



MODELING HYDROLOGICAL RESPONSES TO LAND USE AND LAND COVER
CHANGE IN MEGECHA RIVER CATCHMENT OMO-GIBE BASIN, ETHIOPIA

MASTERS OF SCIENCE THESIS

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A THESIS SUBMITTED TO THE FACULTY OF BIO-SYSTEMS AND WATER
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ADVISORS' APPROVAL SHEET

This is to certify that the thesis entitled “MODELING HYDROLOGICAL RESPONSES TO LAND USE AND LAND COVER CHANGE IN MEGECHA RIVER CATCHMENT OMO-GIBE BASIN, ETHIOPIA” submitted in partial fulfillment of the requirements for the degree of master's with specialization in WATER RESOURCE ENGINEERING AND MANAGEMENT, the Graduate program department of WATER RESOURCE AND IRRIGATION ENGINEERING, and has been carried out by Beakal Yisehak Ashengo, Id No. PGWREMW/ 0006/11 under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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DEDICATION

This thesis manuscript is dedicated to my Mother, Ethagegnehu Meshesha, for her love and unreplaceable sacrifice in the success of my life.

Declaration

I, Beakal Yisehak declare that the content of this thesis is entirely my own work with the exception of such quotations or references which have been attributed to their authors or sources, and that this thesis has not been previously submitted to this or any other university for a degree award.

Signature-----

Beakal Yisehak

Date: MAR/5/2022

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LIST OF ABBREVIATIONS

CN	Curve Number
CSV	Comma Delimited
DEM	Digital Elevation Model
ENMSA	Ethiopian National Meteorological Service Agency
ERDAS	Earth Resources Data Analysis System
ET	Evapotranspiration
ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agriculture Organization
FDC	Flow Duration Curve
GIS	Geographical Information System
GPS	Global Positioning System
ha/year	hectare per year
HRU	Hydrological Response Unit
LU/LC	Land Use and Land Cover Change
LU/LCC	Land Use and Land Cover Change
m/s	meter per seconds
m ³	cubic meter
m ³ /s	cubic meter per seconds
MoWIE	Ministry of water, Irrigation and Energy

NSE	Nash and Sutcliffe Coefficient of Efficiency
OLI/TIRS	Operational Land Imager/Thermal Infrared Sensor
R ²	Coefficient of determination
SNNPR	Southern Nations, Nationalities, and Peoples' Region
SRTM	Shuttle Radar Topography Mission
SWAT	Soil and Water Assessment Tool
SWAT-CUP	Soil and Water Assessment Tool- Calibration and Uncertainty prediction
TM	Thematic Mapper
USDA-ARS	United States Department of Agriculture-Agricultural Research
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 84

Abstract

Land use/ land cover change has been one of factors responsible for altering the stream flow of the watershed on the Megecha River Catchment OMO-GIBE basin leading to impacting river flows. The study mainly focused on to evaluate the impact of land use land cover change on streamflow. Land use change detection was done using remote sensing techniques and the maps were processed through maximum likelihood algorithm of supervised classification using ERDAS Imagine 2014 and ArcGIS 10.4 software. A physical based, semi –distributed hydrological model, SWAT was used to investigate the impact of land cover change on streamflow, of Megecha River Catchment OMO-GIBE Basin. From the land cover change analysis result it was found that there has been a substantial decline of sparse and moderate forest, grass land, bare land and water body. The cropland in the watershed increased from 68.80% in 1996 to 71.13 in 2016. Similarly shrub land and settlement shows increase. This is mainly because of the population growth that caused the increase in demand for new agricultural land and rural settlements which in turn resulted shrinking on other types of land use and land cover of the area. Results have revealed that there is substantial increase in surface runoff volume from 94.34mm to 125.97mm for the LULC map of year 1996 and 2016 respectively. The model evaluation statistics for stream flow provided a very good result since $NSE > 0.75$ and $R^2 > 0.75$. The change in LU/LC ensued in augmented stream flow and in which the expansion of agriculture has also resulted an increase of surface run off, but decreased the ET of river catchment. Therefore, curving the trends of LU/LC towards increasing vegetation covers is very important so as to reduce the seasonal flow and surface runoff, on the other hand to increase ground water flow. One way of increasing vegetation cover in the river catchment is through controlling the expansion of agriculture at the expense of other land covers and improving the productivity of existing farm lands through the provision of improved production inputs and livelihood diversification.

Key words: Land use/Land covers, stream flow, Megecha River catchment, SWAT Model

1. Introduction

1.1 Background

Land use and land cover changes have significant environmental consequences at local, regional, and global scales. Significant changes have taken place in the LULCC, especially in developing countries with agricultural-based economies and rapidly growing populations. A number of natural and human driving forces are responsible for triggering LULCC. Natural causes, such as climate change, are only long-term, whereas human activities can change hydrological and watershed processes drastically (Turner BL and Meyer WB., 1994). Land-use shifts are caused by external and internal drivers and have been influenced by many traditional and modern resource management practices. The drivers of LULCC include social, economic, biophysical, and political factors. In recent decades; anthropogenic land-use/land-cover change has been proceeding much faster than natural change. This unprecedented rate of change has become a major environmental concern worldwide. As a result, almost all ecosystems of the world have been significantly altered or are being altered by humans, undermining the capacity of the planet's ecosystems to provide goods and services. Two main forces responsible for anthropogenic changes are technological development and the burgeoning human population (Lambin, E. and Meyfroidt, P., 2011).

Hydrologic modeling and water resources management studies are intrinsically related to the spatial processes of the hydrologic cycle. Land use and land cover influence watershed hydrological responses by partitioning rainfall between return flow to the atmosphere as evaporation and transpiration and flow to aquifers and rivers. However, techniques for the analysis of the impact of LULCC on modeled hydrological responses are still very much at early stage. The prediction of the effect of future change (and validation of prediction) has hardly started (Beven, 2001). SWAT is one of the models designed to operate at various spatiotemporal scales, environmental conditions, and different spatial and temporal details (Gassman PW., et al., 2014). SWAT is integrated with Geographic Information System (GIS) and handles the spatiotemporal heterogeneity of basin characteristics such as topography, land cover, soil and climate condition (Hsu, K., et al. , 1999) Omo gibe is one of the twelve river basin of Ethiopia. The Megecha River which is located in Sothern nation and nationalities people region (SNNPR) of Ethiopia as part of the Omo Gibe Basin. This study was aimed at investigating the effect of land use and land cover changes on hydrological process of Megecha catchment .Particularly, the

trends of hydrological process under a varying land use land cover and the most vulnerable sub basins of the catchment to the yields of the hydrological process were investigated. Finally, the performance of the SWAT hydrological Model was assessed.

1.2 Statement of the Problem

Human activities have changed and continue to change the earth surface and atmospheric composition. Different study report from deferent part of Ethiopia indicated impacts of LULCC on river discharge. The land use and land cover change caused different problem in existing hydrological condition. Human activities are the main causes of land use and land cover change in Megecha catchment through the resulting demand for agricultural, grazing land, forest, settlement and enset plantation. Change in this area like increasing the percentage of impervious area will increase volume of surface run off, decrease time of concentration as well as decrease the amount of water percolation in the ground and finally imbalance over all hydrological response in catchment. Consequently any change in the spatial and temporal availability of water resources affect agriculture, industry and urban development. In south-western Ethiopia is environmentally challenged mainly due to resource degradation, soil erosion and nutrient depletions. Specifically this research is initiated to understand and estimate the effect of change in LULC on streamflow, which helps finally for better use and management of the natural resources.

1.3 Objective

1.3.1 General Objective

The main objective of this research is to evaluate the impact of land cover and land use change on streamflow of Megecha River in the upper Omo –Gibe river basin, Ethiopia.

1.3.2 Specific Objective

- To detect and analyze the land use land cover changes between 1991-2016 in Megecha River watershed in the upper Omo –Gibe river basin, Ethiopia.
- To quantify the response of stream flow to land use and land cover change in the Megecha watershed.
- To determine the extreme flow extents in the watershed.

1.3.3 Research Question

- What is the historical trend of land use/land cover change in the study watershed between 1991 and 2016?
- How does a land use and land cover change affect the stream flow characteristics of the watershed?
- How does the watershed respond to the extreme flows due to the land use and land cover change?

1.4 Scope of the Study

Assessing the effect of land use land cover change on stream flow is important to have an understanding of the land use land cover pattern and the hydrological process of the watershed. the knowledge how land use land cover change influence watershed hydrology will enable local governments and policy maker to formulate and implement effective and appropriate response strategies to minimize the undesirable effect of land use land cover change or modification. Understanding the types and impacts of land use land cover is essential indicator for resource base analysis and development of effective and appropriate response strategies for sustainable management of natural resources in the country in general and at the study area in particular. Moreover, the study presents a method to quantify land use and land cover change and their impact on stream flow. This was achieved through a method that combines the hydrological model (SWAT) to simulate the hydrological processes, GIS and remote sensing techniques to

analysis the land use land cover change and doesn't include sediment and so-economic condition of the catchment. This research covers detection of the land use and land cover changes between 1996 and 2016 and its impacts on the stream flow characteristics of the river catchment. Quantifying flow regimes through FDC using simulated stream flow due to developed thematic maps in the catchment during the entire study periods. In its geographic scope it was undertaken in Megecha river catchment Omo-gibe basin, Ethiopia and entirely covers a drainage area of about 292 km². Systematically the study used different methods and approaches such as, remote sensing, use of secondary data and different models. The map of LU/LC between 1996 up to 2016 were prepared. By fixing other climate parameters constant, but in changing LU/LC stream flow of the river catchment was simulated and model performance evaluations were carried out using ArcGIS platform of SWAT Model and SWAT-CUP with Sequential Uncertainty Fitting algorithm (SUFI-2) respectively.

1.5 Limitation of the Study

Some crucial parameters for further analysis of the impact of land use and land cover change on hydrology of river catchment such as predicting future land use/land cover and climate change; Assessing the land use/land cover change under different institutional arrangements of natural resource management and observing the responses including those mentioned are not part of study due to shortage of accessible data, time constraint and money.

2. Literature Review

2.1 Land Use Land Cover Detection

The definition of Land use Land Cover are fundamental, because Land Use and Land Cover changes analysis is one of the most useful methodologies to understand how the land was used in the past years, what types of detections are to be expected in the future, as well as the driving forces and processes behind these changes. Land use/ land cover has often been confused and used interchangeably in the literature and also in daily practice. This, it is important to define and understand the meaning of these terms so that they can be used correctly, meaningfully, and to the best advantage. According to (Muluneh, 2010)Improving the understanding of land use and land cover dynamics can help in projecting future changes in land use and land cover and to instigate more appropriate policy interventions for achieving better land management.

2.1.1 Land Use

Land use: refers to the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (FAO/UNEP, 1999). The intended use or management of the land cover type by human beings is used to describe human uses of the land, including actions that modify or convert land cover from one type to another. Thus, land use involves both the manner in which the biophysical attributes of land are manipulated and intent underlining that manipulation (the purpose for which the land is used e.g., agriculture, grazing, etc.), which are more subtle changes that affect the character of the land cover without changing its overall classification (Monica Di Gregorio, et al, 2016).

The land use–land cover of the Megecha catchment can be categorized mainly as agricultural, grazing lands, bare lands, woodlands, forest, settlement area, and water bodies.

2.1.2 Land Cover

Land cover: is the physical material at the surface of the earth such as grass, vegetation, bare ground, impervious surfaces and water on which land use occurs (FAO/UNEP, 1999).

Land cover detection is the process of identifying difference in the state of a feature by observing it at different moments in time. There are large numbers of change detection algorithms or techniques developed and used over the years to estimate changes using remote sensing data. Change in detection algorithms include image overlay, image digitizing, image differencing, image regression, image rationing, vegetation index differencing, principal component analysis,

spectral and temporal classification (Singh, 1989). Land-cover is defined by the characteristics of the earth's land surface which are captured in the spatial and temporal variation of surface and subsurface biotic and abiotic factors including vegetation, desert, ice, biota, soil, topography, surface water and groundwater, and mine exposures. On the other hand, land-use is the proposed employment of land management strategy placed on land-cover by human agents or land managers to utilize the land-cover. It reflects human activities such as industrial zones, residential zones, agricultural zones, grazing fields, logging, and mining among many others. Land cover can be altered by forces other than anthropogenic. Natural events such as weather, flooding, fire, climate fluctuations and ecosystem dynamics may also initiate modifications upon land cover. Globally, land cover today is altered principally by direct human use: by agriculture and livestock raising, forest harvesting and management and urban and sub urban construction and development. There are also incidental impacts on land cover from other human activities such as forest and lakes damaged by acid rain from fossil fuel combustion and crops near cities damaged by troposphere ozone resulting from automobile exhaust (Meyer, 1995).

2.2 Cause of Land Use Land Cover and Management Change

The causes of Land use Land cover change originate from a complex interaction of social, policy and institutional, economic, demographic, technological, cultural and biophysical factors. Political, legal, economic and traditional institutions and their interaction with individual decision making also influence Land use Land cover change.

Demographic change include shifts in fertility and mortality, changes in household structure, the breakdown of extended families into multiple nuclear families and dynamics including; labor availability, migration, urbanization. This urban development has replaced agricultural farmlands and other natural vegetation with paved surfaces and unplanned squatter settlements which are environmentally degrading.

LULC changes are associated with large negative impacts on ecosystems observed at local, regional and global scales. Change in land use/cover can also negatively affect the potential use of an area and may ultimately lead to land degradation. Understanding of the driving forces of LULC changes is essential for effective and sustainable land resource management. Natural land cover can be changed due to dynamic population growth, deforestation, agricultural expansion, improper land management (Alemu, B., et al , 2015).

2.3 Effect of Land Use Land Cover Change on stream flow

These land use land cover change have significant influence on quantity or quality of stream flow (Bewket, W. and Sterk, G. , 2005). Stream flow is the volumetric discharge expressed in volume per unit time (typically cubic meters per second (m^3/s) that takes place in a stream or channel and varies in time and space. (Getahun, Y.S. and Van Lanen, H.A.J. , 2015) Clearly stated that population growth and its effect on the LULC change have been influencing the hydrology of Melka Kuntre watershed by changing the magnitude of stream flow and groundwater flow. There are many factors affecting stream flow, such as soil type, land cover and precipitation. One of the most important issues in water resource management is to understand the impact of land use changes on stream flow.

Land cover changes may have immediate and long lasting impact on terrestrial hydrology and alter the long term balance between rainfall and evapotranspiration and stream flow. In the short term, destructive land use change may affect the hydrological cycle either through increasing the water yield or diminishing or even eliminating the low flow in some circumstances (Worku, 2009). Land use land cover affects runoff in the form of accelerated or retarded overland flow as a result of slow or fast infiltration rate and initial abstraction due to canopy cover (Jinno, K., et al., 2009).

According to (Fisher, T and Mustard, J., 2004) the conversion of the land surface from native cover to managed cropland has an effect on the evapotranspiration, infiltration and overland runoff characteristics of a watershed. Crops need less soil moisture than forests; therefore, the rainfall satisfies the shortage of soil moisture in agricultural lands more quickly than in forests there by generating more runoff. The increased removal of native vegetation and soil compaction decreases soil infiltration capacity. Hence, this leads to an increase in stream flow. Depending on the type of product being grown, croplands tend to have a percentage of bare ground even during the peak of the growing season, and may be completely bare prior to being planted. In both instances, most of the precipitation that lands on these denuded areas will be discharged directly into the stream channel rather than infiltrating into the soil or evaporating/transpiring from the plant surfaces. As a result, conversion to cropland tends to increase water yield compared to native vegetation.

2.4 Application of Hydrological Model.

Modeling is the process of organizing, synthesizing, and integrating component parts into a realistic representation of the prototype. Hydrological models are tools that describe the physical processes controlling the transformation of precipitation to stream flows. Hydrologic models are simplified, conceptual representations of a part of the hydrologic cycle. Their objectives are giving figures to various flows in the hydrological system they also have an important role as pedagogical and research tools. They are made of mathematical representations of the key processes like evapotranspiration, infiltration and transfer in streams. Hydrological models transform input meteorological variables into an output hydrological variable (mainly flow) over a time period. They are primarily used for hydrologic prediction and for understanding hydrologic processes. The prediction ability of these models makes them suitable as management tool for planning and decision making in the watershed.

Hydrological simulation models including: SWAT, MIKE-SHE, HSPF, WASIMETH, DHSVM, HEC-HMS and others have been developed partly to quantify the influence of change in land use, land cover and management practices on the hydrologic cycle. There are several criteria which can be used for selecting the right hydrologic model. Since every research has its own specific requirements and needs most of the criteria are mainly research purpose dependent (Juraj, 2003). Generally based on process description, the hydrological models can be classified into three main groups: lumped models, semi-distributed models and distributed models.

Lumped hydrologic model: The selection of lumped hydrologic models is often attractive user's choice because of their structure, minimum data requirements, fast set up and calibration, and easy for using. The representation of hydrologic process in lumped hydrologic model is usually very simplified; however they can often lead to satisfactory results, especially if the interest is in the discharge prediction only (Juraj, 2003).

Distributed models: Parameters of distributed models are fully allowed to vary in space at a resolution usually chosen by the user. These are broken down into small time and space increments. The physical processes occurring in the watershed may be explicitly simulated and then integrated to produce the watershed response. Examples in this category are MIKE-SHE, Wetspa, CASC2D, WATFLOOD, and others. They can be used to analyze changing conditions such as land use changes, project alternatives, and climate change and they are extendible beyond the calibration range. However, they are data intensive and code development is difficult.

Distributed models generally require large amounts of (often unavailable) data for parameterization in each grid cell. However, the governing physical processes are modeled in detail, and if properly applied, they can provide the highest degree of accuracy (Juraj, 2003)

Semi-distributed models: parameters of semi-distributed models are partially allowed to vary in space by dividing the basin into a number of smaller sub-basins. They are a mixture of empirical and physically -based approaches. They lie between lumped and distributed models. They have the advantage of increased spatial resolution and better process descriptions over simple lumped parameter models. They also maintain the computational advantage over fully distributed, physics-based models. Some of the examples a Semi-distributed model includes SWAT, HEC-HMS, HPV, TOPMODEL, and others (Juraj, 2003).

The main advantage of semi-distributed models is that their structure is more physically based than the structure of lumped models, and that they are less demanding on input data than fully distribute models.

2.5 Hydrological Model Selection Criteria

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

(Beven, 2001)Suggested criterion for selected model structures as below. Consider models which are readily available and whose investment of time and money appeared worthwhile. And decide whether the model under consideration will produce the outputs needed to meet the aims of a particular project. For the accomplishment of objectives the impact of land cover and land use change on streamflow of megecha River in the Omo –Gibe river basin, Ethiopia the following selection criteria were considered for selecting SWAT model :

- SWAT model predicts the output in an acceptable range to meet the objective of the study.
- The model simulates the major hydrological process in the watershed.
- It less demanding on input data

- Technical support: What documentation is available about the model, Ease-of-use, and it is readily and freely available.
- Uses readily available inputs for weather, soil, land, and topography.
- Allows considerable spatial detail for basin scale modeling.
- It is capable of simulating change in watershed characteristics using different scenarios.
- Capability for interface with a geographical information system (GIS).

Based on the above selection criteria SWAT model was selected for detailed analysis and investigation of LULC change effects on stream flow of Megacha watershed.

2.6 Description of SWAT Model

SWAT is a river basin model that was developed for the Agricultural Research Service by the Black land Research Center in Texas (USDA). The SWAT model is a widely known tool that has been used in several cases world-wide. It has the ability to predict the impact of land management practices on water, sediment and agricultural chemical yield, etc. in large complex watersheds (Arnold, 1998).

The SWAT model sub-divides a basin into sub-basins connected by a stream network and further delineates such sub-basins into Hydrologic Response Units (HRUs) consisting of unique combinations of land use and soils. Areas with the same soil type and land use form a HRU, a basic computational unit assumed to be homogenous in hydrologic response to land cover change. The model application can be divided into the following steps; data preparation, sub-basin discretization, Hydrologic Response Unit definition, parameter sensitivity analysis, calibration and validation and uncertainty analysis (Zhang, X., et al. , 2009)

The model was designed to assess long term impact of land management on water balance, sediment transport and non-point source pollution in river basins. In the SWAT model, a watershed is divided into homogeneous hydrological response units (HRUs) which are a combination of land use, management practices, topographical and soil characteristics. The HRUs are represented as a percentage of the sub watershed area and may not be contiguous or spatially identified within a SWAT simulation. Alternatively, a watershed can be subdivided into only sub watersheds that are characterized by dominant land use, soil type, and management. Water balance is the driving force behind all the pro- cesses in SWAT because it impacts plant growth and the movement of sediments, nutrients, pesticides, and pathogens. Simulation of

watershed hydrology is separated into the land phase, which controls the amount of water, sediment, nutrient, and pesticide loadings to the main channel in each sub basin, and the in-stream or routing phase, through the channel network of the watershed to the outlet. (Arnold., et al., 2012)

2.7 digital elevation model (DEM)

A digital elevation model (DEM) is an important spatial input for automatic extraction of topographic parameters for the soil and water assessment tool (SWAT). A SWAT model is the most commonly used tool to study hydrological estimations. Moreover, the objective of SWAT's development was to predict the impact of management on water, sediment, and agricultural chemical yields in large ungagged basins (Arnold.,et al 1998). SWAT is a physically based, semi distributed watershed-scale model that has been used extensively to predict the impact of land management practices on water, sediment, and agricultural chemical transport.

2.8 Satellite Image Classification Image classification

It is the process used to produce thematic maps, which shows the spatial distribution of identifiable earth surface features and provides an informative description of a given area. If a pixel satisfies a certain set of criteria, then the pixel is assigned to the class that corresponds to that criterion (ERDAS imagine user guide, 2013). As a result, the image is partitioned into some non-intersecting regions, such that each region is homogeneous and the union of two adjacent regions is heterogeneous (Vittekk, M.,et al 2014). The resulting raster from image classification can be used to create thematic maps. There are two types of classification: supervised and unsupervised (ERDAS field guide, 2013). Supervised classification is closely controlled by the analyst. The user select pixels that represent patterns or land cover features, or that can be identified with help from other sources, such as aerial photos, ground truth data, or maps. Knowledge of the data, and of the classes desired, is required before classification. By identifying patterns, the user can instruct the computer system to identify pixels with similar characteristics. If the classification is accurate, the resulting classes represent the categories within the data that the user originally identified (ERDAS field guide, 2013). Unsupervised Classification: The computer produces spectral classes based on the digital numbers (DN) without any direction from the user. It is used to cluster pixels in a data set into classes based on statistics only. These classes are spectral classes and their identity is not initially known, until they are compared with some reference data. It gives initial information on the potential spectral

clusters to be assigned to thematic classes. Therefore, subsets of the satellite data were first classified using unsupervised classification. This classification has been used as a guide in the selection of training sites for input into the supervised classification (Orkodjo, 2014)

3. Methods and Materials

3.1 Description of the study area

3.1.1 Location

Megecha watershed is found in the South Nation and Nationalities People Region state (SNNRP) of Ethiopia in the Omo Gibe Basin within coordinate bounds of 7°40'N to 8°20'N latitudes and 37°40'E to 38°10'E longitudes, covering an area of 292.1km². There is large altitudinal variation in the watershed, ranging from 1865m to 3390 m, and slope gradient ranges from zero at the lowest, to 89.9° at the highest, with average slope 50.2° for the entire watershed.

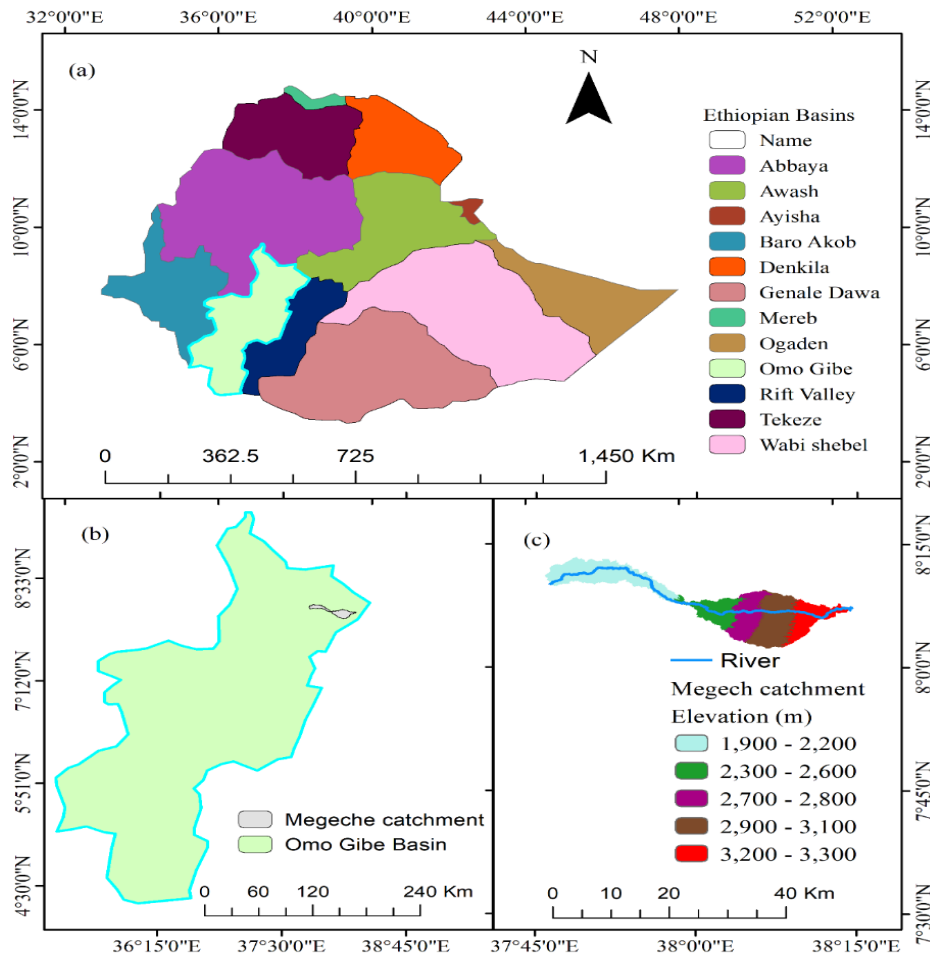


Figure 3:1 Location map of the study area

3.1.2 Topography and River System of the Sub-Basin

The Megecha River catchment topography as the entire is characterized by its physical variation. The Gurage Mountain chain, with the highest elevation of 3,344 m above sea level, accounts for the highest area in the river sub basins, and the lowest elevation of 1,858 m is found in the watershed and covers slope range from flat 0° to steep 49.74° (Figure 3:2 and 3:3), separately. Large parts of the catchment found an elevation between 2000 to 2500m.

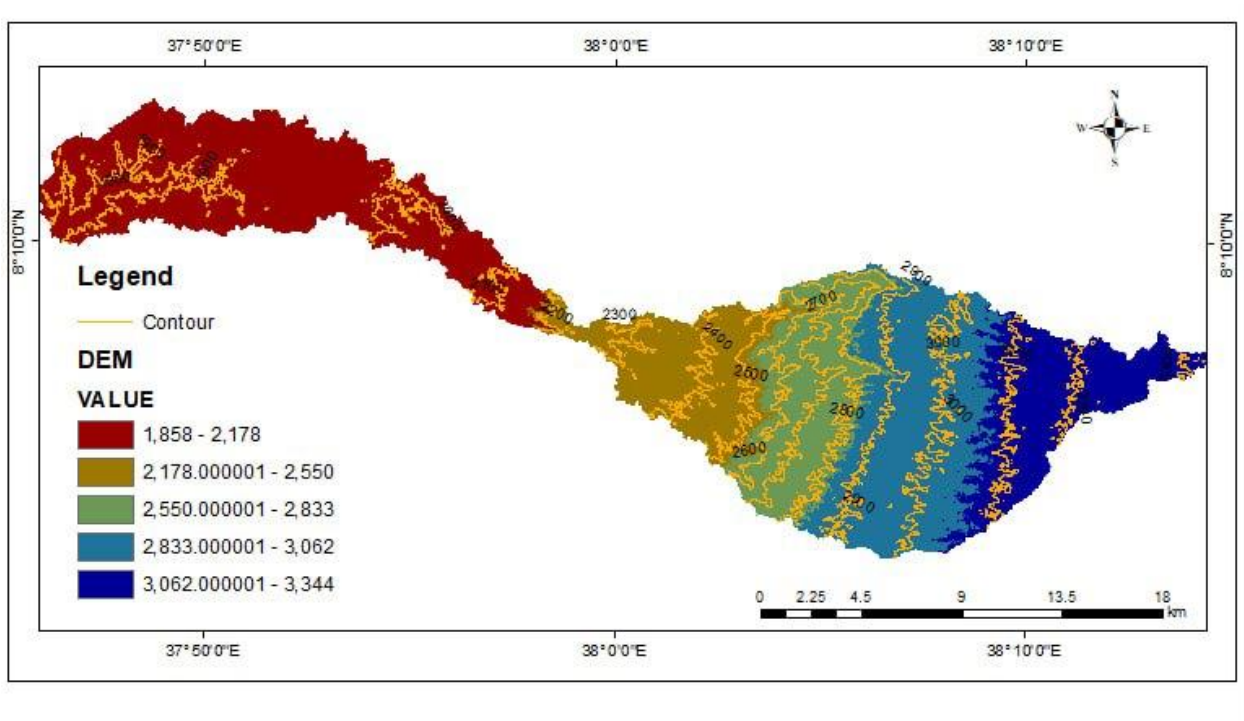


Figure 3: 2 Digital Elevation Model (DEM) and contour map of the study area

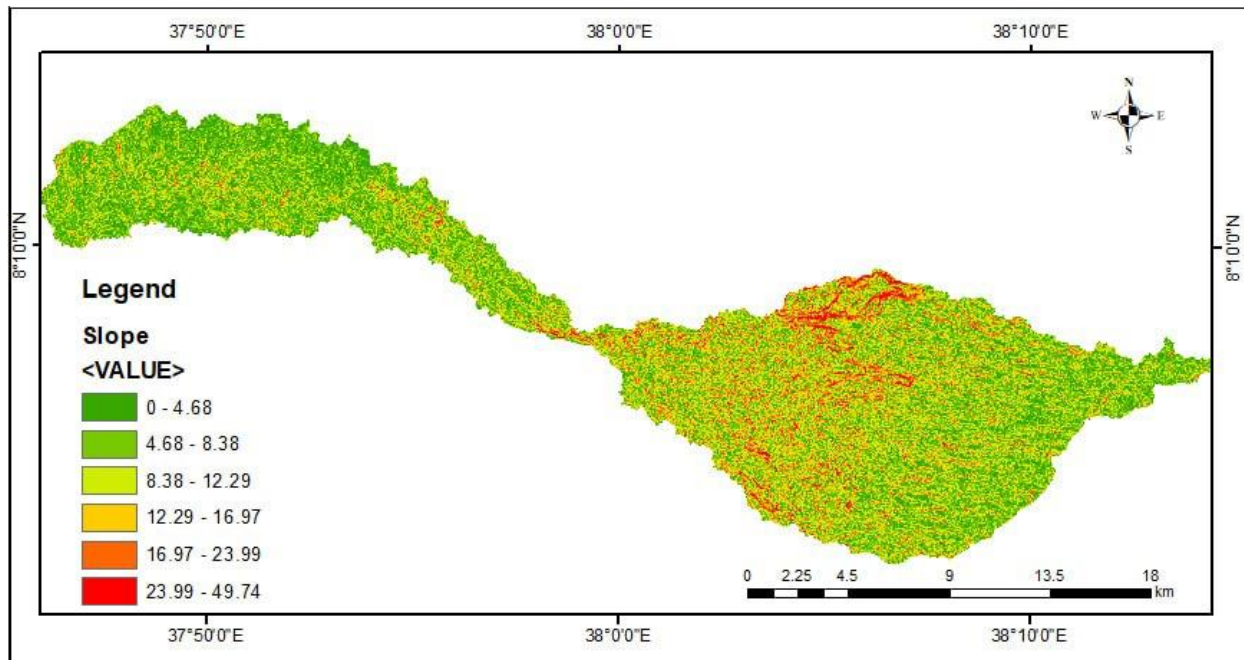


Figure 3:3 Slope map of the study area

3.1.3 Climate and hydrology

Climate is a measure of the average pattern of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle content and other meteorological variables in a given region over long period of time. The climate of Ethiopia can be classified in different ways. The most commonly used systems are the traditional and agro-ecological zone. According to traditional classification, there are five climatic zones namely wurch (cold climate, altitude>3000masl), Dega (temperate like climate, with altitude 2500-3000masl), Woine dega (warm with altitude1500-2500), Kola (hot and arid with altitude<1500masl), and Bereha (hot and hyper-arid type) climates (NMSA. 2001). The study area laid in a climatic zone between wurch and woina-dega. Climate of a location is affected by its latitude, terrain and altitude as well as nearby water bodies and their currents. Altitude, topography and vegetation influence climate greatly, resulting in micro climate in specific localities and macro climate in larger areas.

3.1.4 Temperature

The annual mean temperature calculated from the five meteorological stations is 19.1 °C, with maximum and minimum values of 22.5 °C and 6.7 °C, respectively. The trends of temperature from 1991 to 2016 using the Wolkite metrological station data shows that the average maximum temperature increases from 23°C around 1991 to 25°C around 2006. This shows that the temperature condition of this station in the catchment increased at least by four degree within 15 years.

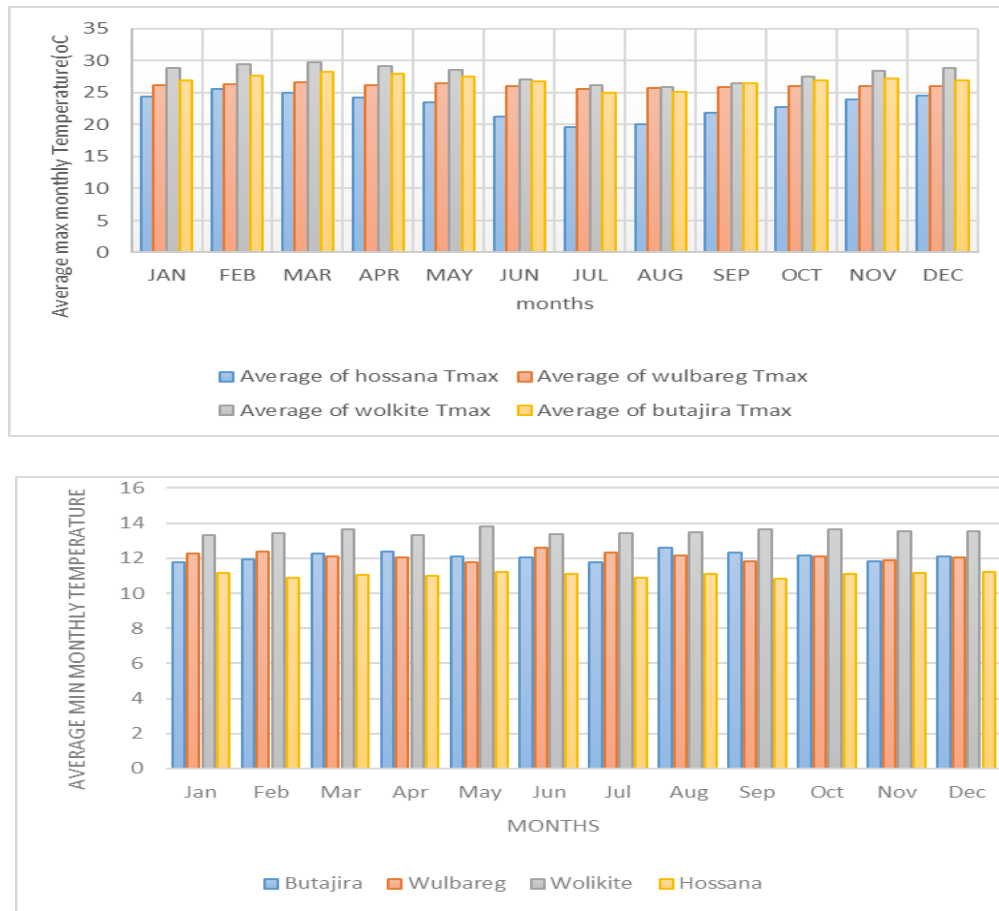


Figure 3: 4 Average monthly maximum and minimum temperatures in the study area.

3.1.5 Rainfall

Average annual rainfall over 25 years (1991–2016) as recorded at five weather stations ranges (Butajira, Wulbareg, Wolkite, Hoassana and Tora) from 856 mm to 1600 mm, with an average annual rainfall of 1389 cm, having a bimodal distribution. The main rainy season extends from June to September and the short rainy season from March to April. Generally, the valley parts of

the watershed are receiving a relatively low amount of rainfall compared to the higher altitude parts of the watershed, likely implying the influence of mountains on rainfall patterns.

Table 3: 1. Mean monthly rainfall (mm) data for 25 years from 1991 to 2016.

Months	Butajira	Wolikite	Wulbareg	Tora	Hossana
Jan	43.15	22.99	37.90	30.60	37.99
Feb	49.29	69.57	34.85	32.06	43.91
Mar	130.42	103.50	106.83	79.88	105.51
Apr	155.49	133.21	145.99	106.77	159.17
May	108.17	174.81	126.14	108.36	135.88
Jun	158.26	204.69	153.61	120.36	146.90
Jul	183.66	216.32	192.78	132.80	149.61
Aug	167.14	198.68	168.10	116.43	176.30
Sep	130.19	85.88	155.14	101.16	148.16
Oct	57.78	24.03	77.08	54.05	78.41
Nov	16.23	19.69	17.93	10.61	19.86
Dec	22.36	21.98	14.69	12.27	25.31

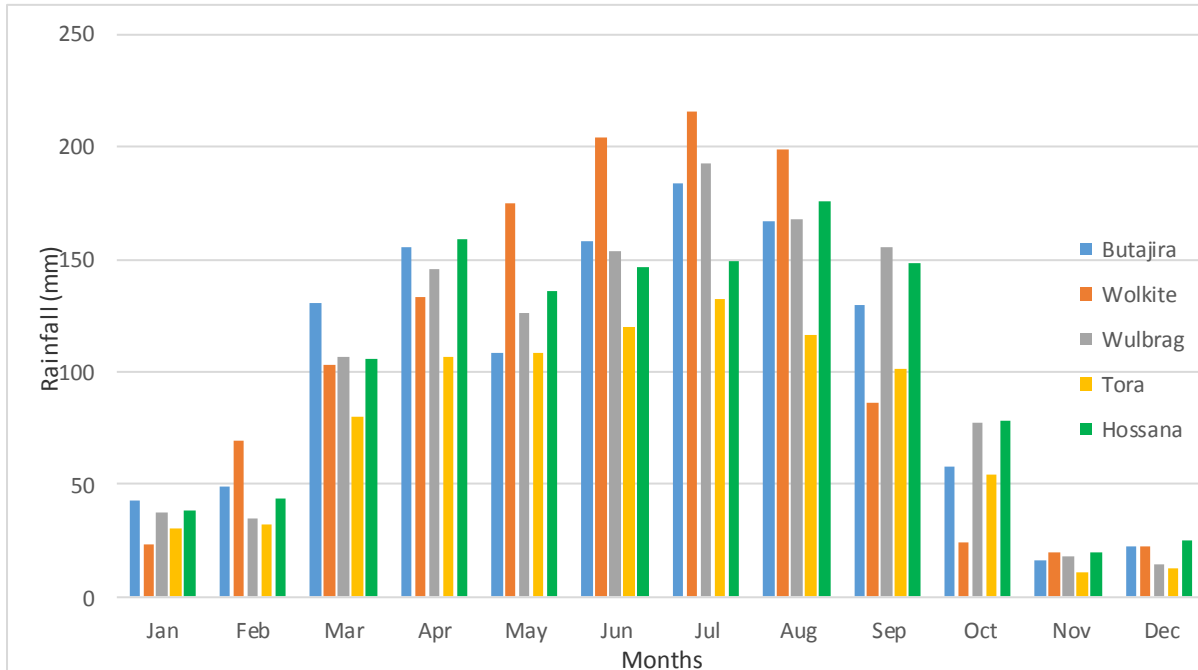


Figure3: 5 Mean monthly rainfall of Megecha catchment (1991-2016)

3.1.5 Soil

Soil input data's are very important because they affect hydrological results where granular or cohesive soils behave very differently in the presence of water (Samuel, 2009). In the river catchments the soil textural classes mostly lie between clay, clay loam, loam, sandy clay loam and sandy loam texture. As noted by (Woldetsadik, 2004), soil colors in the Enset growing areas, like Gurage Zone, range from brown and black to red. The land use–land cover of the Megecha catchment can be categorized mainly as agricultural, grazing lands, bare lands, woodlands, forest, settlement area, and water bodies. Enset is a foremost perennial crop on the areas covered by fertile soils with high-to-mid rainfall characteristics, while maize, teff, sorghum, and wheat are predominant on the lower part of Megecha catchment with low rainfall characteristics and vertisol.

The watershed soil is mainly formed from Eutric vertisols (VRe 65.32%), Humic Nitisols (NTu= 31.26 %,) and Lithic Leptosols (LPq= 3.42 %.).

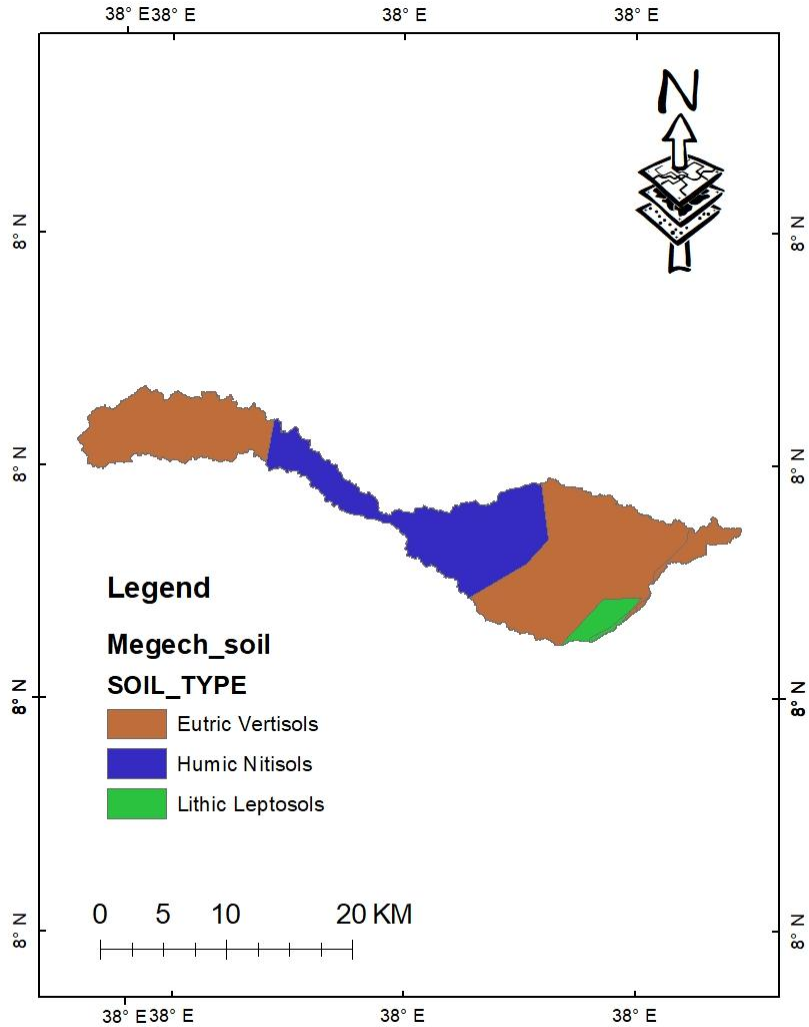


Figure 3: 6 the soil type of Megecha watershed

3.2 Data Sources and Collection

To meet the objectives of this research, different kinds of data were collected from both primary and secondary data sources. Data from primary sources include satellite imagery and field data. Secondary data such as census records and unpublished official documents and reports were gathered from Central Statistical Authority (CSA) of Ethiopia and offices of Agricultural and Rural Development, and Land and Environmental Protection respectively. Additionally past research works were used as supportive secondary data sources.

For proper implementation of this study two tools Arc GIS coupled with SWAT model were used to compile the SWAT input files. The systematic study of land use/ cover dynamics

requires good and adequate data to assess the changes clearly. Parameterization of SWAT model and assessment of hydrologic impacts of land use change were performed based on the spatial and time series data sets available and other data sets obtained by remote sensing.

3.2.1 Spatial Data

Spatial datasets collected for this research work includes Digital Elevation Model (DEM), land use/land cover and soil data for Omo Gibe Basin and after delineating the watershed of Megecha River catchment extracted to the study area using shape file of the river catchment.

Digital Elevation Model (DEM)

DEM is also one of the essential spatial inputs required by SWAT. Topography is defined by a DEM that describes the elevation of any point in a given area at a specific spatial resolution. The DEM was freely downloaded from <https://earthexplorer.usgs.gov/> website. The Digital Elevation Model (DEM) with a 30m spatial resolution were used that clipped from the Shuttle Radar Topography Mission (SRTM) to delineate the watersheds of the study area and its sub-basins and also to generate elevation, slope and to define the location of the streams network/ the drainage pattern of the watershed in a river catchment. The raw DEM were processed and projected using ArcGIS 10.4 interface.

Land Use Land Cover

Land use and land cover maps were developed using satellite image of Landsat5 TM 1996, Landsat7 ETM+ 2006 and Landsat8 OLI/TIRS 2016 through maximum likelihood algorithm of unsupervised classification using ERDAS Imagine 2015 and ArcGIS software for satellite image processing and map preparation. Land use land cover map is very crucial input for SWAT for determining the impacts on watershed hydrology and describe the hydrological response units (HRUs) of the watersheds.

The classification of the land use map was prepared to represent the land use/cover according to the information from USGS Earth Explore. Nine different types of land use and land cover were identified for the study area as shown in Tables 3.2. SWAT model predefined land uses identified by four letter codes (Table 3:2) and it uses these codes to link land use maps to SWAT land use databases.

Table 3: 2 Land use land cover classes used in the study area

Land use land cover Classes	Characterization of features
Grazing Lands	Grass and herb cover with scattered trees and shrubs and are areas with permanent grass cover used for livestock grazing including communal and protected areas. They tend also to be open areas with good visibility on flat areas and hill slopes and are homogeneous, no pattern compared to agricultural land.
Shrubs	Shrubs, bushes and young tree species have increased in density to be co1dominant with herbaceous plants in terms of cover
Cultivated Lands	This unit includes cropping area. Cultivated and fallow lands have a characteristic pattern such as sharp edges between fields.
Forests	Natural forests and woodlands with a composition of different tree species.
Settlements	Rural settlements in the study area.

Source: Hurni and Ludi, 2000

Soil Data

Soils in the study watershed are classified on the basis of the revised FAO/UNESCO ISWC (FAO/UNESCO-ISWC) classification system. The soil data was extracted from the 1: 250000 scale of soil map (Fig. 3.6) developed by Ministry of Water and Energy (MoWE, 2007). In shape file format soil type distribution map of Ethiopia were collected from Ethiopian Ministry of Water, Irrigation and Energy (MoWIE), GIS and Remote sensing department. Soil data is one of the input data for the SWAT model and it has a great effect on amount of runoff generation are

those that describe the hydraulic properties of the soil. The SWAT model requires catchment physical and chemical property of the soil. Soil texture, hydraulic conductivities, available moisture content and bulk density are the main physical properties which govern the movement of water and air through the profile and have a major impact on cycling of water within each HRU. The watershed soil is mainly formed from Eutric vertisols (VRe 65.32%), Humic Nitisols (NTu= 31.26 %,) and Lithic Leptosols (LPq= 3.42 %.).

Accuracy Assessment

Accuracy assessment is an important step in the image classification process. The objective of this process is to quantitatively determine how effectively pixels were grouped into the correct feature classes in the area under investigation. It is a process used to estimate the accuracy of image classification by comparing the classified map with a reference map. The most widely used classification accuracy assessment is in the form of error matrix which can be used to derive a series of descriptive and analytical statistics. The accuracy assessment of the classified map has been done through the comparison of the classified image and the sampling points from the Google Earth Imageries for land use and land cover of 1996, 2006 and 2016. In this study the assessment was carried out using entirely 82, 82 and 72 testing sample points selected randomly for LU/LC map of 1996, 2006 and 2016 respectively. Therefore, the error matrix overall accuracy and kappa statistics were used to interpret the classification accuracy.

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

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

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

Kappa Coefficient (K): Kappa is a measure of the difference between the observed agreements between maps as reported by the diagonal entries in the error matrix.

Table 3:3 Layout of a typical error or confusion matrix

Actual class		A	B	C	D	Σ
Predicted class	A	nAA	Nab	nAC	nAD	nA+
	B	nBA	Nbb	nBC	nBD	nB+
	C	nCA	Ncb	nCC	nCD	nC+
	D	nDA	Ndb	nDC	nDD	nD+
	Σ	n+A	n+B	n+C	n+D	n

The overall accuracy and Kappa coefficient are calculated as shown below.

$$\text{Total (overall) accuracy} = \sum_{k=1}^q \frac{n_{kk}}{N} * 100 \quad 3.8$$

$$\text{Kappa coefficient} = \frac{N \sum_{k=1}^q n_{kk} - \sum_{k=1}^q n_{k+n+k}}{N^2 - \sum_{k=1}^q n_{k+n+k}} * 100 \quad 3.9$$

If the result of the Kappa coefficient value is greater than 0.81, the interpretation of the agreement is almost perfect agreement, the actual land use/cover with classified land use/cover and also if the value of the Kappa coefficient is in between 0.61 and 0.80 the interpretation agreement is substantial agreement (Bogoliubova & Tymków, 2014a).

3.2.2 Time Series Data

Time series data that are collected for proper implementation of this study were precipitation, minimum and maximum temperature, wind speed, relative humidity and hydrological data.

Climate data were obtained from the national meteorological agency (NMA) of Ethiopia whereas hydrological data were collected from Ethiopian ministry of water, irrigation and electricity (MWIE).

Stream Flow Data

Water resource studies highly depend on stream flow data. Daily stream flow data for Megecha River from 1991 to 2006 GC, was collected from the Ministry of Water, Irrigation, and Electricity of Ethiopia. The gauging station has good streamflow records from 1991 to 2006 GC. This data was used for calibration and validation purposes to analyze the impacts of LULCC on streamflow.

Meteorological Data

Meteorological data which include daily rainfall, daily maximum and minimum temperature and weather data such as relative humidity, sunshine hours, and wind speed from 1991-2006. These meteorological data were collected from the national meteorological service agency of Ethiopia. Daily meteorological data recorded at five meteorological stations as shown in appendix A were collected from NMSAE. This meteorological data needed by the SWAT model to simulate the hydrological condition of the basin. Since there may be few meteorological station which have relatively long period of recorded 5 meteorological stations are selected and the collected data range in time between 1991-2016.

Table 3:4 Meteorological dataset, their location and stations name used for study

S. No.	Station Name	Latitude	Longitude	Elevation (m)	RF	Temp (Max,Min)	Relative Humidity	Sun Hr.	Wind speed
1	Butajira	08 ⁰ 07' 21.4" N	038 ⁰ 22' 33.4" E	2074	Yes	Yes	No	No	No
2	Hossana	07 ⁰ 34' 04.1" N	037 ⁰ 51' 22.1" E	2306	Yes	Yes	Yes	Yes	Yes
3	Wulbrag	07 ⁰ 07' 06.0" N	038 ⁰ 56' 10.4" E	1992	Yes	Yes	Yes	Yes	Yes
4	Tora	7 ⁰ 57'.072"N	38 ⁰ 49'.8"E	1600	Yes	No	No	No	No
5	Wolkite	08 ⁰ 16' 50.5" N	037 ⁰ 46' 28.4" E	1884	Yes	Yes	No	No	No

Hydrological Data

The Ethiopian Minister of Water Resources installed the gauging station Megecha near to guber this river which is the main tributary of the flow of river catchment. SWAT requires daily stream flow data for base line period calibration of the model. Stream flow data of Megecha Rivers were collected from Ethiopian Ministry of Water, Irrigation and Energy (MoWIE) hydrology department for a length of 21 years (1990 to 2016). In total, it has 13 sub-watersheds and covers a drainage area of about 292.1km². Flow data collected were used for sensitivity analysis, calibration and validation of the model. Based on the data from 1985-2006 records the watershed has an average annual flow of 3.11m³/sec

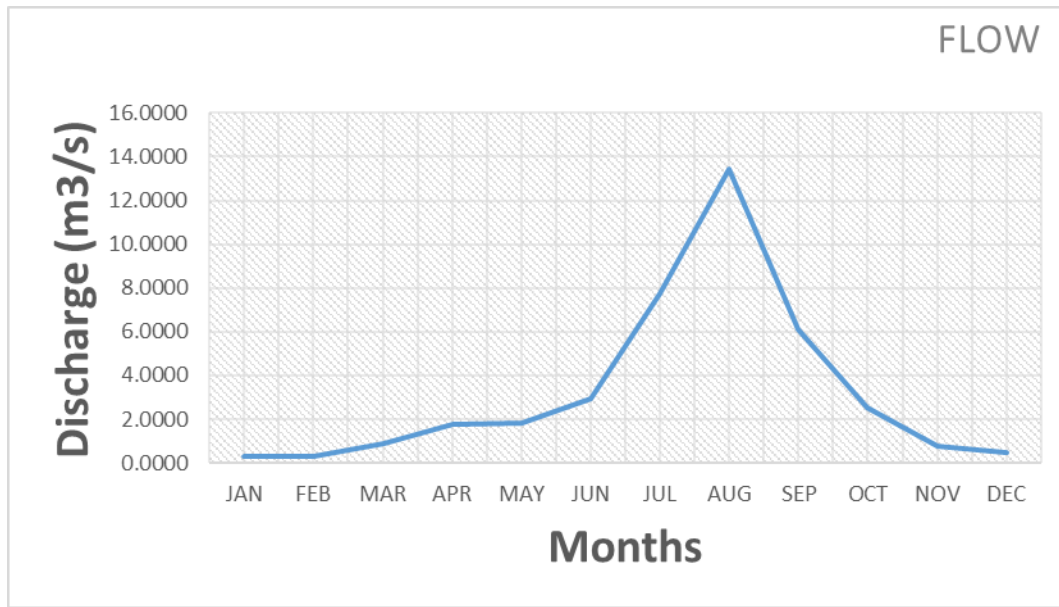


Figure 3: 7 Monthly average discharge at Megecha near Guber gauging station

3.3 Data Analysis

3.3.1 Missing Data Value Estimation

The selection of hydro-climatic stations has been based on the following three criteria: (i) gaps (missing value) in the time series, (ii) homogeneity of the time series, and (iii) consistency. The first criterion applied to control the quality of the data was checking the gaps in all climate time series. Missing data can obscure meteorological research analysis, which may be due to the absence of observer, short disturbances in observations due to breakage, malfunction, and calibration problem of instruments during a certain time period, and therefore, we need to solve this before going for further analyses. There are station average method, normal ratio method, quadrant method, and inverse-distance weighting method and regression methods. In this study, the inverse-distance weighting method was used to fill the missing records for the WEGEN user stations because Prediction at a point is more influenced by nearby measurements than that by distant measurements. The prediction at an ungagged point is inversely proportional to the distance to the measurement points by Compute distance (d_i) from ungagged point to all measurement points and Compute the precipitation at the ungagged point using the following formula

$$\hat{P} = \frac{\sum_{i=1}^N \left(\frac{P_i}{d_i^2} \right)}{\sum_{i=1}^N \left[\frac{1}{d_i^2} \right]}$$

3.1

Where: distance (d_i),

P_i is the missing precipitation value for station i ($i=1, 2, 3...n$),

and $P_1, P_2... P_n$ are precipitation values at the adjacent stations for the same period and N is the number of nearby stations.

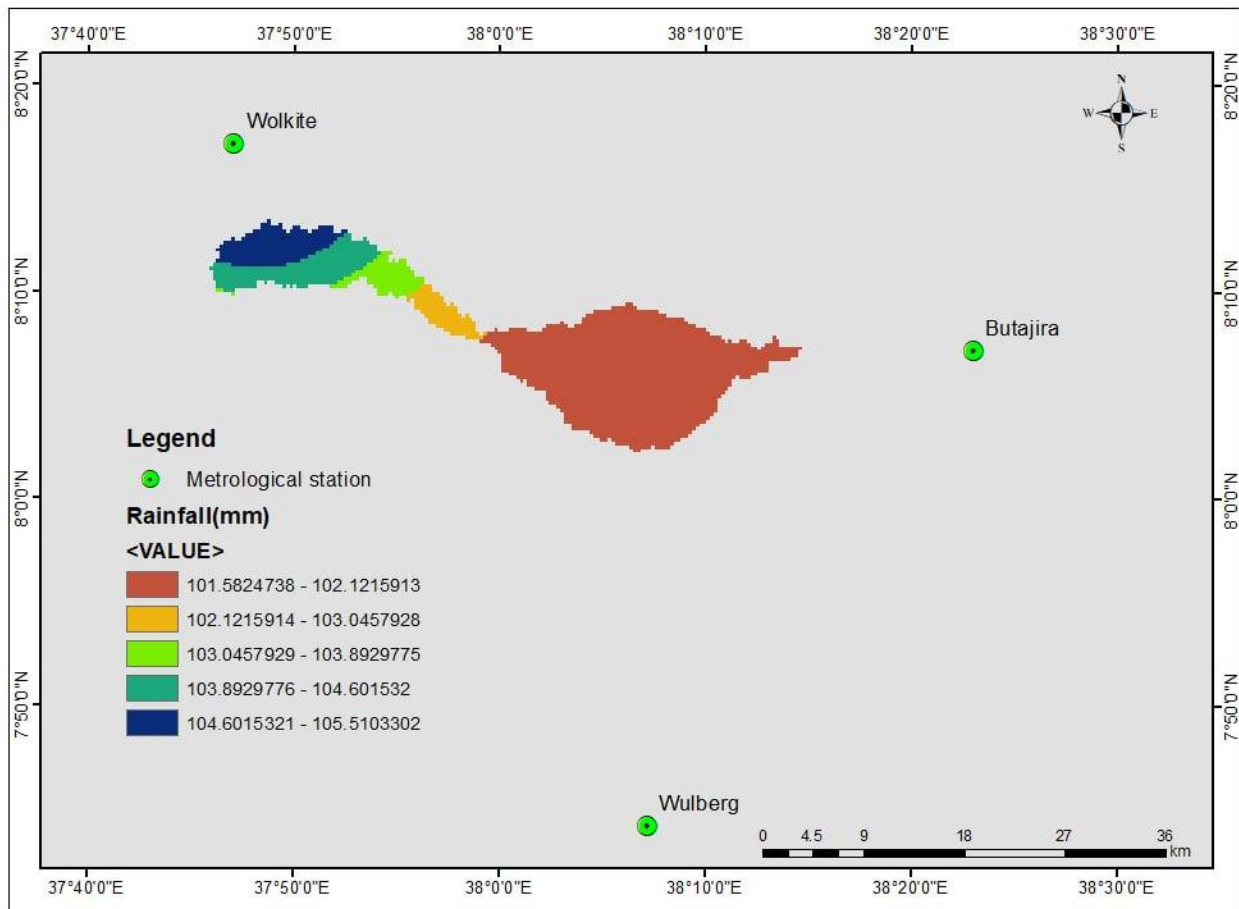


Figure 3: 8 Hydro-Meteorological stations in and around of Megecha River catchment

3.3.2 Homogeneity Test

After the missing value analysis homogeneity test were applied for five stations. To evaluate the performance of the methods used, three different testing variables were used, which are annual mean, annual maximum and annual median. As stated above, the homogeneity of the annual mean precipitation series of the stations throughout Megecha watershed were tested for the whole 1990–2016 period. The annual mean precipitation series for five stations (Butajira, Tora, Wolkite, Wulbareg and Hossana) were calculated by using daily data. The result was evaluated for a significance level of 5% and change point along a time series were not observed. The homogeneity test for Wolkite station is shown as a typical example (see Fig. 3.9).

According to (peterson, et al. , 1998) the recommended method to apply homogeneity has been tested with respect to neighboring stations that is supposedly homogeneous. Hence, to choice the representative meteorological station for the analysis of areal rainfall estimation, checking homogeneity of group stations is essential, the homogeneity of the selected gauging stations monthly rainfall records were computed as defined below.

$$p_i = \frac{P_{i,av}}{P_{av}} * 100 \quad 3.2$$

Where,

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

$P_{i,av}$ =Over years averaged monthly precipitation for the station i

P_{av} = the over years averaged yearly precipitation of the station i

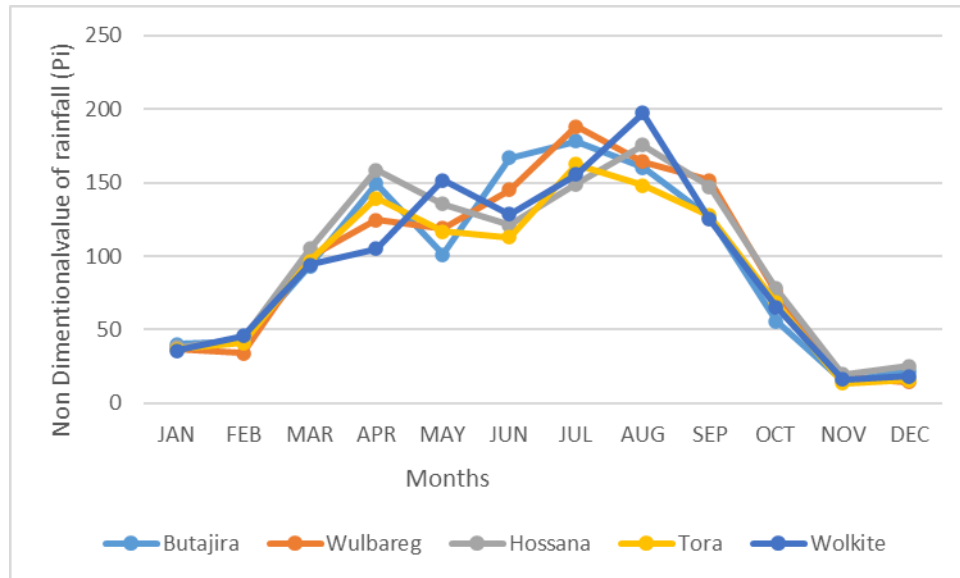


Figure 3: 9 Homogeneity test of selected stations with in and around of Megecha catchment

3.3.3 Checking Consistency and Adjustment of Stations Data

The rain gauge stations have under gone a significant change during the period of record with various reasons; inconsistency would arise in the rainfall data of that station. This inconsistency of a record was done by the double mass curve analysis technique. The theory of double mass curve is based on a graph of cumulative amounts of the station under consideration against the cumulative amounts of a set of neighboring stations during the same period. If the processing is homogeneous, the graph plots a straight line. Time series analysis of rainfall data before using rainfall records at a station for any analysis, the data has to be checked for continuity and consistency. Double mass curve indicates that there is no break point at any stations as shown in Fig. 3:10. It is seen that all stations rainfall are consistent in double mass curve analysis method.

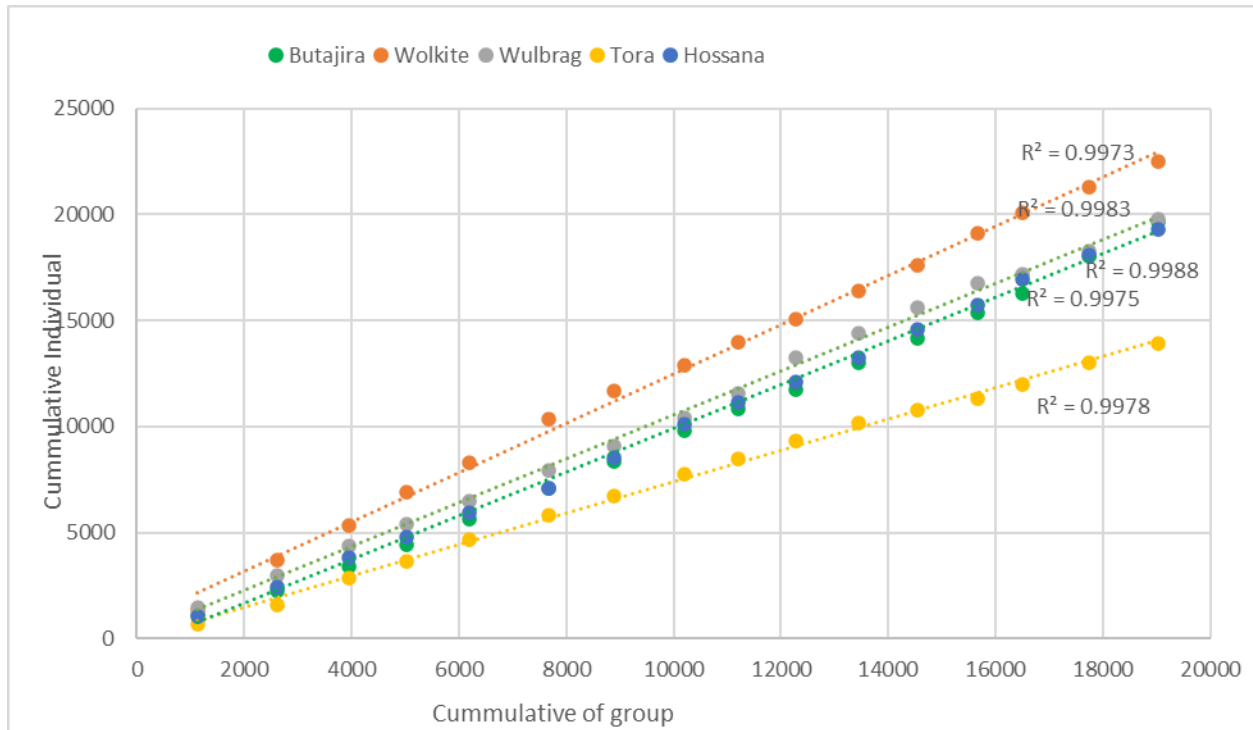


Figure 3: 10 Double mass curve for the selected meteorological stations

3.3.4 Thiessen Polygons Methods

To convert the point rainfall values at various stations into an average value over a catchment, there are a large number of techniques that can be used includes, Arithmetic mean method, Thiessen polygon method and Isohyetal rainfall estimation methods. Thiessen method is more accurate than that of the station average method. However, the accuracy of Isohyetal method depends on knowledge and skill of the hydrologist. Areal rainfall of Megechs watershed was calculated by Thiessen polygon method. It is one way of calculating areal precipitation. The method gives weight to stations data in proportion to space between stations. Lines are drawn between adjacent stations on map. The area of each polygon inside the sub basin area is calculated. This factor is then used as weight of station studies with in that the polygon according the proportion of the total watershed area that is geographically closed to each of the rain gages. Thiessen polygon is drawn by using ArcGIS software. After drawing the polygon it is necessary to find percentage of area that each rainfall station represents. To determine mean areal rain fall amount of each station multiplied by area of its polygon and the sum of those products is divided by total area of the catchment. Each polygon area is assumed to be influenced by the rain gauge station inside it, i.e., if $P_1, P_2, P_3 \dots p_n$ are the rainfalls at the individual stations and $A_1, A_2, A_3 \dots$

An are the areas of the polygon surrounding these stations respectively, the average depth of rainfall for the entire watershed is given by equation 3.3.

$$P_{av} = \frac{\sum_{i=1}^n A_i P_i}{\sum_{i=1}^n A_i} \quad 3.3$$

Where, P_{av} =Average areal rainfall (mm),

$\sum_{i=1}^n A_i$ =total area of the watershed

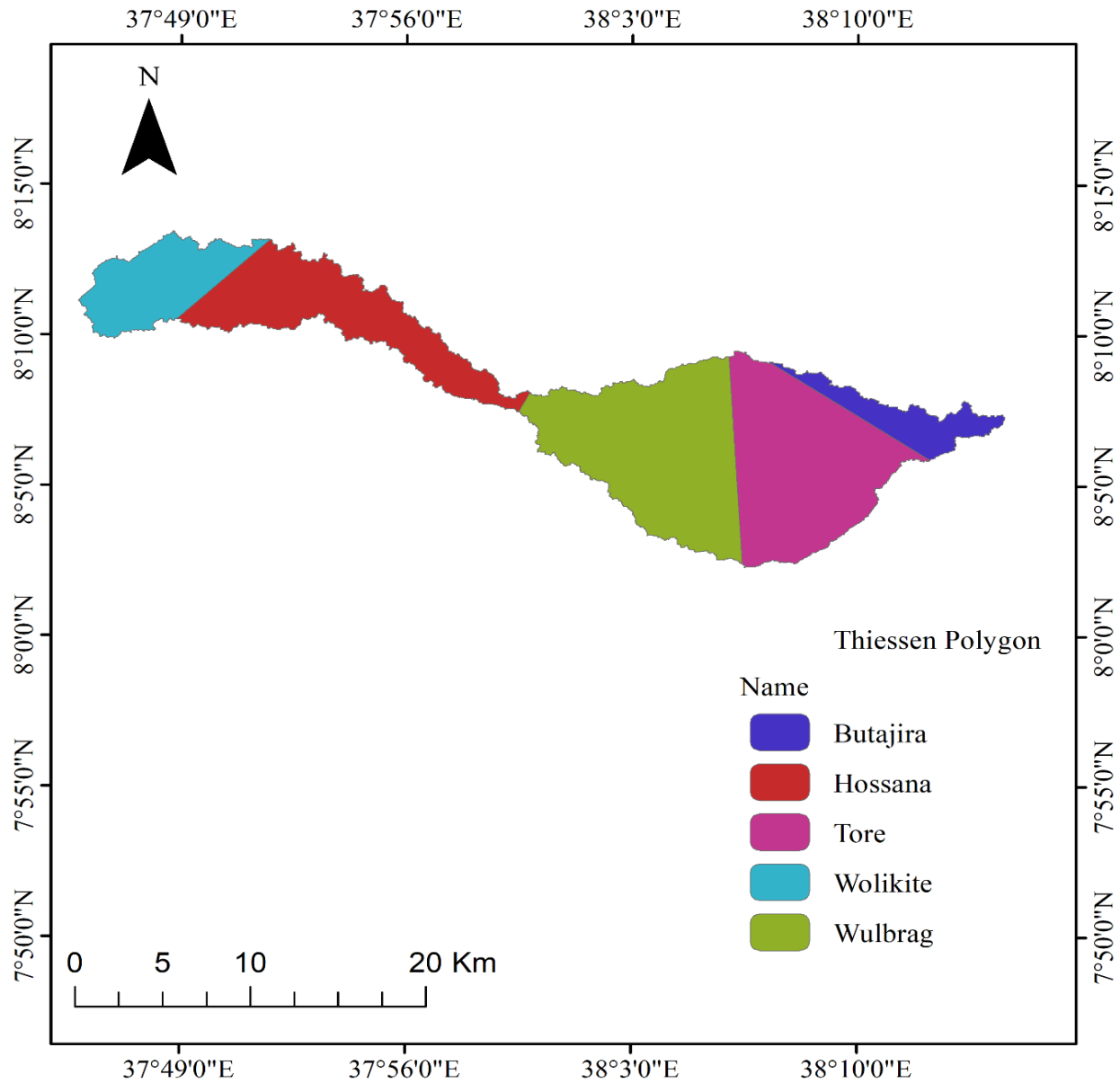


Figure 3: 11 Areal rainfall representation using Thiessen method

Table 3: 5 Thiessen polygon area ratio of Megecha River catchment

S.No	Station_Name	Shape_Area ratio	Latitude	Longitude	Elevation
1	Butajira	0.07	8.15	37.37	2074
2	Wolikite	0.12	8.27	37.75	1884
3	Wulbareg	0.32	7.74	38.12	1992
4	Tora	0.29	7.87	38.42	1600
5	Hossana	0.20	7.57	37.85	2307

3.4 Methodology

3.4.1 Land Use/ Cover Change Detection Analysis and Image Classification

A remote sensing technique was used to detect the general trends of land use/land cover change over the past 20 years period (1996, 2006 and 2016). A pixel based unsupervised image classification with maximum likelihood classification algorithm was used to map the land use/land cover classification of the three period Landsat imageries with ERDAS Imagine 2014 Software. For this purpose from USGS (U.S. Geological Survey) website satellite images were downloaded for the study area. To detect the change through time, the whole 20 years period was grouped into two periods (1996-2006 and 2006 -2016) and used 30m spatial resolution imagery. The Megecha River catchments covered by one scene and were downloaded from <https://earthexplorer.usgs.gov/>. Then the panchromatic bands in the scene were stacked together to produce a multispectral image for each scene. For layer stacking of TM and ETM+ images band 1, 2, 3, 4, 5 and 7 were used while band 1, 2, 3, 4, 5, 6 and 9 were used for OLI/TIRS image. Then geometric and radiometric corrections and image enhancement were done. The references used to select the training sites for the unsupervised image classification was the google earth high resolution imagery. Training areas were derived by connecting ERDAS Imagine 2014 software with google earth and then determine the cover type by examining the image in google earth for each colors having the same cluster from satellite image. The signature level taken was between 15 and 45 for each of the land cover classes over an image. The image data files were downloaded in zipped files and were extracted to tiff format files which were consist of seven image bands. These bands simultaneously record reflected or emitted radiation from the earth's surface in the blue, green, red, near infrared, mid-infrared, and the far-infrared portions of the electromagnetic spectrum. Similar dates of the TM and google earth images were taken while selecting training areas. After the signature was achieved for each class using MLC algorithm nine different land cover classes was made, namely: (1) Crop land; (2) Grass land; (3) Sparse forest; (4) Moderate forest; (5) water body; (6) Open shrub land; (7) closed shrub land (8) Bare land and (9) Settlement were selected for the three land use/ cover periods.

The estimation of the rate of change for the different LULC was calculated based on the following formulas (Kashaigili and Majaliwa, 2013).

$$\% \text{ LULCC} = \frac{\text{Area}_{i \text{ year } x} - \text{Area}_{i \text{ year } x+1}}{\sum_1^n \text{Area}_{i \text{ year } x}} * 100 \quad 3.4$$

$$\text{Annual rate of change} = \frac{\text{Area}_{i \text{ year } x} - \text{Area}_{i \text{ year } x+1}}{t_{\text{years}}} \quad 3.5$$

$$\% \text{ Annual rate of change} = \frac{\text{Area}_{i \text{ year } x} - \text{Area}_{i \text{ year } x+1}}{\text{Area}_{i \text{ year } x} * t_{\text{years}}} * 100 \quad 3.6$$

Where, $\text{Area}_{i \text{ year } x}$ the area of cover i at the first date,

$\text{Area}_{i \text{ year } x+1}$, Area of cover i at the second date,

$\sum_1^n \text{Area}_{i \text{ year } x}$, Is the total cover area at the first date

t_{years} , Is the period in years between the first and second scene acquisition date.

3.4.2 The Swat Model

SWAT is a river basin model that was developed for the Agricultural Research Service by the Black land Research Center in Texas (USDA). The SWAT model is a widely known tool that has been used in several cases world-wide. It has the ability to predict the impact of land management practices on water, sediment and agricultural chemical yield, etc. in large complex watersheds (Arnold, 1998).

The SWAT model sub-divides a basin into sub-basins connected by a stream network and further delineates such sub-basins into Hydrologic Response Units (HRUs) consisting of unique combinations of land use and soils. Areas with the same soil type and land use form a HRU, a basic computational unit assumed to be homogenous in hydrologic response to land cover change. The model application can be divided into the following steps; data preparation, sub-basin discretization, Hydrologic Response Unit definition, parameter sensitivity analysis, calibration and validation and uncertainty analysis (Zhang, et al., 2009)

Soil and Water Assessment Tool (SWAT) is a physically-based semi-distributed model that operates on continuous time scale (Arnold, 1998). SWAT model operates on a daily time step and predicts the impact of land management in large complex watersheds with varying soils,

land use and management conditions. Major model components include DEM, weather, hydrology, soil and properties and land management (Neitsch, et al., 2009). SWAT model is the distributed rainfall-runoff model dividing the river into smaller discrete units for which spatial variations of the major physical properties are limited and treated as homogenous (Arnold, et al 2012)

3.4.2.1 Equations of Watershed Hydrology

The important equations to predict the watershed of hydrology is given below. The hydrologic cycle simulated by the SWAT is based on water balance equation (Neitsch, et al 2005)

$$SW_t = SW_o + \sum_{i=1}^t (R_i - Q_i - ET_i - P_i - QR_i) \quad 3.7$$

Where, SW_t and SW_o are the final and initial soil water content respectively (mm), i is time in days for the simulation period t , R = daily rainfall (mm), Q = daily surface runoff (mm), ET = daily evapotranspiration (mm), P = daily percolation (mm) and QR = daily lateral flow (mm)

3.4.2.2 Hydrological Component of SWAT Model

The simulation of the hydrology of a watershed is classified in two. One is the land phase of the hydrological cycle that controls the amount of water, sediment, nutrient and pesticide loading to the main channel in each sub-basin. Hydrological components simulated in land phase of the hydrological cycle are canopy, storage, infiltration, redistribution, evapotranspiration, lateral surface flow, surface flow, surface runoff, pond, tributary channels and return flow.

The second division is routing phase of the hydrologic cycle that can be defined as the movement of water, sediment, nutrients and organic chemicals through the channels network of the watershed to the outlet (Neitsch, S.L., et al 2005)

3.4.3 Model Setup

In this model set up the following steps were followed: Data preparation, watershed delineation, HRUs definition, weather write up, SWAT simulation, sensitivity analysis, calibration and validation. Data preparation: the collected DEM were projected to, UTM 37N. The satellite image were also classified using ERDAS Imagine and saved to raster data format (UTM 37N). Following DEM data preparation, watershed delineation proceeded using the projected 30 m by 30 m DEM and generate prevailing stream network from the indicated digital elevation model with assigned draining area threshold magnitude. The smaller the draining area threshold the

denser the stream network. This helps to capture the spatial variability of a channel network at very small areal extent. As a result of this, the whole watershed was divided into 13 sub basins as shown in Fig. 3:12. The area delineated by the Arc SWAT interface was found to 292.1 km² which is similar to the manually delineated area. After watershed delineation land use and soil map along with their respective look up tables prepared earlier were supplied to the model for reclassification according to SWAT coding convention. Further entire watershed was classified into five slope categories i.e. (0-2), (2-10), (10-15), (15-30) and (30-99) using the interface. The land use, soil and slope datasets were imported overlaid and linked with the SWAT databases. To define the distributions of HRUs multiple HRU definition options were tested. For multiple HRU definition 5 percent land use, 10 percent soil and 10 percent slope threshold were used. After sub-basin discretization writing up of the prepared weather data to the model were done. Weather data can be entered in SWAT interface following the reclassification of land use/cover slope and soil data. Daily time-series of weather data, which includes precipitation, maximum and minimum air temperature data, daily sunshine hour, daily wind duration and relative humidity is required for SWAT modeling. From the five weather stations, Wolkite was selected to be principal station for the weather generator. Missing values of climatic variables were supplied as the model input. These missed weather data were generated by model itself. SWAT uses the weather generator program (WXGEN) to generate weather data. It is used in SWAT model to generate climatic data or to fill missing data using monthly statistics which is calculated from existing daily data. To perform this necessary statistical parameter WGNmaker4.1 excel macro program was downloaded from SWAT website and integrated the result into SWAT weather generator database. This excel macro program is designed to calculate the monthly averages and standard deviations of all variables as well as probability of wet and dry days, skew coefficient and average number of precipitation days in the month. Average daily dew point temperature was also calculated using the dew point calculator (dew02) from daily maximum temperature, daily minimum temperature and average relative humidity. The results of WGNmaker4.1 are used by SWAT's weather generator to fill in missing 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. WXGEN parameter and location table of climate data (daily precipitation data files, maximum and minimum

temperatures, wind speed, relative humidity and daily solar radiation which was calculated from the daily available sunshine hours data) were loaded with the missing data filled with a missing data identifier of -99 to link them up with the required files already created for the purpose. After loading all the input data and generating the required database files, SWAT model was initially run on monthly basis using default parameter values. The entire simulation period is from 1996 to 2016.

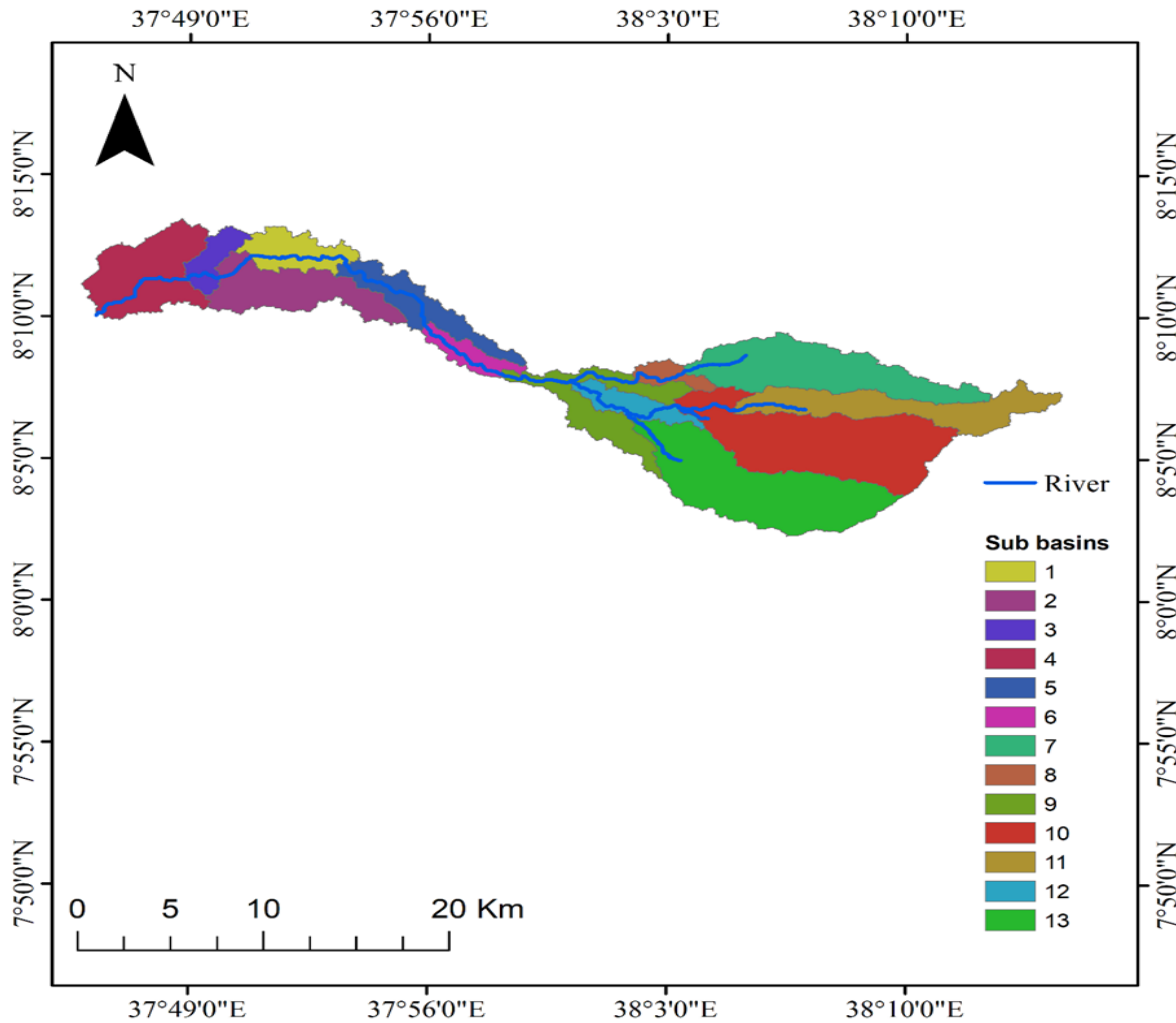


Figure 3: 12 Total Sub-basins of Megacha River Catchment

3.4.4 Sensitivity Model Calibration And Validation

Stream flow data was used for calibration and validation. The model parameters were automatically calibrated by using SUFI-2 algorithm in SWAT-CUP for 10 years and the sensitive parameters which govern the watershed were obtained and ranked according to their

sensitivity rank. Calibration was done by adjusting the model sensitive parameter values until the simulated results much with observed data. For this study, three-year land use land cover map (1996, 2006, 2016) were prepared and also the calibration is operated. As based on the watershed characteristics used for evaluation of land use land cover change on stream flow.

Model validation is testing of calibrated model results with independent set of measured data (stream flow) without any further adjustment of parameters. For this study five years of flow and data used for validation period.

In order to utilize the calibrated model for estimating the effectiveness of future potential, the model tested against an independent set of measured data. This testing of a model on an independent set of data set is commonly referred to as model validation. As the model predictive capability was demonstrated as being reasonable in both the calibration and validation phases, the model was used for future predictions under different management scenario. After calibrating and validation, simulated flow was executed and the hydrographs are well observed and the graph used for analysis. The agreement between the observed stream flow and simulated flow was generally very good, which are verified by NSE, PBIAS and RMS an acceptable result was obtained according to the model evaluation guideline (Moriassi, et al. , 2007).

3.4.4.1 Sensitivity Analysis

Sensitivity analysis is conduct to determine the influence of a set of parameters had on predicting total flow, and other model output of interest. It is a method of identifying the most sensitive parameters that have a significant effect on model calibration or on model prediction (Dilnesaw, 2006). A model sensitivity analysis can be helpful in understanding which model inputs are most important or sensitive and to understand potential limitations of the model. For large hydrological models like SWAT, which involve a wide range of data and parameters in the simulation process calibration is a quite complicated task. On the other hand, SWAT input parameters must be held within a realistic uncertainty range since most of the parameters are process based. Therefore, determination of the most sensitive parameters for a given watershed or sub basin is the first step in the calibration and validation process. The modeler should be identifying sensitive parameters to allow the possible reduction in the number of parameters that must be calibrated afterward reducing the computational time required for model calibration.

Several statistical methods are employed to perform uncertainty analysis, sensitivity analysis, calibration, and validation. SWAT-CUP is an interface that was developed for SWAT model from other developers include the methods of Sequential Uncertainty Fitting (SUFI-2), Particle Swarm Optimization (PSO), Generalized Likelihood Uncertainty Estimation (GLUE), ParaSol (Parameter Solutions), Parameter Estimation (PEST), and Markov Chain Monte-Carlo (MCMC) (Gassman, P.W., et al, 2007). It is automated model calibration requiring that the uncertain model parameters are systematically changed, the model is run, and the required outputs (corresponding to measured data) are extracted from the model output files.

The t-stat which gives a measure of the sensitivity of a parameter (larger absolute values are more sensitive) and the p-value, the significance of the sensitivity of that parameter (a value close to zero has more significance) were used to rank the various parameters considered to influence stream flow. 21 SWAT flow governing parameters were selected and in initializing the sensitivity analysis, the parameters listed in Table 4:6 were considered and the final sensitive parameters were selected based on the t-stat and the p-value.

3.4.4.2 Uncertainties Analysis

Uncertainty analysis was performed to quantify the uncertainty associated with model simulations. The p-factor (percentage of measured data bracketed by the 95 % prediction boundary), often referred to as 95PPU, the r-factor performance statistics and dot plots were used to quantify all the uncertainties associated with the SWAT model. During the initialization of model parameters, SUFI-2 assumes a large parameter uncertainty and then decreases this uncertainty through the p-factor and the r-factor performance statistics. The range of the p-factor varies from 0 to 1, with values close to 1 indicating a very high model performance and efficiency, while the r-factor is the average width of the 95PPU band divided by the standard deviation of the measured variable and varies in the range 0-1) (Yang, J., et al., 2008).

P-factor is the percentage of observed data enveloped by our modeling result, the 95PPU. R-factor is the thickness of the 95PPU envelop. In SUFI2, we try to get reasonable values of these two factors. For P-factor, we suggested a value of >70% for discharge, while having R-factor of around 1. For sediment, a smaller P-factor and a larger R-factor could be acceptable. The goodness of fit and the degree to which the calibrated model accounts for the uncertainties are assessed by the above two measures. Theoretically, the value for P-factor ranges between 0 and

100%, while that of R-factor ranges between 0 and infinity. A P-factor of 1 and R-factor of zero is a simulation that exactly corresponds to measured data. The degree to which we are away from these numbers can be used to judge the strength of our calibration and validation.

3.4.5. Model Performance Evaluation

Model performance evaluation is an essential measure to verify the robustness of the model and to judge on the extent to which it satisfies objective of simulating the real world phenomena, or the extent to which the achieved level of accuracy persists through different sample of data (consistency) and on the extent to which it can sustain the achieved level of accuracy when subjected to diverse application tests other than those used for calibrating the model (versatility).

The performances of SWAT were evaluated using statistical measures to determine the quality and reliability of predictions when compared to observed values. In this study, three model evaluation methods were used, which were coefficient of determination (R^2), Percent bias (PBIAS) and Nash and Sutcliff Simulation Efficiency (ENS).

The coefficient of determination (R^2)

The coefficient of determination (R^2) value shows how well a data fit into a statistical model. The range of coefficient of determination lies between 0 and 1. The closer the value of R^2 to 1, the higher is the agreement between the simulated and the measured flows, When R^2 value is 1, it can be describes that the regression line perfectly fits the data while R^2 value is 0 shows that the line does not fit the data at all. It is calculated as:

$$R^2 = \frac{[\sum_i (Q_{m,i} - \bar{Q}_m)(Q_{s,i} - \bar{Q}_s)]^2}{\sum_i (Q_{m,i} - \bar{Q}_m)^2 \sum_i (Q_{s,i} - \bar{Q}_s)^2} \quad 3.8$$

Where, R^2 is coefficient of determination, Q is a variable (e.g. Discharge), and m and s stand for measured and simulated, i is the i^{th} measured or simulated data.

Percent bias (PBIAS)

It is the deviation of simulated data from observed data being evaluated, which is expressed as a percentage. The low magnitude values indicate accurate simulation of the model. Percent bias

measures the average tendency of the simulated data to be larger or smaller than the observations. The optimal value of PBIAS is zero, with low-magnitude values indicating accurate model simulation. Positive values indicate model underestimation bias, and negative values indicate model overestimation (Gupta *et al.*, 1999).

$$\%BIAS = 100 * \frac{\sum_{i=1}^n (Q_m - Q_s)_i}{\sum_{i=1}^n Q_{m,i}} \quad 3.25$$

Where, Q is a variable (e.g. Discharge) and m and s stand for measured and simulated respectively.

Nash-Sutcliffe efficiency (NSE)

The Nash-Sutcliffe model efficiency shows how much the model accurately simulated the natural process. The value of NSE can range from $-\infty$ to 1 and when efficiency is equal to 1 it indicates a perfect match of estimated discharge with the observed data. When the value of NSE is 0.75 to 1.00, 0.65 to 0.75, 0.50 to 0.65 and if below 0.50 the performance rating for intervals is very good, good, satisfactory and unsatisfactory respectively (Moriasi, 2007).

$$NSE = 1 - \frac{\sum_i (Q_m - Q_s)_i^2}{\sum_i (Q_{m,i} - \bar{Q}_m)^2} \quad 3.10$$

Where, **NSE** is Nash-Sutcliffe efficiency, Q is a variable (e.g. Discharge), m and s stand for measured and simulated respectively and the bar stands for an average.

3.5 Conceptual Framework of The Research

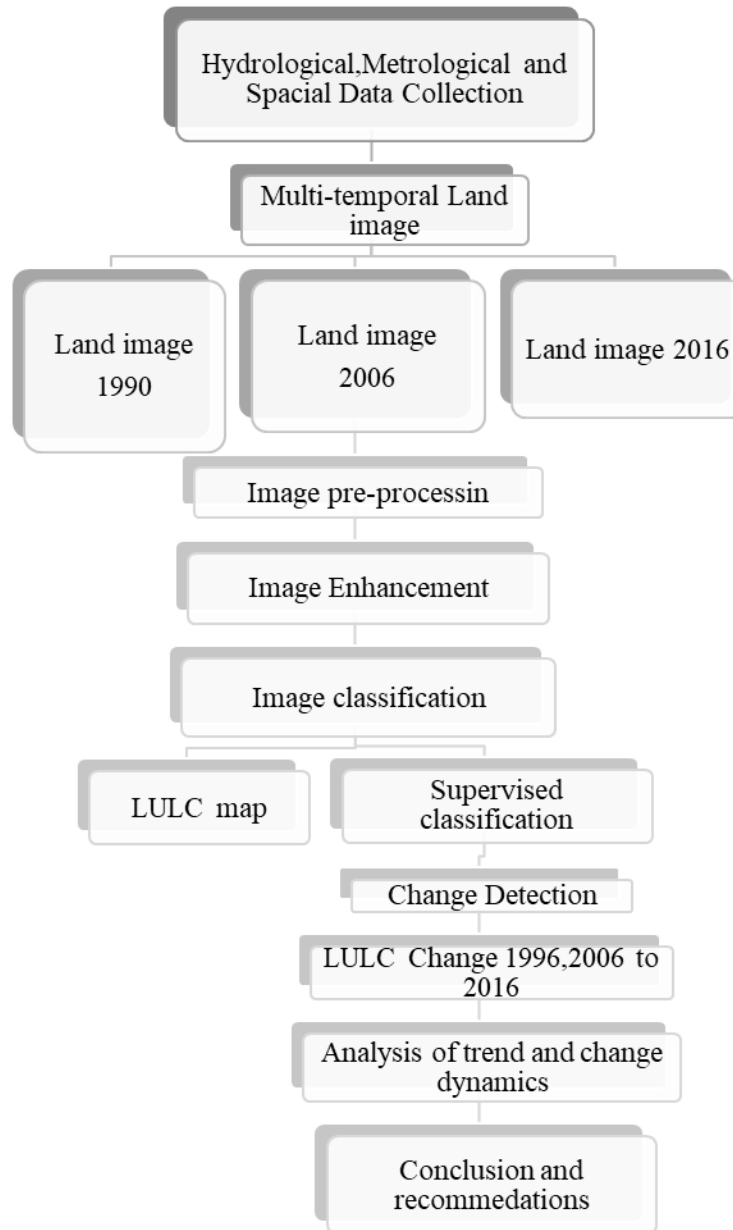


Figure 3:13 Conceptual framework of the study

4. Results And Discussions

4.1. Analyses Of Land Use Land Cover Change

LU/LC classes categorized from Landsat TM (1996), ETM+ (2006) and OLI-TIRS (2016) includes water body, sparse forest, moderate forest, shrub land, grass land, crop land, settlement and bare land. The results of the land use classified maps are presented in Fig.4.1. The details of this land use/land cover types; classification and coverage area under different time periods are listed below.

Table 4.1 LU/LC types and coverage area in Megecha River catchment (1996-2016)

LU/LC category	1996		2006		2016	
	Area (km ²)	%	Area (km ²)	%	Area (km ²)	%
Bare land	6.46	2.21	2.14	0.73	0.23	0.08
Closed shrub land	40.98	14.03	45.91	15.71	51.12	17.50
Cropland	200.92	68.80	206.29	70.58	207.76	71.13
Grassland	18.14	6.21	18.49	6.33	13.11	4.49
Moderate forest	11.55	3.95	5.37	1.84	5.90	2.02
Open shrub land	2.22	0.76	3.64	1.25	4.12	1.41
Settlement	3.18	1.09	4.65	1.59	6.75	2.31
Sparse forest	8.50	2.91	5.72	1.96	3.07	1.05
Waterbody	0.09	0.03	0.06	0.02	0.03	0.01
Total	292.028	100	292.262	100	292.085	100

Classified Land Use For Map Of 1996

The 1996's land use in the Megecha watershed was mainly classified as cropland, which takes up about 68.80% (200.92 km²) of the total watershed area. About 14.03% (40.98km²) of the land use was defined as closed shrub land and 6.21%% (18.14 km²), 0.03 % (0.09 km²), 2.21% (6.46km²) , 6.86% (20.05 km²) and 1.09%(3.18km²) was listed as grass land, waterbody, bare

land , forest land (moderate & sparse)and settlement respectively. The details of these land use classification is listed on the Table 4.1 & Fig. 4.1 below.

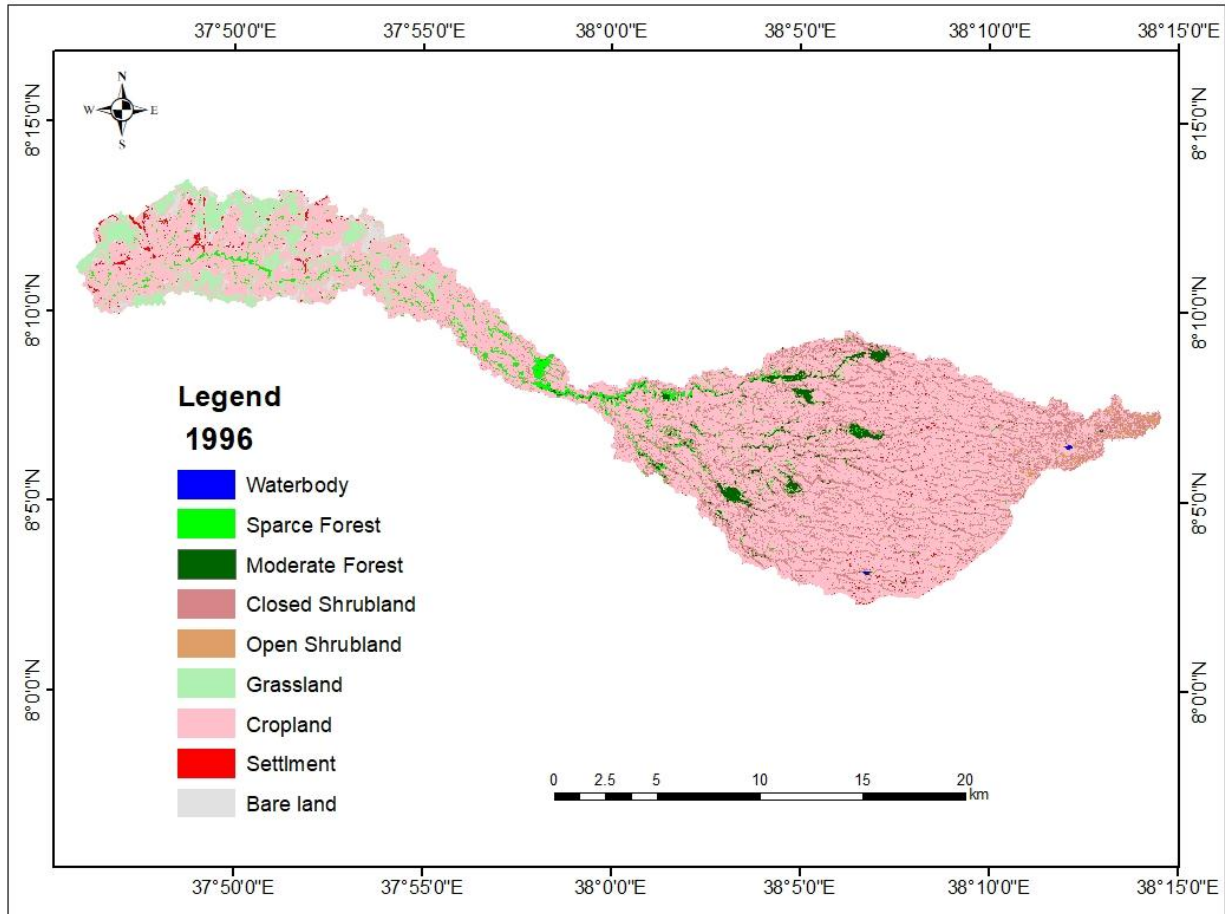


Figure 4:1 Land use land/ cover map of Megecha watershed in 1996

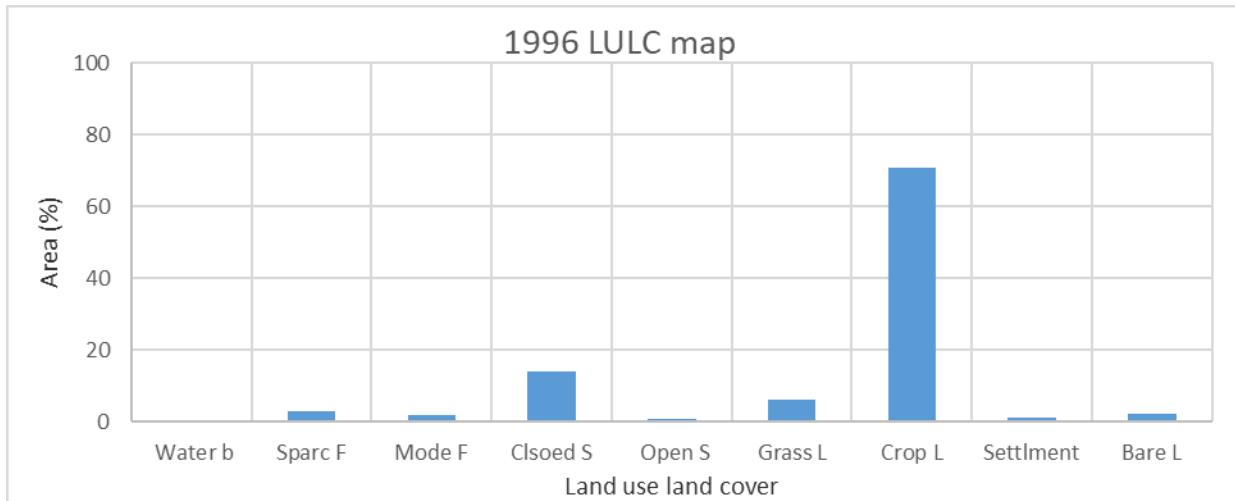


Figure 4:2 Comparison of LU/LC coverage classes of 1996 map

Classified Land Use For Map of 2006

The land cover map of 2006 and the histogram of the land class coverage shown that about 70.58% (206.49 km²) of the Megecha River catchment was covered by crop land, 15.71(45.91 km²) by close shrub land, 1.59%(4.65 km²) by settlement, 6.33%(18.49km²) by grass land, 0.02% (0.06 km²) waterbody, 3.8%(11.09 km²) by forest land, 0.73%(2.14 km²) by bare land and open shrub land 1.25%(3.64 km²). The distribution of land cover class had shown in the Figure 4-2. During this period the cropland land was predominantly distributed at lower, central, southeastern and northern part of the catchment in expense of bare land, grassland and forest land. However in contrast settlement and shrub land was expanded.

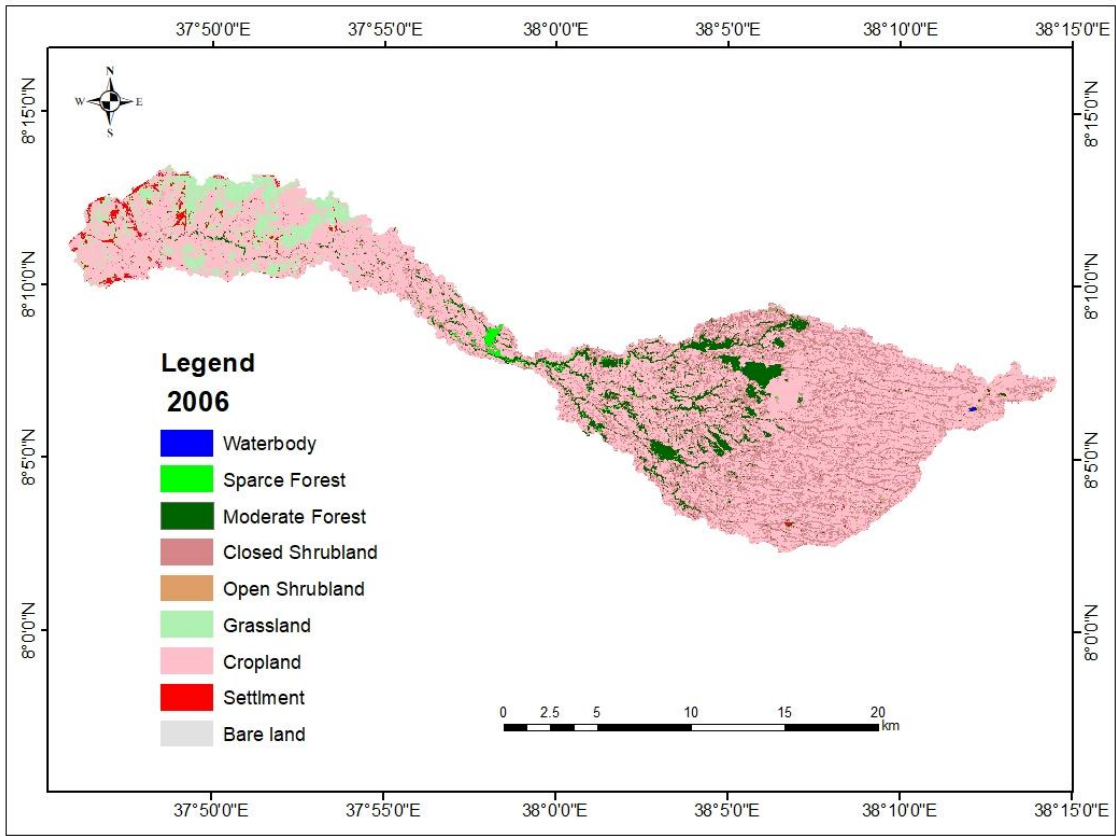


Figure 4.3 Land use land/ cover map of Megecha watershed in 2006

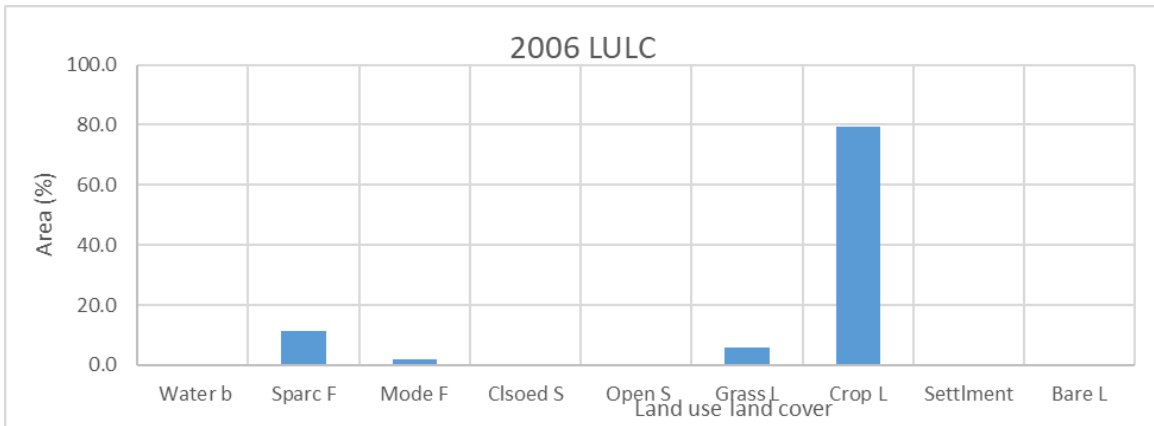


Figure 4.4 Comparison of LU/LC coverage classes of 1996 map

Classified Land Use for Map of 2016

The land cover map of 2016 and the histogram of the land class coverage shown that about 71.13 % (207.76 km²) of the river catchment was covered by crop land, 17.50(51.12 km²) % by shrub land, 2.31%(6375 km²) by settlement, 4.49%(13.11 km²) by grass land, 3.07%(8.97 km²) by forest land, 0.01% (0.03 km²) by water body and 0.08% (0.23 km²) by bare land. The distribution of land cover class was as shown in the Figure 4-3. In this period due to high increase of population growth most of the catchment area was transformed into cropland and settlement. Owing to this predominantly the crop land was spread alarmingly throughout the catchment in expense of shrub land. In similar settlement also expanded; especially forest cover was amplified in disbursement of grassland and agroforestry in the northern, northeastern and at eastern part of the catchment and built up area increased tremendously in northwestern part and central, wester part of the catchment.

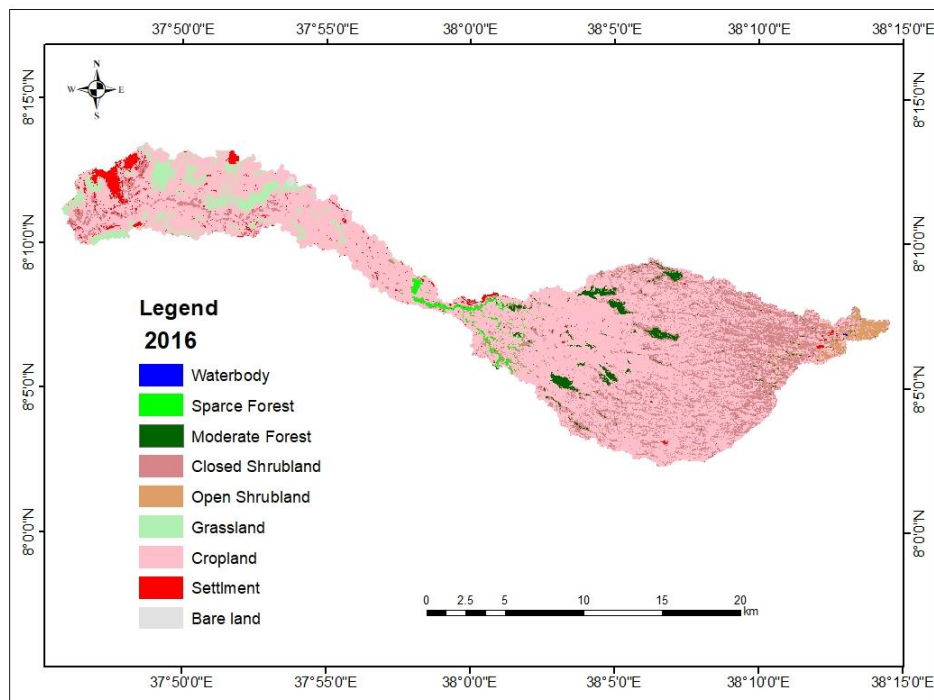


Figure 4:5 Land use land/ cover map of Megecha watershed in 2016

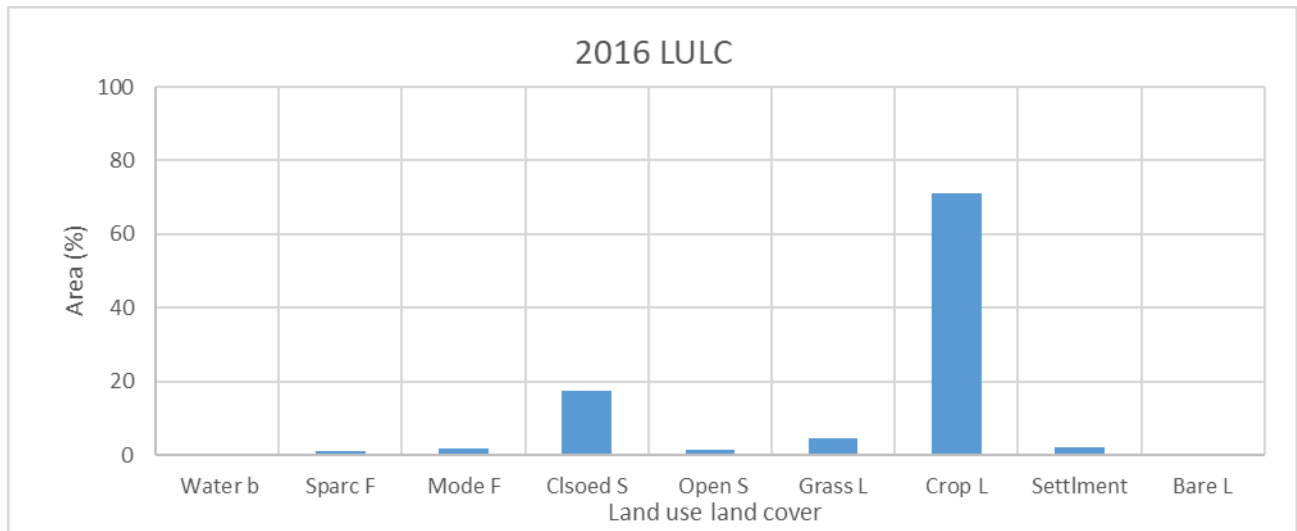


Figure 4:6 Comparison of LU/LC coverage classes of 2016 map

4.2 Land Use/Land Cover Change Detection

On the basis of the change detection analysis from the LULC data, the cropland in the watershed increased from 68.80% in 1996 to 71.13 in 2016. Similarly shrub land and settlement shows slight increase. The rest showed a decrement in area coverage. It can be observed that there was an agricultural expansion during the periods 1996– 2016, with a rapid increase of crop land by 3.4% and a decrease of forest land, grass land and water body by -55%, -28% and -67%, respectively. This is believed that the crop land areas expanded at the expense of grass land, forest land and water body. This is mainly be because of the population growth that caused the increase in demand for new agricultural land and rural settlements which in turn resulted shrinking on other types of land use and land cover of the area. The study in different parts of Ethiopia had a similar trend of land use and land cover change with this study.

Table 4.2 land use land cover map of Megecha watershed for different period

LU/LC category	1996-2006		2006-2016		1996-2016	
	Change in km2	% change	Change in km2	% change	Change in km2	% change
Bare land	-4.32	-16.08	-1.91	-9.65	-6.22	-13.88
Closed shrub	4.93	18.35	5.21	26.37	10.14	22.61

land						
Cropland	5.37	20.01	1.47	7.46	6.85	15.27
Grassland	0.35	1.31	-5.38	-27.21	-5.02	-11.21
Moderate forest	-6.18	-23.04	0.54	2.71	-5.65	-12.60
Open shrub land	1.42	5.30	0.48	2.41	1.90	4.24
Settlement	1.47	5.46	2.10	10.61	3.56	7.95
Sparse forest	-2.78	-10.34	-2.66	-13.45	-5.43	-12.12
Waterbody	-0.03	-0.11	-0.03	-0.15	-0.06	-0.13
Total	26.846		19.757		44.831	

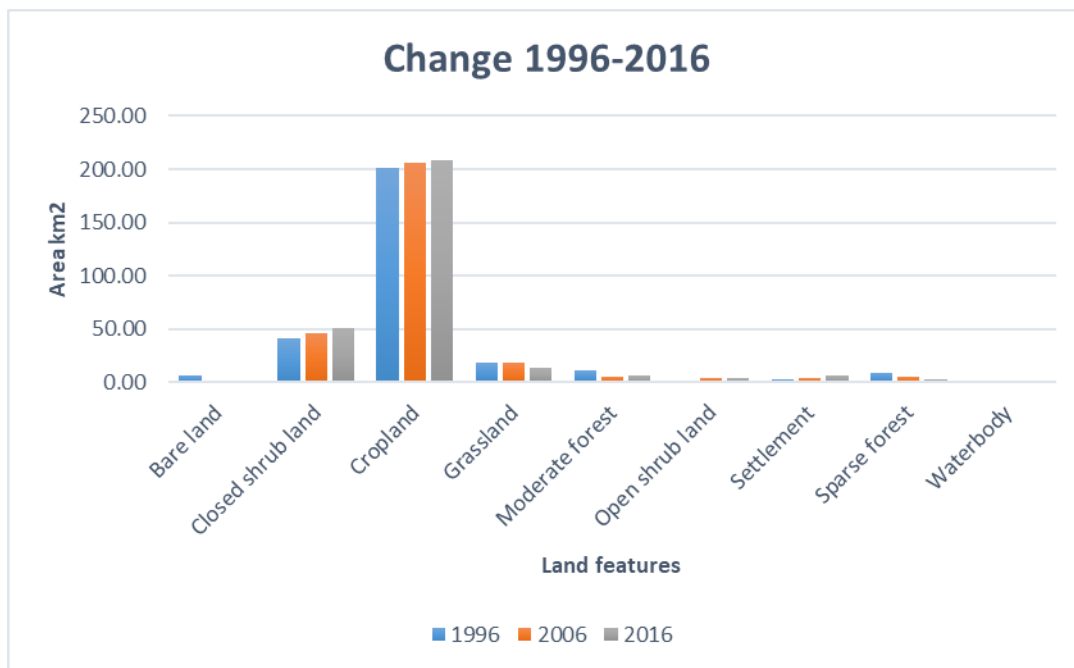


Figure 4:7 Comparisons of percent of land use category

4.3. Accuracy Assessment Of Land Cover Classification

An accuracy of image classification was estimated for 1996, 2006 and 2016 land use/ cover periods using randomly selected control points. Each classified point was then compared with these field data to ascertain the classification accuracy. The 1996, 2006 and 2016 land use classification has showed. 87.80%, 91.46% and 97.56% respectively (Table 4.3, 4.4 & 4.5) which indicated the classification is almost perfect since it is greater than 80%.

Table 4:3 Accuracy assessment of land use/land cover classification of **1996**

Class name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Water body	2	2	2	100.00%	100.00%
Sparse Forest	9	10	8	88.89%	80.00%
Moderate Forest	11	10	9	81.82%	90.00%
Closed Shrub land	9	10	9	100.00%	90.00%
Open Shrub land	12	10	9	75.00%	90.00%
Grassland	10	10	8	80.00%	80.00%
Cropland	11	10	9	81.82%	90.00%
Settlement	9	10	9	100.00%	90.00%
Bare land	9	10	9	100.00%	90.00%
Totals	82	82	72		

Overall Classification Accuracy = **87.80%**

Kappa coefficient=0.8625

Table 4:4 Accuracy assessment of land use/land cover classification of 2006

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Water body	2	2	2	100.00%	100.00%
Sparse Forest	9	10	9	100.00%	90.00%
Moderate Forest	11	10	10	90.91%	100.00%
Closed Shrub land	9	10	9	100.00%	90.00%
Open Shrub land	13	10	10	76.92%	100.00%
Grassland	9	10	8	88.89%	80.00%
Cropland	11	10	9	81.82%	90.00%
Settlement	9	10	9	100.00%	90.00%
Bare land	9	10	9	100.00%	90.00%
Totals	82	82	75		

Overall Classification Accuracy = **91.46%**

Kappa coefficient=0.9000

Table 4:5 Accuracy assessment of land use/land cover classification of 2016

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Water body	2	2	2	100.00%	100.00%
Sparse Forest	10	10	10	100.00%	100.00%
Moderate Forest	10	10	10	100.00%	100.00%
Closed Shrub land	10	10	10	100.00%	100.00%
Open Shrub land	11	10	10	90.91%	100.00%
Grassland	10	10	9	90.00%	90.00%
Cropland	9	10	9	100.00%	90.00%
Settlement	10	10	10	100.00%	100.00%
Bare land	10	10	10	100.00%	100.00%
Totals	82	82	80		

Overall Classification Accuracy = **97.56%**

Kappa coefficient=0.975

4.4 Model Sensitivity, Calibration And Validation

4.4.1. Sensitivity Analysis

Sensitivity analysis for simulated stream flow of the catchment was done using monthly average Megecha river discharge for identifying the most sensitive parameters and for further calibration and validation of the simulated flow. Before performing the calibration, the sensitivity of the parameter was carried out using the Latin hypercube one-factor-at-a-time (LH-OAT) method of SWAT (Van Griensven, 2006) SWAT hydrologic model sensitivity analysis was carried out to identify which model parameter is most sensitive in the Megecha Gubere watershed. It was done for a period of eleven years, which includes one warm-up period (January 1, 1991 to December 31, 1991) and ten years calibration period (January 1, 1992 to December 31, 2001). Based on the results obtained from sensitivity analysis using SUFI-2, the ranks of parameters assigned depending on p-value and t-stat. P-value indicates significance of sensitivity and t- stat provides the measure of parameter sensitivity. Larger in the absolute value of t-stat means the parameter is more sensitive and p-value closer to zero means parameter has more significance. 21 parameters were used to check sensitivity analysis and the parameters that influence runoff in the study area from high, medium and low were identified based on the associated p-value and corresponding high t-stat values shown in Table 4.6 From those out 21 parameters three parameters showed high sensitivity (CN2, ALPHA_BF, EPCO), four parameters showed moderate sensitivity, four relatively moderate parameters showed low sensitivity and the effect of the change of the rest parameters were very small or negligible. The results of the sensitivity analysis gave the degree of sensitivity of 21 parameters and the parameter bound which was important for the manual and auto-calibration activities.

Table 4:6 Identified sensitive flow parameters and theirs rank in the Megecha Gubere watershed

Parameter Name	Description	t-Stat	P-Value	Rank	Sensitivity
CN2	SCS runoff curve number	68.37	0.00	1	High
ALPHA_BF	Alpha base flow recession constant	-2.36	0.02	2	High
EPCO	Plant uptake compensation factor	-2.10	0.04	3	High
GW_REVAP	Groundwater "revap" coefficient	-1.37	0.17	4	Moderate
SOL_K	Saturated hydraulic conductivity	-1.21	0.23	5	Moderate
SLSUBBSN	Average slope length	-1.21	0.23	6	Moderate
REVAPMN	Threshold depth of water in the aquifer for "revap" to occur	1.20	0.23	7	Moderate
CANMX	Maximum canopy storage	-1.20	0.23	8	Relatively moderate
CH_K2	Effective hydraulic conductivity in main channel	-1.04	0.30	9	Relatively moderate
SOL_AWC	Available water content of soil	-0.88	0.38	10	Relatively moderate
RCHRG_DP	Deep aquifer percolation fraction	-0.82	0.41	11	Low
SOL_Z	Soil depth (for each layer)	-0.79	0.43	12	Low
CH_COV1	Channel erodibility factor	0.77	0.44	13	Low
SURLAG	Surface runoff lag time	-0.76	0.45	14	Low
GWQMN	Threshold depth of water in the shallow aquifer	0.73	0.47	15	Low
CH_COV2	Channel cover factor	0.72	0.47	16	least
CH_S2	Average slope of main channel	-0.70	0.48	17	least
CH_N2	Manning's "n" value for the main channel	0.50	0.62	18	least
GW_DELAY	Groundwater delay	-0.36	0.72	19	least
PPERCO	Phosphorus percolation coefficient	0.32	0.75	20	least
ESCO	soil evaporation compensation factor	0.30	0.76	21	least

The result of the analysis indicate that ten parameters namely; curve number (CN), soil available water capacity (SOL_AWC), Saturated hydraulic conductivity (SOL_K), Alpha base flow recession constant (ALPHA_BF) and maximum canopy index (CANMX), Threshold depth of water in the aquifer for "revap" to occur(REVAPMN), Groundwater "revap" coefficient (GW_REVAP), Average slope length (SLSUBBSN), Effective hydraulic conductivity in main channel (CH_K2) and soil evaporation compensation factor (ESCO) are the most important parameters for the studied watershed shown in below Table.

From those ten parameters listed, the first three curve number (CN), Alpha base flow recession constant (ALPHA_BF) and Groundwater "revap" coefficient (GW_REVAP) were the most sensitive highly sensitive parameter and given to high priority for calibration

Calibration and Validation Results

The aim of calibration process is to create agreement between the simulated and observed value by adjusting the sensitive flow parameters in the recommended range. The ten more influential flow parameters from high to relatively moderate sensitive and which were used for further iterations in the calibration period. From the analysis result, simulated and observed mean monthly stream flow matched well in the calibration and validation periods with good NSE and R2 values. The calibrated SWAT model reasonably reproduced coefficient of determination ($R^2 \geq 0.79$), pattern (NSE ≥ 0.75) and RSR ≤ 0.50 for three land use land cover change maps. The results show that there is significant increase in surface run off (14.54 to 33.53%) for the LULC map of 1996 and 2016.

Table 4:7 Calibrated values of model parameters and values of objective functions

Parameter Name	Range	Min value	Max value	Fitted Value
CN2	35- 98	-25%	+25%	40.33
ALPHA_BF	0- 1	0.08	0.43	0.28
GW_REVAP	0.02- 0.2	0.15	0.20	0.17
REVAPMN	0-500	480.00	500.00	487.55
SOL_AWC	0- 1	0.000	0.001	0.001
CH_K2	0- 500	490.00	500.00	496.73
EPCO	0-500	0.90	1.00	0.94
CNMX	0- 10	0.00	0.20	0.01
SLSUBBSN	10- 150	10.00	12.00	11.68
SOL_K	0-2000	1980.00	2000.00	1998.75

Table 4:8 SWAT performances during the calibration and validation periods

1996 LULC	p-factor	r-factor	R^2	NSE	PBIAS	RSR
Calibration	0.75	0.80	0.80	0.80	-1.00	0.45
Validation	0.68	0.82	0.80	0.80	-1.00	0.45
2006 LULC	p-factor	r-factor	R^2	NSE	PBIAS	RSR
Calibration	0.73	0.84	0.79	0.75	10.80	0.50
Validation	0.78	0.85	0.80	0.77	10.00	0.48
2016 LULC	p-factor	r-factor	R^2	NSE	PBIAS	RSR
Calibration	0.75	0.81	0.81	0.80	-0.80	0.45
Validation	0.68	0.82	0.80	0.80	-0.90	0.45

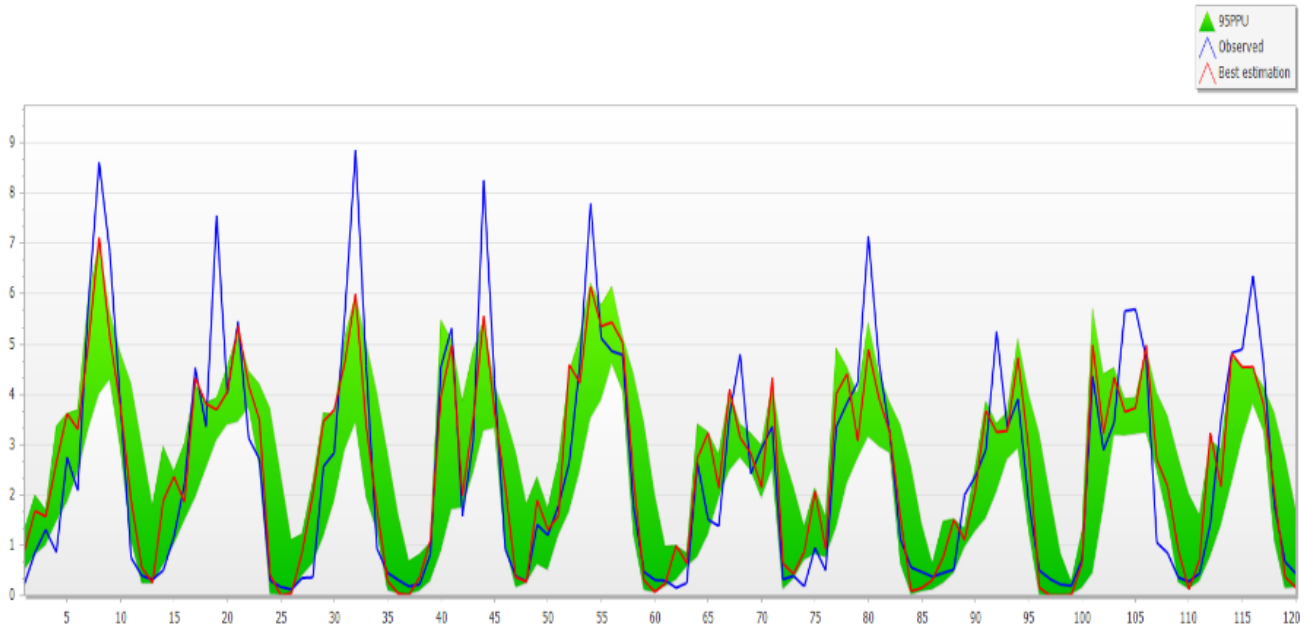


Figure 4:8 Observed and simulated hydrograph for LULC 1996 in between lower and upper bounds

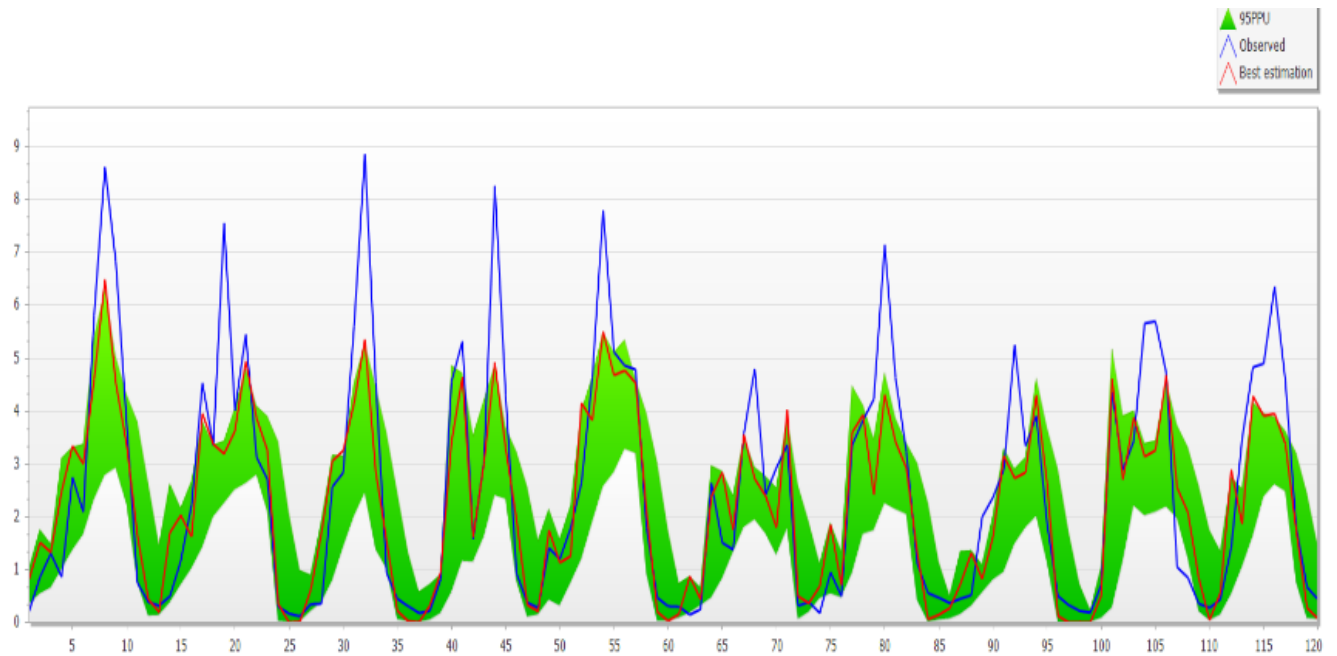


Figure 4:9 Observed and simulated hydrograph for LULC 2006 in between lower and upper bounds

The monthly measured and simulated flows have a satisfactory correlation and agreement, according to the model performance assessment. The SWAT model's simulation capabilities for

the studied watershed is demonstrated by a comparison of the hydrographs of actual and simulated flow levels. As a result, the model can estimate the composition of streamflow and contributions from various land use/cover classifications. As a result, the model simulations may be used to numerous elements of water resource management and development.

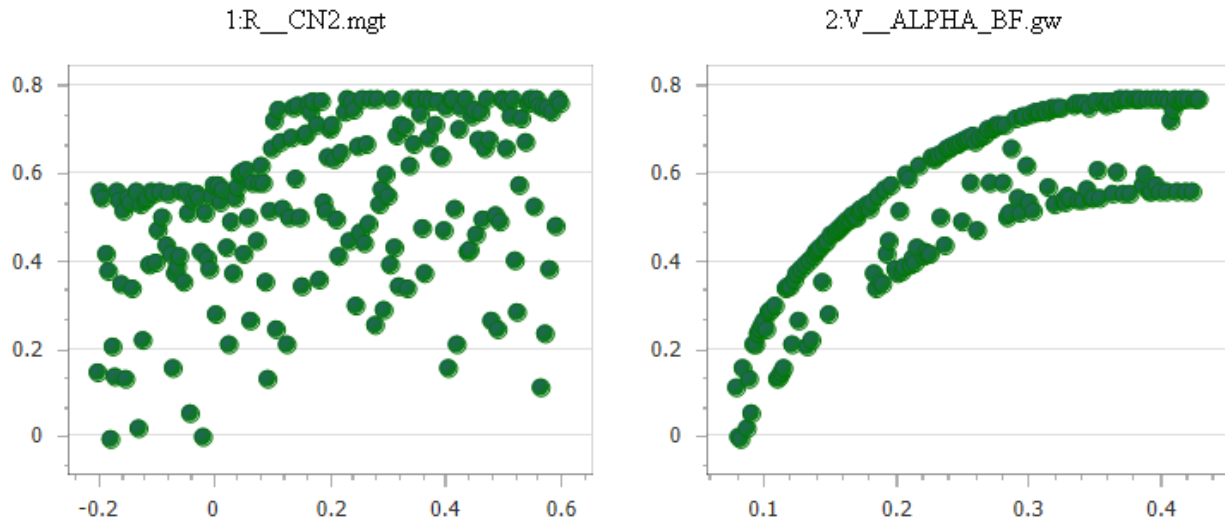


Figure 4:10 Dotty plots of the uncertainty output for calibration periods

The uncertainty of the calibrated and validated model in SUFI-2, 95PPUs, is the combination of uncertainties in the input data, model structure and model parameters. Uncertainty measure of SUFI-2 showed that P-factor of 0.75 and R-factor of 0.80 for calibration of 1996 LULC, P-factor 0.73 and R-factor 0.84 for 2006 LULC and P-factor 0.75 and R-factor 0.81 for 2016 LULC. It means that about 73% of data of the 1996 LULC and 78% of data of the 2006 LULC and 70 % data of the 20016 LULC was bracketed by the 95PPU band with a better strength of estimation (R-factor <1) for all cases. This indicates the SWAT model has acceptable level of uncertainty for estimation of flow of the study in this watershed (Table 4:8).

4.4. SWAT Model Land Use Land Cover Change Responses

The hydrological impacts of land use have received a considerable amount of interest in hydrology. LULC is an important characteristic in the surface runoff process that affects infiltration, erosion, and evapo-transpiration. Understanding the effects of historic land use changes have had on River flow is required to understand the future effects of land use and land cover on hydrological regimes at a watershed level.

The SWAT model simulated for the three time periods corresponding to the land use map of 1996, 2006 and 2016, Simulation runs were conducted on monthly basis to compare the modeling outputs using the 1996, 2006 and 2016 maps. A comparison of annual stream flow from each land use land cover maps were presented shows the significant change and the result would be described in tabular.

The result indicated that the mean annual stream flow of 2006 LULC increased by 14.54% compared from 1996 LULC. Also, LULC 2016 simulated mean annual stream flow increased 16.57% from 2006 LULC. The increase of agricultural land and the expansion of urbanization in the area reduced infiltration and increase runoff from one decade to other decades. The study addressed that, the expansion and reduction of agricultural land was strong relation for increasing and decreasing of stream flow from the watershed and decreased stream flow when increased afforestation.

Table 4:9 Hydrological process from annual simulations of different years land use

Hydrological Balance Components	LULC 1996	LULC 2006	LULC 2016
SURF Q (mm)	94.34	108.06	125.97
Lat Q (mm)	124.82	133.3	105.21
Water yield (mm)	219.91	241.45	231.38
ET (mm)	116.12	104.9	112.36
PET (mm)	835.91	835.91	835.91

One factor affecting the water production of a drainage basin is the quantity and type of vegetative land cover. In comparison to grass or shrub areas, forests have higher rates of evapotranspiration and interception, both of which affect how much water is available for aquifer recharging or direct drainage into streams. Compared to other forms of vegetation, trees have lower surface albedo, higher surface aerodynamic roughness, larger leaf surface area, and deeper roots; each of these traits tends to enhance evapotranspiration of water and decrease stream flow discharge. During precipitation events, interception has a greater impact on the water balance.

The features of a watershed's evapotranspiration, infiltration, and overland runoff are affected as the land surface changes from native vegetation to managed farmland. Because crops require less soil moisture than forests do, the lack of soil moisture in agricultural fields is cured by rainfall more rapidly than it is in forests, resulting in the increased runoff. The ability of the soil to

absorb water is reduced by soil compaction and greater loss of natural plants. As a result, the stream flow increases. Croplands may be entirely barren before being planted, depending on the product being cultivated, and tend to have some bare ground even during the height of the growing season. In both cases, the majority of the precipitation that falls on these exposed portions will be discharged straight into the stream channel as opposed to permeating the soil or transpiring from the plant surfaces. Therefore, compared to natural vegetation, farmland conversion tends to enhance water yield.

The simulation result showed that, from 1996 to 2016 surface runoff and Water yield (mm) were increased from 94.34 mm to 125.97 mm and 219.91 mm to 231.38 mm, respectively. While ET has decreased from 116.12 mm to 112.36 mm, respectively. The others result of land cover map impacts on hydrological process is discussed above table clearly. According to the result of land cover change map, areas of forest and shrub land have decreased which has contributed to the increased surface runoff and reduction of water infiltrating into the ground, this indicate that the decrease the forest land and expansion of agricultural land in watershed. There fore the surface run off and forest land of the watershed shows inverse proportionality.

4.5 Evaluation of Extreme Flows of River Catchment

The exploration outcomes of flow duration curve for the three thematic map (see Figure 4-1, 4-3 and 4-5), the high flows at Megecha River catchment near to Guber gauging station increased by about 14.54% in between 1992 and 2006, increased by 16.57% in between 2006 and 2016. Therefore, results from the monthly flow duration curve analysis (see Figure 4-12) for different thematic maps shown an increase for the high flows at 5% and for the low flows at 95% time equaled or exceeded in the catchment. This is due to the expansion of agricultural land over others and its strong influence on evapotranspiration, surface runoff and the amount of water that percolates to the underlying aquifer.

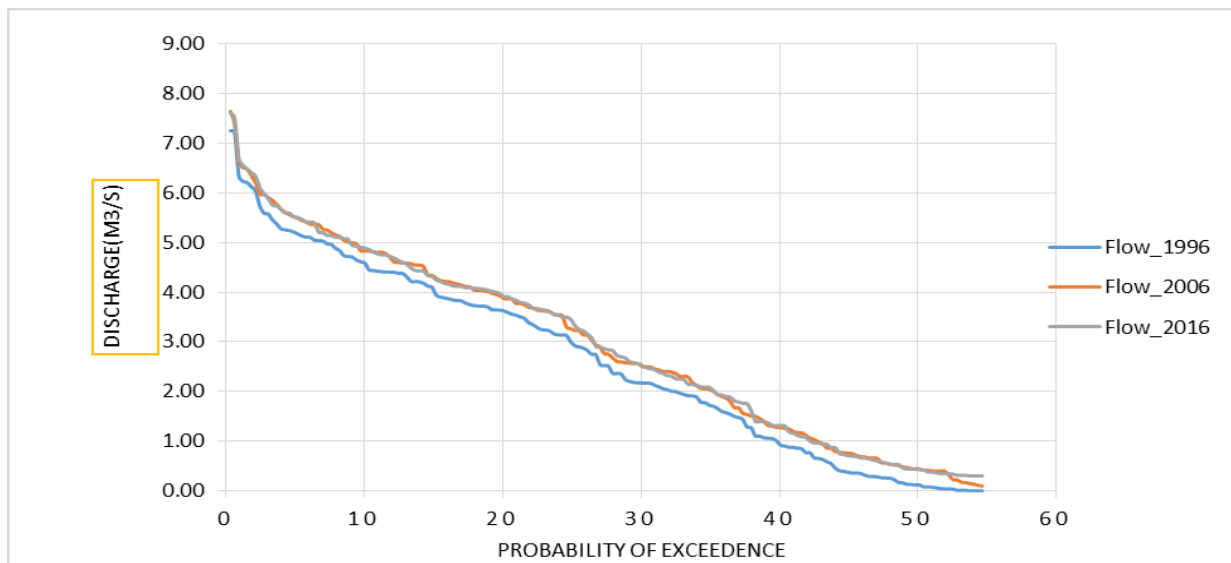


Figure 4:11 Flow duration curve show the mean monthly discharge versus with the percentage of time in which equaled or exceeded

5 Conclusion And Recommendation

5.1 Conclusion

During the study period Megecha Guber watershed has been undergoing different LU/LC changes. On the basis of the change detection analysis from the LULC data, the cropland in the watershed increased from 68.80% in 1996 to 71.13 in 2016. Similarly shrub land and settlement shows slight increase. The rest showed a decrement in area coverage. It can be observed that there was an agricultural expansion during the periods 1996– 2016, with a rapid increase of crop land and a decrease of forest land, grass land and water body respectively. This is believed that the crop land areas expanded at the expense of grass land, forest land and water body. This is mainly because of the population growth that caused the increase in demand for new agricultural land and rural settlements which in turn resulted shrinking on other types of land use and land cover of the area. The result indicated that the mean annual stream flow of 2006 LULC increased by 14.54% compared from 1996 LULC. Also, LULC 2016 simulated mean annual stream flow increased 16.57% from 2006 LULC. The increase of agricultural land and the expansion of rural settlement in the area reduced infiltration and increase runoff from one decade to other decades. The study addressed that, the expansion and reduction of agricultural land was strong relation for increasing and decreasing of stream flow from the watershed and decreased streamflow when increased settlement. The simulation result showed that, from 1996 to 2016 surface runoff and Water yield (mm) were increased from 94.34 mm to 125.97 mm and 219.91 mm to 231.38 mm, respectively. While ET has decreased from 116.12 mm to 112.36 mm, respectively. According to the result of land cover change map, areas of forest and bare land have decreased which has contributed to the increased surface runoff and reduction of water infiltrating into the ground, this indicate that the decrease the forest land and expansion of agricultural land in watershed. There fore the surface run off and forest land of the watershed shows inverse proportionality. Correspondingly The effects of LU/LC changes on stream flow, surface runoff, groundwater flow, lateral flow and water yield are very significant in both the annual and monthly average values. However, the LU/LC change effect on PET is very small in both annual and monthly average values. SWAT model was then applied to examine land use land cover change impacts on stream flow. Results have revealed that there is substantial increase in surface runoff volume from 94.34mm to 125.97mm for the LULC map of year 1996 and 2016 respectively. The model evaluation statistics for stream flow provided a very good result since

NSE >0.75 and $R^2 > 0.75$. The change in LU/LC ensued in augmented stream flow and in which the expansion of agriculture has also resulted an increase of surface run off, but decreased the ET of river catchment. Therefore, curving the trends of LU/LC towards increasing vegetation covers is very important so as to reduce the seasonal flow and surface runoff, on the other hand to increase ground water flow. One way of increasing vegetation cover in the river catchment is through controlling the expansion of agriculture at the expense of other land covers and improving the productivity of existing farm lands through the provision of improved production inputs and livelihood diversification. Finally, by taking appropriate soil and water conservation measures in the river catchment through creating awareness to the community the effect of unplanned land use practices had on the environment, natural resources and ecosystem is of paramount significance for the catchment management.

5.2. Recommendation

- Changes of land use/land cover in Megecha Gubere watershed are due to anthropogenic activity mainly expansion of crop land is the major proximate causes of LU/LC change in river catchment for loss of several hectares of grassland, agroforestry and bareland. The major root causes for these changes are population growth in the study area. Therefore, it is recommended that controlling the expansion of agriculture at the expense of other land covers improving the productivity of existing farm lands through the provision of improved production inputs and livelihood diversification and also controlling the population growth and illegal settlements and its associated impacts on the natural environment through awareness creation is mandatory.
- The availability of adequate data with good quantity and quality was a great challenge in the study area. Most of the meteorological and hydrological stations within and surrounding the watershed were not functional. Hence, it is highly recommended to establish a good gauging network of both hydrological and meteorological stations.
- This study model simulation considered only land use change effects by assuming all other variables were constant. But climate change will also have a great impact on the rainfall-runoff process of the watershed. Therefore, there is a need for further research to ascertain the hydrological impacts of climate change on the watershed.

- The result of this study could help different stakeholders plan and implement appropriate soil and water conservation strategies in the watershed. The model developed could be used in modeling the watershed to take appropriate measures in advance.

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Appendix

Appendix A: Annual precipitation in and around of Megecha River catchment

Year	Butajira	Wolkite	Wulbrag	Tora	Hossana
1991	1089.4	1381.5	1447.7	696.7	1049.1
1992	1188.6	2336.4	1552.3	898.2	1387.6
1993	1136.0	1594.0	1378.5	1261.7	1413.5
1994	1031.2	1592.0	1027.2	803.8	920.4
1995	1168.8	1390.4	1093.5	1010.5	1160.7
1996	1483.8	2062.5	1427.9	1158.6	1168.2
1997	1240.3	1349.6	1152.3	913.5	1442.5
1998	1459.9	1168.9	1349.9	1022.3	1556.4
1999	1054.4	1110.6	1136.2	720.2	1011.3
2000	865.6	1075.7	1663.0	841.9	991.9
2001	1291.5	1319.9	1200.0	822.2	1145.5
2002	1159.9	1217.9	1163.6	614.4	1346.4
2003	1187.8	1537.5	1176.5	572.5	1152.9
2004	913.4	969.0	426.4	649.5	1185.1
2005	1783.6	1186.1	1060.2	997.8	1179.0
2006	1572.3	1212.9	1530.8	918.1	1201.7

Appendix B: Monthly minimum temperature in and around of Megecha River catchment

Months	Butajira	Wulbareg	Wolikite	Hossana
Jan	11.77667	12.29189	13.29284	11.17335
Feb	11.95004	12.37014	13.41818	10.86713
Mar	12.29189	12.11519	13.6513	11.06007
Apr	12.37014	12.04757	13.33802	10.99062
May	12.11431	11.79271	13.82899	11.19445
Jun	12.04757	12.60458	13.35157	11.13186
Jul	11.79271	12.34151	13.41285	10.87317
Aug	12.60458	12.13396	13.47339	11.08416
Sep	12.34151	11.83982	13.62674	10.81562
Oct	12.13396	12.10691	13.62188	11.11861
Nov	11.83982	11.8772	13.55118	11.17999
Dec	12.10691	12.03306	13.51752	11.2145

Appendix C: Annual maximum temperature in and around of Megecha River catchment

Row Labels	Average of hossana Tmax	Average of wulbareg Tmax	Average of wolkite Tmax	Average of butajira Tmax
1991	22.51459697	26.30435727	26.90958904	27.88041731
1992	23.15480227	25.5968254	26.35163934	29.59135155
1993	25.19497366	26.37556635	26.40986301	29.65533024
1994	25.19497366	27.95950513	27.46767123	27.77383859
1995	23.71400851	26.95849937	28.67671233	25.65863014
1996	22.17431694	25.91170191	27.74590164	25.32076503
1997	22.79506849	25.11232877	28.26136986	25.84821918
1998	22.57167123	25.94351598	27.73260274	28.85692879
1999	22.64767123	26.04767123	28.10575342	26.84646544
2000	22.75355191	26.03196721	28.70054645	26.00710383
2001	22.2569863	25.58136986	28.87287671	25.88708904
2002	22.81430398	25.88712329	29.25616438	26.34907763
2003	22.86882696	25.55287671	28.10575342	25.98027397
2004	22.42240437	26.81733132	29.04398907	26.34781421
2005	22.82868493	25.7569863	28.0660274	26.40886187
2006	23.04903598	25.51917808	28.83589041	25.98328767

Appendix D: Average monthly stream flow of Megecha River (m³/s)

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1991	0.41	0.23	2.92	5.48	1.18	3.35	7.67	16.70	7.03	1.09	1.02	1.25
1992	0.22	0.86	1.31	0.86	0.65	1.09	5.82	24.14	10.32	3.78	0.75	0.39
1993	0.32	0.50	0.17	1.07	3.83	3.00	11.93	11.28	7.45	3.13	0.71	0.30
1994	0.17	0.12	0.35	0.36	0.57	0.84	13.12	17.87	6.17	0.94	0.45	0.31
1995	0.18	0.22	0.21	1.20	0.66	0.54	6.02	11.99	9.15	0.93	0.38	0.28
1996	0.41	0.20	1.79	2.64	5.63	16.18	11.88	17.76	4.79	1.80	0.47	0.31
1997	0.30	0.15	0.25	2.64	0.51	0.38	3.58	8.16	2.42	1.93	1.10	0.32
1998	0.39	0.18	0.33	0.50	1.26	1.83	15.08	21.60	9.74	7.77	1.12	0.56
1999	0.47	0.37	0.45	0.52	2.00	5.37	2.90	5.25	3.34	1.91	1.86	0.50
2000	0.33	0.22	0.19	0.22	0.31	0.30	2.44	9.66	5.70	5.72	1.05	0.85
2001	0.36	0.28	0.44	0.42	3.47	7.53	13.94	17.34	7.57	1.79	0.67	0.44
2002	0.52	0.33	0.53	0.39	0.64	2.04	5.24	13.17	0.18	1.37	0.76	0.59
2003	0.40	0.29	0.39	0.96	0.41	0.72	6.57	11.74	6.00	1.77	0.47	0.29
2004	0.27	0.19	0.17	1.64	0.72	0.89	4.86	12.50	5.51	4.08	0.97	0.75
2005	0.18	0.12	3.50	5.14	4.33	1.36	9.85	8.53	6.28	1.35	0.43	0.22
2006	0.14	0.12	0.68	3.74	2.65	2.02	2.95	7.41	6.09	0.94	0.28	0.20

Appendix: E SWAT Model Parameters and sensitivity analysis result

Parameter Name	Description	t-Stat	P-Value	Rank	Sensitivity
CN2	SCS runoff curve number	68.37	0.00	1	High
ALPHA_BF	Alpha base flow recession constan	-2.36	0.02	2	High
EPCO	Plant uptake compensation factor	-2.10	0.04	3	High
GW_REVAP	Groundwater "revap" coefficient	-1.37	0.17	4	Moderate
SOL_K	Saturated hydraulic conductivity	-1.21	0.23	5	Moderate
SLSUBBSN	Average slope length	-1.21	0.23	6	Moderate
REVAPMN	Threshold depth of water in the aquifer for "revap" to occur	1.20	0.23	7	Low
CANMX	Maximum canopy storage	-1.20	0.23	8	Low
CH_K2	Effective hydraulic conductivity in main channel	-1.04	0.30	9	Low
SOL_AWC	Available water content of soil	-0.88	0.38	10	Low
RCHRG_DP	Deep aquifer percolation fraction	-0.82	0.41	11	least
SOL_Z	Soil depth (for each layer)	-0.79	0.43	12	least
CH_COV1	Channel erodibility factor	0.77	0.44	13	least
SURLAG	Surface runoff lag time	-0.76	0.45	14	least
GWQMN	Treshold depth of water in the shallow aquifer	0.73	0.47	15	least
CH_COV2	Channel cover factor	0.72	0.47	16	least
CH_S2	Average slope of main channel	-0.70	0.48	17	least
CH_N2	Manning's "n" value for the main channel	0.50	0.62	18	least
GW_DELAY	Groundwater delay	-0.36	0.72	19	least
PPERCO	Phosphorus percolation coefficient	0.32	0.75	20	least
ESCO	soil evaporation compensation factor	0.30	0.76	21	least

Appendix: F Average Monthly observed and simulated flow of 1996, 2006 and 2016 LULC map

Monthly	Q sim in 1996	Q sim in 2006	Q sim in 2016
Jan	0.58	0.88	0.87
Feb	0.93	1.24	1.22
Mar	1.29	1.60	1.58
Apr	2.80	3.11	3.04
May	3.82	4.12	4.08
Jun	3.64	3.94	3.98
Jul	4.41	4.72	4.70
Aug	5.15	5.46	5.46
Sep	4.15	4.45	4.52
Oct	3.01	3.31	3.37
Nov	1.57	1.87	1.97
Dec	0.36	0.66	0.72