77	1396493.07	Agriculture Land
33	336767.65	1394164.01	Forest Land	133	323397.77	1396048.57	Agriculture Land
34	330911.62	1393121.81	Forest Land	134	324056.59	1396048.57	Agriculture Land
35	330574.27	1393316.28	Forest Land	135	330000.20	1395989.04	Agriculture Land
36	333225.40	1392847.47	Forest Land	136	330944.77	1395227.04	Agriculture Land
37	332665.81	1393709.19	Forest Land	137	328404.76	1393224.14	Agriculture Land
38	336433.05	1384049.06	Forest Land	138	325983.82	1391861.53	Agriculture Land
39	339341.36	1383496.61	Forest Land	139	327384.53	1392265.64	Agriculture Land
40	339792.21	1385122.21	Forest Land	140	328231.20	1392117.47	Agriculture Land
41	339233.41	1385839.76	Forest Land	141	329215.45	1391942.85	Agriculture Land
42	342618.73	1384882.18	Forest Land	142	336341.96	1394866.08	Agriculture Land
43	343121.65	1383893.10	Forest Land	143	338318.40	1394707.33	Agriculture Land
44	344244.84	1386491.53	Forest Land	144	338905.78	1394040.58	Agriculture Land
45	346256.52	1384077.51	Forest Land	145	342900.99	1394436.96	Agriculture Land
46	344211.31	1386774.18	Forest Land	146	343879.95	1394337.74	Agriculture Land
47	343926.32	1389106.72	Forest Land	147	345037.50	1394066.54	Agriculture Land
48	346290.05	1389676.69	Forest Land	148	345335.16	1393206.64	Agriculture Land
49	344277.64	1396555.79	Forest Land	149	348387.25	1394192.22	Agriculture Land
50	344092.43	1392692.87	Forest Land	150	328512.95	1385980.34	Agriculture Land

51	342584.31	1396661.63	Forest Land
52	334270.44	1395882.94	Built up
53	333945.00	1395184.45	Built up
54	333571.94	1394612.94	Built up
55	333230.63	1393604.88	Built up
56	333452.88	1392993.69	Built up
57	331571.68	1395009.82	Built up
58	331952.69	1394049.38	Built up
59	331611.37	1393406.44	Built up
60	331690.75	1393088.94	Built up
61	332032.06	1392652.38	Built up
62	332554.35	1392022.14	Built up
63	332845.60	1391349.04	Built up
64	332609.52	1390597.62	Built up
65	330337.35	1392333.29	Built up
66	330845.35	1390671.70	Built up
67	329755.26	1389428.16	Built up
68	329580.64	138591.91	Built up
69	329326.64	1388348.66	Built up
70	329181.76	1388110.53	Built up
71	330104.51	1387793.03	Built up
72	330755.39	1387840.66	Built up
73	330882.39	1387554.91	Built up
74	330842.70	1386361.63	Built up
75	330860.91	1385644.50	Built up
76	329478.19	1384966.11	Built up
77	329789.34	1385004.21	Built up
78	332977.05	1382978.56	Built up
79	330856.14	1385740.81	Built up
80	332379.51	1381968.91	Built up
81	333027.21	1351600.60	Built up
82	336680.06	1383962.81	Built up
83	332756.01	1383539.74	Built up
84	330927.77	1391183.18	Built up
85	329407.73	1390553.47	Built up
86	329566.48	1389772.95	Built up
87	330214.71	1390143.37	Built up
88	340476.60	1408250.16	Agriculture Land
89	340032.10	1407879.75	Agriculture Land
90	340611.54	1409110.01	Agriculture Land
91	342510.14	1407695.42	Agriculture Land
92	343081.69	1407531.38	Agriculture Land
93	343605.56	1407086.88	Agriculture Land
94	343801.36	1406695.29	Agriculture Land
95	340150.10	1406749.97	Agriculture Land
96	340435.85	1405543.47	Agriculture Land
97	341308.98	1405551.41	Agriculture Land
98	338443.54	1405511.72	Agriculture Land
99	337633.91	1405932.41	Agriculture Land
100	337387.85	1406138.78	Agriculture Land

151	329267.02	1385107.22	Agriculture Land
152	33.702.383	1384802.95	Agriculture Land
153	331681.34	1385418.10	Agriculture Land
154	333341.61	1384941.85	Agriculture Land
155	334261.04	1384624.35	Agriculture Land
156	335392.13	138517.36	Agriculture Land
157	335200.31	1385001.38	Agriculture Land
158	337997.99	1393277.32	Agriculture Land
159	338421.33	1393078.88	Agriculture Land
160	338798.36	1392463.72	Agriculture Land
161	340108.05	1392304.97	Agriculture Land
162	341847.69	1393290.55	Agriculture Land
163	342310.71	1392820.91	Agriculture Land
164	348119.65	1393497.81	Agriculture Land
165	347124.81	1392407.72	Agriculture Land
166	347564.02	1391905.01	Agriculture Land
167	347093.05	13911804.5	Agriculture Land
168	331824.46	1385470.23	Agriculture Land
169	331692.17	1385099.81	Agriculture Land
170	331917.66	1384504.49	Agriculture Land
171	333980.82	1384782.31	Agriculture Land
172	334867.17	1384901.37	Agriculture Land
173	337129.37	1387057.73	Agriculture Land
174	337764.37	1386250.75	Agriculture Land
175	339034.37	1384755.85	Agriculture Land
176	338994.68	13841187.0	Agriculture Land
177	331295.29	1384822.00	Agriculture Land
178	331837.69	1385086.58	Agriculture Land
179	334139.57	1384729.39	Agriculture Land
180	330805.81	1384398.66	Agriculture Land
181	335158.22	1385007.20	Agriculture Land
182	335872.59	1384332.52	Agriculture Land
183	337089.68	1384266.37	Agriculture Land
184	333557.48	1384147.31	Agriculture Land
185	3363622.1	1383538.76	Agriculture Land
186	334840.72	1383538.76	Agriculture Land
187	336362.07	1383194.80	Agriculture Land
188	334615.82	1383194.80	Agriculture Land
189	333345.82	1383446.16	Agriculture Land
190	334668.74	1382334.91	Agriculture Land
191	331454.04	1395152.73	Agriculture Land
192	332525.61	1384107.62	Agriculture Land
193	333411.96	1383300.64	Agriculture Land
194	333610.40	1382718.55	Agriculture Land
195	334681.97	1382295.22	Agriculture Land
196	332300.71	1381607.30	Agriculture Land
197	331162.99	1381938.03	Agriculture Land
198	332234.56	1381355.15	Agriculture Land
199	334695.19	1382242.30	Agriculture Land
200	331493.73	1382242.30	Agriculture Land