STREAM FLOW RESPONSE TO LAND USE/LAND COVER CHANGE-:

(THE CASE OF GELANA CATCHMENT, RIFT VALLEY LAKE BASIN, ETHIOPIA)

M.Sc. THESIS

ENKU SIYOUM MENEBO

HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

OCTOBER, 2020

STREAM FLOW RESPONSE TO LAND USE/LAND COVER CHANGE-:
(THE CASE OF GELANA CATCHMENT, RIFT VALLEY LAKE BASIN,
ETHIOPIA)

ENKU SIYOUM MENEBO

A THESIS SUBMITTED TO THE
FACULTY OF BIOSYSTEMS AND WATER RESOURCES ENGINEERING,

DEPARTMENT OF WATER RESOURCES, AND HYDRAULIC

ENGINEERING
HAWASSA UNIVERSITY INSTITUTE OF TECHNOLOGY, SCHOOL OF
GRADUATE STUDIES, HAWASSA UNIVERSITY
HAWASSA, ETHIOPIA

IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE
DEGREE OF

MASTER OF SCIENCE IN HYDRAULIC ENGINEERING
(SPECIALIZATION: HYDRAULIC ENGINEERING)

OCTOBER, 2020

ADVISORS' APPROVAL

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY ADVISORS' APPROVAL SHEET

This is to certify that the thesis entitled "STREAM FLOW RESPONSE TO LAND USE /LAND COVER CHANGE-: (THE CASE OF GELANA CATCHMENT, RIFT VALLEY LAKE BASIN, ETHIOPIA)" submitted in partial fulfillment of the requirements for the degree of Master of Science with specialization in Hydraulic Engineering, the Graduate Program of the department of water resources and hydraulic engineering school of graduate studies, and has been carried out by Enku Siyoum ID№ GPHydr/006/11 under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence here by can submit the thesis to the department.

Sirak Tekleab (Ph.D.)	……………………………..	……………………….
Major advisor	Signature	Date
Sisu Biru (M.Sc.)	…………………………….	……………………….
Co-advisor	Signature	Date

EXAMINERS' APPROVAL

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY EXAMINERS' APPROVAL SHEET

We, the undersigned, members of the Board of Examiners of the final open defense by Enku Siyoum have read and evaluated her thesis entitled "STREAM FLOW RESPONSE TO LAND USE/LAND COVER CHANGE-: (THE CASE OF GELANA CATCHMENT, RIFT VALLEY LAKE BASIN, ETHIOPIA)", and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree master of science.

………………………….	……………….	………………..
Name of Major Advisor	Signature	Date
…………………………..	…………………	………………
Name of internal Examiner I	Signature	Date
…………………………..	…………………	………………
Name of internal Examiner II	Signature	Date
…………………………..	..………………...	…………….
Name of external Examiner	Signature	Date
………………………….	…………………..	……………
SGS Approval	Signature	Date

ACKNOWLEDGMENTS

I owe my heartfelt gratitude for all whose help has been invaluable throughout this work. Special thanks go to "**Great Yahweh Elohim**" who has done for me is really beyond what I can imagine.

I thank the Ethiopian Roads Authority (ERA) for providing me the financial support of the postgraduate program.

I also acknowledge with sincere thanks to the following, without them this work could not be succeeded. Primarily my beloved Family for their absolute love, motivation and always encouraging me, support me, and give to me the strength to go through my thesis work additionally my friends who have supported me through their friendship and professional help.

My deep gratitude spirits to my advisor Dr. Sirak Tekleab for his advice, support, and guidance, and sincere gratitude goes to my co-advisor Mr. Sisu Biru for his encouragement and support.

I would like to acknowledge the Ministry of Water, Irrigation, and Electricity (MOWIE) particularly hydrology, GIS department, and Library, National Meteorological Agency (NMA), and Ethiopian mapping agency (EMA) for providing the relevant data and information required free of payment.

TABLE OF CONTENT ……………………………………………..Page №

DEDICATION

TO MY RESPECTED AND BELOVED BROTHER WUBSHET SIYOUM (ABI)

LIST OF ABBREVIATIONS

ARC GIS	Aeronautical Reconnaissance Coverage Geographic Information System
CN	Curve Number
DEM	Digital Elevation Model
DMC	Double Mass Curve
EMA	Ethiopian mapping agency
ERA	Ethiopian Roads Authority
ERDAS	Earth Resources Data Analysis System
ETM	Enhanced thematic Mapper
FAO	Food and Agriculture organization
FDC	Flow Duration Curve
GLUE	Generalized Likelihood Uncertainty Estimation
HBV	Hydrologiska Byråns Vattenbalansavdelning
HRU	Hydrological Response Unit
IP	Image Processer
ITCZ	Inter-tropical convergence zone
LU/LCC	Land use/land cover change
M.a.s.l	Meter above Sea Level
Max.temp.	Maximum temperature
Min.temp.	Minimum temperature
MCMC	Markov chain Monte Carlo
MLC	Maximum Likelihood Classification
MIKE-SHE	European Hydrological System model (From Danish Hydraulic Institute)
MoWIE	Ministry of Water, Irrigation, and Electricity

NMA	National Meteorological Agency
NRCS	Natural resources conservation service
NSE	Nash-Sutcliffe Efficiency
OLI	Operational Land Imager
OIDA	Oromia Irrigation Development Authority
ParaSol	Parameter Solution
R^2	Coefficient of determination
RH	Relative humidity
RS	Remote Sensing
SCS	Soil Conservation Service
SNNPRS	South nation nationality people regional state
SLR	Solar radiation
SWAT	Soil and Water Assessment Tool
SWAT-CUP	Soil and water assessment tool -Calibration and Uncertainty Procedures
SUFI2	Sequential Uncertainty Fitting
TIF	Tagged file formats
TOPMODEL	Topographic model
TM	Thematic Mapper
WGS84	World Geodetic System 84
WND	Wind speed
WXGEN	Weather generator
USDA ARS	United States Department of Agriculture-Agricultural Research Service
USGS	United State Geological survey

LIST OF TABLES

LIST OF FIGURES

DECLARATION

I, the undersigned person, declare that this M.Sc. thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

Name: Enku Siyoum Menebo

Signature: ....

Place: Hawassa University

Date of submission: ……………………………...

ABSTRACT

Water resources are significantly affected by land use/land cover change (LU/LCC) at multiple spatial scales. This change is overwhelming in recent years globally. LU/LCC also aggravated in Gelana catchment within space and time. The main objective of this study was to detect the LU/LCC and investigating its effect on stream flow in the Gelana catchment, Rift valley Lake basin, Ethiopia. Spatio-temporal data were gathered and analyzed. Meteorological data from 1987 to 2018 and hydrological data from 1991 up to 2010 were used for characterizing the climate and used as model input. ERDAS 2014 was used to process preliminary data extracting, layer stacking, pan sharpening of images, image classification, and accuracy assessment for the Landsat image of 1988, 2003 and 2018. The Soil and Water Assessment Tool (SWAT) was used to perform stream flow simulation. The model was calibrated and validated on a monthly and daily time scale for a period of 1991 to 2005 and 2006 to 2010 during calibration and validation respectively. The accuracy of LU/LC classification was achieved by overall, user, producer accuracy and kappa coefficient. Results of the LU/LCC detection show that from the year 1988 to 2018 cultivation land increased by 39.7%, grass land increased by 3.7% and, the settlement area increased by 1.3%. While, mixed forest area and shrub land decreased by 38.3% and, 6.1% respectively. The model result depicts that the SWAT model run on a monthly time scale could able to capture the different response mode of the catchment well reasonably as evaluated through the coefficient of determination, Nash Sutcliffe efficiencies and PBAIS of 0.82, 0.77 and -9 during calibration and 0.76, 0.7 and -10.4 during validation respectively. From this study, it was perceived that, expansion of farming land and reduction of forest and shrub land affect stream flow volume of the catchment. The stream flow results indicated that 1-day and 7-day max flow increased in 4.3m^3/s, 5.1 m^3/s and 1-day and 7-day min flows were by 0.12m^3/s and 0.1 m^3/s respectively in comparing 1988 and 2018 simulation period. Beside the volume of annual flow increased by 0.94 m^3/s during from 1988 simulation period to 2018 simulation period. Moreover; past LU/LCC affects the wet season flow it increased in 1.56 m^3/s, and the dry season flow was decreased in 0.32 m^3/s in comparing 1988 and 2018 simulation period. The findings of this study indicate that water resources development in the catchment needs a proper understanding of the LU/LCC and its effect on stream flow. Thus, for sustainable water resources development, catchment interventions aiming at reducing high flows and increasing base flows are recommended.

KEYWORDS: SWAT, stream flow responses, Land use/ land cover change, Gelana catchment

1. INTRODUCTION

1.1. Background

Water and land are highly valuable, and strongly interrelated resources; without them life is imaginary. People relay their life and exploit those resources for thousands of years to meet their needs. Any change in land use will have an impact on the hydrological system of the catchment and the available water resources (Chen, Xu, and Yin, 2009). Lists of factors are considered to be a rationale for this continuous change throughout the globe. To illustrate, the advancement of technology, spreading out of industrial zones, expansion of intensive agricultural land, and urbanization. Those factors changed land use land cover in the past humankind history and will have a possibility to bring a change in the coming season (Schilling et al., 2008).

The impacts of land use land cover changes (LU/LCC) in the amount of water in any type of catchment were mainly determined by the biophysical characteristics of land use/ land cover (LU/LC) composition. Vegetated land has relatively lower water holding capacity due to higher rates of Evapotranspiration and water infiltration. Built-up areas and bare land have a higher water holding capacity as a result of their impermeable surface (Babar et al., 2015). Reduction in vegetative cover could also affect infiltration and will lead to reduced groundwater levels and consequently the base flow of streams drops (Li et al.,2018). Evapotranspiration, infiltration, surface runoff, groundwater flow, and lateral flow are some of the hydrological processes that are affected by land use and land cover change (Getachew and Melesse, 2012). The future availability of water resources fundamentally depends upon the planning and management of land use in this changing environment. However, the continual human interactions within the environment and substantial growth in population number are keep on modifying the (LU/LC) to fulfil the increasing demand to wards better services (Li et al., 2018).

Ethiopia, like other countries, has been experiencing frequent amendment of land cover due to a number of factors such as the growth of population number, climatic variability, and national policies. In recent decades, the forest cover of the country is declined; consequently, land degradation and hydrological disturbance of the catchment is occurred (Kebede et al., 2014). Experts agreed that the main reason for the conversion of land especially, the alteration of forest land to the agricultural area is due to unsustainable wood consumption, lack of appropriate institutional, legal and regulatory frameworks, economic and demographic factors (Demissew, 2017). To envision the future effects of (LU/LCC) on river flow it is vital to have an understanding of the effects of historic land use/land cover changes on the catchment hydrological system because it enables local governments and policymakers to formulate and implement effective and appropriate response strategies to minimize the undesirable effects of future land change or modifications (Munoth and Goyal, 2019).

The study area is the Gelana catchment which is part of the Gelana River. The River originates from the Yirgachefe area, Gedeo zone. This catchment is part of the Rift Valley Lake Basin that drains into Lake Abaya which is situated on the South Western side of Lake Abaya (Selvaraj and Bucha, 2019). Even though some part of the Gelana watershed is good in land cover; the area where the catchment exists is facing land cover change due to population number increment, and which in turn becomes the cause for high sediment accumulation in the catchment (Mengist, 2017). Assessing the main impact of (LULCC) is mandatory for sustainable utilization of this limited resource and to monitor catchment quality.

1.2. Statement of the problem

Now a day LU/LCC accelerated by human activities has become a serious environmental problem. Thus, conserving the catchment area is essential for the quality of the ecosystem. Gelana catchment is experiencing land cover changes particularly, as local people search for vacant land for cultivation. People use an extensive area of land for crop production to sustain their life. As they live hand to mouth, they cannot afford to invest in resource conserving practices. Even if the available land is suitable, the area is misused much of the land currently used under agriculture is deteriorating due to inappropriate planning, implementation, and management practices (Gelana large scale irrigation project, 2016). Most of the forest and shrub land is converted into farming land. The rapid growth of the population, which is the case for many developing countries, forces the people to highly reliance on land within the Gelana catchment. Due to this reason, this limited resource faces a lot of changes. This change can be on agricultural land, grazing, and settlement. The people who are living within Gelana catchment cut trees and change the original land cover to satisfy their need which in turn becomes a consequence for soil erosion, land degradation, and highly affects the normal hydrological cycle (Mengist, 2017). Only a few studies were conducted in the Gelana catchment such as (Selvaraj and Bucha 2019; Mengist, 2017). Those studies address only the amount of sediment yield of the catchment and flood mapping of the whole Gelana watershed. No study considers the impact of LU/LCC on stream flow on the catchment. Therefore, this study specifically focused on simulating stream flow under the impacts of past land use/cover changes.

1.3. Objectives of the study

1.3.1. General Objective of the study

The main objective of the study was to investigate the impact of land use/land cover change on stream flow in the Gelana catchment, rift valley lake basin, Ethiopia.

1.3.2. Specific Objectives: -

- To analyze the spatial and temporal trend of LU/LC cover in the study area
- To investigate the LU/LCC effects on the indicators of high flows (1D and 7D max. flows) and low flows (1D and 7D min. flows).
- To quantify the stream flow changes on mean annual and seasonal time scales

1.4 . Research Questions

- What the trends of LU/LC change in the Gelana catchment over the past 30 years look like on spatio-temporal scales?
- To what extent the LU/LCC affects high and low stream flow magnitude over the past 30 years?
- To what extent the LU/LCC affects the stream flow on mean annual and seasonal time scales?

1.5. Significance of the study

Understanding and investigating the impacts of LU/LCC is an essential indicator for resource base analysis, and development of effective and appropriate response strategies for sustainable management of land and water resources. Above all, it is an important step for conserving and wisely utilization of water resources in the country in general and in the study area in particular. The government of Ethiopia has formulated a water and land conservation policy and strategies (Demissew, 2017). The overall goal of the policy is to enhance and promote all national efforts towards an efficient and sustainable utilization of the resources. Therefore, this kind of study helps to meet the targeted goal.

1.6. Scope of the study

There is LU/LCC in a different area of the country which can induce a negative effect on the water body. But the scope of this study is limited and focused only on the impacts of LU/LCC on Gelana catchment stream flow which is part of the big Gelana watershed using the SWAT model incorporated with GIS not consider climate variability and change impact. This model was used to simulate LU/LLC impact on the catchment. The land cover changes have been identified by preparing 1988,2003, and 2018 land cover map using ERDAS imagine software. The model input data are meteorological data, hydrological data, and spatial data. The time frame within which the study has to be completed was limited the study to include many LU/LCC maps dynamically into the SWAT model.

1.7. Organization of the Thesis

This research paper is organized into five chapters the first chapter was the introductory which presents the background, statement of the problem, the objective of the study, the research question, the significance and scope of the study. The second chapter was review of related literatures, the concepts of LU/LC, catchment response to land cover change, the application of remote sensing on LU/LCC, ERDAS software, land use/land cover map preparation, an introduction to the SWAT model, and application of the SWAT model at global and local scale were well synthesized. Under the third chapter description of the study area, data collection and analysis, model setup and performance evaluation were well presented. Under fourth chapter results and discussion were well presented including LU/LC change analysis, sensitivity analysis, calibration, validation and evaluation of the model, and lastly estimation and analysis of stream flow variation due to LU/LCC. Finally; under chapter five: the conclusions and recommendations of the study were presented based on the findings of the study.

2. LITERATURE REVIEW

2.1. Land use/ land cover change

The term LU/LCC is commonly applied to indicate the amendment of the earth's terrestrial surface regarding biological and physical cover, classifying as vegetation, water bodies, bare land, or manmade structures (Gomez et al., 2016). Conversion of land surface from one cover type to another type (e.g. from shrub land to farming land) and modification of the existing feature of the earth surface (e.g. from rural settlement to urbanization) is also recognized as land use land cover change (Turner et al., 2007). The pattern of LU/LCC in any place is the result of natural, socio-economic factors, and human being exploitation within time and space (Rawat et al., 2013).

Numerous studies show that an extensive area of land is constantly changing throughout the world and only a few areas of land is remaining in their natural state. Even though the land use land cover change is a natural process which is also controlled and driven by some anthropogenic factors (Rawat and Kumar, 2015). To illustrate urbanization, intensive farming systems, deforestation, expansions of industrial zones are some of the human-induced activities causing alteration on this limited resource (Rawat et al., 2013). Related to this rural-to-urban migration, or reclassification of rural areas as urban areas, lack of assessment of ecological services, poverty, unawareness of biophysical limitations, and use of ecologically incompatible technologies also the reason for land cover conversion (Mallupattu and Sreenivasula, 2013).

Owing to the rise in population numbers particularly in developing continents like Africa, for centuries the land cover is continuously changing to satisfy the increasing demand for human beings (Mutayoba et al., 2018). In Ethiopia also, the land cover change is not current phenomena but provoked by the extent, rate, and long-standing nature of civilization. Recognizing the time and space-based changes in the land cover are important for change analysis and a guideline for land policymaker and planner (Hailemariam et al., 2016). Therefore, comprehensive understanding concerning land cover change trends is vital to protect the ecosystem well-being.

2.2. Catchment Response to LU/LCC

The availability of water within the catchment can be affected by the continuous change of land use/land cover, besides nature and interactions of surface and subsurface water also influenced by land use land cover dynamics (Butt et al., 2015). Amini et al. (2011) quantified the possible effects of LULC changes on stream flow at the Damansara watershed of Malaysia. They concluded that land cover degradation resulted in a flood peak in the study area. Due to the expansion of urbanization the watershed experienced occasional flooding and stream flow volume is increased. The study is crucial because they applied different land-use scenarios to show the effects and also consider the contribution of each sub basin to peak stream flow. From this study, it is clear that progressive amendment of land cover changes can influence local hydrological cycle by creating problems with stream flows, water yields, low or high flows, surface runoff, erosion, soil moisture, and Evapotranspiration (Amini et al., 2011).

The hydrological balance of the catchment can be maintained by the proper distribution of water within the water bodies (Li et al., 2018). They assess the response of hydrological processes for land use/land cover changes in the Taihu Lake Basin of China. The authors in the assessment indicate that the farmland reduced the water yield of the Taihu lake basin significantly. As they suggested in their study permeability and Evapotranspiration will be decreased if vegetated land is converted into a built-up area. Finally, they concluded that the changes in lu/lc patterns particularly changes due to urbanization considerably exaggerated the hydrological characteristics of the basin.

The impact of LU/LCC can be exhibited on the surface flow of catchment hydrology and the services afforded by them (Kebede et al., 2014). For instance, Gebresamuel et al. (2010) indicate that owing to the expansion of rural settlement and over-exploitation of grazing land, surface runoff is increased at Gum Selassa and Maileba Tigray region Ethiopia. Evapotranspiration, infiltration, surface runoff, and groundwater flow, are some of the hydrological processes that are affected by spatial and temporal LU/LCC (Chen et al., 2009).

Even though Ethiopia is gifted with plentiful water resources in its 12 basins, the vegetation cover of the country has been declined followed by land degradation and high surface flow (Kebede et al., 2014). As indicated in many studies LU/LCC has been responsible in Ethiopia for altering the hydrologic response of catchment and fluctuating river flows.

Evaluating the impact of LU/LCC on the catchment was studied extensively because, these changes cause modification in hydrological regimes that affect not only the stream flow volume but also the pattern of stream flow and peak flows (Gumindoga et al., 2014). Gumindoga et al. (2014) analyzed the hydrological response to the land cover change in the upper Gilgel Abaya basin. The analysis result showed that the highest peak flow, as well as the annual stream flow volume, varied to different land cover types. The key conclusion draws from this article is that the conversion of forest area to agricultural land impacted and contributes to a high runoff in the upper Gilgel Abay River basin of Ethiopia. Similarly, Kebede et al. (2014) examined the Subsequent impact of land cover alteration on stream flow dynamics in the Tikur-Wuha catchment. As indicated in the report owing to land use land cover change the discharge is increased irrespective of insignificant changes in annual rainfall pattern.

Conservation of water and land resources is essential in the preservation of ecosystem balance. Many severe ecological problems are caused including soil erosion and increased runoff due to improper management and modification of land cover (Apollonio et al., 2016). Converting natural forest cover whether to agriculture or pasture lands has the potential to reduce dry-season flows and to intensify peak flows (Ogden et al.,2013). Having an understanding of the influence of land use change on watershed hydrology will enable local governments and policymakers to formulate and implement effective and appropriate response strategies to minimize the undesirable effects of future land use or modification (Rawat and Kumar, 2015).

2.3. Previous land cover characterization and change detection studies

Change detection is a process comprises of multispectral data sets and different kinds of classification methods to distinguish land cover change between dates of imageries (Ayele et al., 2018). Now a day land use land cover change is considered as a key component for ecosystem monitoring. The change detection and exploration of features of Earth's surface are crucial to know in-depth the connection between human activities and the environment and also helpful for monitoring, evaluating, protecting, and planning for earth resources (Butt et al., 2015).

Numerous studies are conducted globally and nationwide to shows the dynamics of land cover and its potential impact on the ecosystem. Rawat and Kumar (2015) analyzed the historical landscape dynamics of the Hawalbagh block of district Almora in India by using multispectral images. The study results indicate that vegetation and built-up land have shown increments in contrary agriculture, barren land and water body have decreased due to expansion of town area.

Many works of literature point out that anthropogenic factor is the leading cause of the continuous change in land use land cover in Ethiopia. Tahir et al. (2017) presents that there is a continuous change in land cover in Mekelle city of Ethiopia. The researchers consider the period from 1985 to 2010 to show the changing trend of the city. The article indicated that the city is expanded by engulfing nearby rural farmland owing to the increasing demand for land for residential housing within the city. Similarly, the built-up area and cultivated land are increased in the Angereb catchment which is located north of Lake Tana basin (Getachew and Melesse, 2012). Gumindoga et al. (2014) also reported that a significant decrease in forest cover is observed in the upper Gilgel Abbay catchment Blue Nile basin Ethiopia mainly due to the expansion of agricultural land.

In the Tekeze catchment which is part of the Tekeze River; much of the land is converted from grassland and shrub land to cultivation land, consequently, annual and seasonal stream flow, as well as sediment yield, is increased (Welde and Gebremariam, 2017). The changes in land cover also observed in the Abaya-Chamo Basin from 1985 up to 2010. The area comprises the southern section of the major Ethiopia rift valley. The finding indicates there is an incredible reduction in shrub land and natural grassland and an increase in arable land (Wolde yohannes et al., 2018). Additionally, Hailemariam et al. (2016) identified that there was an intensification of farming land in the bale mountain Eco region at the expense of forest land cover for the last thirty years. In this particular area, anthropogenic factors are accountable for land cover changes as concluded by researchers.

Another study by Choto and Fetene (2019) shows that there is a considerable change in the land cover in Gojeb catchment, Omo-Gibe basin of Ethiopia. According to the authors the conversion is from forest area to intensive cultivation area from 1989 up to 2013. In the central Rift valley of Ethiopia, much of the original forest is converted to cultivation land (Ariti et al., 2015). The cumulative result of those studies in Ethiopia shows that the expansion of cultivated land and urban land at the expense of natural forests and shrub lands is increased.

2.4. Application of Remote Sensing for LU/LCC Detection

Remotely sensed (RS) data can be a means for obtaining information about the change in the earth's surface. Now a day it became an important means of mapping, detecting, and analyzing spatio-temporal changes over large landscapes (Tahir et al., 2017). Recently several researchers have shown a tendency towards using RS incorporation with GIS for extracting land surface information and land cover map preparation which are an important input for hydrological models and useful to attain realistic results (Apollonio et al., 2016). Apollonio et al. 2016 used remotely sensed imageries to produce LULC maps covering a time trend of 28 years of Cervaro basin in Southern Italy. They show that using remotely sensed data is highly significant to detect historical land cover change trends.

Butt et al. (2015) conducted study incorporating RS and GIS for land cover characterization and change detection. This pivotal study is crucial because it structured scientific procedures to analyze the nature of land cover change in the Simly watershed, Islamabad Pakistan. The key implication drawn from this study is that RS and GIS is a vital tool to provide essential information about the spatio-temporal distribution, nature, and pattern of land cover changes. The tool is also essential for an enhanced understanding of the relationships and interactions between human and the natural environment furthermore, this knowledge can be a guidance for land policymaker and planner (Butt et al., 2015).

Another study by Fichera et al. (2012) indicates that it is possible to prepare a land cover map and to analyze the change in land cover for a long period by integrating RS and GIS. The article illustrates that RS and GIS can be applied, and useful to analyze land cover change and to understand the factors that can drive the dynamic processes of rural-urban land conversion in the area of Avellino Southern Italy since the area is experiencing land cover change due to pressure on the countryside and after the disastrous Irpinia earthquake.

Besides, in Ethiopia applying RS for land use/land cover map preparation and change detection is common now a day, and confirmed as a significant tool in several articles. To illustrate Ayele et al. (2018) analyzed the time series changing trend of north Ethiopia using multi-temporal, remotely sensed imageries. The image data were constructive for analyzing the rate, trend and magnitude of spatial and temporal land cover change for two decades starting from 1995 up to 2004. The data were significant to detect the amount of environmental change in the form of deforestation, cultivation, and development activities.

2.5. Land use/land cover (LU/LC) Map Preparation

Preparing land cover map is fundamental for many scientific studies including spatial analysis of land cover change pattern and overall land cover change with time. To preserve the present natural resources and to recognize the causes and consequences of overutilization of land resources, the LU/LC mapping is indispensable (Kaul and Sopan, 2012). For preparing representative land cover map satellite image analysis, classification and accuracy assessment are fundamental steps.

2.5.1. Image Analysis and classification

Image processing and classification methods may affect the success of a classification. Selection of appropriate classification system, image preprocessing, feature extraction, post-classification processing, and finally accuracy assessment taken as the major step in image classification and final map preparation. Land cover classification methods were developed in the last decades. The classification can be done by pixel-based classification methods such as supervised or unsupervised classification (Phiri and Morgenroth, 2017). The unsupervised classification method does not involve training sample of image. Nonetheless, supervised classification is an appropriate classification system and adequate numbers of training samples are basics for a successful classification (Costa et al., 2018).

Unlike unsupervised classification, numerous scholars used a supervised classification method to prepare a land cover map by applying the Maximum Likelihood Classification Algorithm (MLCA) and got the enhanced results (Kaul and Sopan, 2012). A MLCA is one of the well-known parametric classifies used for supervised classification (Otukei and Blaschke, 2010). The algorithm used by the MLC tool is based on Bayes' theorem of decision making where the cells in each class sample in the multidimensional space are normally distributed. With the assumption that the distribution of a class sample is normal, a class can be characterized by the mean vector and the covariance matrix (Srivastava et al., 2012). For this particular study supervise image classification with MLCA was chosen owing to its simplicity and applicability, and it is also well known and has already effectively applied.

2.5.2. Accuracy Assessment

Accuracy assessment is one of the most important final steps in the classification process. This aims to quantitatively assess how effectively the pixels were sampled into the correct land cover classes. Classifications are often evaluated regarding the magnitude of their estimated accuracy. The map is generally judged to be sufficiently accurate if the calculated accuracy value is equals or exceeds the target value. Assessing the quality of a classification result is of high importance in remote sensing since it gives evidence of how well the classifier is capable of extracting the specified objects from the image (Costa et al., 2018).

The most widely used approach for accuracy assessment for the classified image is a confusion or error matrix. In principle, this matrix provides a simple summary of classification accuracy and highlights the two types of thematic errors that may occur omission, and commission. This not only summarizes the accuracy of the classification but also may convey useful information to enhance analyses based on the classification (Costa et al., 2018). Kappa analysis is a discrete multivariate technique. Both the error matrix and kappa coefficient have become a typical means of valuation of image classification accuracy. Furthermore, Error matrix or confusion have been used in several land classification studies (Rwanga and Ndambuki ,2017).

2.5.3. ERDAS Imagine software

The Earth Resources Data Analysis System (ERDAS) software is digital image processing (IP) software developed and marketed worldwide by ERDAS Inc. of Atlanta, Georgia, U.S.A. The first ERDAS system was created in early 1979 by a group of multidisciplinary professionals at the University of Georgia. The software is used to process, analyses, and integrate spatial data and geographic information to prepare a land cover map of the land surface (Guide, 1999).

Many researchers have used ERDAS imagine software for the classification and final map preparation purposes. For instance, a study was done by Kaul and Sopan (2012) for monitoring the land cover change of Jalgaon district India. The article is crucial because it uses high-resolution temporal satellite data and applied scientifically accepted procedures for final map preparation in ERDAS imagine software. The study result concluded that ERDAS imagine is an important tool and capable of land cover map preparation with an excellent overall quality.

In Ethiopia also ERDAS imagine software applied widely to prepare a land cover map of an area. To mention few lists, Kebede et al. (2014) use the ERDAS software to prepare the LU/LC map of the watershed lake Hawassa Ethiopia for the years 1986, 1999, and 2011. LU/LCC was assessed and mapped by interpreting Landsat satellite images and applying a supervised classification approach. The classification results were reasonable for further analysis. Another study in Ethiopia by Choto and Fetene (2019) applied ERDAS Imagine software with supervised classification, and with MLCA to prepare a land cover map for three periods 1989, 2000, and 2013 from Landsat image of the Gojeb watershed, Omo-Gibe basin, Ethiopia with best classification result. Hence from may article witness and software efficiency in land cover map preparing ERDAS were selected for this particular study.

2.6. Hydrological Models

This day numerous hydrological models have been developed to investigate climate, land use, and soil heterogeneity impact on catchment hydrology. Each model has its exceptional characteristics and can be applied from small to the complex river basin. The different models need a different type of input data. Rainfall and drainage area are the two main input data for all models (Devia et al., 2015). Hydrological models are tools that assimilate our understanding of hydrologic systems to simulate the real-world hydrologic processes. These models consist of a set of mathematical descriptions of sections of the hydrologic cycle and they are based on a set of interconnected equations (Singh and Woolhiser, 2002).

The amendment of land use land cover can influence the hydrological behavior of a basin, due to this reason physical based, spatially distributed hydrological model are in need to handle the complex process within the catchment (Garg et al., 2019). The hydrological models can be classified as an empirical model, conceptual models, and physically based models (Devia et al., 2015).

2.6.1. Empirical Models (Metric Model)

These are data driven or observation-oriented models because they take only the information from the existing data without considering the features and processes of the hydrological system. The models involve mathematical equations, and they are valid only within the bounders for example unit hydrograph model.

2.6.2. Conceptual Models

These models illustrate the entire component of hydrological processes. A large number of meteorological and hydrological records are required for calibration. The model parameters are evaluated from field data and longtime meteorological and hydrological records required for model calibration. Semi empirical equations are used in this model.

2.6.3. Physically Based Models

These models are called the mechanistic model and mathematically idealized depiction of the real phenomenon which includes the principles of physical processes. It uses state variables that are measurable and are functions of both time and space. The hydrological processes of water movement are represented by finite difference equations. The models require wide-ranging hydrological and meteorological data for their calibration. The following Table 2.1 compares the four selected hydrological models.

Table 2.0.1: Hydrological models (source: Brebante, 2017)

Description	SWAT	TOPMODEL	MIKE-SHE	HBV
Model type	Semi distributed physically-based	Semi distributed Conceptual model	Distributed physically-based	Semi distributed Conceptual model
Model objective	Predict the impact of land management practice on water and sediment	Simulate the rainfall-runoff process of watershed	simulate surface and groundwater movement and their interaction	Simulate Groundwater recharge runoff and flood forecasting
Temporal scale	Day/ semi- day	Day	Day	Daily /monthly
Spatial scale	Medium	Flexible	Medium	Flexible
Process modeled	Continuous	Event	Continuous and event	Continuous and event
Cost	Public domain	Public domain	Commercial	Public domain

2.7. The Hydrological Model SWAT

The Soil and Water Assessment Tool (SWAT) is a semi distributed, continuous-time, basin scale hydrologic model developed by the United States Department of Agricultural Research Service (USDARS) in early 1990. owing to its wide-ranging applicability, user friendly model interfaces, and automatic calibration the model is capable of performing long term simulations (White et al., 2014). The model breaks the entire basin into sub basins which are further divided into hydrologic response units (HRU). For this particular study, semi-distributed models are selected because their structure is more physically based than the structure of lumped, and they are less demanding on input data than distributed models. The software is public domain and the availability of the model and technical support were a reason for selecting this model.

2.8. Previous studies using the SWAT model to address LU/LCC impacts on stream flow

The SWAT model among other models has been widely used and effectively applied throughout the globe to simulate the land cover change impacts on different hydrological processes of several river basins. For example, Babar and Ramesh (2015) use the SWAT model to assess stream flow response to LU/LCC over the Nethravathi River Basin of India. Two land cover map of the year 2003 and 2013 were used in this study. The result of this study shows that small change in the catchment was a reason for high runoff, and leads to peak stream flow. Similarly, Munoth and Goyal (2019) used the SWAT model to examine the impacts of LU/LCC on runoff and sediment yield of upper Tapi River Sub Basin in India. The land use dynamics of the sub basin was assessed through the analysis of four land use maps corresponding to the year 1975, 1990, 2000, and 2016. The article shows that the model is effective to simulate catchment hydrology. The change in land covers in the study area leads to land deterioration and cause in the increment of surface runoff, water yield, and sediment yield.

Mutayoba et al. (2018) conducted a study in the upper great Ruaha sub basin, Mbarali River Tanzania; applied the SWAT model for assessing the impacts of land use and land cover changes on stream flows and hydrological water balance components. The land use and land cover (LULC) maps for 1990, 2006, and 2017 were created. The study result shows that surface water and water yield were increased compared to the baseline period and the model SWAT simulates successfully the basin hydrological process. In another study by Ghaffari et al. (2010) Presents the hydrological impact of LU/LCC in the Zanjanrood basin of Northwest Iran by using the SWAT model. The model was used to simulate the main components of the hydrological cycle and land cover data of 1967, 1994, and 2007 were used to study the effects. In this particular area, the change in land cover causes an increase in the amount of surface runoff and a decrease in the groundwater recharge.

In Ethiopia context, SWAT hydrological model is appropriate to estimate the LU/LCC impact on the catchment, and many studies confirmed its applicability to simulate different hydrological processes. For instance, Welde and Gebremariam (2017) present the effect of LU/LC dynamics on hydrological response especially, its influence on stream flow and sediment yield of the Tekeze Dam watershed in north Ethiopia. The study result shows that there were considerable land cover changes in the study area. The hydrological process is simulated using the SWAT model and the model efficiency result was reasonable. With another study in Ethiopia using the

SWAT model, Abdrhaman (2011) showed the impact of LU/LCC on the hydrological component Akaki catchment Addis Abeba. The amendment of land cover was observed in the catchment starting from 1973 up to 2000, due to expansion of urban areas as a result, annual stream flow was influenced according to his finding.

In another study, Getachew (2018) applied SWAT hydrological model to simulate historical land cover change and future climate change impact on a surface runoff on the Anger sub basin of Ethiopia. The author illustrates that the dynamics of land cover potentially impacted the mean annual and seasonal surface run off the sub basin. The hydrological response of the sub basin was effectively simulated by using the SWAT model with a good model evaluation result. In Gelana catchment SWAT was used to simulate the sediment yield of the catchment by Mengist (2017) the outcome was reasonably accurate with good model efficiency result.

From those reviewed studies it can be concluded that the hydrological model SWAT is applicable in Ethiopia and in Gelana catchment to simulate the impact of historical LU/LCC on stream flow with accepted model evaluation results.

3. MATERIALS AND METHODS

3.1. Description of the study area

3.1.1. Location

The study area is located in Gelana valley in Abaya-Chamo sub-Basin of the rift valley lakes basin and sited southern part of Ethiopia within the Oromia and South Nation Nationality People Regional States (SNNPRS). The catchment is part of the Gelana watershed surrounded by 5º 50'- 6º 18' north and 37º50'- 38º20' east about 450 kilometers far from Addis Abeba. The area coverage of the catchment is estimated to be 649.94km^2.

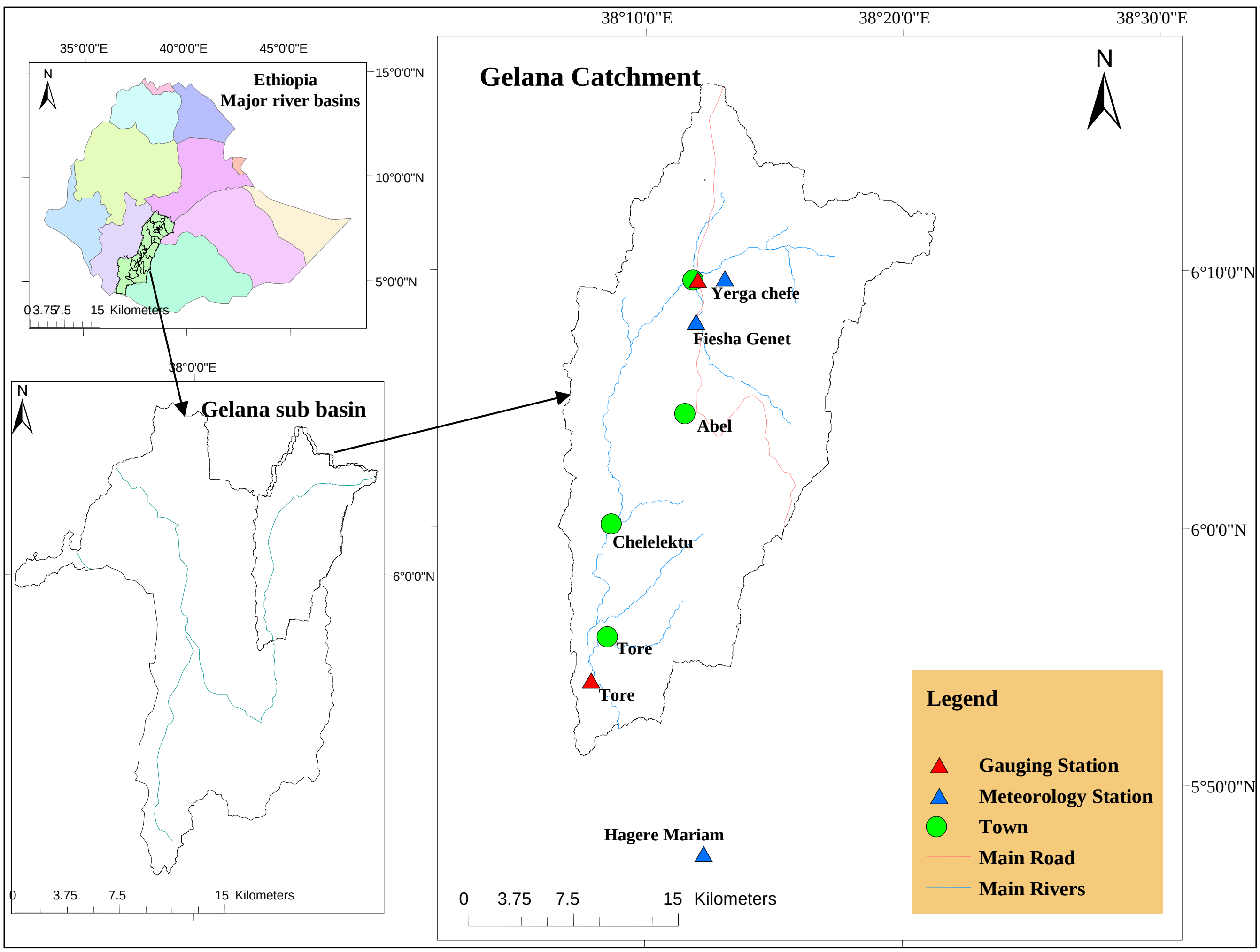


Figure 3.1: Location map of the study area

3.1.2. Topography

The Gelana catchment is characterized by mainly undulating, hilly topography. The low-lying part of the catchment is characterized by the valley floor with flat to gentle slopes. Topography in the central part of the study area is subdued with low gradients having abrupt boundary to the adjacent ridge of hills and the whole catchment has an altitude range of 1652.9 to 3077.8 m.a.s.l (Gelana large scale irrigation project, 2016). The micro topography is also uneven to the west of the Bone River where there are very frequent termite mounds (Study and design of Gelana irrigation project, 2008).

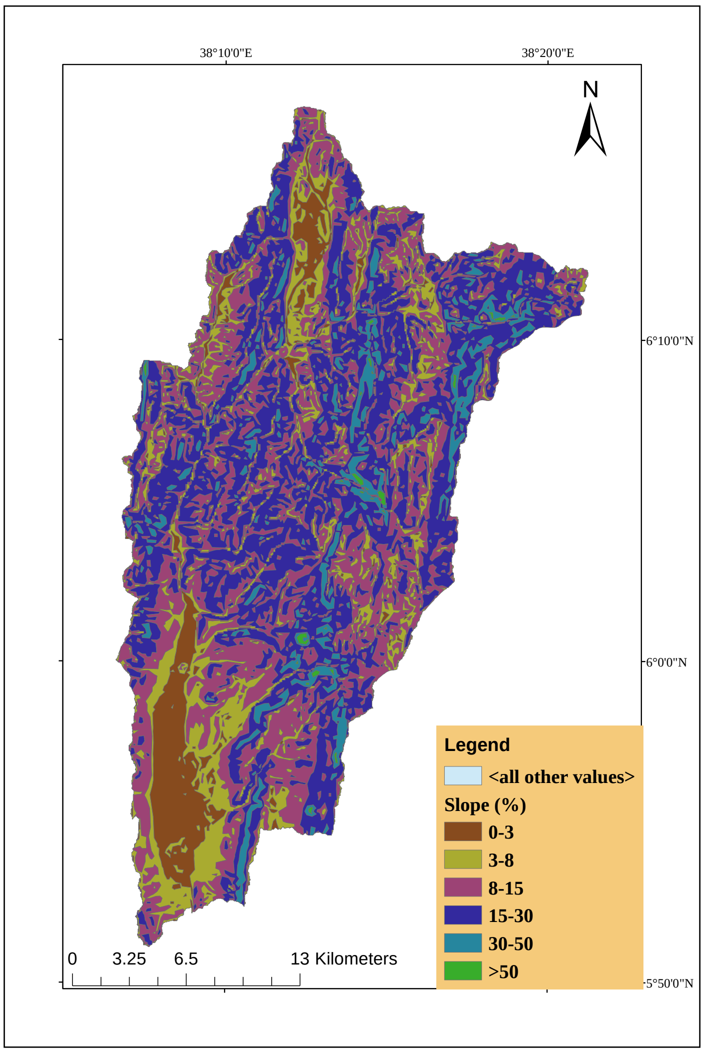


Figure 3.2: Slope of study area

3.1.3. Climate

The climate of Ethiopia is mainly controlled by the seasonal migration of the Inter-tropical convergence zone (ITCZ) and its associated atmospheric circulation but climate conditions change with elevation. The traditional climate classification of the country is based on altitude and temperature shows the presence of five climatic zones namely: Wurch (cold climate at more than 3000 m altitudes), Dega (like highland climate with 2500-3000 m altitude), Woina Dega (warm 1500-2500 m altitude), Kola (hot and arid type, less than 1500 m in altitude), and Bereha (hot and hyper-arid type) climate (Shaka, 2008).

There is a bimodal type of rain that occurred in the project area. The rainfall occurs from April to May and also from September to November. ITCZ is the major rain causing mechanism in Ethiopia. The movement of ITCZ in the northward direction brings moisture from the South Atlantic Ocean, which results in the high rainfall in the project area (Gelana large scale irrigation project, 2016). The following bar chart (Figure 3.2) shows the mean monthly precipitation for three stations within and near to Gelana catchment.

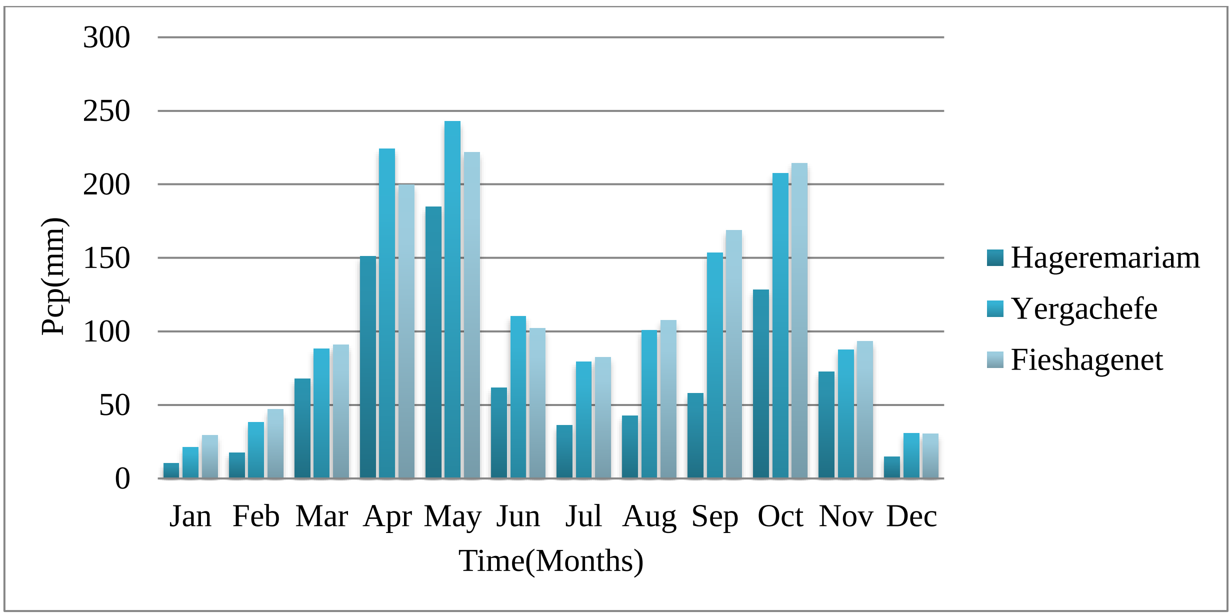


Figure 3.3: Mean monthly Rainfall from 1987-2018

3.1.4. Hydrology

The catchment area is part of Gelana watershed which is drained to Gelana River, and at the end; it drains to the Abaya lakes. The Gelana river and its tributaries are the main sources of surface water in the study area the only source for irrigation. The hydrological data shows the mean monthly flow of Gelana River at Tore gauging station is small. The lowest mean flow usually occurs in March while the highest flow occurs in May. The river Gelana flows south from Yegachefe pass chelelektu in a narrow alluvial plain described as the upper valley and enters a narrow gorge through which it descends down the eastern edge of the Ethiopia rift valley. As the feasibility study of Gelana irrigation project the annual flow of the Gelana River in the upper valley varies considerably.

3.1.5. Geology

The study area is found at the southern portion of the Main Ethiopian Rift system, which is a part of the East African rift system and is divided into the south-western rift system, the main Ethiopian rift, and the Afar Depression. The catchment is in filled with substantial depth of alluvial and colluvial deposits which forms parent material of the soils. The oldest rocks in the Gelana catchment area are the Precambrian foliated biotite and amphibole gneiss of the basement complex. These are found in the Amaro Mountains which form the western, fault-controlled margin of the Gelana catchment. The general geological setting of the surrounding summarized as Oligocene to middle Miocene basalt distributed in Yergachefe area.

3.1.6. Soil

The soil parent materials are alluvial and colluvial deposit which fills the Gelana valley to a considerable depth. The deposit originating from the western side is predominantly coarse while those originating from the basaltic rock of the eastern side are much finer. As indicated in (Gelana large scale irrigation project, 2016) broad divisions of soil types were grouped as clay and clay loam. The soil types found in Gelana catchment are Eutric Cambisols, Dystric Nitosols, Orthic Solonchaks, Calcic Xerosols, Dystric Gleysols, and Eutiric Nitisols. The following figure is the main soil type in the study area. The most dominant soil type in the study area are listed in table 3.1 below and figure 3.3 shows the soil type of Gelana catchment.

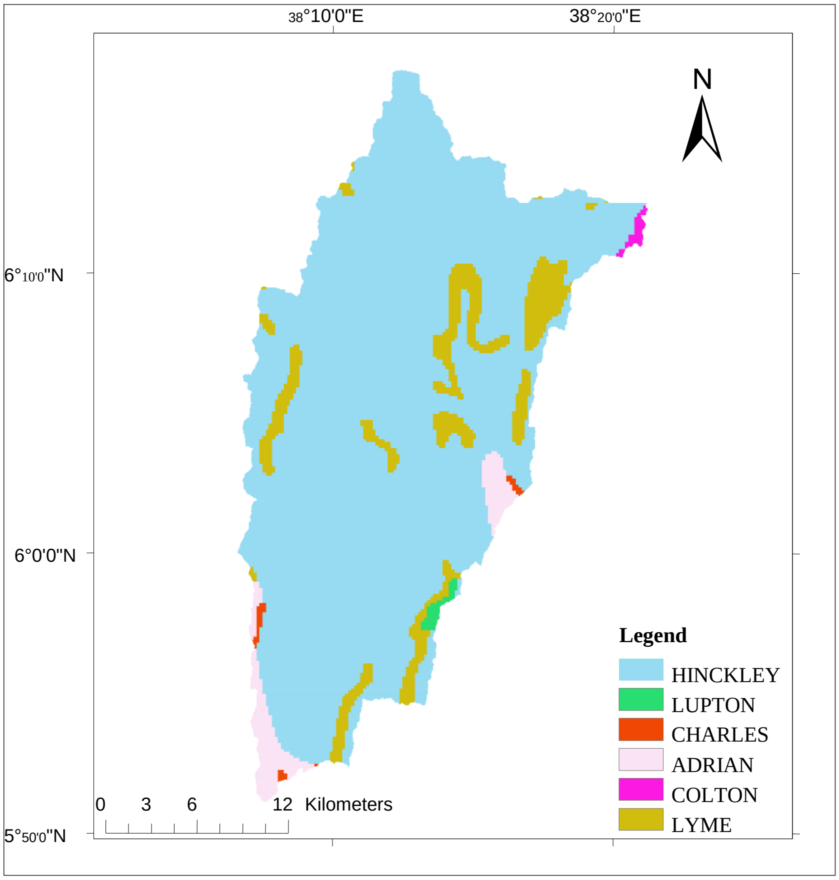


Figure 3.4: Soil type in the study area

Table 3.1: Soil type of study area

Soil Type	SWAT CODE	% Catchment Area	Area(km^2)
1, Dystric Nitosols	HINCKLEY	87.024	565.6
2, Dystric Gleysols	COLTON	0.26	1.7
3, Eutiric Nitosols	LYME	8.749	56.9
4, Orthic Solonchaks	ADRIAN	3.247	21.1
5, Calcic Xerosols	CHARLES	0.328	2.1
6, Eutric Cambisols	LUPTON	0.391	2.5

3.1.7. Land Use and Land Cover

A small portion area of land is covers by natural vegetation such as scattered tress and some savannah grassland, scattered settlement area. In the Gelana catchment, land use and land cover rapidly changing due to high population growth in the basin. Agricultural land is dominant in the catchment. The vegetation cover is mostly a dry acacia thorn bush of varying density. In the dry season, the farmer burns the bush land cover; these provide a certain amount of grazing for cattle and encourage regeneration of grass. The densest vegetation is found adjacent to the Gelana.

3.1.8. Temperature

The mean monthly maximum temperature at the study area is estimated to be about 27 .6ºc and the mean minimum temperature is 8.1ºc. The following two bar charts show the maximum and minimum mean monthly temperature for three station near and within Gelana catchment respectively.

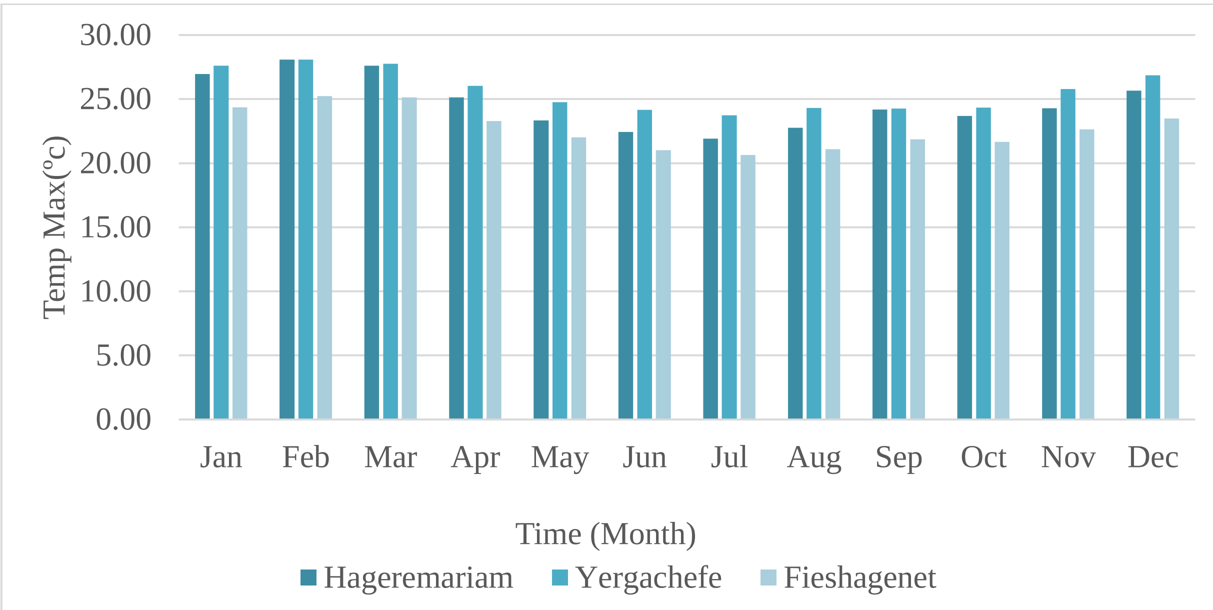


Figure 3.5: Maximum temperature from 1987 up to 2018

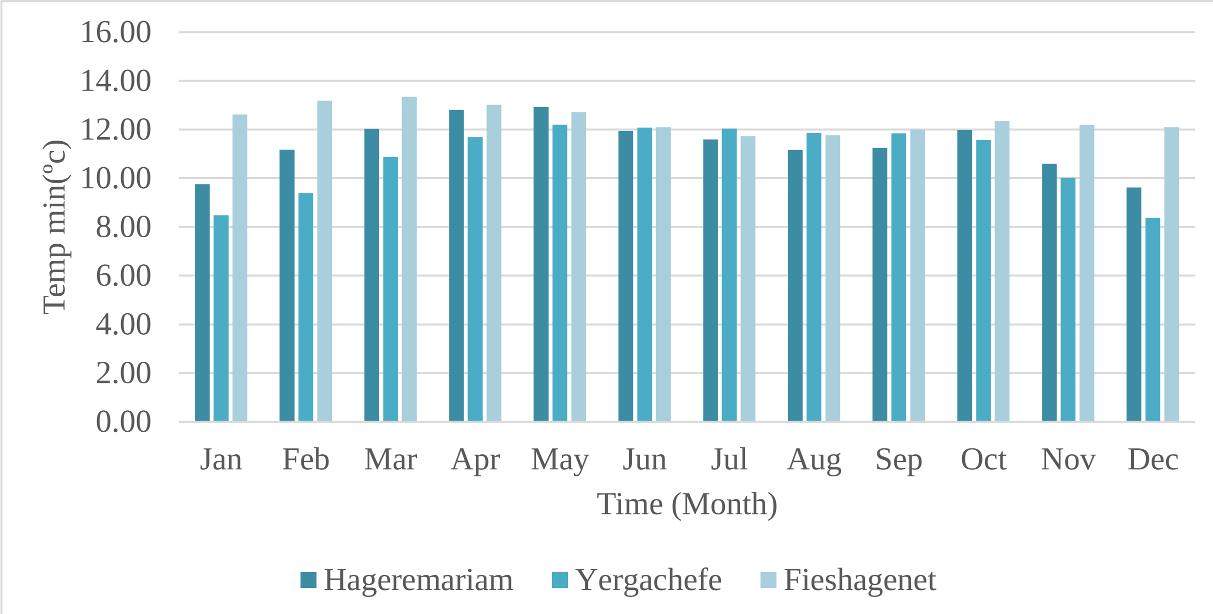


Figure 3.6: Minimum temperature from 1987 up to 2018

3.2. Data collection and Analyses

The hydrological model SWAT is a highly data intensive model that requires detail information about the catchment such as topography, land use/land cover, soil properties, and climate condition. These data were collected from different sources and databases.

3.2.1. LU/LC Data and study area characterization

The study was carried out using different Landsat satellite imageries acquired in 1988, 2003, and 2018. The images, which are georeferenced and radiometrically corrected, were accessed from the United States Geological Survey (USGS) website (http://www.usgs.gov, accessed on December 2019) and from Ethiopian mapping agency (EMA). With the current accessibility of global spatial datasets, a common way to map land cover changes is through satellite image classifications (Verburg, Neumann, and Nol, 2011). The acquisition year of images were based on fifteen years' interval to easily visualize changes in Spatio-temporal LULC patterns. All images are acquired on a cloud-free season to properly analyze the detection process. The dry and cloud free seasons are mostly considered the best period for image acquisition, as the difference between croplands and the natural environments is best marked (Hailemariam et al., 2016). Therefore, the acquisition was carried out within January. Since the image had a different file format, it was imported into the tagged file formats (TIF). The acquisition dates, sensor, path/row, resolution of the imageries are shown in table 3.2 below.

Table 3.2: Land sat image data

Data Type	Acquisition Date	Number of Bands	Path and Rows	Spatial Resolution(m)
TM (Landsat 5)	1988/01/08	6	168/56	30*30
ETM (Landsat5)	2003/01/10	7	168/56	30*30
OLI (Landsat 8)	2018/01/27	11	168/56	15*15

3.2.1.1. Image pre-processing

All the preprocessing and post classification steps were completed using the software packages Earth Resource Data Analysis System (ERDAS) imagine 2014 and Arc GIS 10.3 software. The preprocessing steps include layer stacking of the separated bands of the datasets, false color composition, pan sharpening, and sub setting the images of the study area. Then, all the acquired satellite images were corrected geometrically and radiometrically before analysis to improve image quality. All the satellite datasets were projected to the Universal Transverse Mercator (UTM) map projection system zone 37N and datum of World Geodetic System 84 (WGS84), for ensuring consistency between datasets during analysis. The following flow chart (figure 3.7) clearly depicts the overall classification process of the three Landsat images.

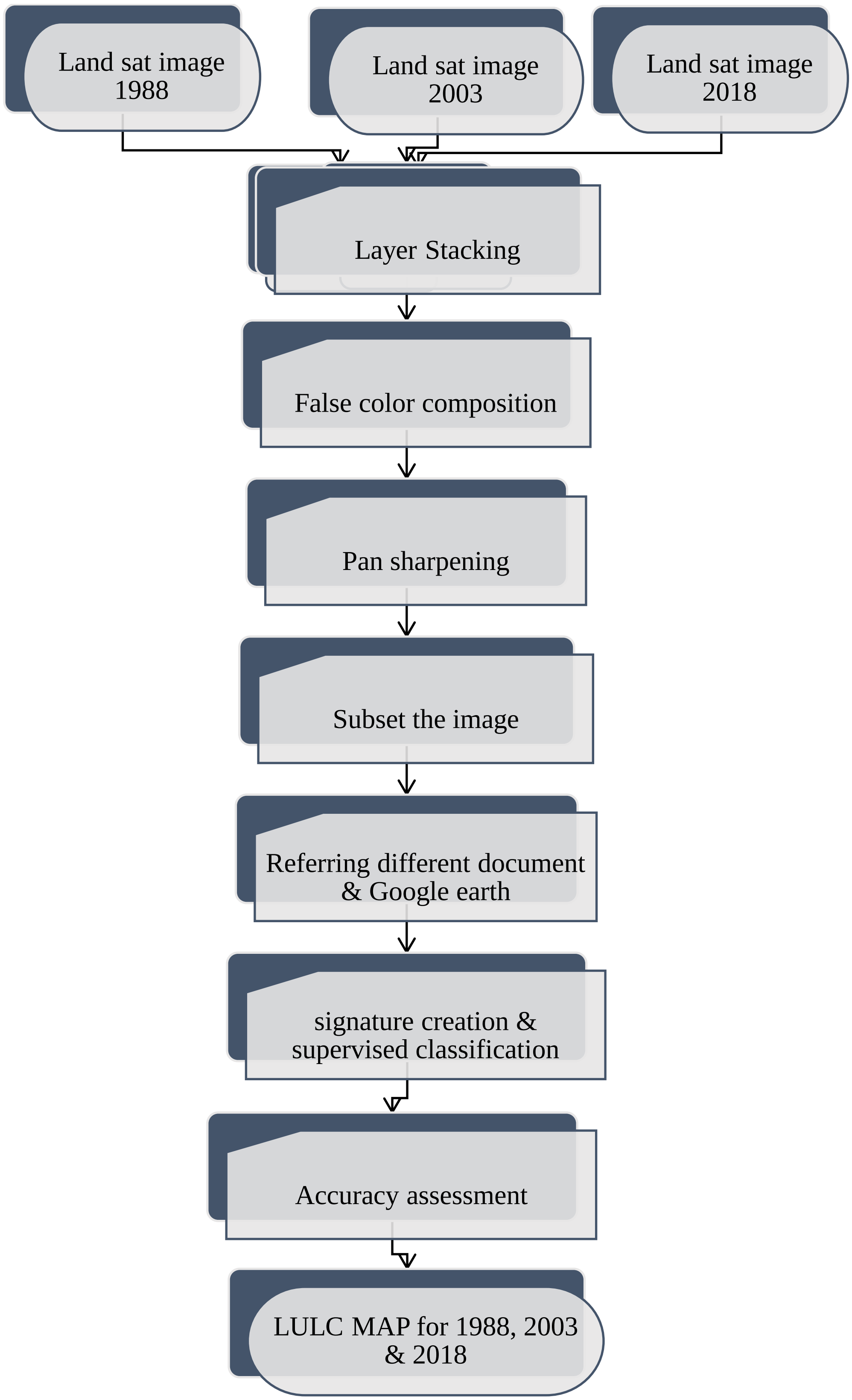


Figure 3.7: Schematic representation for Land covers map preparation

3.2.1.2. Image Classification

Image classification is the process of assigning pixels to the predefined land cover classes (Abburu and Golla, 2015). Remotely sensed images were analyzed using pixel-based supervised classification and MLA that use the means and variances of the training data to estimate the probability that a pixel is a member of a class. The first step of the supervised classification process is to collect reference training sites for each land cover type to generate training signatures. The classification process comprises deriving area of interest which were done by using Google earth, by reviewing the literature and general study area knowledge. Based on the classification the following five types of land cover are identified in the Gelana catchment. The reference data for land cover classification is collected by a random stratified method since this method considers the diversity of the sample.

Cultivated land: - area used for crop cultivation both annuals and perennials, and the scattered rural settlements that are closely associated with the cultivated fields. Due to the difficulty come across in identifying the dispersed rural settlements this kind of land cover was combined with the cultivated land during classification.

Mixed Forest land: - land covered with the dense tree which includes evergreen forest land and plantation forests.

Shrub/bush land: **-** areas covered with shrubs, bushes, small trees

Grassland: - grass and bare land

Settlement: - area covers with building rural residential houses infrastructure roads.

3.2.1.3. Accuracy assessment

One of the most important and the final step in the classification process is accuracy assessment. Which is aims to quantitatively assess how effectively the pixels were sampled into the correct land cover classes. Overall accuracy, User accuracy, producer’s accuracy, and Kappa coefficient statistics (K) were used to assess the accuracy of the classified image. For image classification and for doing accuracy assessment 145,151 and 164 points were taken for 1988, 2003 and 2018 Landsat images respectively. For wide area many numbers were taken for small area small number were taken. The Landsat images of 1988 were taken as baseline by considering the land cover reform in Ethiopia.

Overall accuracy: One of the basic accuracy measures is the overall accuracy, which were calculated by dividing the total number of correctly classified pixels (sum of the values in the main diagonal) by the total number of pixels in the error matrix.

Overall accuracy (%) = (Correctly classified pixels/Total number of pixels) ……………… 3.1

Besides the overall accuracy, the classification accuracy of individual classes has been calculated because the overall accuracy does not indicate how the accuracy is distributed across the individual categories (Bharatkar and Patel, 2013). Hence producer and user accuracy were calculated for individual land cover.

Producer accuracy: The producer accuracy is calculated by dividing the number of correctly classified pixels (diagonal elements) in the category by the total number of pixels of the category in the reference data (column total).

User accuracy: The user accuracy is the ratio between the number of correctly classified pixels (diagonal elements) and the total number of pixels assigned to the same class by the classification procedure (row total).

Kappa coefficient:

$$K = \frac{N * \sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} \left(X_{i+} * X_{+i} \right)}{N^2 - \sum_{i=1}^{r} \left(X_{i+} * X_{+i} \right)} \quad \text{……………………………………………………………}3.2$$

Where: -

N = is the total number of samples in the matrix

r = corresponds to the number of rows in the matrix

X_{ii} = is the number in row i and column i

X_{+i} = is the total for row i

X_i = is the total for column i

3.2.2. Meteorological Data

Meteorological data are among the main demanding input data for the SWAT simulation. The meteorological input data required for SWAT simulation consists of; daily precipitation, maximum and minimum temperature, relative humidity, wind speed, and solar radiation. These data were obtained from the Ethiopian National Metrological Agency (NMA). Three meteorological stations are selected for this study by taking into consideration their distance to the catchment and data availability. From the three stations, only one station contains the five meteorological data. In table 3.3 below the meteorological data location, time scale, and percentage (%) of missing is described.

Table 3.3: Meteorological stations within and near Gelana catchment

Ser №	Station name	Lat	Long	PCP	Max and Min temp	RH	SLR	WND	Time scale	% missing
1	Hagere Mariam	5.53	38.2	✓	✓	✓	✓	✓	daily	<10
2	Yerga Chefe	6.1	38.2	✓	✓				daily	<10
3	Fiseha Genet	6.06	38.1	✓	✓				daily	<10

3.2.1.1. Filling missing data

It is always necessary to estimate the missing meteorological data record since some meteorological stations may have short breaks in the records because of the absence of the observer or instrumental failures. Missed meteorological data may face many problems in hydrologic analysis and design. Hence, to tackle this difficulty missed data were filled using simple arithmetic mean method and the normal ratio method in this study due to its simplicity and also scientifically accepted.

A, Simple Arithmetic Mean Method

This method is the simplest technique regularly used to fill the missing meteorological and hydrological statistics (Ismail and Zin, 2017). According to the Arithmetic mean method the lacking precipitation P_x is given as:

$$\mathbf{P_x} = \frac{1}{n}\sum_{i=1}^{n} P_i \qquad (3.3)$$

Where: - n = is the number of nearby stations or number of years

P_i = is precipitation at the i^{th} stations or the date of the same date with different years

P_x = is missing precipitation at the target station or date

B, Normal Ratio Method

This method is weighted based on the ratio mean of the available data between the target station and the ith neighboring station (Ismail and Zin, 2017). According to the normal ratio method the missing precipitation P_x is given as:

$$\mathbf{P_x} = \frac{1}{n}\sum_{i=1}^{n}\frac{N_x}{N_i}P_i \quad \text{...} \quad 3.4$$

Where: - P_x = the missing precipitation for station x

P_i = the precipitation for the same period for the ith station of a group of index station

N_x = the normal annual precipitation value for the x station

N_i = the normal annual precipitation value for the i^{th} station

3.2.1.2. Homogeneity test

Homogenization is the elimination of non-climatic change since climatic data series can be affected by non-climatic factors. The causes can be either natural or manmade for instance, the method used for data collection, the situation around the observation site, reliability of the measurement, site relocation. Due to this reason, the time series data taken from the meteorological station should be tested for reliability and homogeneity earlier to their use in the analysis (Dhorde and Zarenistanak, 2013). The homogeneity of the selected gauging stations precipitation records was carried out by non-dimensional equation 3.5 below and the result is also shown in figure 3.8 based on homogeneity test analysis the data is homogeneous.

$$P_i = \frac{P_{iavrg}}{P_{avrg}} \quad \text{...} \quad 3.5$$

P_i = non- dimensional value of precipitation for the month in the station i

P_{iavrg} = over year's average monthly precipitation for the station i

P_{avrg} = over year average yearly precipitation for station i

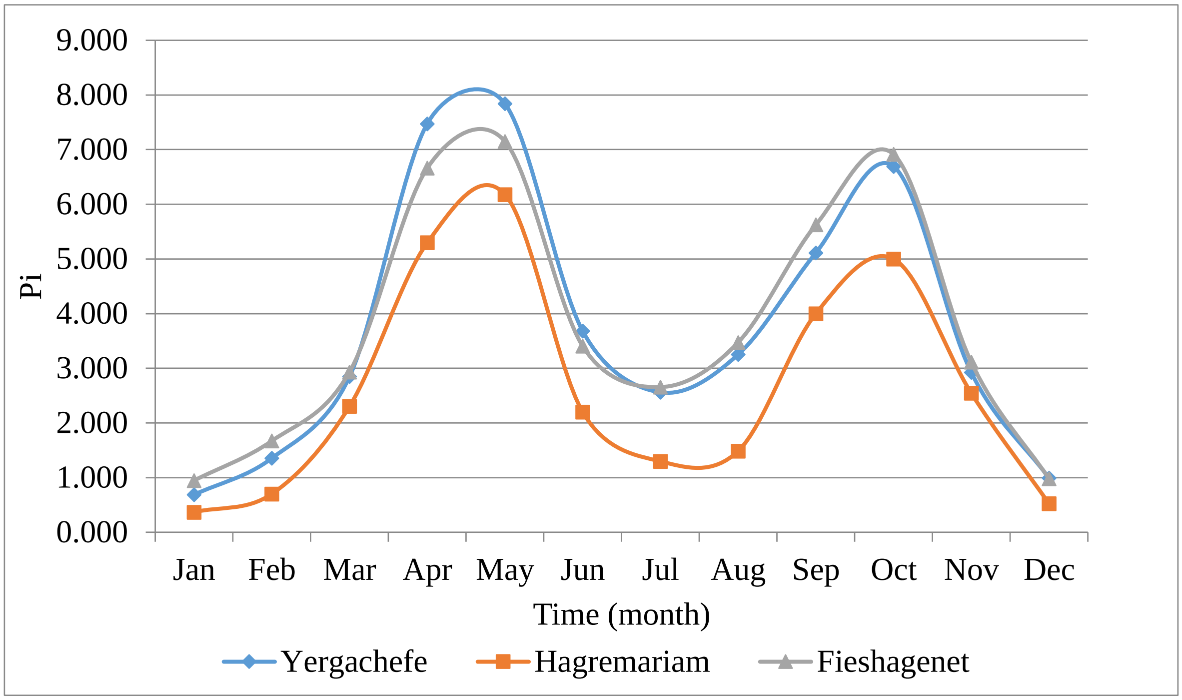


Figure 3.0.8: Data homogeneity analysis

3.2.1.3. Data Consistency

A Double Mass Curve (DMC) was used to check the consistency of rainfall for adjustment of inconsistent data. This technique is based on the principle that when each record data comes from the same parent sample, they are consistent. The annual cumulative of each station are compared with the corresponding annual average cumulative of all station. If significant change in the regime of the curve is observed, it should be corrected by using equation 3.6 below which shows that if any inconsistency occurs in data it can be corrected using the correction slope of the line (Garg, 1976). However, based on the analysis the precipitation data in Gelana catchment is consistent. The result of the DMC analysis shown in figure 3.9 below

$$P'_x = P_x * \frac{M'}{M} \quad \text{......} \quad 3.6$$

Where: -

P'_x = corrected precipitation at station x

P_x = original recorded point at station x

M' =corrected slope of the double mass curve

M= original slope of the double mass curve

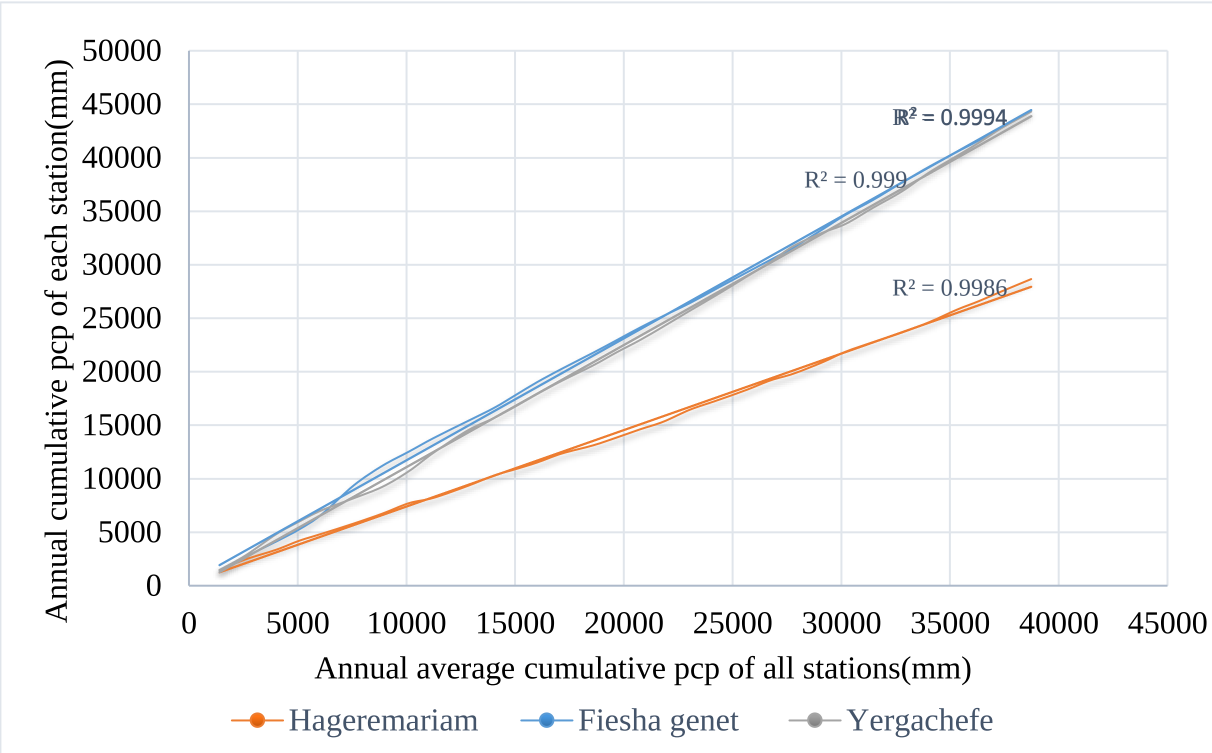


Figure 3.0.9: Double mass curve analysis

3.2.3. Hydrological Data

The hydrological data were collected from the Ethiopian ministry of water, irrigation, and electricity (MoWIE) for the Tore and Yergachefe gauging station with in the catchment. But Tore gauging station were selected since it is near to catchment out let. The data were collected and rearranged as per the requirement of the SWAT model. The missed data were filled by using linear regression in XLSTAT. This data was used for sensitivity analysis, calibration, and validation. Hence, monthly and daily flow data were used from 1991 up to 2005 for model calibration and from 2006 up to 2010 for model validation.

3.2.4. Mean annual Evapotranspiration and precipitation

Based on the stream flow observed period which is (1991-2010) the trend of mean annual evapotranspiration and precipitation data were checked from 1991 up to 2010. Stream flow were converted to mm/year by multiplying with catchment area. The mean annual evapotranspiration was calculated by using equation 3.7 below.

ET= Pcp - Q……………………………………………………………………………… 3.7

Where: -

ET =Evapotranspiration (mm/year)

Pcp= precipitation (mm/year)

Q= Observed Stream flow(mm/year)

Figure 3.10 and 3.11 are presents the graphical representation of mean annual evapotranspiration and precipitation from 1991 up to 2010.

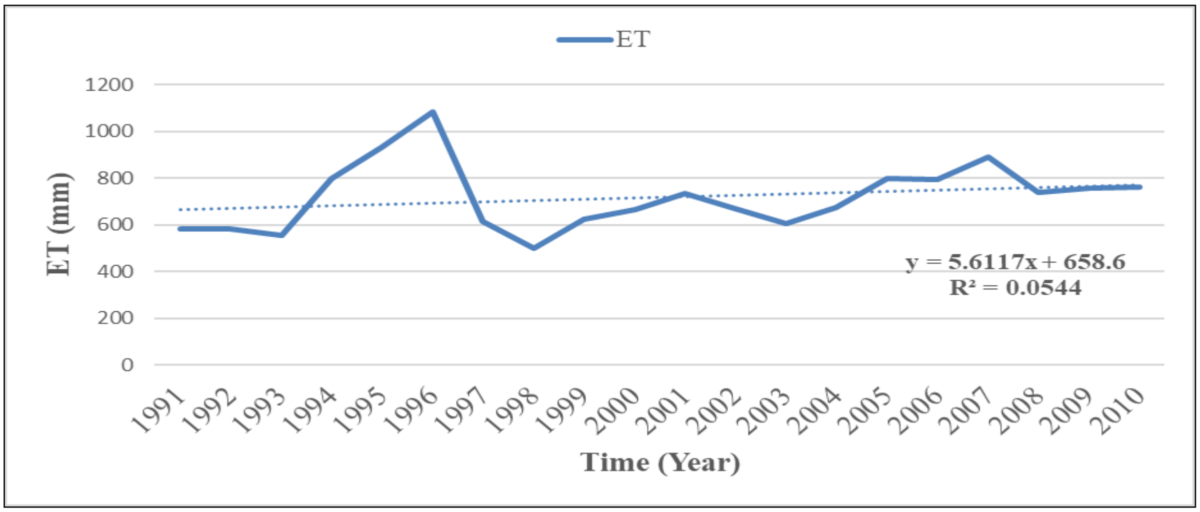


Figure 3.10: Mean Annual Evapotranspiration of Gelana catchment from 1991 to 2010

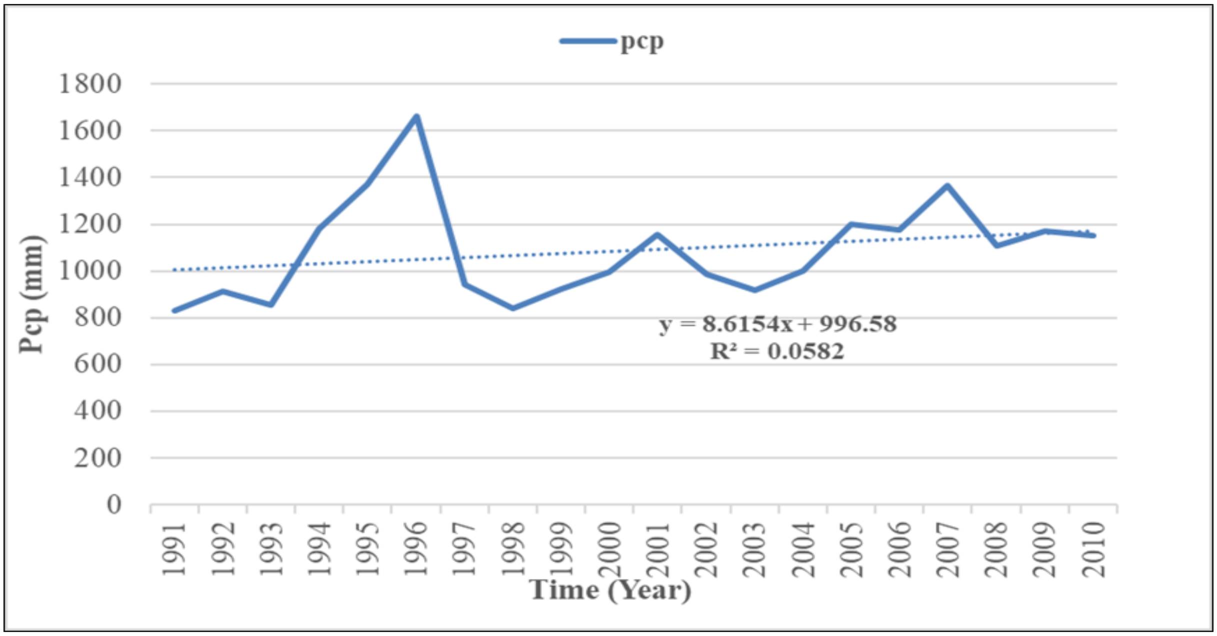


Figure 3.11: Mean Annual rainfall of Gelana catchment from 1991 to 2010

3.2.5. Digital Elevation Model (DEM)

The topography was defined by a Digital Elevation Model (DEM), which describes the drainage pattern of surface area, sub basin parameters such as slope length, stream flow characteristics, and the elevation of any point in a given area at a specific spatial resolution as a digital file. DEM data also required to calculate the flow accumulation, stream networks, and catchment delineation using SWAT catchment delineator tools. A 30m by 30m resolution DEM was obtained from the (MoWIE).

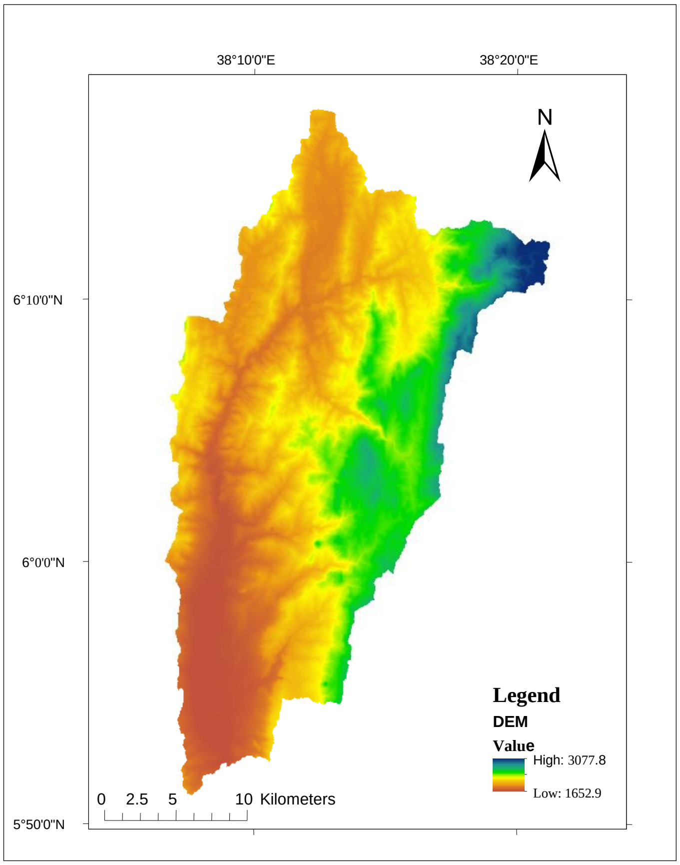


Figure 3.12: DEM of the study area

3.3. Description of SWAT model

The Soil and water assessment tool (SWAT) were applied in the Gelana catchment to assess the impact of LU/LCC on stream flow. This model is selected based on the benefits it provides to meet the objectives of the study. The SWAT model is an extension of Arc GIS that can assimilate a range of readily available geospatial data to accurately represent the characteristics of catchments. The SWAT model is one of the most applicable model developed by the USDA-ARS to predict the impacts of land management practices on water, sediment, and agricultural chemicals yields in catchments with varying soils, land use, and management practices over long periods (White et al., 2014).

As a physical based model, SWAT uses HRU to describe spatial heterogeneity in terms of land use, soil types, and slope within the catchment. To simulate hydrological processes in the catchment, SWAT divides the catchment into sub-basins based upon drainage areas of the tributaries. The sub-basins are further divided into smaller spatial hydrological units known as HRUs, depending on land use/land cover, soil, and slope characteristics. For simulation, SWAT needs DEM, land use and land cover map, soil data, and meteorology data of the study area. These data are used as input for the analysis of stream flow simulation of the catchment. SWAT divides hydrological simulations of a catchment into two major phases: the land phases and routing phases. The land phases of the hydrological simulation control the amount of water, sediment, nutrient, and pesticide loadings to the main channel in each sub-basin. While the routing phases consider the movement of water, sediment, and agricultural chemicals through the channel network to the catchment outlet. The land phases of the hydrological simulation are modeled in SWAT based on a water balance equation as shown in equation 3.8 below.

$$S_{wt} = S_{wo} + \sum_{i=1}^{t}\left(R_{day} - Q_{surf} - E_{a} - W_{seep} - Q_{gw}\right) \quad \text{..} \quad 3.8$$

Where: -

S_{wt} = The final soil water content (mm)

S_{wo} = The initial soil water content (mm)

t = Time in (days)

R_{day} = The amount of precipitation on day i (mm)

Q_{surf} = The amount of surface runoff on day i (mm)

Ea = The amount of Evapotranspiration on day i (mm)

W_{seep} =The amount of water entering the vadose zone from the day i (mm)

Q_{gw} = The amount of return flow on a day i (mm)

3.3.1. Surface runoff

Surface runoff refers to the portion of rainwater that is not lost through interception, infiltration, and evaporation. The general equation for the soil conservation service (SCS) curve number method is expressed in equation 3.9 below.

$$Q_{surf} = \frac{\left(R_{day} - Ia\right)^2}{\left(R_{day} - Ia + S\right)} \quad \text{..} \quad 3.9$$

Where: -

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

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

Ia = is an initial abstraction which includes surface storage, interception, and infiltration before runoff (mm water)

S = is the retention parameter (mm water)

The retention parameter varies spatially due to changes with land surface features such as land use, slope, and management practices. This parameter can also be affected temporally due to changes in soil water content. It is mathematically expressed in equation 3.10 as: -

$$S = 25.4 * \left(\frac{1000}{CN} - 10\right) \quad \text{3.10}$$

Where: - CN is the curve number its value is the function of land use, soil permeability, and soil hydrologic group. The initial abstraction, Ia is commonly approximated as 0.2S and equation 3.9 becomes

$$Q_{surf} = \frac{\left(R_{day} - 0.2S\right)^2}{\left(R_{day} + 0.8S\right)} \quad \text{3.11}$$

For the definition of hydrological groups, the model uses the U.S. Natural resources conservation service (NRCS) classification. The classification defines a hydrological group as a group of soils having similar runoff potential under similar storm and land cover conditions. Accordingly, soils are classified into four hydrological groups A, B, C, and D based on infiltration which represents high, moderate, slow, and very slow infiltration rates, respectively.

3.3.2. Ground water flow

To simulate the groundwater, SWAT partitions groundwater into two aquifer systems: a shallow, unconfined aquifer that contributes return flow to stream within the catchment and a deep, confined aquifer which contributes return flow to streams outside the catchment.

$$A_{qshi} = A_{qshi-1} + W_{rchrg} - Q_{gw} - W_{revap} - W_{deep} - W_{pumpsh} \quad \text{3.12}$$

Where: -

A_{qshi}= the amount of water stored in the shallow aquifer on a day i (mm)

$A_{qsh\,i-1}$= the amount of water stored in the shallow aquifer on day i-1(mm)

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

Q_{gw} = the groundwater flow, or base flow, or return flow, into the main channel on day i (mm)

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

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

W_{pumpsh}= the amount of water removed from the shallow aquifer by pumping on a day i (mm)

3.3.3. Lateral flow

Lateral flow occurs in soil layers with high hydraulic conductivities and an impermeable or semi-permeable layer at a shallow depth. The Rainfall will infiltrate vertically down to the impermeable layer and develops a saturated zone above the impermeable layer and which become the source of water for lateral subsurface flow. Lateral flow moves through the soil layers and joins the nearest channel.

SWAT model calculates the amount of lateral flow released to the main channel as:

$$Q_{lat} = (Q'_{lat} + Q_{latstore,i-1}) * (1 - \exp[-1/t_{lag}]) \quad \text{3.13}$$

Where: -

Q_{lat} =the amount of lateral flow discharged to the main channel on the given day (mm)

Q'_{lat} = the amount of lateral flow generated in a sub-basin on a given day (mm)

$Q_{latstore,i-1}$ = the lateral flow stored or lagged from the previous day (mm)

t_{lag} = the lateral flow lag time

3.3.4. Evapotranspiration

Different approaches are used to estimate Evapotranspiration (ET). SWAT computes Evapotranspiration (ET) using three methods; the Priestley-Taylor method (Priestley and Taylor, 1972), Hargreaves method (Hargreaves, 2003), and the Penman-Monteith method (Monteith, 1965). Penman- Monteith's (1965) method requires solar radiation, air temperature, relative humidity, and wind sped; Priestley-Taylor method (1972) requires solar radiation, air temperature, and relative humidity; whereas (Hargreaves, 2003) method requires an air temperature only. For this study, the Penman-Monteith method was used to estimate Evapotranspiration. The Penman-Monteith equation that estimates Evapotranspiration is given as follows in equation 3.14.

$$ET = \frac{0.408(R_{net} + G) + \gamma \frac{900}{(T + 278)} U(e_s - e_a)}{\Delta + \gamma(1 + 0.34U)} \quad \text{...} \quad 3.14$$

Where: -

ET = Daily reference crop Evapotranspiration [mm day^{-1}]

R_{net} = Net radiations flux [MJm-2 day^{-1}]

G = Heat flux density in the soil [MJ m^{-2} day^{-1}]

T = Mean daily air temperature [^{O}C],

γ= Psychometric constant [KPA $^{o}C^{-1}$],

U= Wind speed measured at 2 m height [ms^{-1}]

e_s =The saturation vapor pressure e_a= e_s *RH/100 [KPA]

RH =Relative humidity [%]

Δ = The slope of the saturation vapor pressure curve [$KPa^{o}C^{-1}$]

3.3.5. Flow routing phase

The second component of the simulation of the hydrology of the catchment is the routing phase of the hydrological cycle. It consists of the movement of water, sediment, and other constituents (E.g. nutrients, pesticides) in the stream network. Two options are available to route the flow in the channel network: the available storage and Muskingum methods. The available storage method uses a simple continuity equation in routing the storage volume, whereas the Muskingum routing method models the storage volume in channel length as a combination of wedge and prism storages. In the later method, when a flood wave advances in to reach segment, inflow exceeds outflow, and wedge storage is produced. As a flood wave recedes or retreats, outflow exceeds inflow in the reach segment and the negative wedge is produced. In addition to the wedge storage, the reach segment contains a prism of storage formed by a volume of the constant cross section along the reach length. Equation 3.15 below describes the available storage method for the flow routing phase.

$\Delta V_{stored} = V_{in} - V_{out}$ 3.15

Where: -

ΔV_{stored} = a change in the volume of storage during the time step (m^3water)

V_{in} = the volume of inflow during the time step (m^3water)

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

3.4. Flow duration curve (FDC) and 1-Day and 7-Day Max and min flow analyses

The flow duration curve describes the streamflow against the percentage of time in which the streamflow is equaled or exceeded. It is a simple and powerful way of summarizing the distribution of stream flow for a given catchment (Shao et al., 2009). which is also helpful to understand the hydrological process of the catchment by comparing the high flow index (Q_5 /Q_{50}) and the low flow index (Q_{95} /Q_{50}). The high flow index (Q_5/Q_{50}), defined as the ratio between monthly stream flow exceeded 5% of the time (Q_5) and monthly stream flow exceeded 50% of the time (Q_{50}). The low flow index (Q_{95} /Q_{50}), defined similarly as the ratio between monthly stream flow exceeded 95% of the time (Q_{95}) and monthly stream flow exceeded 50% of the time (Q_{50}). Monthly flow duration curve for the simulated stream flow time series was computed to evaluate flow regime change in relation to the LULC condition in 1988, 2003, and 2018.

The possible impact of land use land cover change on the indicators of high flows and low flows have also been investigated. For this particular study 1-day and 7-day maximum and minimum flow selected to examine the land cover impact on high and low extreme flow because it is widely applied to evaluate stream flow variation. 1-day min and 1-day max flow is defined as the lowest and highest 1- day stream flow in a given month respectively. 7-day min and 7-day max flow is the lowest and highest seven-day running average stream flow for that month respectively (Singh et al., 2016).

The following flow chart (figure 3.13) clearly represent the overall simulation process starting with data collection up to final stream flow simulation results.

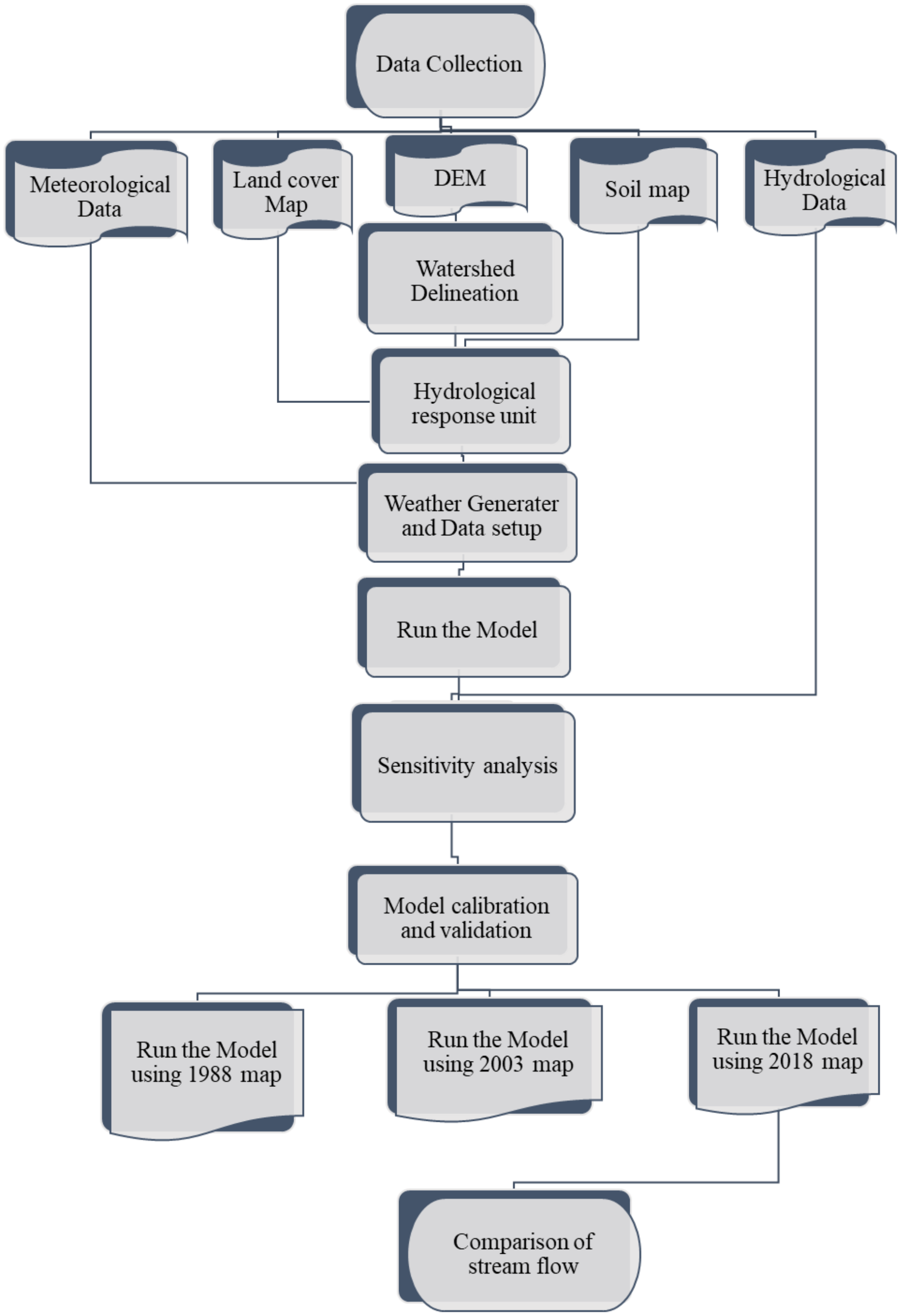


Figure 3.13: Schematic representation of the SWAT model simulation process

3.5. SWAT model setup

3.5.1. Catchment Delineation

The delineation of the catchment was done by using 30m resolution DEM data and the ARCSWAT model. To do this first SWAT set up were created. The catchment delineation processes consist of five major steps, DEM setup, stream definition, outlet and inlet definition, catchment outlet selection definition, and calculation of sub-basin parameters. Once, the DEM setup was completed, the model automatically calculates the flow direction and flow accumulation. Afterward, stream network creation and stream outlets were created. The outlet of the catchment was added manually taking the Gelana dam out let coordinate point 405800E and 648800N, and then the catchment delineated. Finally, the number of sub basin and basin parameters were determined. The Gelana catchment was delineated into 17 sub-basins having an estimated total area of 646.94km^2. During the catchment delineation process, the topographic parameters of the catchment and its sub-basin were also generated from the DEM data.

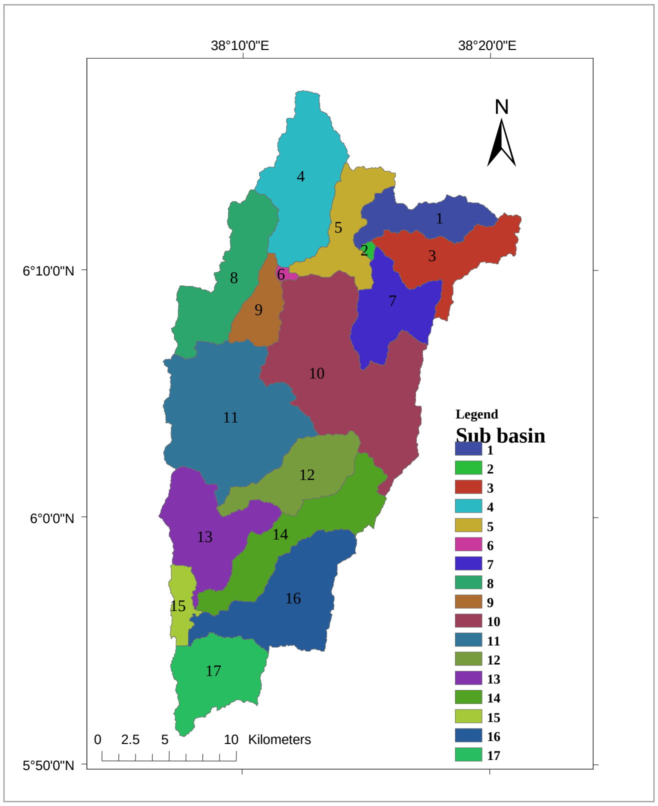


Figure 3.12: Sub-basin map of the Gelana catchment

3.5.2. Hydrologic Response Units (HRU) Analysis

The sub basin of the catchment is divided into smaller homogenous hydrological unit HRU. Land use, soil, and slope characterization for the catchment were performed using commands from the HRU analysis menu on the SWAT Toolbar. With this toolbar land use/land cover and soil maps were loaded into the current project and slope class was assigned. SWAT demands that land cover and soil data should be accompanied by a lookup table with attribute information for each specific land cover and soil type. The slope of the catchment area was determined from the DEM data which was added during catchment delineation process. After loading and reclassification of the input spatial data, all the data were overlaid; for each unique combination of slope, land use, and soil class an HRU was created.

In the model, two options are available in defining HRU distribution: assign a single HRU to each sub basin or assign multiple HRUs to each sub basin based on certain threshold values. In common, the threshold level is used to eliminate minor land use and land covers in sub-basin, minor soil within land use and land cover area, and minor slope classes within a soil on specific land use and land cover area. Following minor eradication, the area of remaining land use and land covers, soils, and slope classes are reassigned so that 100% of their respective area modeled by SWAT. Hence, for this study, HRU definition with multiple was selected with a threshold 15%, 15%, 10%, and HRUs were created each has unique land use and soil combination the number of the HRUs varies within the sub basins.

3.5.3. Weather Generator and weather data definition

Another most important step in the SWAT model is adding meteorological data. The Model requires the daily values of all metrological variables from measured data or generated from the available station. In Ethiopia like most developing countries, there is a lack of a full and realistic long period of meteorological data. Some of the meteorological variables are missed for the station within the catchment. Meteorological data of relative humidity, sunshine hour, and wind speed of Yergachefe and Fisehagenet were missed. Consequently, the weather generator solves this difficulty by generating data from the available meteorological station. This study used measured data for all meteorological variables from the station of Hageremariam with continuous records were used as input to determine the values of weather generator parameters.

The SWAT model contains a Weather generator model called wxgen. It's far used in the SWAT version to generate weather data or to fill missing records of monthly information which is calculated from existing day by day information. The missed meteorological data were filled in wxgen generator by entering -99 code. The weather generator first one at a time generates precipitation for the day. Maximum temperature, minimal temperature, solar radiation, and relative humidity are generated lastly, wind speed is generated independently. Thus, for weather data definition, the weather generators data file wgnstations.txt was selected first then, rainfall data, temperature data, relative humidity data, solar radiation data, and wind speed data had been selected on and delivered to the model.

3.5.4. Parameter estimation and Sensitivity analysis

Sensitivity can be measured as the response of an output variable to a change in an input parameter; with the greater the change in output response resultant to greater sensitivity. Sensitivity analysis examines how different parameters manipulate a predicted output (White and Chaubey, 2005). Most of the time it is difficult to find which parameter is the most influential in stream flow analysis even though parameters have a significant impact on the specific model. To do this sensitivity analysis is done previous to model calibration and validation. The estimated parameters in the analysis were used to calibrate the model.

The average monthly stream flow data of fifteen years from 1991-2005 at the Tore gauging station were used to compute the sensitivity of stream flow parameters. SWAT has an extension tool SWAT-CUP (Soil and water assessment tool-Calibration and Uncertainty Procedures) to perform the sensitivity analysis provided with a possible range of a parameter. In the sensitivity process, first, the SWAT simulation was specified for performing the sensitivity analysis. For the simulated stream flow of Gelana catchment sensitivity analysis was done Twenty-one flow parameters were checked. Then, selected parameters were entered for sensitivity analysis with the default lower and upper parameter bounds, and the rank of sensitivity was based on the value of t-sat and p-values.

3.5.5. Model calibration, validation and Uncertainty

After performing sensitivity analysis model calibration was done to obtain optimum values for sensitive parameters. This is a mandatory step in increasing certainty, user confidence and to effectively apply the model by enhancing its predictive abilities. SWAT provides three alternatives for calibration the first one is manual calibration, auto-calibration, and a combination of these two methods. In this particular study, both manual calibration and auto-calibration are used. Auto-calibration was done by SWAT-CUP using measured stream flow data covering from 1991 up to 2005. A few lists of calibration procedure methods are available to illustrate, Generalized Likelihood Uncertainty Estimation (GLUE), Parameter Solution (ParaSol), and Sequential Uncertainty Fitting (SUFI2), and Markov chain Monte Carlo (MCMC). SUFI2 option was selected for this study since it is applicable to both simple and complex hydrological models. In this study, the length of the time period used for both calibration and validation were determined depending on the existing observed data records. The model was run using the best parameter output values and the simulations have been compared with observed stream flow data using Nash Sutcliffe coefficient of efficiency (ENS), coefficient of determination (R^2), and PBAIS.

Model validation is a comparison of model outputs with an independent data set without making further adjustments which may adjust during the calibration process. The measured data of stream flow data of five years from 2006-2010 were used for the model validation process. It is necessary to consider uncertainties in predicting the hydrology of the catchment. There are different sources of uncertainties, which lead not completely matching between observed and simulated graphs. During this study the observed data collected have missing. Land use classifications have been not completely accurate and it may have effects on HRU class determination. The other uncertainty is simulation or prediction uncertainty by means of the model. Therefore, with those uncertainties, the model gave considerable outcomes.

3.5.6. Model Performance Evaluation

To use a trustworthy model result, model evaluation is the fundamental measure. In this study, three model evaluation methods were used, which were Nash Sutcliffe efficiency (NSE), the coefficient of determination (R^2) and PBIAS.

Nash-Sutcliffe model efficiency (E_{NS})

The Nash-Sutcliffe simulation performance (E_{NS}) suggests that the plot of observed values to simulated values of the data suits the 1:1. If the measured value is the same as all predictions, E_{NS} is 1. If the E_{NS} between 0 and 1, it shows deviations between measured and predicted values.

If E_{NS} is negative, predictions are very poor, and the average value of output is a higher estimate than the model prediction (Nash. Sutcliffe, 1970).

$$NSE = \left[1 - \frac{\sum_{i=1}^{n} (Q_{si} - Q_{oi})^2}{\sum_{i=1}^{n} (Q_{oi} - Q_{oavrg})^2} \right] \quad \ldots\ldots 3.16$$

Where: -

Q_{oi} = observed value

Q_{si} = simulated value

Q_{oavrg} = average observed value

Coefficient of determination (R^2): The R^2 value is an indicator of the strength of the relationship between the observed and simulated values. R^2 ranges from zero to one with higher values indicating better agreement.

$$R^2 = \left(\frac{\sum_{i=1}^{n} (Q_{oi} - Q_{oavrg})(Q_{si} - Q_{savrg})}{\sqrt{\sum_{i=1}^{n} (Q_{oi} - Q_{oavrg})^2} \sqrt{\sum_{i=1}^{n} (Q_{si} - Q_{savrg})^2}} \right) \quad \ldots\ldots 3.17$$

Where: -

Q_{oi} = observed value

Q_{si} = simulated value

Q_{oavrg} = average observed value

Q_{savrg} = average simulated value

Percent bias (PBIAS): It measures the average tendency of the simulated data to be larger or smaller than the observed values.

$$PBIAS = \left[\frac{\sum_{i=1}^{n} (Q_{oi} - Q_{si})}{\sum_{i=1}^{n} (Q_{oi})} \right] \quad \text{3.18}$$

Where: -

Q_{oi} = observed value

Q_{si} = simulated value

4. RESULTS AND DISCUSSION

4.1. LU/LCC Detection

In the study area land cover conversion were observed. This LU/LC conversion was well recognized on cultivation land and mixed forest land than other types of land cover type.

4.1.1. Accuracy Assessment

An error matrix in ERDAS software is prepared after classifying the land sat images from those prepared error matrix User accuracy, Producer accuracy, Overall accuracy, and Kappa coefficient were calculated for each classified image.

4.1.1.1. Overall accuracy

The overall accuracy is one of the basic accuracy measures which is calculated by dividing the total number of correct pixels (diagonals) by the total number of pixels in the error matrix. The analysis result indicates the overall accuracy of the classified image for the year 1988, 2003, and 2018 were 88%, 91%, and 89% respectively.

4.1.1.2. Kappa coefficient

The kappa coefficient gives the agreement between the classified image and reference data. The calculated kappa coefficients were 85%, 89%, and 85% for the years 1988, 2003, and 2018 respectively.

4.1.1.3. Producer’s and user Accuracy

Besides overall classification accuracy, the individual classes or individual category accuracies were calculated. Based on the classification the producer accuracy ranged from 67% to 100% and the user accuracy ranged from 73% to 100%. Table 4.1, 4.2, and 4.3 below shows an error matrix for the three classified land sat images.

Table 4.1: Error matrix for 1988

		Reference Data						
		MF	CUL	SRB	SET	GRS	Row total	User Accuracy
Classification Data	MF	50	3	0	0	0	53	94%
	CUL	3	30	0	2	1	36	83%
	SRB	2	0	22	2	1	27	81%
	SET	0	1	1	8	1	11	73%
	GRS	0	0	0	0	18	18	100%
	Column total	55	34	23	12	21	145	
	Producer Accuracy	88%	88%	96%	67%	86%		Overall accuracy=88%

Kappa coefficient =85%

Note: - MF=Mixed forest, CUL=cultivation land, SRB=Shrub land, GRS=Grass land, SET=Settlement

Table 4.2: Error matrix for 2003

		Reference Data						
		MF	CUL	SRB	SET	GRS	Row total	User Accuracy
Classification Data	MF	40	0	0	0	2	42	95%
	CUL	0	50	1	1	1	53	94%
	SRB	0	0	14	1	0	15	93%
	SET	0	1	0	18	1	20	90%
	GRS	5	0	0	0	16	21	76%
	Column total	45	51	15	20	20	151	
	Producer Accuracy	89%	98%	93%	90%	80%		Overall accuracy=91%

Kappa coefficient =89%

Note: MF=Mixed forest, CUL=cultivation land, SRB=Shrub land GRS=Grass land, SET=Settlement

Table 4.3: Error matrix 2018

		Reference Data						
		CUL	MF	GRS	SET	SRB	Row total	User Accuracy
Classification Data	CUL	70	5	0	2	0	77	91%
	MF	3	24	0	0	0	27	89%
	GRS	2	0	20	0	1	23	87%
	SET	0	0	0	18	0	18	100%
	SRB	4	1	0	0	14	19	74%
	Column total	79	30	20	20	15	164	
	Producer Accuracy	89%	80%	100%	90%	93%		Overall accuracy=89%

Kappa coefficient=85%

Note: MF=Mixed forest, CUL=cultivation land, SRB=Shrub land, GRS=Grass land, SET=Settlement

Even though the overall accuracy for the classified images are excellent, the producer and user accuracy of settlement land cover for the 1988 land cover map is 67% and 73% respectively and also the user accuracy for shrub land for the 2018 land cover map is 74% which might have occurred due to the combination of omission and commission errors. While mixed forest, grassland, and cultivation area give excellent results for all accuracy type. According to Bharatkar and Patel (2013), if K is greater than 0.75, it is an excellent kappa coefficient. The kappa coefficient calculated in this study shows that there is better agreement between reference data and prepared map hence, the classified maps have acceptable kappa results for further analysis. Additionally, Lea and Curtis (2010) suggest that accuracy assessment requires the overall classification accuracy above 85% which is successfully achieved in the present study.

In summary, the accuracy assessment results of the classified images are acceptable for further analysis and change detection.

4.1.2. Spatio-temporal LU/LCC Analysis

The share of mixed forest cover during the study period (1988-2018) exhibited a downward trend from 50.7% to 12.4% on the contrary; cultivation land exhibited an increasing trend from 34.8% to 74.5% (Figure 4.1). For each corresponding year land cover area coverage in percentile is presented in Figure 4.1 below.

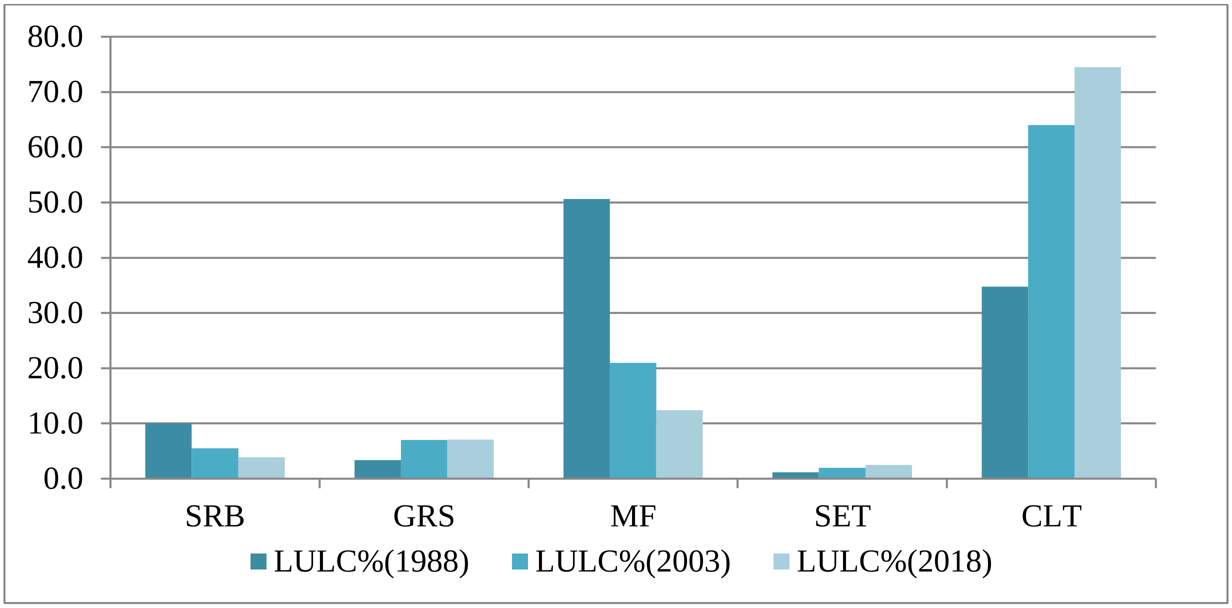


Figure 4.1: LU/LC Area in percentage

Note: - MF=Mixed forest, CUL=cultivation land, SRB=Shrub land, GRS=Grass land, SET=Settlement

Out of the five Land cover types in the study area, it is clearly shown that there were increments in the area of cultivation land, grassland, and settlement area and decrements in the area of mixed forest and shrub land within 30 years. Within the analysis period, Cultivation land increased by 39.7%, and mixed forest and shrub land shrank by 38.1% and 6.1% respectively. Table 4.4 below clearly presents land cover gain and loss in percent for each land cover within study period.

Table 4.4: LU/LC Area gain and loss in percentage

Land cover type	Land cover Area change in %		
	1988-2003	2003-2018	1988-2018
Cultivation	+29.2	+10.5	+39.7
Mixed Forest	-29.7	-8.6	-38.3
Shrub Land	-4.5	-1.6	-6.1
Grass Land	+3.6	+0.10	+3.7
Settlement	+0.8	+0.5	+1.3

This is an important finding in the understanding of Spatio-temporal land cover change of study area. In Gelana catchment vast areas of land were converted into cultivation land predominantly from 1988 to 2003. Shrub land is also exhibited a decreasing trend especially from 1988 to 2003 (Table 4.4). Even though most of the mixed forests and shrub land is converted to cultivation, the conversion is decreased in the analysis period of (2003-2018) compared to the analysis period of (1988-2003) this is because of a huge area of land cover is already converted in the study period of (1988-2003) into cultivation land. Cultivation land increased by 10.5% only from 2003 to 2018 it was small when compared to (1988 to 2003) it was 29.2%.

The three LU/LC maps of 1988, 2003, and 2018 year generated from the land sat TM, ETM+, and OLI imagery classification are presented in Figure 4.2 below, and Table 4.5, show the area coverage in kilometer square (km^2) and percentage amount for each year and land cover type.

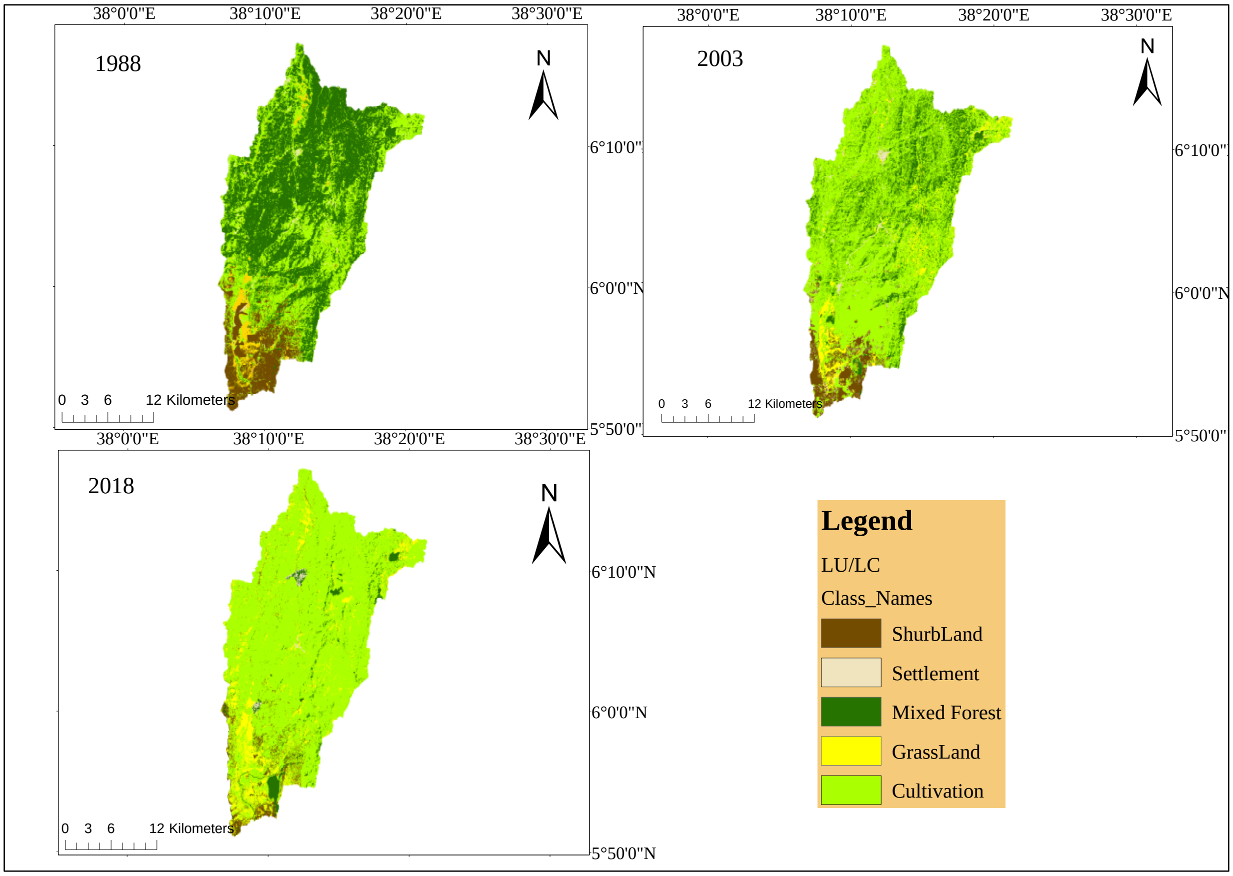


Figure 4.2: Land cover map for the year 1988, 2003 and 2018

Table 4.5: LULC Area for 1988,2003 and 2018

LULCC Type	SWAT CODE	1988		2003		2018	
		Area (Km^2)	Area(%)	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)
Cultivation	AGRL	224.8	34.7	417.0	64.0	482.4	74.5
Mixed Forest	FRST	330.7	50.7	135.8	21.0	80.2	12
Shrub Land	RNGB	65.04	10	36.6	5.5	25.2	3.9
Grass Land	RNGE	21.8	3.4	46.6	7.5	45.9	7.1
Settlement	URML	7.6	1.2	13.9	2	16.2	2.5
Total		649.94	100	649.94	100	649.94	100

From the above (Table 4.5) can be concluded that 257.6km^2, 24.1km^2, 8.6km^2 area is converted into Cultivated land, Grass land and settlement respectively within 30 years from 250.5km^2 area of mixed forest land and 39.84km^2 shrub land. In the study area cultivation land expanded intensively compared to other land cover types. This is mainly due to the increasing population number and the need for huge land for crop production.

The study result is consistent with what has been found in a previous study in the Gojeb watershed Omo Gibe basin, the result reported that cultivation land is increased in the expense of forest land (Choto and Fetene, 2019). A similar pattern of the result was also obtained in the Anger sub-basin of the Didessa basin, Ethiopia. The sub basin has undergone several land use land cover changes. Forest land and shrub land cover decreased noticeably between 1986 and 2010 by 39.5%. Cultivation land was increased as the population number increased in the study area (Getachew, 2018). Additionally, Dinka and Chaka (2019) reported that in the Adei watershed, central highlands of Ethiopia the land cover showed Spatio-temporal dynamics within the period of (1986–2009). The derived LULC map of the Gelana catchment area and change detection analysis may be used for effective land use planning and management.

4.2. Stream Flow Simulation

4.2.1. Sensitivity Analysis

Twenty-one flow parameters were checked to perform sensitivity analysis and from them, the following six parameters were the most sensitive parameter for the study area. Table 4.6 below presents the most sensitive parameter with their maximum, minimum, sensitivity rank, and fitted value.

Table 4.6: Sensitive parameters and their value based on P-value and t-stat

Serial №	Parameter Name	Sensitivity Rank	Min-value	Max-value	Fitted value
1	CN2	1	-0.2	0.2	-0.01
2	GWQMN	2	0	5000	250
3	SLSUBBSN	3	10	150	68.2
4	SOL_Z	4	0	3500	0.82
5	GW_REVAP	5	0.02	0.2	0.18
6	SOL_AWC	6	0	1	0.8

The sensitive parameter presented in table 4.6 above was ranked based on P_value and t_stat. P_value and t_stat indicates the significance (value close to zero has more significance of sensitivity) and measure of sensitivity (larger in absolute values are more sensitive) respectively. From the above result the most controlling and sensitive parameter in Gelana catchment was the SCS runoff curve number (CN2.mgt) followed by (GWQMN.gw) which means threshold depth of water in the shallow aquifer required for return flow to occur. The curve number of a catchment area is a function of land use/land cover and soil characteristics.

4.2.2. Calibration Validation and Uncertainty analysis

The simulation of the model with the default value of parameters in Gelana catchment showed relatively weak matching between the observed and the simulated stream flow. After sensitivity analysis has been done, the calibration of stream flow was done manually and by auto calibration.

The model is calibrated for fifteen years from1991-2005 on both monthly and daily time scales by using land cover map of 1988. The result of calibration for the average monthly stream flow showed a good agreement between observed and simulated stream flow with Nash-Sutcliffe simulation efficiency of 0.77, coefficient of determination 0.82, and Pbias -9. After doing calibration and getting acceptable values of NSE, $R^{2,}$ and Pbias validation of simulated flows for five years' period from 2006-2010 were performed and Validation was checked using monthly and daily observed flows. The model validation also showed a good agreement between simulated and measured monthly flow with the NSE value of 0.7, the coefficient of determination 0.76, and Pbaise -10.4. Similar results were reported by Mengist (2017) for calibration and validation in the Gelana catchment study area for NSE and R^2 but he does not consider Pbias. Figure 4.3 below presents the calibration and validation result of Gelana catchment on a monthly time scale.

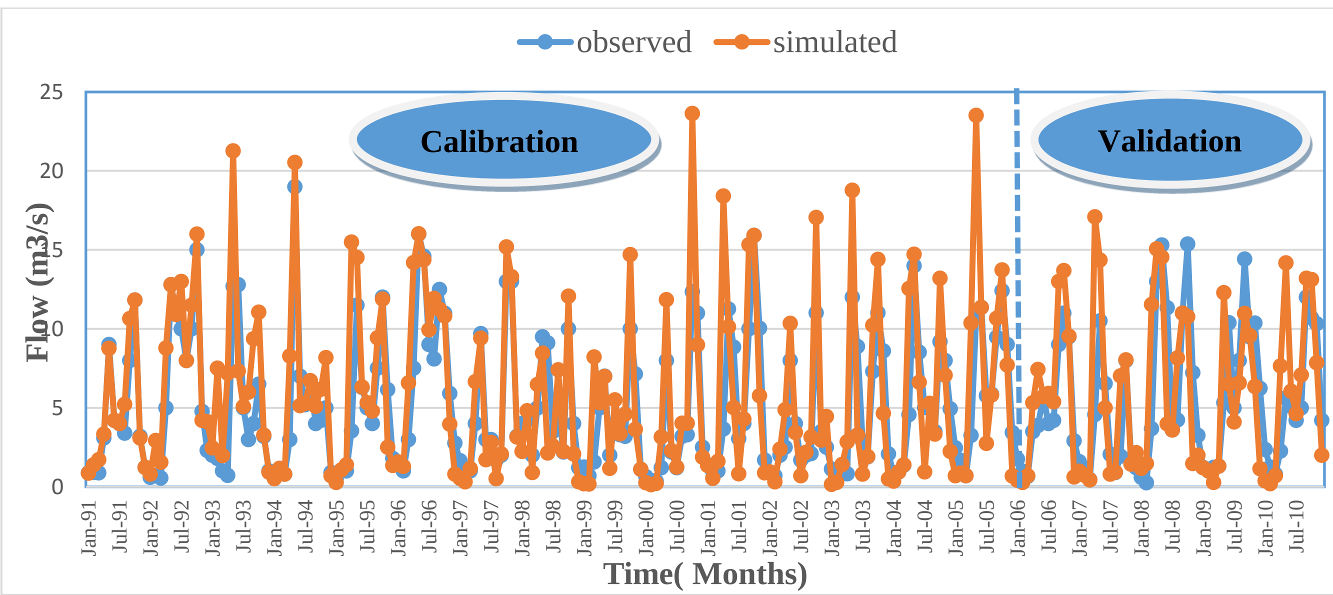


Figure 4.3: Calibration (1991-2005) and validation (2006-2010) of Monthly stream flow

The graphical representation of calibration and validation of monthly steam flow data for measured and simulated was fitted well (Figure4.3) for daily calibration and validation graphical representation found in (Appendix_ D). Statistical parameter values are summarized in table 4.7 below for mean daily and mean monthly simulation for model performance efficiency.

Table 4.7: Statistical value for model performance for monthly and daily simulation

Statistics	**R^2**	**NSE**	**PBIAS**	**p_factor**	**r_factor**
Monthly calibration	0.82	0.77	-9	0.7	0.48
Monthly validation	0.76	0.7	-10.4	0.6	0.51
Daily calibration	0.62	0.53	-23.6	0.54	0.42
Daily validation	0.6	0.5	-25	0.51	0.4

The SWAT model simulates stream flow of the study area more efficiently on a monthly time scale than a daily time scale. Nevertheless, all numerical model performance measures are in the acceptable range and the SWAT model accurately simulated the measured stream flow. According to Santhi et al. (2001) an acceptable calibration for hydrology at a $R^2 > 0.6$, NSE $\geq$ 0.5. the uncertainty analysis which are indicated by p_factor and r_factor was within acceptable range. Girum (2018) reported that the model simulates the monthly stream flow of the Borkena watershed in Ethiopia with an acceptable statistical parameter. Additionally, Abdrhaman (2011) presents that the model SWAT simulates the monthly stream flow of Akaki catchment with excellent model efficiency.

4.3. LU/LCC impact analysis on stream flow

After model calibration and validation, SWAT was run using the land cover map of 1988, 2003, and 2018 while putting the other input variables the same for all simulation to quantify the variability of stream flow due to the changes in land use and land cover.

4.3.1. LU/LCC impact analysis on high flow and low flow indicators

The high flow and low flow indicators response to land use land cover change on the Gelana catchment were calculated. Table 4.8 below presents 1-day and 7-day maximum and minimum flows for the land use land cover of 1988, 2003, and 2018 stream flow simulations.

Table 4.8: 1-day max, 1-day min, 7-day max and 7-day min stream flow

	LULC 1988	LULC 2003	LULC 2018
1-Day Max	29 m^3/s	32.4 m^3/s	33.3 m^3/s
1-Day min	0.64m^3/s	0. 58m^3/s	0.52m^3/s
7-Day Max	27.5m^3/s	31 m^3/s	32.6 m^3/s
7-Day min	0.6m^3/s	0.54 m^3/s	0.5m^3/s

The above table is an important finding in the understanding of high flow and low flow variation owing to land use land cover change. Low flow analysis is done by evaluating 1-day and 7-day minimum flow. As presented in table 4.8 there is an increment of high flow and in contrast reduction of low flow within 30 periods of time. From 1988 to 2003, from 2003 to 2018, and from 1988 to 2018. 1-day max flow increased by 3.4 m^3/s,0.9 m^3/s, and 4.3m^3/s, and 7-day max flow increased by 3.5 m^3/s,1.6 m^3/s, and 5.1 m^3/s respectively. In contrast 1-day min and 7-day min flow decreased by 0.06 m^3/s ,0.06 m^3/s 0.12 m^3/s and 0.06 m^3/s ,0.04 m^3/s, 0.1 m^3/s respectively from 1988 to 2003, from 2003 to 2018 and from 1988 to 2018.

According to the simulation result, land cover change on Gelana catchment puts its potential influence on 1-day and 7-day extreme flow within 30 years. During the rainy season, the precipitated rain will infiltrate into the soil through plant roots by this mechanism ground water will be recharged and became sources of stream flow in the dry season. Nevertheless, in the Gelana catchment, a huge area of mixed forest land and shrub land were converted into cultivation land. Since the water holding capacity of cultivated land is less compared to forest and shrub land, the infiltrating amount of water was decreased as well. On the contrary, 1 day and 7-day maximum flow increased. The result indicates there is a direct linkage between land cover change and catchment stream flow processes. High and low flow analysis is important for drought and flood impact control and mitigation therefore the study result is important for land planner and policy makers. But it is beyond the scope of this study to address the question of how to mitigate and control drought and flood events.

4.3.2. Flow duration curve (FDC) analysis

Monthly flow duration curve has been computed by using each land cover map as in put data. Figure 4.4 below shows the flow duration curve for land cover map of 1988, 2003, and 2018 stream flow simulation.

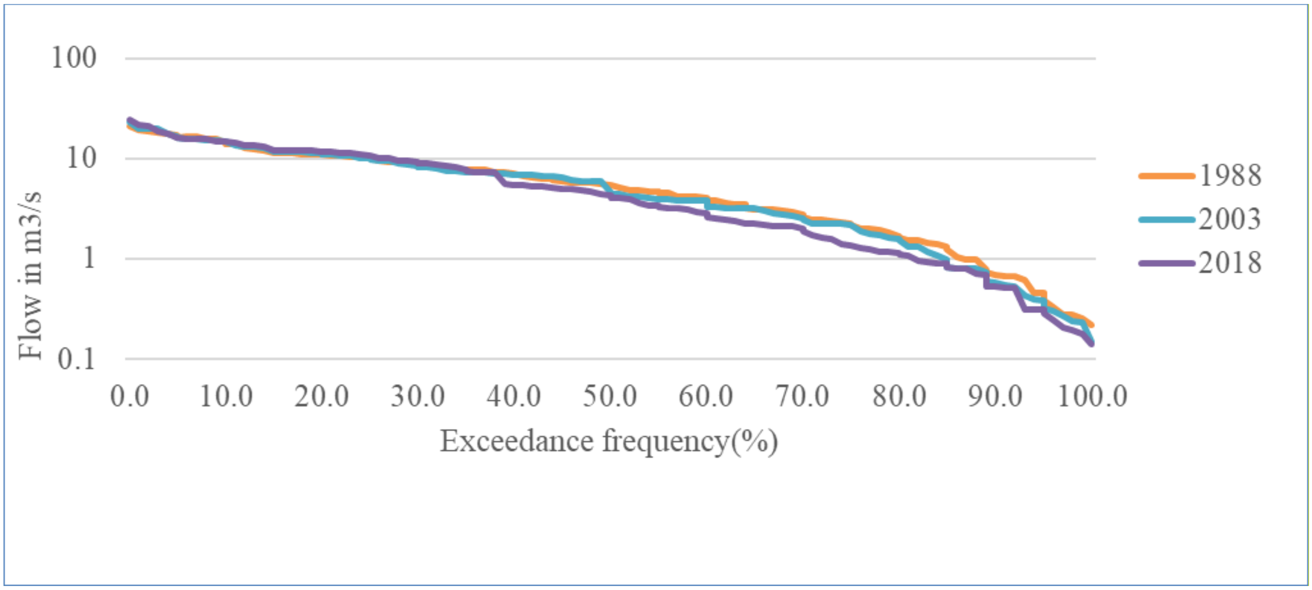


Figure 4.4: Flow duration curve (FDC) for the land cover map of 1988,2003,2018

The result from monthly flow duration curve for a land cover of 1988, 2003, and 2018 demonstrates that high flow which is represented by Q_5 (the flow equal or exceeded 5% of the time) increased by 1.02m^3/s, 0.43m^3/s, and 1.45m^3/s from 1988 to 2003, from 2003 to 2018 and 1988 and 2018 respectively. Q_{50} (the flow equal or exceeded 50% of the time) was decreased by 1m^3/s, 0.29m^3/s, and1.3 m^3/s from 1988 to 2003, from 2003 to 2018 and 1988 and 2018 respectively. Low flow which is represented by Q_{95}(the flow equal or exceeded 95%) was decreased by 0.15m^3/s, 0.08 m^3 /s, and 0.23 m^3/s from 1988 to 2003, from 2003 to 2018, and 1988 and 2018, respectively. The impact is higher in low flow season than on high flow season. Table 4.9 below presents high flow and low flow index for each land cover simulation.

Table 4.9: High and Low flow index

Flow index	1988	2003	2018
Q_5/Q_{50}	3.5	3.59	3.64
Q_{95}/Q_{50}	0.1	0.08	0.05

From the above (Table 4.9) and (Figure 4.4) it is clear that the high flow index (Q_5/Q_{50}) increased whereas the low flow index (Q_{95}/Q_{50}) decreased. This can be confirmed that the land cover change within the study area results in low flow which may also be a consequence in water deficiency and drought in dry period. The finding of study is similar with study result in Gedeb catchment Choke Mountain range of Ethiopia. According Koch et al. (2012) report the land cover dynamics were observed in Gedeb and result in reduction of dry season flow. The study result is very helpful for deeply understand the catchment process of Gelana catchment and to wisely manage the catchment.

4.3.3. LU/LCC impact analysis on mean annual flow and seasonal flow

In the Gelana catchment, the rainfall patterns reflect the Bi-Modal regime with wet, intermediate, and dry seasons (Gelana large scale irrigation project, 2016; NMA). Table 4.10 below presents the mean seasonal and annual variation of stream flow in Gelana catchment due to land use land cover change.

Table 4.0.10: Mean annual and season flow of the catchment

	LULC 1988	LULC2003	LULC2018
Wet season(m^3/s)	10.80	12.24	12.36
Intermediate season(m^3/s)	6.06	6.77	7.01
Dry Season(m^3/s)	3.1	2.85	2.78
Mean annual(m^3/s)	6.85	7.74	7.79

The above table result provides evidence to land cover change impact on stream flow. In the study area stream flow volume of mean annual, wet and intermediate season has been increased owing to the land cover change. Mean annual stream flow from 1988 to 2003, from 2003 to 2018, and 1988 to 2018 land cover was increased by 0.89 m^3/s, 0.05m^3/s, and 0.94 m^3/s

respectively. Similarly, wet season and intermediate season results show increasing pattern by 1.44 m^3/s,0.12 m^3/s,1.56 m^3/s and 0.77 m^3/s,0.24 m^3/s,0.95 m^3/s respectively for same analysis period. The study area gets a high amount of flow in May and October which is contributing to the wet season and intermediate season. Dry season flow decreased by 0.25m^3/s, 0.07 m^3/s and 0.32 m^3/s from 1988 to 2003, from 2003 to 2018 and 1988 to 2018 respectively. The study result is similar with the feasibility study result of the Gelana dam (Gelana dam final feasibility study, 2007). Due to the land use land cover change, there is variation in the wet season, intermediate season, and dry season flow. These changes have serious implications for water security and basin management.

The study result ties well with previous study result in Gojeb catchment. In Gojeb catchment stream flow increased by the amount of 8.6m^3/s with 31 period analysis due to land cover change (Choto and Fetene 2019). Increment of wet season flow by 8.6m^3/s and decrement of dry season flow by 9.3m^3/s were also observed in Katar watershed due to land cover change (Tolera, 2018). The study finding is important for effective catchment management.

4.3.4. The impact of LU/LCC on the Hydrological process

The evaluation was also done in terms of the response of land use and land cover changes on the hydrological process. Table 4.11 below illustrates the mean annual hydrological process for different land cover simulation.

Table 4.0.11: Mean annual hydrological process for LU/LCC of 1988, 2003, 2018

Year	Mean annual LAT_Q(mm)	Mean annual GW_Q(mm)	Mean annual SUR_Q(mm)	Mean annual ET (mm)
1988	605.2	196.6	34.5	500.7
2003	574.2	194.9	66.8	509.4
2018	567.2	192.8	75.4	510.4

From the above result, it is clear that owing to land cover change the hydrological process of Gelana catchment is affected. The contribution of surface runoff to stream flow is increased from 1988 to 2003, from 2003 to 2018, and from 1988 to 2018 by the amount of 32.3mm, 8.6mm, and 40.9mm respectively. The land cover changes also affected the contribution of groundwater flow and lateral flow to stream flow. For lateral flow the result shows there is a reduction by the amount of 31mm, 7mm, 38mm, and there is also a reduction in the contribution of ground water for stream flow by the amount of 2.1mm, 1.7mm, and 3.8mm from 1988 to2003 from 2003 to 2018 and from 1988 to 2018 respectively. A little increment of Evapotranspiration was observed from one observation land cover year to another.

LU/LCC can affects the runoff process, infiltration, and Evapotranspiration. Along with these changes, considerable consequences are expected in the hydrological cycles and subsequent effects on water resources (Githui et al., 2009). The increment of surface runoff is related to the expansion of cultivation land since cultivated land has a high potential for surface runoff contribution (Gumindoga et al., 2014). In the study area cultivation land is increased at expense of mixed forest and shrub lands. The farming land expansion results in the variation of groundwater storage this can be explained in terms of crop soil moisture demands. Crops need less soil moisture than forests consequently, the rainfall satisfies the soil moisture deficit in agricultural lands more quickly than in forests thereby generating more surface runoff and infiltration and interception will be decreased (Czemiel et al., 2008).

The study result agrees with previous studies done in the different catchments of the country. To illustrate Girum (2018) reported the increment of surface runoff and reduction of ground water contribution for stream flow owing to the land cover change in Borkena watershed of Ethiopia. Abdrhaman (2011) also reported that surface runoff is increased as the land cover is changed in Akaki catchment from 1973 to 2000. Additionally, Kebede et al. (2014) studied in Lake Hawassa watershed and reported that there is a direct relationship between land cover change and catchment hydrological process. These results demonstrate that land use and land cover change have a significant effect on ground water and runoff production.

When comparing the overall result to those older studies similar things were observed. From the whole stream flow simulation result, it is clear that as the land cover is degraded or converted from mixed forest to cultivation land, stream flow variation also noticed and consequently affected healthily catchment function significantly.

5. SUMMARY AND CONCLUSION

5.1. SUMMARY

The major concern of this study was to quantify stream flow response of Gelana catchment to land use/land cover changes over the period 1988-2018. Study also try to analyze the land cover change trend of study area and its impact on high flow and low flows and on some components of stream flow. The study was conducted in Gelana catchment which is part the big Gelana watershed. The major tool/model applied in this study were SWAT hydrological model which is extension of ARCGIS. ERDAS IMAGE 2014 were also use for land cover classification and change detection analysis in combination with ARCGIS. Meteorological data (from1987- 2018) and hydrological data (from 1991- 2010) were used for simulation of the model. The missed data for both meteorological and hydrological data were properly handled. For land cover characterization data extracting, layer stacking, pan sharpening of images, image classification, and accuracy assessment for the Landsat image of 1988, 2003 and 2018 were done.

In the study area cultivation land were increased followed by grass land and settlement. In contrary mixed forest land were decreased; shrub land also exhibited a decreasing trend. Due to expansion cultivation land 1-day and 7-day max flow were increased in opposite 1-day and 7-day min flow was decreased. Besides increment of wet season flow, intermediate season flow and mean annual flow were observed in contrary dry season flow were decreased. Furthermore, the land cover change altered the contribution of lateral water flow, ground water flow and surface run off water flow to stream flow.

In short, even though lu/lc is a natural process, it should be utilized, managed and conserved wisely to reduce negative impact on waterbodies. Lu/lc study in relation to catchment response will increases the likelihood to protect the catchment well-being and also enhance people awareness towards land and water resource conservation.

5.2. CONCLUSION

Spatio-temporal LU/LCC was detected over 30 periods by using ERDAS imagine software and ARCGIS. The catchment area classified in to five land cover types such as cultivation land, mixed forest, shrub land, grass land, and settlement. From those land use/land covers cultivation land changed significantly and expanded at expense of mixed forest land and shrub land. The Cultivated land increased by 39.9% over the period (1988-2018), and a wide area of mixed forest land was reduced by 38.3% within a similar period.

The study also investigates the impact of LU/LCC on high and low flow indicators by using 1-day and 7-day max and min flows. 1-day max and 7-day max flows were increased by 4.3m^3/s and 5.1 m^3/s respectively from 1988 simulation period to 2018. while 1-day min and 7-day min flow decreased by 0.12 m^3/s and 0.1 m^3/s respectively for the same analysis period.

Finally stream flow response for each period of land use land cover map (1988,2003 and 2018) on mean annual and seasonal flow were analyzed. Mean annual flow of the catchment increased by the amount of 0.94m^3/s from 1988 simulation period to 2018. The result of simulation indicates that during the wet season and intermediate season stream flow were increased by 1.56 m3/s and 0.95 m3/s respectively from 1988 simulation period to 2018. While dry season flow decreased by 0.32m^3/s with in similar analysis period due to expansion of cultivation land.

Based on the findings of the study, the following recommendations were suggested: -

- Extensive expansion of cultivation land and mixed forest reduction was observed in study area. unplanned expansion of farming activities should be avoided instead proper land use planning must be done before any developmental activities in the catchment to tackle land cover change related problems which needs effective and participatory integrated watershed management.
- The Gelana River is the source of water for people who live within the catchment. The unwise land exploitation significantly disturbed the river high and low flow amount and hydrological process. Hence, awareness should be created for people about how unwise usage of land can affect the river flow and planned utilization should be every one responsibility who live within the catchment. Moreover, for sustainable water resources development, catchment interventions aiming at reducing high flows and increasing low flows should be implemented.

- The availability of adequate data with good quantity and quality was a great challenge in this study. The model simulates by using three meteorological stations only since, most of the meteorological and hydrological stations within and surrounding the catchment were not functional and has a long-time missing data. Hence, it is highly recommended to establish good gauging networks of both hydrological and meteorological stations.
- Further study should be conducted in Gelana catchment since this study only consider land cover change impact on stream flow. Climate variability and land management impact on stream flow also ought to be addressed.

REFERENCES

Abburu, S. and Golla, S.B., 2015. Satellite image classification methods and techniques: A review. International journal of computer applications, 119(8).

Abdrhaman, B. (2011). The effect of land use change on hydrology of Akaki Catchment. Msc Thesis, Addis Ababa University:116.

Amini, Ata, Thamer Mohammad Ali, Abdul Halim B. Ghazali, Azlan A. Aziz, and Shatirah Mohd Akib. (2011). "Impacts of Land-Use Change on Streamflows in the Damansara Watershed, Malaysia." *Arabian Journal for Science and Engineering* 36(5):713–20.

Apollonio, Ciro, Gabriella Balacco, Antonio Novelli, Eufemia Tarantino, and Alberto Ferruccio Piccinni. (2016). "Land Use Change Impact on Flooding Areas: The Case Study of Cervaro Basin (Italy)." *Sustainability (Switzerland)* 8(10).

Ariti, Adenew Taffa, Jasper van Vliet, and Peter H. Verburg. (2015). "Land-Use and Land-Cover Changes in the Central Rift Valley of Ethiopia: Assessment of Perception and Adaptation of Stakeholders." *Applied Geography* 65:28–37.

Ayele, Gebiaw T., Aschalew K. Tebeje, Solomon S. Demissie, Mulugeta A. Belete, Mengistu A. Jemberrie, Wondie M. Teshome, Dereje T. Mengistu, and Engidasew Z. Teshale. (2018). "Time Series Land Cover Mapping and Change Detection Analysis Using Geographic Information System and Remote Sensing, Northern Ethiopia." *Air, Soil, and Water Research* 11.

Babar, Santosh, and H. Ramesh. (2015). "Streamflow Response to Land Use-Land Cover Change over the Nethravathi River Basin, India." *Journal of Hydrologic Engineering* 20(10).

Bharatkar, Pravada S., and Rahila Patel. (2013). "Approach to Accuracy Assessment Tor RS Image Classification Techniques." *International Journal of Scientific & Engineering Research* 4(12):79–86.

Brebante, B. M. (2017). *Analyzing the effects of land cover/land use changes on flashflood: a case study of Marikina River Basin (MRB), Philippines* (Master's thesis, University of Twente).

Butt, Amna, Rabia Shabbir, Sheikh Saeed Ahmad, and Neelam Aziz. (2015). "Land Use Change

Mapping and Analysis Using Remote Sensing and GIS: A Case Study of Simly Watershed, Islamabad, Pakistan.” *Egyptian Journal of Remote Sensing and Space Science* 18(2):251–59.

Chen, Ying, Youpeng Xu, and Yixing Yin. (2009). “Impacts of Land Use Change Scenarios on Storm-Runoff Generation in Xitiaoxi Basin, China.” *Quaternary International* 208(1–2):121–28.

Choto, Misganaw, and Aramde Fetene. (2019). “Impacts of Land Use/Land Cover Change on Stream Flow and Sediment Yield of Gojeb Watershed, Omo-Gibe Basin, Ethiopia.” *Remote Sensing Applications: Society and Environment* 14:84–99.

Costa, Hugo, Giles M. Foody, and Doreen S. Boyd. (2018). “Supervised Methods of Image Segmentation Accuracy Assessment in Land Cover Mapping.” *Remote Sensing of Environment* 205(December 2016):338–51.

Czemiel, Justyna, Lars Bengtsson, and Kenji Jinno. (2008). “Runoff Water Quality from Intensive and Extensive Vegetated Roofs.” 5:369–80.

Demissew, S. (2017). Environmental and Social Management Framework (ESMF).

Devia, Gayathri K., B. P. Ganasri, and G. S. Dwarakish. (2015). “A Review on Hydrological Models.” *Aquatic Procedia* 4(Icwrcoe):1001–7.

Dhorde, Amit G., and Mohammad Zarenistanak. (2013). “Three-Way Approach to Test Data Homogeneity : An Analysis of Temperature and Precipitation Series over Southwestern Islamic Republic of Iran.” *J. Ind. Geophys. Union* 17(3):233–42.

Dinka, Megersa Olumana, and Degefa Dhuga Chaka. (2019). “Analysis of Land Use/Land Cover Change in Adei Watershed, Central Highlands of Ethiopia.” *Journal of Water and Land Development* 41(1):146–53.

Fichera, Carmelo Riccardo, Giuseppe Modica, and Maurizio Pollino. (2012). “Land Cover Classification and Change-Detection Analysis Using Multi-Temporal Remote Sensed Imagery and Landscape Metrics.” *European Journal of Remote Sensing* 45(1):1–18.

Garg, K. (1976). *Irrigation engineering and Hydraulic structures.* Delhi: KHANNA publisher.

Garg, Vaibhav, Bhaskar Ramchandra Nikam, Praveen Kumar Thakur, Shiv Prasad Aggarwal, Prasun Kumar Gupta, and Sushil Kumar Srivastav. (2019). "Human-Induced Land Use Land Cover Change and Its Impact on Hydrology." *HydroResearch* 1:48–56.

Gebresamuel, Girmay, Ram Singh Bal, and Dick Øystein. (2010). "Land-Use Changes and Their Impacts on Soil Degradation and Surface Runoff of Two Catchments of Northern Ethiopia." *Acta Agriculturae Scandinavica Section B: Soil and Plant Science* 60(3):211–26.

Gelana large scale irrigation project. (2016). Oromia water works design and supervision enterprise(OWWDSE).

Getachew, H. E., & Melesse, A. M. (2012). The impact of land use change on the hydrology of the Angereb Watershed, Ethiopia. *International Journal of Water Sciences*, *1*(4).

Getachew, R. (2018). Simulation of Runoff under the past impacts of land use land cover and future climate change (Case Study of Anger sub basin). Msc Thesis, Addis Ababa University:110.

Ghaffari, Golaleh, Saskia Keesstra, Jamal Ghodousi, and Hassan Ahmadi. (2010). "SWAT-Simulated Hydrological Impact of Land-Use Change in the Zanjanrood Basin, Northwest Iran." *Hydrological Processes* 24(7):892–903.

Girum, M. (2018). *Impact of land use land cover change on hydrology of Borkena watershed, Ethiopia* . Msc Thesis, Addis Ababa University:87.

Githui, Faith, Francis Mutua, and Willy Bauwens. (2009). "Estimating the Impacts of Land-Cover Change on Runoff Using the Soil and Water Assessment Tool (SWAT): Case Study of Nzoia Catchment, Kenya." *Hydrological Sciences Journal* 54(5):899–908.

Gomez, Cristina, Joanne C. White, and Michael A. Wulder. (2016). "Optical Remotely Sensed Time Series Data for Land Cover Classification: A Review." *ISPRS Journal of Photogrammetry and Remote Sensing* 116:55–72.

Guide, E. F. (1999). Earth resources data analysis system. ERDAS Inc. Atlanta, Georgia, 628.

Gumindoga, W., T. H. M. Rientjes, A. T. Haile, and T. Dube. (2014). "Predicting Streamflow for Land Cover Changes in the Upper Gilgel Abay River Basin, Ethiopia: A TOPMODEL Based Approach." *Physics and Chemistry of the Earth* 76–78(2015):3–15.

Hailemariam, Sisay Nune, Teshome Soromessa, and Demel Teketay. (2016). "Land Use and

Land Cover Change in the Bale Mountain Eco-Region of Ethiopia during 1985 to 2015." *Land* 5(4).

Ismail, Wan Norliyana Wan, and Wan Zawiah Wan Zin. (2017). "Estimation of Rainfall and Stream Flow Missing Data for Terengganu , Malaysia by Using Interpolation Technique Methods." *Malaysian Journal of Fundamental and Applied Sciences* 13(3):213–17.

Kaul, Harshika a, and Ingle Sopan. (2012). "Land Use Land Cover Classification and Change Detection Using High Resolution Temporal Satellite Data." *Journal of Environment* 01(04):146–52.

Kebede, Wolka, Mengistu Tefera, Taddese Habitamu, and Tolera Alemayehu. (2014). "Impact of Land Cover Change on Water Quality and Stream Flow in Lake Hawassa Watershed of Ethiopia." *Agricultural Sciences* 05(08):647–59.

Koch, F.J., Van Griensven, A., Uhlenbrook, S., Tekleab, S. and Teferi, E., 2012. The Effects of land use change on hydrological responses in the choke mountain range (Ethiopia)-a new approach addressing land use dynamics in the model SWAT.

Li, Pengcheng, Hengpeng Li, Guishan Yang, Qi Zhang, and Yaqin Diao. (2018). "Assessing the Hydrologic Impacts of Land Use Change in the Taihu Lake Basin of China from 1985 to 2010." *Water (Switzerland)* 10(11).

Li, Suxiao, Hong Yang, Martin Lacayo, Junguo Liu, and Guangchun Lei. (2018). "Impacts of Land-Use and Land-Cover Changes on Water Yield: A Case Study in Jing-Jin-Ji, China." *Sustainability (Switzerland)* 10(4):1–16.

Mallupattu, P.K. and Sreenivasula Reddy, J.R., 2013. Analysis of land use/land cover changes using remote sensing data and GIS at an Urban Area, Tirupati, India. *The Scientific World Journal*, *2013*.

Mengist, A. (2017). *Estimation of catchment sediment yield using SWAT model case study Gelana reservior Riftvalley lake basin Ethiopia.* Msc Thesis, Addis Ababa University:97.

Munoth, Priyamitra, and Rohit Goyal. (2019). "Impacts of Land Use Land Cover Change on Runoff and Sediment Yield of Upper Tapi River Sub-Basin, India." *International Journal of River Basin Management* 0(0):1–13.

Mutayoba, Edmund, Japhet J. Kashaigili, Frederick C. Kahimba, Winfred Mbungu, and Nyemo

A. Chilagane. (2018). “Assessing the Impacts of Land Use and Land Cover Changes on Hydrology of the Mbarali River Sub-Catchment. The Case of Upper Great Ruaha Sub-Basin, Tanzania.” *Engineering* 10(09):616–35.

Ogden, F.L., Crouch, T.D., Stallard, R.F. and Hall, J.S., 2013. Effect of land cover and use on dry season river runoff, runoff efficiency, and peak storm runoff in the seasonal tropics of Central Panama. *Water Resources Research*, *49*(12), pp.8443-8462.

Otukei, J. R., and T. Blaschke. (2010). “Land Cover Change Assessment Using Decision Trees, Support Vector Machines and Maximum Likelihood Classification Algorithms.” *International Journal of Applied Earth Observation and Geoinformation* 12(SUPPL. 1):27–31.

Phiri, Darius, and Justin Morgenroth. (2017). “Developments in Landsat Land Cover Classification Methods: A Review.” *Remote Sensing* 9(9),p.967.

Rawat, J. S., Vivekanand Biswas, and Manish Kumar. (2013). “Changes in Land Use/Cover Using Geospatial Techniques: A Case Study of Ramnagar Town Area, District Nainital, Uttarakhand, India.” *Egyptian Journal of Remote Sensing and Space Science* 16(1):111–17.

Rawat, J. S., and Manish Kumar. (2015). “Monitoring Land Use/Cover Change Using Remote Sensing and GIS Techniques: A Case Study of Hawalbagh Block, District Almora, Uttarakhand, India.” *Egyptian Journal of Remote Sensing and Space Science* 18(1):77–84.

Rwanga, S. S., and Ndambuki, J. M. (2017). Accuracy assessment of land use/land cover classification using remote sensing and GIS. International Journal of Geosciences, 8(04), 611.

Schilling, Keith E., Manoj K. Jha, You-kuan Zhang, Philip W. Gassman, and Calvin F. Wolter. (2008). “Impact of Land Use and Land Cover Change on the Water Balance of a Large Agricultural Watershed : Historical Effects and Future Directions.” 44:1–12.

Selvaraj, Rabin, and Nebiyu Mohammed Bucha. (2019). “Flood Frequency Analysis in Gelana in Ethiopia.” 8(4):380–85.

Shaka, A. K. (2008). Assessment of climate change impacts on the hydrology of Gilgel Abbay catchment in lake Tana basin, Ethiopia. ITC.

Shao, Q., Zhang, L., Chen, Y.D. and Singh, V.P., 2009. A new method for modelling flow duration curves and predicting streamflow regimes under altered land-use conditions/Une nouvelle méthode de modélisation des courbes de débits classés et de prévision des régimes d'écoulement sous conditions modifiées d'occupation du sol. *Hydrological sciences journal*, *54*(3), pp.606-622.

Singh, Sarmistha, Puneet Srivastava, Subhasis Mitra, and Ash Abebe. (2016). "Climate Variability and Irrigation Impacts on Streamflows in a Karst Watershed—A Systematic Evaluation." *Journal of Hydrology: Regional Studies* 8:274–86.

Singh, V.P. and Woolhiser, D.A., 2002. Mathematical modeling of watershed hydrology. Journal of hydrologic engineering, 7(4), pp.270-292.

Srivastava, Prashant K., Dawei Han, Miguel A. Rico-Ramirez, Michaela Bray, and Tanvir Islam. (2012). "Selection of Classification Techniques for Land Use/Land Cover Change Investigation." *Advances in Space Research* 50(9):1250–65.

Study and design of Gelana irrigation project. (2008). *Final Feasibility study*. Water works design and supervision enterprise in association with consulting engineering service(India).

Tahir, Mary, Ekwal Imam, and Tahir Hussain. (2017). "Evaluation of Land Use/Land Cover Changes in Mekelle City, Ethiopia Using Remote Sensing and GIS." *International Journal of Civil Engineering and Technology* 8(5):217–23.

Tolera, K. (2018). *Assessment of Land Use/Land Cover Change Impact on Stream Flow Using SWAT.* Msc Thesis, Addis Ababa University:91.

Turner, B. L., Lambin, E. F., and Reenberg, A. (2007). The emergence of land change science for global environmental change and sustainability. Proceedings of the National Academy of Sciences, 104(52), 20666-20671.

Verburg, P.H., Neumann, K. and Nol, L., 2011. Challenges in using land use and land cover data for global change studies. *Global change biology*, *17*(2), pp.974-989.

Welde, Kidane, and Bogale Gebremariam. (2017). "Effect of Land Use Land Cover Dynamics on Hydrological Response of Watershed: Case Study of Tekeze Dam Watershed, Northern

Ethiopia." *International Soil and Water Conservation Research* 5(1):1–16.

White, Kati L., and Indrajeet Chaubey. (2005). "Sensitivity Analysis, Calibration, and Validations for a Multisite and Multivariable SWAT Model." *Journal of the American Water Resources Association* 41(5):1077–89.

White, Michael J., R. Daren Harmel, Jeff G. Arnold, and Jimmy R. Williams. (2014). "SWAT Check: A Screening Tool to Assist Users in the Identification of Potential Model Application Problems." *Journal of Environmental Quality* 43(1):208–14.

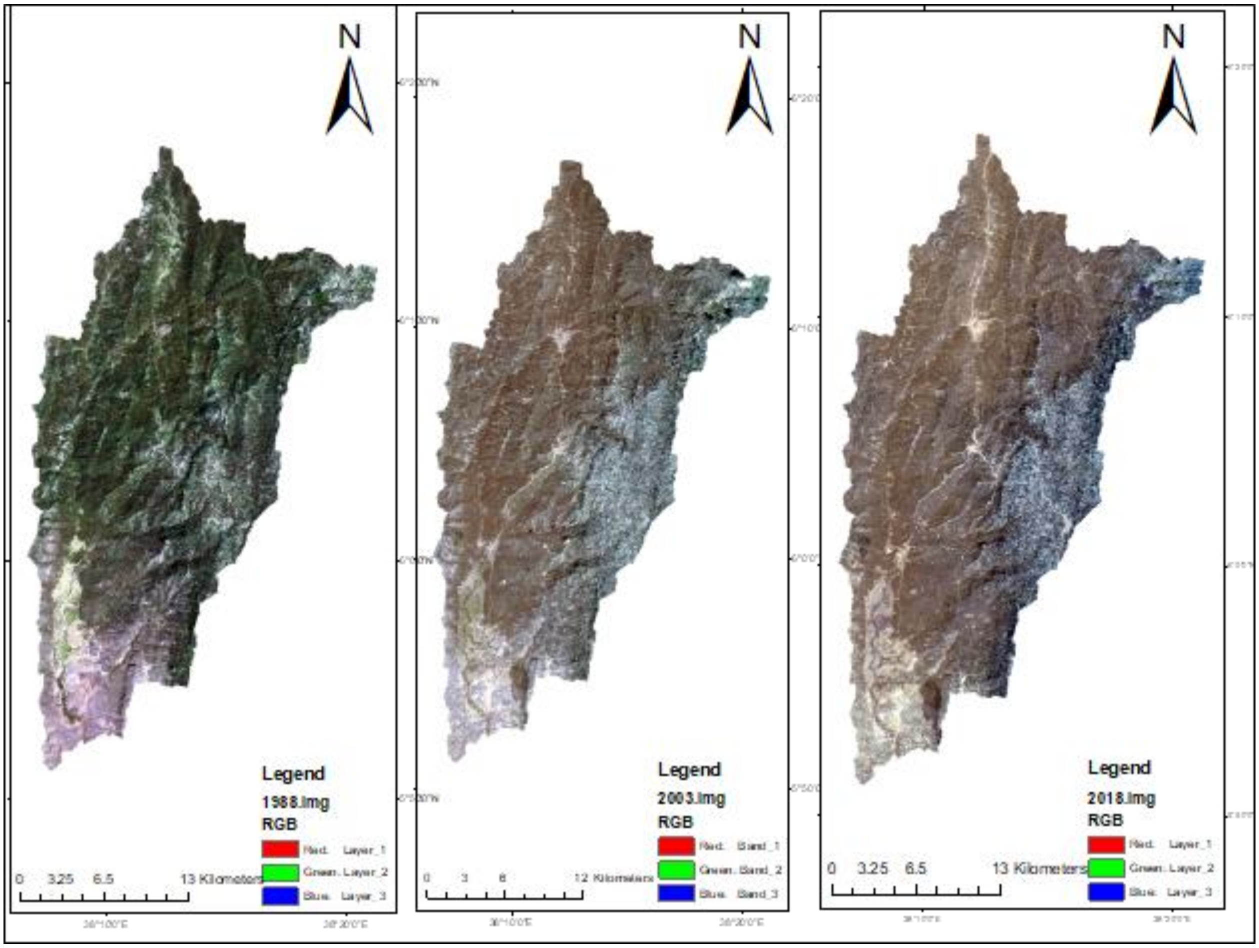
WoldeYohannes, A., Cotter, M., Kelboro, G., & Dessalegn, W. (2018). Land use and land cover changes and their effects on the landscape of Abaya-Chamo Basin, Southern Ethiopia Land, 7(1), 2.

APPENDICES

A: Symbols and description of weather generator (WGEN) parameters

Symbol	Description
TMPMX	Average or mean daily maximum air temperature for a month (^{0}C)
TMPMN	Average or mean daily minimum air temperature for a month (^{0}C)
TMPSTDMX	The standard deviation for daily maximum air temperature for a month (^{0}C)
TMPSTDMN	The standard deviation for daily minimum air temperature for a month (^{0}C)
PCPMM	Average or mean total monthly precipitation (mm H2O)
PCPSTD	The standard deviation for daily precipitation for a month (mm H2O/day)
PCPSKW	The skew coefficient for daily precipitation in the month
PR_W1	Probability of a wet day following a dry day in the month
PR_W2	Probability of a wet day following a wet day in the month
PCPD	The average number of days of precipitation in the month
SOLARAV	Average daily solar radiation for a month (MJ/m^2/day)
WNDAV	Average daily wind for a month

B: False color composition of land sat image for 1988, 2003 and 2018



C: Stream flow at Tore Gauging in m^3/s station for calibration and validation

i, Observed stream flow data for calibration from 1991 up to 2005

Month \ year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Jan	0.9	0.6	2.0	0.9	0.5	1.5	1.7	4.0	1.2	0.7	1.4	0.9	1.1	1.1	1.1
Feb	0.9	0.7	1.8	1.0	1.0	1.0	1.1	4.2	0.7	0.4	1.0	0.7	0.7	0.7	0.7
Mar	0.9	0.6	1.0	0.8	1.0	3.0	1.0	2.0	1.6	0.4	1.0	2.0	0.9	0.9	0.9
Apr	3.1	5.0	0.7	3.0	3.5	7.5	4.0	5.0	5.0	1.2	3.7	2.5	0.8	0.8	0.8
May	9.0	12.8	12.7	19.0	11.5	16.0	9.7	9.5	7.0	8.0	11.3	8.0	12.0	12.0	12.0
Jun	4.2	10.9	12.8	7.0	6.3	14.6	3.0	9.1	2.0	2.2	8.8	4.0	8.9	8.9	8.9
Jul	4.0	10.0	5.0	5.2	5.0	9.0	3.0	3.5	4.0	1.2	3.1	1.7	2.9	2.9	2.9
Aug	3.4	8.0	3.0	6.7	4.0	8.1	1.7	5.2	3.3	3.2	4.0	2.0	1.9	1.9	1.9
Sep	8.0	10.0	4.0	4.0	7.5	12.5	2.0	2.2	3.2	3.3	10.0	2.1	7.3	7.3	7.3
Oct	11.8	15.0	6.5	4.2	12.0	11.0	13.0	10.0	10.0	12.3	15.9	11.0	11.0	11.0	11.0
Nov	3.2	4.8	3.2	5.0	6.1	5.9	13.0	4.0	7.1	11.0	10.0	3.5	8.6	8.6	8.6
Dec	1.2	2.3	1.0	0.9	1.8	2.8	3.2	1.2	1.1	2.5	1.7	2.5	2.1	2.1	2.1

ii, Observed stream flow for validation from 2006 up to 2010

Month \ Year	2006	2007	2008	2009	2010
Jan	1.7	1.6	0.6	1.2	2.4
Feb	1.0	1.2	0.3	1.0	1.2
Mar	0.7	0.5	3.7	1.2	0.8
Apr	3.5	4.6	13.0	1.3	2.3
May	3.9	10.5	15.3	5.3	5.6
Jun	5.7	6.5	11.3	10.4	5.1
Jul	4.0	2.1	3.6	5.0	4.2
Aug	4.2	0.9	4.2	8.0	5.0
Sep	9.0	1.9	11.0	14.4	12.0
Oct	11.0	8.0	15.4	9.5	10.7
Nov	9.5	1.8	7.2	10.4	10.3
Dec	2.9	1.2	3.2	6.2	4.2

D: Daily flow calibration and validation from 1991-2010