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JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF POSTGRADUATE STUDIES

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

CHAIR OF HYDROLOGY AND HYDRAULIC ENGINEERING

MASTER OF SCIENCE PROGRAM IN HYDRAULIC ENGINEERIG

HYDROLOGICAL RESPONSE TO LAND USE LAND COVER CHANGE: THE CASE OF AWASH-AWASH SUB BASIN, AWASH RIVER BASIN, ETHIOPIA.

By: Gizachew Negussu Adugna

A Thesis Submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Hydraulic Engineering.

December, 2021

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Advisors

Main Advisor: - Fayera Gudu (Ass. Prof)

Co-Advisor: - Mr. Abebe Chala (MSc)

December, 2021

Jimma, Ethiopia

DECLARATION

I hereby declare that this thesis entitled "HYDROLOGICAL RESPONSE TO LAND USE LAND COVER CHANGE: THE CASE OF AWASH-AWASH SUB BASIN, AWASH RIVER BASIN, ETHIOPIA." is my original work which I submit for partial fulfillment of the degree of Master of Science in Hydraulic Engineering to school of graduate studies; Hydrology and Hydraulic Engineering Chair, Jimma Institute of Technology, Jimma University. The thesis was conducted under the guidance of main advisor, Fayera Gudu (Ass.Prof) and Co-Advisor, Mr. Abebe chala (MSc)

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This thesis has been submitted for examination with my approval as a university supervisor.

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Fayera Gudu (Ass.Prof)	__________	24/01/2022
Co-Advisor	Signature	Date
Mr. Abebe chala (MSc)	__________	24/01/2022

APPROVAL PAGE

This is to certify that the thesis prepared by **Mr. Gizachew Negussu Adugna** entitled "HYDROLOGICAL RESPONSE TO LAND USE LAND COVER CHANGE: THE CASE OF AWASH-AWASH SUB BASIN, AWASH RIVER BASIN, ETHIOPIA." and submitted as a partial fulfillment for the award of the Degree of Master of Science in Hydraulic Engineering complies with the regulations of the university and meets the accepted standards with respect to originality, content and quality.

Signed by Examining board

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ABSTRACT

Land use land cover change is a global phenomenon that affects the watershed hydrological process and is subject to changes causing the area to form an impervious surface that affects the hydrological processes. Therefore, this study aimed to investigate the impact of land use/land cover change on the stream flow of the Awash-Awash Sub-Basin, from 1990 to 2019. Geographic Information System (Arc GIS10.4.1) and Earth Resources Data Analysis System (ERDAS) imagine (2015) were used to prepare land use/cover map from Land sat image acquired in 1990, 2000, and 2019 respectively through the Maximum Likelihood Algorithm of Supervised Classification. The results indicated that, cultivated land, built-up area and bare land expanded (by 7.28 %, 2.62%, and 3.46%), (by 2.59%, 0.57%, and 8%) and (by 9.87%, 3.19%, and 11.46%) for LULC of 1990-2000, 2000-2019 and 1990-2019 respectively. Whereas, there was a decline in forest (by -7.48%, -1.74% and -9.22%), rangeland (by -0.1%, -5.41% and -5.51%) and grassland (by -5.82%, -4% and -9.82%) for land use /cover change (LULC) of 1990-2000, 2000-2019 and 1990-2019 respectively at which water body shows fluctuation. Using the three-land use/cover map Soil and Water Assessment Tools (SWAT) model was set up, run and the default simulation was compared with the observed data. Then sensitivity analysis was made on monthly basis using 20 flow parameters where only 10 parameters were identified as influencing the flow. The model calibration was done from 1990 to 2006 and the validation period from 2007 to 2013. The calibration and validation results showed good match of simulation with observation with Nash-Sutcliff efficiency (NSE) 0.68 , 0.65 , 0.74), coefficient of determination (R^2)(0.81 , 0.78, 0.82)and Percent bias (PBIAS) values of (-20.1,-21.5,-14) for calibration and (NSE) (0.76 ,0.62,0.64) , (R^2) (0.84 , 0.78 , 0.79) and (PBIAS) (-12.8,-16.7,-18.5) for validation 1990, 2000 and 2019 respectively . The result showed that the mean wet monthly flow increased by 12.54% (from 36.23m^3/s in1990 to 39.45m^3/s in 2019) and the mean dry monthly flow decreased by 59.50% (from 10.37m^3/s in 1990 to 4.2m^3/s in 2019). Overall, these findings provide water management authorities with useful information to face land use/cover change.

Key words: *Hydrological process***,** *LULCC, SWAT Simulation, Awash-Awash Sub-Basin.*

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ACRONYMS and ABBREVIATIONS

DEM	Digital Elevation Model
ENS	Nash-Sutcliff efficiency
ERDAS	Earth Resources Data Analysis System
ETB	Ethiopian Birr
GIS	Geographic Information System
GLUE	Generalized Likelihood Uncertainty Estimation
GPS	Global Positioning System
GUI	Graphical user interface
HEC-HMS	Hydraulic Engineering Centre-Hydrologic Modeling System
HRUs	Hydrological Response Units
LUCC	Land Use and Land Cover Change
MCMC	Mark chain Monte Carlo
MoWIE	Ministry of Water, Irrigation, and Electricity
NMSA	National Meteorological Service Agency
POS	Particle Swarm Optimization
R^2	coefficient of determination
SUFI-2	Sequential uncertainty fitting
SWAT	Soil and Water Assessment Tools
SWAT-CUP	SWAT- Calibration and Uncertainty Programs
US	United State
USDA-ARS	United States Department of Agriculture-Agricultural Research services

1. INTRODUCTION

1.1. Background

Water is the most essential natural resource for living species. Since the available amount of water is limited, scarce, and not spatially distributed about the population needs, proper management of water resources is essential to satisfy the current demands as well as to maintain sustainability (Cosgrove and Loucks, 2015) . Land Use/Land Cover (LU/LC) change is one of the reasons that directly affect the watershed hydrological cycle (Brook H. *et al*.,2015) . It is well-established that land-use changes may alter the water balance components, which can cause both positive and negative impacts (Dossantos *et al*., 2018).

Research on land use/land cover change is needed to explore how land use land cover change influences watershed hydrology. Besides, detecting and simulating the effects of land use land cover change on the catchment hydrological process requires a new, strategic and improved procedure to conserve the catchment based on the hydrological sensitivity as a result of land-use change at sub-watershed (Dibaba *et al*, 2016) The study by (Dwarakish and Ganasri, 2015) showed that land use/land cover change affect different hydrological components like; interception, infiltration, and evapotranspiration thereby influencing soil moisture content, runoff generation (both process and volume) and stream flow regimes. Land under little vegetative cover is subject to high surface runoff amounts, low infiltration rate, and reduced groundwater recharge.

The Land use and Land cover conversion, such as from forest to various land-use types is a common experience in most areas of Eastern African countries including Ethiopia, were ranked as the highest in Africa at a rate of 0.94% (1990-2000) and 0.97% per year (2000-2005) due to increasing human and livestock population in protected areas (Garedew *et al*., 2009). In developing countries, which are characterized by agriculture-based economies and rapidly increasing human population, land use and land cover changes are highly detected. Conversion of land, to feed and shelter, the growing human population has been one of the primary modes for human conversion and/or modification of the environment (Piao *et al*., 2007). As is the case in many other developing countries, most of the population of Ethiopia live in rural areas and depends directly on the land for their livelihood. This rural population is currently growing rapidly, and consequently inducing many effects on the resource base. As stated by (Bewke and Sterk., 2005), one such effect is a very dynamic land use and land cover. Land use/land cover change largely affects the water balance mainly by changing the process of evaporation, transpiration, interception, and surface runoff (Tekleab *et a*l., 2014).

In Ethiopia, primary water resources management challenges are the extreme hydrological variability and seasonality nature of its most significant surface water resources. Although, the country is endowed with abundant water resources in its twelve major river basins, in recent decades natural forest cover has declined and been blamed for contributing to land degradation and water flow extremes (Wolka, 2014) Because of the rugged terrain, the rate of soil erosion and land degradation in Ethiopia is very high (Setegn, 2008) Land degradation is also attributed to poor land-use practices, improper management systems, and lack of appropriate soil conservation measures. Hence, land degradation is becoming a serious problem for the whole country (Andualem, 2014).

Therefore, one of the main aims of this study is to quantify and identify the scale and impact of land use/cover change on the watershed hydrological responses of the Awash-Awash catchment. Particularly, the trends of hydrological process under a varying land use land cover and the most vulnerable basins of the catchment to the yields of the hydrological process were investigated using the SWAT hydrological model. GIS and remote sensing were served to prepare inputs to the SWAT model which helped to predict and quantify the impacts of land-use change on the stream flow of watershed. Consequently, such effect of land use/cover change was widely contributing to change of hydrological parameters in Awash-Awash catchment.

1.2. Statement of the Problem

Sustainable development of water resources and effective management of these resources effectively needs understanding of the responses of hydrological processes to LCLU changes (Yan *et al*., 2017). (Guzha *et a*l, 2018) reported highly variable watershed hydrological responses to forest cover loss in East Africa, where some watersheds, which experienced 39% forest cover loss produced non-significant trends in annual discharge, low flows, and high flows, while watersheds with 12% and 50% forest cover loss produced significant increasing trends in annual discharge and decreasing trends in low flows and high flows. Land use/land cover change is responsible for altering the hydrologic response of watersheds leading to affect the stream flow. With the fast-growing population, the uncontrolled agricultural activities to bring more land to agriculture have deteriorated the environment (Tekle & Hedlund, 2000). Vegetation losses, consequent runoff increase, and a decrease in infiltration reduce water tables, leading to situations of below optimal base flow recharge during the dry season.

The performed studies about the factors that could affect the hydrological process at the watershed level are not much as in the largest basins of the country. As (Miheretu and Yimer, 2018) stated, studies of LULC dynamics at the sub-watershed level are rare in Ethiopia. (Ewane and Lee, 2020) Stated that the impact of LULCC on hydrological variables can be detected more in small sub-watersheds than in large sub-watersheds due to more complex interacting watershed-specific characteristics such as climate, soil, topography, and geology at large spatial scales.

How the discharge regime of Awash-Awash Sub-Basin catchment reacts to the changing land use/cover is a central question of interest to be integrated into watershed management at the watershed level. Therefore, a strong need was identified for the hydrological techniques and tools that can assess the effects of land cover changes on the hydrologic response of a watershed. Such techniques and tools were provided information that used for water resources management at a watershed. This research applies the Soil and Water Assessment Tools (SWAT) to understand the hydrological process of Awash Basin on the cause of Awash- Awash Sub-Basin to investigate the land-use dynamics in the Sub-Basin. So that to estimate and predict the demands for different water resources schemes and to balance the LULC effect with hydrology, the study should be conducted which can give knowledge on how the relation of land use/cover with the hydrological process was in past periods as well as to predict what will be the future hydrology of a catchment. By changing the land use which results in increasing knowledge of different decision-makers on how land use can affect certain catchments to take mitigation and remedial measure for the particular problem.

1.3. Objectives.

1.3.1 General objective

The general objective of this study is to assess the Hydrological response to land use land cover change: Awash-Awash Sub- Basin, Awash Basin Ethiopia.

1.3.2. Specific objectives

I. To develop land use/land cover map of Awash-Awash Sub- Basin, by Using ERDAS for different Specified periods.
II. To assess the performance of the SWAT model for stream flow prediction.
III. To assess the impact of land use land cover changes on stream flow for different Specified periods.

1.4. Research Questions

To address the above objectives, the following research questions were developed:

I. What was the land use/land cover map in Awash-Awash Sub- Basin?
II. How does the SWAT model perform for the stream flow?
III. How does LULC change influence the stream flow of the watershed?

1.5 Significance of the study

The knowledge of how land use and the land cover change influences watershed hydrology could enable local governments and policy makers to plan and employ appropriate response strategies to minimize the undesirable effects of future land use/land cover change or modifications on the hydrological process. Various water resources project planning and implementation require knowledge of the extent of land use and land cover changes on watershed hydrology.

This study is expected to help concerned sectors in planning, implementing, and managing water resource projects in the study area and be input for those who are interested in further research in related fields and area of study. Since most of the study watershed is located in the rural agricultural area, farmers could play an important role to minimize the changes in land use and land cover if they gained awareness of its impacts. Therefore, understanding the changes in the land use/land cover and its impact on the yield from the land and on the hydrological process helps the concerned body to give awareness for farmers thereby, sound policies would have been formulated and implemented to minimize undesirable future impacts and devise management alternatives.

1.6 Scope of the study

The scope of this study was concentrated on the effect of land use and land cover change on the hydrological process of Awash Basin in the Awash-Awash sub-basin. Within the time provided for this study, the objectives set were addressed and the asked research questions were answered. The land use land cover change scenario that was assumed to take place in the Awash-Awash sub-basin was determined and the effect of these changes on the stream flow of the watershed was discussed.

1.7 Limitation of the study

This study is geographically limited to, Awash-Awash sub-basin, Awash basin, Ethiopia. It is not possible to cover all aspects of the study area like climate change and LULC interaction Due to the time. Therefore, the study was limited to focusing on the Hydrological response to land use land cover change using the SWAT model for impact simulation in the Awash-Awash sub-basin.

2. LITERATURE REVIEW

2.1 Definitions and Concepts

The terms Land use and Land cover are often used interchangeably, but each term has a very specific meaning with some fundamental differences. Land cover on the other hand denotes the biophysical cover over the surface including such features as vegetation, urban infrastructure, water, bare soil, or others. It does not describe the use of land, which may be different for lands with the same cover type. On the other hand, land use refers to the purpose the land serves and describes the human influence of the land, or immediate actions modifying or converting land cover (Ellis, 2009).

Land use and land cover characteristics have many connections with the hydrological cycle. The land use land cover type can affect both the infiltration and runoff amount by following the falling of precipitation. Both surface runoff and ground water flow are significantly affected by types of land cover (Abebe, 2005). These flows are the two components of the stream flow. Surface runoff is mostly contributed directly from rainfall, whereas ground water flow is contributed from infiltrated water. However, the source of stream flow is mostly from surface runoff during the wet months, whereas during the dry months the stream flows from the ground water.

An increase in crop lands and a decrease in the forest results from an increase in stream flow because of the crop soil moisture demand. Crops need less soil moisture than forests; therefore, the rainfall satisfies the shortage of soil moisture in agricultural lands more quickly than in forests there by generating more runoff when the area under agricultural land is extensive. Hence, this leads to increases in stream flow. In addition, deforestation also has its impact on hydrological processes, leading to declines in rainfall, and more rapid runoff after precipitation (Legesse *et al*., 2003). Therefore, such changes in land use and land cover may have impacts on the stream flow during the wet and dry months, and on the components of stream flow (surface runoff and ground water flow), and assessing such impacts is the core of this study. Generally, knowing of the impact of land use and land cover change on the natural resources like water resources depends on an understanding of the past land-use practices, current land use and land cover patterns, and projection of future land use and land cover, as affected by population size and distribution, economic development, technology, and other factors. The land use land cover change assessment is an important step in planning sustainable land management that can be Assessing the Impact of LULC change on Hydrology of the Upper Gilo watershed help to minimize agro-biodiversity losses and land degradation, especially in developing countries like Ethiopia (Hadgu, 2008).

2.2 Deriving Forces for Land use and Land Cover Change

Several natural and human driving forces cause Land cover changes. The effects of human activities are immediate and often radical; whereas, natural effects such as climate change are felt only over a long period results in a decrease of evapotranspiration and water recycling that causes a reduction in rainfall, (Bewket, 2002). Land use and land cover change vary often due to the growing population and economy. In human history land, a fundamental factor of production has been coupled to economic growth (Subhash *et al*, 2016). The rapidly increasing population pressure in many rural areas of developing countries has often led to changes in land use in terms of deforestation, reclamation of wetlands, etc. mainly aiming at agricultural production. Neither population nor poverty alone constitutes the sole and major underlying causes of land cover change worldwide (Gassman *et al.*, 2007). Destructive land-use change may also affect the hydrological cycle either through increasing the water yield during the wet season or through diminishing or even eliminating the low flow during the dry season in certain circumstances. The central theme in land use/land cover change (LULCC) issues is the interaction between human beings and the environment they live in. Land use/land cover change has a direct relationship with the productivity of the land and biological diversity in protected areas.

As a result, identifying the root causes of LULCCs and monitoring their dynamics and impact is critical to environmental sustainability efforts (Belay *et al*., 2014). According to (Miheretu and Yimer, 2018), socio-economic and biophysical variables act as the driving forces of land-use changes. Driving forces are generally subdivided into two groups: proximate causes and underlying causes. Proximate causes are the activities and actions that directly affect land use like wood extraction or road building. Underlying causes are the fundamental forces that underpin the proximate causes, including demographic, economic, technological, institutional, and cultural factors.

2.3 Land Use and Land Cover Change Impacts on Hydrology

Water on earth exists in a space called the hydrosphere and lithosphere, circulates and forming hydrologic cycle. The cycle has no beginning and no ending and can be affected by different factors. Among those factors, manmade activities, land use, and land cover change can affect hydrological processes such as infiltration, runoff, and groundwater recharge. Different studies indicate that land use and land cover change have an impact on hydrologic components. For instance, (Adamu, 2013) concluded that land use and land cover changes have major impacts on hydrological processes, such as runoff and ground water flow, (Melesse, 2012)concluded that the decrease of forest land and grass land was accompanied by the increase in agricultural and built-up areas and this change in land use and land cover increased surface run off during wet seasons and reduced base flow during the dry seasons. (Gebrie, 2016) Concluded that the land use and land cover change have a great influence on stream flow especially during the wet season than the dry season. Cultivation of land exerts a major influence on the relationship between surface and subsurface flow. According to data from long-term observations done in paired catchments, in the forest zone of Central Russia (Golosov and Panin , 2006) Surface runoff is extremely limited under grass or forest vegetation compared with agricultural land.

2.4 Land Use and Land Cover Change Studies in Ethiopia.

In Ethiopia, the land has been used to grow crops, trees, animals for food, as building sites for houses and roads, or recreational purposes. Most of the land in the country is being used by smallholders who farm for subsistence. With the rapid population growth and in the absence of agricultural intensification, smallholders require more land to grow crops and earn a living; it results in deforestation and land-use conversions from other types of land cover to cropland. The researches that have been conducted in different parts of Ethiopia have shown that there were considerable LULC changes in the country. Most of these studies indicated that croplands have expanded at the expanse of natural vegetation including forests and shrub lands; for example (Kidanu, 2004) in the northern part of Ethiopia, (Zeleke & Hurni, 2001) in the north western part of Ethiopia, (Kassa, 2003) in the north eastern part of Ethiopia;

(Feoli *et al*., 2002) Reported the expansion of evergreen vegetation with an increase in population. According to much literature, population growth has a paramount impact on the environment. For instance, population pressure has been found to hurt Riverine vegetation, scrublands, and forests in Kalu district (Tekle & Hedlund, 2000) Riverine trees in the Chemoga watershed (Beweket, 2003), and natural forest cover in Dembecha Woreda north -western Ethiopia (Zeleke & Hurni, 2001) Similarly, (Pender *et al*., 2001) report that the population growth has a significant effect on land degradation, poverty, and food insecurity in the northern Ethiopian highlands.

However, most of the empirical evidence indicated that LULC changes and socioeconomic dynamics have a strong relationship; as population increases the need for cultivated land, grazing land, fuel wood; settlement areas also increase to meet the growing demand for food and energy, and livestock population. Thus, population pressure, lack of awareness, and weak management are considered as the major causes for the deforestation and degradation of natural resources in Ethiopia.

2.5 LULC Change studies in Ethiopia at sub-basin levels.

Different researchers conducted their research on LULC change studies in Ethiopia at sub-basin levels using SWAT model.The researches conducted by different researchers in different parts of the country at sub-basin levels indicate that there were LU/LC changes in the study area. For instance (Getu *et al*.,2021) was done The study on " Land Use/Land Cover Change Impact on Hydrological Process inthe Upper Baro Basin, Ethiopia"which is one of the sub –basin of Baro-Akobo river basin. The study was identified that LU/LC analysis shows there was a drastic decrease of grassland by 15.64% and shrubland by 9.56% while an increase of agricultural land and settlement by 18.01% and 13.01%, respectively, for 30 years .The other similar study was done by (Mathewos & Ayano, 2020) on Wabe sub-basin Omo-Gibe Basin, Ethiopia, which The results shown that there was an incessant expansion of agricultural land, built-up area and forest cover, on the other hand declining of agroforestry; grassland and woodland were happened during from the 1988 to 2018 periods.

2.6 Hydrological Models

Hydrologic modeling has proved to be a very important tool that can be applied to understand and explain the effects of LU/LC change on the hydrologic response of a catchment (Baldyga, 2005) Hydrological models are mathematical descriptions of components of the hydrologic cycle. They have been developed for many different reasons and therefore have many different forms. However, hydrological models are in general designed to get a better understanding of the hydrologic processes in a watershed and of how changes in the watershed may these phenomena and for hydrologic prediction (Kassa, 2007) They are also providing valuable information for studying potential impacts of changes in land use and land cover or climate change. There are many classifications of hydrologic models, deterministic versus stochastic, lumped versus distributed, etc. On the basis of process description, the hydrological models can be classified into three main categories: lumped models, semi-distributed models and distributed models (Kassa, 2009).

i. Lumped models

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

ii. Distributed models

Parameters of distributed models are fully allowed to vary in space at resolution chosen by the user. Distributed modeling approach attempts to incorporate data concerning the spatial distribution of parameters together with computational algorithms to evaluate the influence of this distribution on simulated precipitation runoff behavior. Distributed models generally require a large amount of data.

iii. Semi distributed models

Parameters of semi-distributed models are partially allowed to vary in space by dividing the basin into several smaller sub-basins. The main advantage of these models is that their structure is more physically based than the structure of lumped models and needs fewer input data than fully distributed models. SWAT, HEC-HMS, and HBV are Considered semi-distributed models.

2.7 Hydrological Model Selection Criteria

Many criteria can be used for choosing the right hydrologic model. These criteria are always project-dependent since every project has its specific requirements and needs. Further, some criteria are user-dependent, such as the personal preference for graphical user interface (GUI), computer operating system, input out management system, and structure. The four fundamental criteria that must be considered for model selections are:

I. Predict the impact of land management practices on water, sediment, and agricultural yields in large complex watersheds with varying soils, land use, and management conditions over long periods
II. Requires specific information about weather, soil properties, topography, vegetation, and land management practices in the watershed. SWAT models water movement, sediment movement, crop growth, and nutrient cycling with this information. Therefore, watersheds with no monitoring data can be modeled, and the effect of changes in input data can be quantified
III. Hydrological processes that need to be modeled to estimate the desired outputs adequately (Is the model capable of simulating single event or continuous processes?)
IV. Available input data (Can all the inputs required by the model be provided within the time and cost constraints of the project? In addition, the model must be readily and freely available within available documentation and should be applied over a range of catchment sizes from large to global. For this study SWAT (semi-distributed model) is selected because its structure is more physically based than the structure of the lumped model, is freely available, and meets the objective of this study.

2.8 Introduction to the SWAT model

The SWAT (Soil and Water Assessment Tool) model is one of the most recent models developed at the United States Department of Agriculture Research Service (USDA-ARS) during the early 1970s. The SWAT model is semi-distributed physically based on a simulation model to predict the impacts of land-use change and management practices on hydrological regimes over long periods and primarily as a strategic planning tool (Neitsch *et al*, 2009). It can also be used to simulate water and soil loss in agriculturally dominated small watersheds (Tripathi *et al*, 2003).SWAT has been updated to the most recent version, Arc SWAT 2012 which is an ArcGIS 10. x extension. This interface streamlines data entry, the creation of required input files, and parameter editing, all while allowing spatial parameters to be easily observed in the ArcGIS environment. In Arc SWAT, the watershed is delineated into several sub-basins which are further divided into Hydrological Response Units (HRUs) that consist of homogeneous land use, management, and soil characteristics. The HRUs represent percentages of the sub-watershed area and are not identified spatially within a simulation (Fadil *et al*, 2011). Subdividing the watershed into HRUs enables the model to reflect differences in evapotranspiration and other hydrologic conditions for different land covers and soils. Runoff is predicted separately for each HRU and routed to obtain the total runoff for the watershed which increases the accuracy of load predictions (Neitsch *et al*, 2009). By delineating the watershed, the user can reference different areas of the watershed to one another spatially. For each sub-basin input, information is grouped into the following categories: climate, groundwater, HRUs, ponds/wetlands, and the main channel draining the sub-basin (Gassman *et al*, 2007)

SWAT was chosen for the compatibility of available data and software and its complex representation of fine spatial scales. Moreover, SWAT has become popular among environmental managers since it has been adopted as a component of the US Environmental Protection Agency's Better Assessment Science Integrating Point and Non-Point Sources (BASINS) software packages (Tripathi *et al*, 2003). SWAT has shown to be successful for land-use change assessments and has generated an expanding body of research projects. The SWAT model application can have grouped into five main steps: (1) data preparation, (2) sub-basin discretization, (3) HRU definition, (4) parameter sensitivity analysis, (5) calibration, and validation. The SWAT model simulates major components: hydrology, weather, sedimentation, soil temperature, crop growth, nutrients, pesticides, and agricultural management.

2.8. 1 SWAT Model Application Worldwide.

The SWAT model has a good reputation for best use in agricultural watersheds and its uses have been successfully calibrated and validated in many areas of the USA and other continents (Tripathi *et al*, 2003) The studies indicated that the SWAT model is capable of simulating hydrological process and erosion/sediment yield from complex and data-poor watersheds with reasonable model performance statistical values. (Ndomba, 2002) Was applied the SWAT model in the modeling of the Pangani River (Tanzania) to evaluate the applicability of the model in complex and data-poor watersheds. (Tripathi *et al*., 2003) applied the SWAT model for Nagwan watershed in India to identify and prioritize critical sub-watersheds to develop an effective management plan and the model was verified for both surface runoff and sediment yield. Accordingly, the study concluded that the SWAT model can be used in ungauged watersheds to simulate the hydrological and sediment processes. SWAT has gained international acceptance as a robust interdisciplinary watershed modeling tool as evidenced by international SWAT conferences, hundreds of SWAT-related papers presented at numerous other scientific meetings, and a large number of articles published in peer-reviewed journals (Gassman *et al*, 2007).

However, (CibinI *et al*., 2010) indicated that SWAT model parameters show varying sensitivity in different years of simulation suggesting the requirement for dynamic updating of parameters during the simulation. The same study also indicated that the sensitivity of parameters during various flow regimes (low, medium, and high flow) is also found to be uneven, which suggests the significance of a multi-criteria approach for the calibration of the model.

2.8.2 SWAT Model Application in Ethiopia.

The SWAT model application was calibrated and validated in some parts of Ethiopia, frequently in the Blue Nile basin, through modeling of Gumara watershed (in Lake Tana basin), (Awulachew *et al*., 2008) indicated that stream flow and sediment yield simulated with SWAT were reasonably accurate. A study conducted on modeling of the Lake Tana basin with the SWAT model also showed that the SWAT model was successfully calibrated and validated (Setegn *et al.*, 2008).

This study reported that the model can produce reliable estimates of stream flow and sediment yield from complex watersheds. (Gessese, 2008) Used the SWAT model performed to predict the Legedadi reservoir sedimentation. According to this study, the SWAT model performed well in predicting sediment yield to the Legedadi reservoir. The study further put that the model proved to be worthwhile in capturing the process of stream flow and sediment transport of the watersheds of the Legedadi reservoir.

In addition to the above, the SWAT model was tested for the prediction of sediment yield in the Anjani gauged watershed by (Setegn *et al.*, 2008). The study found that the observed values showed a good agreement at Nash-Sutcliff efficiency (ENS) of 80 %. In light of this, the study suggested that the SWAT model can be used for further analysis of different management scenarios that could help different stakeholders to plan and implement appropriate soil and water conservation strategies. The SWAT model showed a good match between measured and simulated flow and sediment yield in the Gumara watershed both in calibration and validation periods (Asres and Awulachew, 2010). (Tekle, 2010) Through modeling of bilate watershed also indicated that SWAT Model was able to simulate stream flow at reasonable accuracy

2.9. SWAT-CUP

The SWAT-CUP (SWAT-Calibration and Uncertainty Programs) is a computer program developed for the calibration and uncertainty analysis of the SWAT model (Vilaysane *et al*, 2015). It enables sensitivity analysis, calibration, and validation of the SWAT model through procedures embedded in it. The SWAT-CUP is linked to five different algorithms such as Sequential Uncertainty Fitting SUFI-2, Particle Swarm Optimization, (POS), Generalized Likelihood Uncertainty Estimation (GLUE), Parameter Solution (ParaSol), and Mark chain Monte Carlo (MCMC) (Abbaspour et al, 2004).GLUE is an uncertainty analysis technique inspired by importance sampling and regional sensitivity analysis (Yang *et al* , 2008). Disaggregation of the error into its source components is difficult, particularly in cases common to hydrology where the model is non-linear and different sources of error may interact to produce the measured deviation (Mirzaei *et al*, 2015). In the Parasol technique, the simulations performed are divided into ‘‘good’’ simulations and ‘‘not good’’ simulations by a threshold value of the objective function (Yang *et al*., 2008). MCMC methods are a class of algorithms for sampling from probability distributions based on constructing a Markov chain that has the desired distribution as its equilibrium distribution (Yang *et al*., 2008).

2.10. LULC classification by the ERDAS imagine software

The Earth Resources Data Analysis System (ERDAS) imagine software is a powerful tool for studying geographic data quickly and accurately (Long And Srihann, 2004). It uses the spectral Information represented by the digital numbers in one or more spectral bands to assign all Pixels in the image to particular classes or themes. The ERDAS imagine uses two approaches in image classification: Per-pixel and Object-oriented classification (Guide, 2010). In per-pixel Classification, the algorithm categorizes each input pixel into a spectral feature class based solely on its multispectral vector (signature). Object-oriented classification-the Input pixels grouped into spectral features (objects) using an image segmentation algorithm. The three common per-pixel methods are supervised classification, unsupervised classification, and rule-based classification (Long And Srihann, 2004). Supervised classification-the analyst supervises the categorization of a set of specific classes by providing training statistics that identify each category. Unsupervised classification-the raw spectral data are grouped first, based solely on the statistical structure of the data. Rule-based classification-spectrally categorized pixels are classified using ancillary data in a GIS model.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

Based on the hydrological and drainage characteristics; the Awash River basin master plan classified the basin into six major sub-basins. Namely Awash upstream Koka, Awash-Awash, Awash Haledabi, Awash Adaitu, Awash terminal, and the Eastern Catchment constitute the river basin. Awash-Awash sub-basin is a sub-catchment of the Awash River basin (Fig. 1). Awash-Awash sub- basin covers the catchment areas immediate from Koka reservoir outlet to Awash at Awash hydrological station and located between 07°51′00″and 09°13′09″ N, and 39°40′08″ and 40°38′04″ E.

The Awash-Awash sub-basin has varying topography with the highest elevation found in the south of the basin at the mount Chilalo northern hillsides and the lowest elevation is found at the reaches of Awash Sebat kilo bridges area in the Afar. The Upper valley between Koka and awash station (1,500-1,000m altitude). The catchment covers a drainage area of about 8467.38 sq. km. The average annual rainfall of the basin is about 870 mm. In the sub-basin Dega, Woyna Dega, and Kola agro-climatic zones are familiars. Mean monthly temperature varies from about 12.5 ^{0}C in July in the highlands to more than 33.7^{0}C in June the lowlands while the average annual temperature of the basin is around 21.1^{0}C. (Atlas, 2018). Leptosoils, chromic, eutric, districts, and vertice are the dominant soil type.

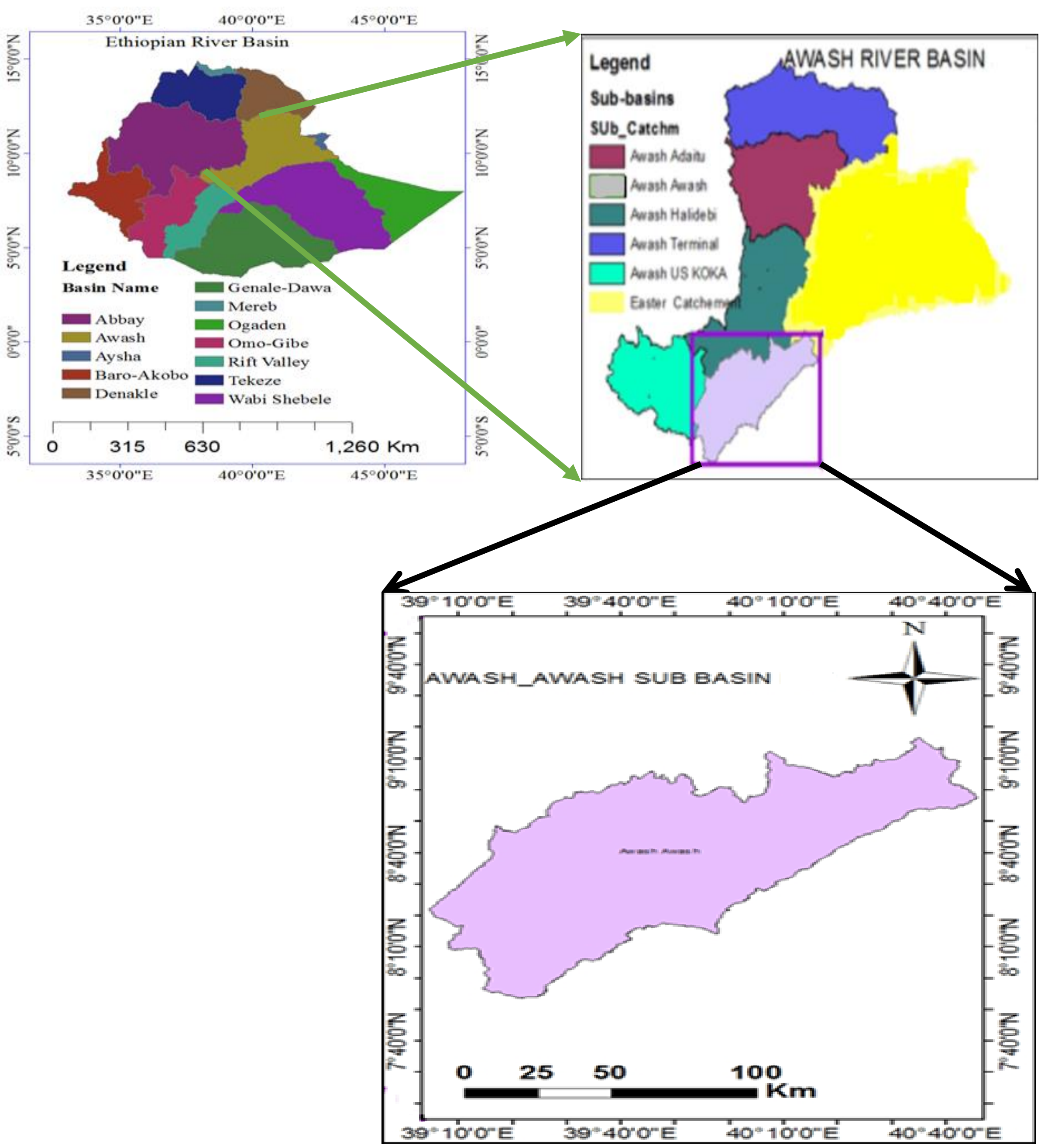

Figure 3. 1:Location of the study area

3.2 Methodology of the study

The procedures to be followed during the study was included the following starting from data collection to analysis of the hydrological Response on Land Use Land Cover and finally, the output was discussed by tables, figures, and charts.

The general methodology of this study was depending on the data which are collected from different organizations. The methodological framework followed for the study involves: (i) the preparation of spatial and hydro-metrological data into SWAT format; (ii) model setup, including watershed delineation and Hydrologic Response Units (HRUs) definition; (iii) model calibration and validation; (iv) assessment of LULC change; and finally (v) application into the hydrologic model.

3.3 Input Data collection and Sources

SWAT is a highly data-intensive model that requires specific information about the watershed such as topography, land use, and land cover, soil properties, weather data. These data were collected from different sources and databases.

Dataset was collected from primary and secondary sources. Primary data are the ground truth data about the LULC and was gained from the study area by using different methods such as; interviewing with those who are living at the site, discussing with others who have information about the field, and data was collected with GPS for the recent period during field observation for ground truth verification of mapped features by collecting GPS data. The GPS was used to collect coordinates for geo-referencing the satellite images, aerial photographs and to verify the accuracy of the classified satellite images. The objective was to get information on the land-use history of the sub-catchment, factors contributing to land use. Whereas, secondary data are recorded data, were collected from different sources. These data are: weather data that was collected from the National Meteorological Service Agency (NMSA) of Ethiopia, land use and land cover data that was prepared by using ERDAS Software, soil data which was collected from the GIS department of the Ministry of Water, Irrigation and Electricity (MoWIE), the stream flow data that was gained from the hydrology department of the Ministry of Water, Irrigation and Electricity (MoWIE) and Topographic data or (DEM) for this study was obtained from Ministry of Water, Irrigation and Electricity (MoWIE).

3.4.1 Digital Elevation Model (DEM)

Digital Elevation Model (DEM) was the first inputs of the SWAT model. A Digital Elevation Model (DEM) is a digital representation of ground surface topography or terrain. It is also widely known as a Digital Terrain Model (DTM). A DEM can be represented as a raster (a grid of squares) or as a triangular irregular network. The type of DEM used for the SWAT model in this study was 30 by 30m resolution DEM that downloaded from the website of (https://earthexplorer.usgs.gov/) websites. Using 30 by 30m DEM was useful to show smaller streams clearly during watershed delineation. Since the study area could not be covered with one image, more images were downloaded and mosaicked with the aid of Arc GIS before extracting the area of interest. All spatial data sets were projected to UTM 37 North and D_WGS_1984 datum. The DEM was used for the determination of flow direction and flow accumulation calculation, drainage network generation, watershed delineation, sub-basin definition, and HRUs setup. The topographic parameters of the studied watershed such as terrain slope, channel slope, or reach length were also resulted from Digital Elevation Model (DEM). Based on the topographic features and area of the watershed, the SWAT model had identified 29 sub-basins in the studied watershed. The DEM of the studied watershed is shown in Figure 3.2.

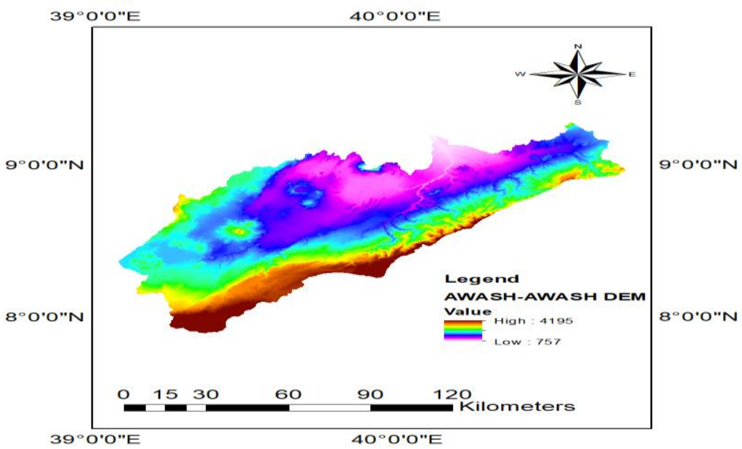

Figure 3. 2: DEM of the study area

3.4.2 Land Use/Land Cover Data

Land use/land cover data is the essential input in hydrological models because; it largely affects the water balance mainly by varying the process of evaporation, transpiration, interception, and surface runoff (Tekleab *et al*., 2014). For the classification process of the land use/ cover maps of Awash-Awash watershed area ERDAS Imagine 2015 was used. This is a geospatial data analysis and remote sensing software. The LULC map and all datasets for the years 1990, 2000, and 2019 were collected from USGS Earth Explore. The land use map of the area was reclassified based on the available topographic map and satellite images. The reclassification of the land use map was done to characterize the land use according to the specific land cover types such as type of crop, pasture, and forest. A lookup table that identifies the SWAT land-use code for the different categories of LULC was also prepared to relate the grid values to SWAT LULC classes.

The images were identified by the Landsat grid describing path (p) and row (r) for which the Awash –Awash watershed is covered with 1670 and 1680 paths and 54 rows. For this study, the Landsat imageries, Landsat-5 Thematic Mapper for 1990, Landsat-7 Enhanced Thematic Mapper plus for 2000, and Landsat-8 Operational Land Imager and Thermal Infrared Remote Sensing for 2019 were used. The summary of sensor type, acquisition date, path and row, spatial resolution, producer, and the bands of the satellite data used for this particular study are shown in Table 3.1.

Table 3. 1: The summary of satellite data used

Year	Sensor	Acquisition date	Path –Row	Resolution	Producer	bands
1990	TM	22/1/1990	1670-54	30m	USGS	1-5,7
	TM	22/1/1990	1680-54	30m	USGS	1-5,7
2000	ETM+	11/2/2000	1670-54	30m	USGS	1-5,7 and 8
	ETM+	11/2/2000	1680-54	30m	USGS	1-5,7 and 8
2019	OLI	8/1/2019	1670-54	30m	USGS	1-5,9 and 8
	OLI	8/1/2019	1680-54	30m	USGS	1-5,9 and 8

3.4.2.1 Landsat image pre-processing

This study used remote sensing techniques to detect the land use/ land cover changes over the past 30 years (1990-2019) using ERDAS imagine 2015 software. For this period, three images were selected for land cover mapping. Landsat TM, ETM+, and OLI_TIRS were selected for 1990, 2000, and 2019 respectively. Bands of the related spatial resolution were combined through layer stacking. As one image could not cover the study area, a two-layer stacked image was mosaicked for each year's images. Since ETM+ and OLI_TIRS have multispectral images of 30m and panchromatic images of 15m spatial resolution, image fusion (pan-sharpening) techniques were done to improve the visualization of images for better analysis of LULC. The images used in this study area were prepared in the same projection to a projected coordinate system UTM WGS Zone 37 and were rectified using orthophotos using first-order polynomial method and nearest neighbor image re-sampling algorithm. Clipping the mosaicked image with a shape file of the watershed was done by using ERDAS imagine 2015 through Sub setting to reduce the size of an image to the area of interest. Band compositions of those satellite images that are used for this study were 4, 3, and 2.

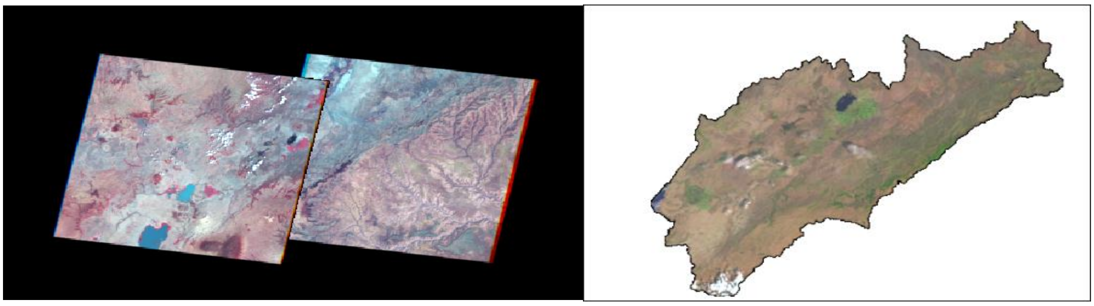

Figure 3. 3: Subset images

3.4.2.2 Site observation

The primary data were collected in the field by moving through selected Areas and looking for the present land use and land cover and questioning elder people living a long time in the area about the land feature of the past. During the field observation, GPS was used for conducting land features at different coordinates for selected representative Areas. The collected Ground control points were used as training points for supervised classification accuracy assessment and geometric correction of satellite images of the watershed

3.4.2.3 Image classification

Image classification is the process of assigning defined land use land cover classes for pixels of a continuous raster image (Guide, 2010). There are unsupervised and supervised types of image classification systems. In the Unsupervised classification method, the combined satellite images were classified by using an Iterative Self-

Organizing Data Analysis Techniques algorithm (ISODATA) with ERDAS imagines software. ISODATA is a clustering algorithm that uses an iterative process to separate image pixels into spectrally similar clusters based upon their position in the dimensional spectral space (Enderle and Weih, 2005). In this type of classification since it could not be supported with field work, one land feature might be classified as another which will not much with ground truth.

However, in supervised classification pixels of similar spectral value could be classified into the same land use land cover classes based on the ground truth of the area. For this study, the land classified with unsupervised classification was followed by the supervised classification technique which was supported by field work for further definition of the classes and thematic map preparation by using ERDAS imagine (version 2015) software.

The Signature Editor in ERDAS imagines is an important tool for creating a supervised classification from selected areas of interest. Once each training area was developed on the image need to be classified, the spectral characteristics across all bands and all dates for each pixel in the training area were then inputted into the Signature Editor. The signature for that training area was labeled, evaluated, edited, merged for similar features, and then incorporated into the supervised classification. The Signature Editor is a means of managing all of the spectral signatures from the training areas for the image(s) being classified (Enderle and Weih, 2005).

The supervised classification, using the maximum likelihood classification method utilized 234,223 and 220 individual selected points in signature Editor for LULC of 1990, 2000, and 2019 years respectively as in table 4.1. Finally, for the Awash-Awash sub-basin watershed, seven land use/land cover was identified and given the code having four letters which the SWAT model can understand as in Table 3.2.The SWAT codes given for seven classes LULC of Awash-Awash sub-basin are; WATR FRST, RNGB, PAST, AGRL, BARR, and URBN for Forest, Rangeland, Grassland, Cultivated land, Built-up area, and Water body, respectively. The prepared maps were used independently to uncover the hydrological impacts of LULC changes in the study watershed.

Table 3. 2: Land use/land covers SWAT Code Description.

SWAT code	LULC type	Description
WATER	Water Body	Water bodies in the land area
RNGB	Range Land	Include areas covered with small trees, less dense forests, bushes and shrubs.
FRST	Forest	Areas covered with dense growth of trees were included here
AGRL	Cultivated land	Include areas used for perennial and annual crops, irrigated areas and the scattered rural settlements
PAST	Grassland	Areas used for Livestock grazing, as well as bare land that has very little or no grass cover (exposed rocks) but with the same Tone on the aerial photographs were included here.
URBN	Built-up Area	Areas used for construction sites, both zone and woreda's town And also roads were classified here due to their similar reflectance.
BARR	Bare land	Bare areas

3.4.2.4 Accuracy assessments of the classified land use/cover map

The Land use/land cover map was prepared through supervised classification by utilizing the present land use and land cover data of the field-collected by GPS, information of the past times from elders living at the study area, and Google Earth as a reference data. Finally, image classification accuracy was evaluated and summarized by the error matrix and kappa coefficients (Table 4.1) and in appendix 1. Kappa value typically lies between 0 and 1 where the value greater than 0.8 denotes a strong agreement, and values between 0.75 and 0.8 are very good indicators of the classified image (Viera and Garrett, 2005).

In thematic mapping from remotely sensed data, the term accuracy is used typically to express the degree of 'correctness' of a map or classification. A thematic map derived with a classification may be considered accurate if it provides an unbiased representation of the land cover of the region it portrays. In essence, therefore, classification accuracy is typically taken to mean the degree to which the derived image classification agrees with reality or conforms to the 'truth'.

Kappa co-efficient of agreement: Cohen's kappa coefficient is a chance-adjusted measure that was established and has often been used and adopted as a standard measure of classification accuracy. The kappa coefficient states the proportionate reduction in error generated by a classification process compared with the error of a completely random classification or unsupervised classification. (Monserud, 1990) (Rientjes et al., 2011) reported that a kappa value of < 40 % is poor, 40-55 % fair, 55-70% good, 70-85 % very good and >85% excellent.

$$\text{Kappa Coefficient } = \frac{N(\sum_{i=1}^{r} Xii) - (\sum_{i=1}^{r}(X_{i+}X_{+i})}{N^2 - \sum_{i=1}^{r}(X_{i+}X_{+i})} * 100$$

Where r =number of rows in the error matrix

Xii =number of observations in row i and column i (on the major diagonal)

Xi+=total of observations in row i

X+i =total of observations in column i

N =total number of observations included in the matrix

3.4.3 Soil Data

SWAT model requires soil physical and chemical properties such as soil texture, available water content, hydraulic conductivity, bulk density, and organic carbon content for different layers of each soil type. According to FAO/UNESCO-ISRIC classification, major soil groups were identified in the Awash-Awash Sub-Basin. These data were obtained from the Ministry of Water, Irrigation, and Electricity (MoWIE). To integrate the soil map with the SWAT model, a user soil database that contains textural and chemical properties of soils was prepared for each soil layer and added to the SWAT user soil databases using the data management append tool in ArcGIS. Major soil types in the watershed are chromic vertisols, Eutric cambisols, Eutric Regosols, Eutric-Nitosols, Haplic-Xerosols, Calcic-Xerosols, and Gypsic-Xerosols,at which SWAT soil code Shown in Figure (3.4).

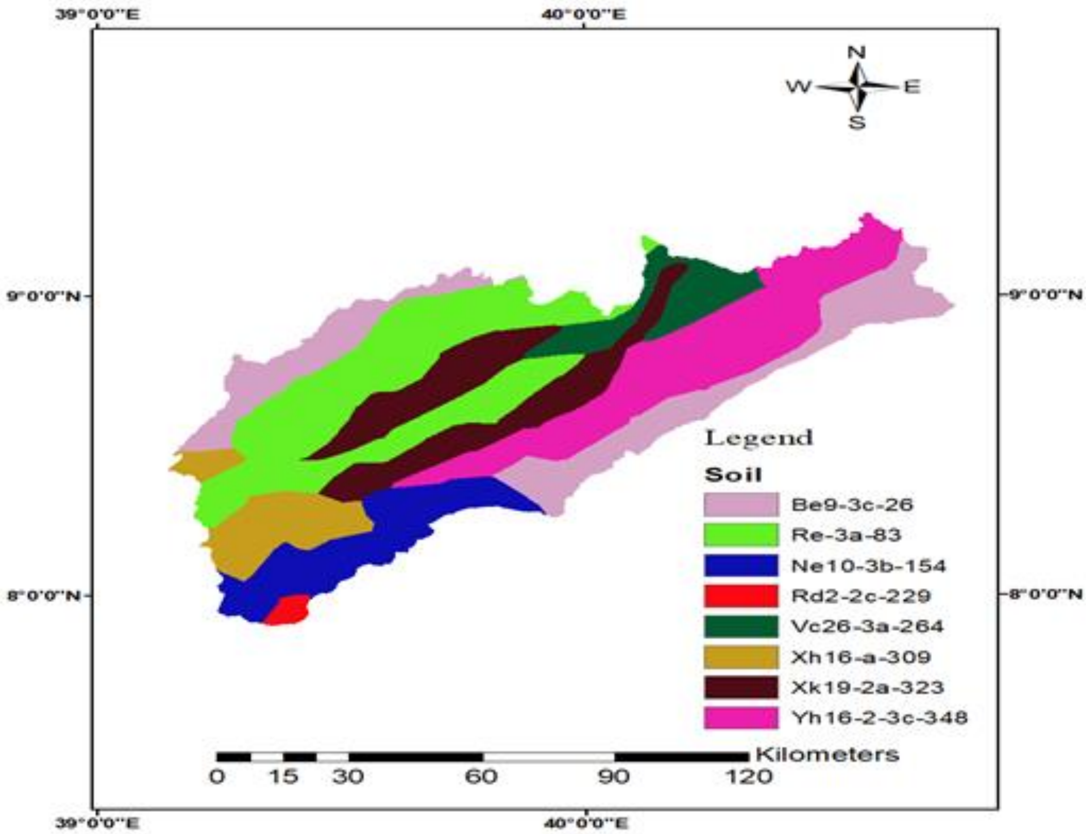

Figure 3. 4: SWAT Soil code of the study area

Table 3. 3: major soil types of the study area

No	Soil Type	SWAT code	Area	
			Ha	Percentage area (%)
1	Eutric-Cambisols	Be9-3c-26	237654	18.1034
2	Eutric-Regosols	Re-3a-83	318298	24.2465
3	Eutric –Nitosols	Ne10-3b-154	131109	9.9873
4	Dystric-Regosols	Rd2-2c-229	9023	0.687332
5	Cheromic - Vertisols	Vc26-3a-264	76712	5.84358
6	Hplic-Xerosols	Xh16-a-309	94876	7.22723
7	Calcic-Xerosols	Xk19-2a-323	192522	14.6655
8	Gypsic-xerosols	Yh16-2-3c-348	252563	19.2391

3.4.4 Meteorological and Hydrological Data

3.4.4.1 Meteorological Data

SWAT requires daily meteorological data that could either be read from a measured data set or be created by a weather generator model. Awash River Basin has better hydro-meteorological stations as compared to other Ethiopian basins concerning both densities of gauging stations and the record length of data. According to data available on the number of stations and density per kilometer square, Awash River Basin has a better density of stations next to Rift Valley Lakes Basin and Blue Nile River Basin (Kloos and Legess, 2010).In this study, there are a total of five meteorological stations named Kulumsa, Metehara, Abomsa, Adama, and Gelemso. Data of precipitation, maximum and minimum temperatures, sunshine hours, relative humidity, and wind speed were collected within and around the catchment Area. This data was collected from the National Meteorology Service Agency, Addis Ababa (NMSA). The climatic data used for this study covers 30 years from January 1990 to December 2019.

Based on the class of the stations, the number of weather variables collected varies from station to station that is grouped into two. The first group contains only rainfall data and maximum/minimum temperature. The second group contains variables like maximum-minimum temperature, humidity, sunshine hours, and wind speed, and rainfall.

The SWAT weather generator model (WXGEN) was used to fill missing values in weather data. The monthly generator parameters values were estimated from the two weather stations (Kulumsa and Metehara). Finally, the weather data were prepared in text format with lookup tables as required by the model.

Table 3. 4: List of weather Stations, Name, Location and Meteorological Variables

Station name	Latitude	Longitude	RF	MAX Temp	MIN Temp	RH	WS	SSH	Elevation(m)
Kulumsa	8.00	39.15	√	√	√	√	√	√	2211.00
Metehara	8.85	39.91	√	√	√	√	√	√	944.00
Abomsa	8.47	39.83	√	√	√	√	X	X	1630.00
Adama	8.55	39.28	√	√	√	X	X	X	1622.00
Gelemso	8.81	40.52	√	√	√	X	X	X	1739.00

√ = Represents data available and X= represents data not available.

Where, RF-Rainfall, RH-Relative Humidity, WS-Wind Speed,and SSH-Sunshine hours.

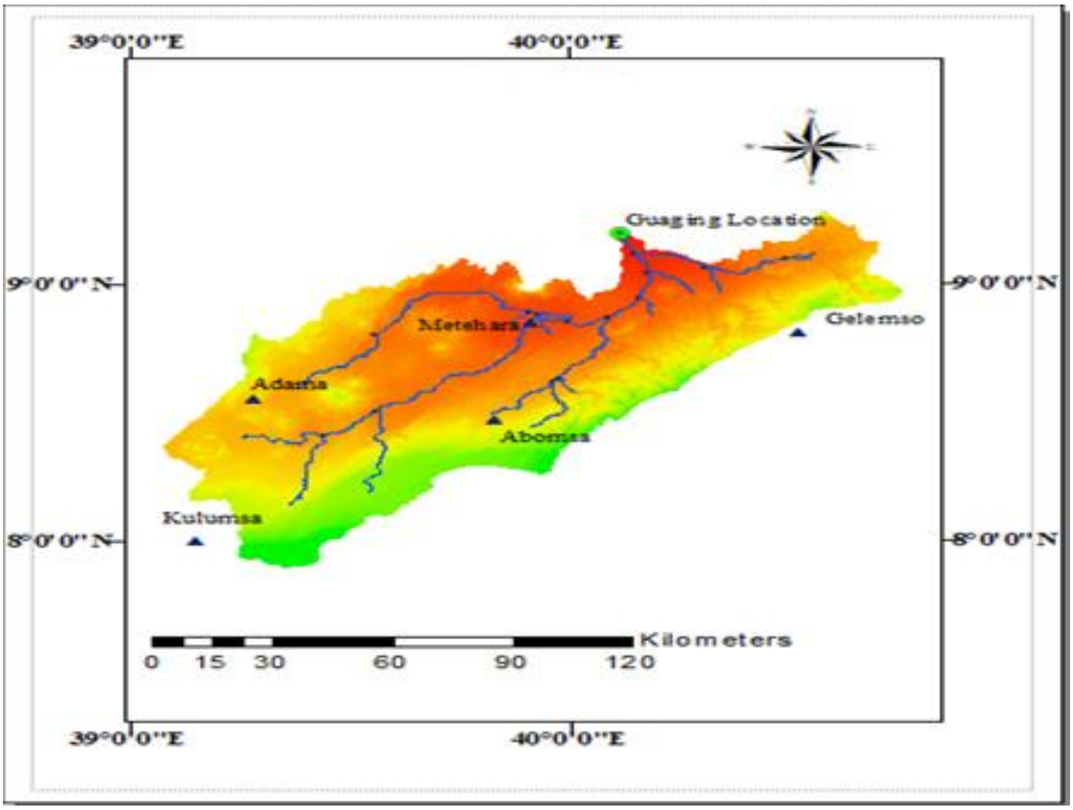

Figure 3. 5: Location Map of Meteorological and gauging Stations in the Study Area.

3.4.4.2 Hydrological data

Daily flow data is required for SWAT simulation outcome calibration and validation. Daily stream flow data were collected from the Hydrology Department of the Ministry of Water, Irrigation, and Electricity (MoWIE), Addis Ababa. Depending on the extent of calibration and validation, flow data was collected and arranged per the requirement of the SWAT model. The stream flow measured at Awash -7 was used for calibrating and validating the model. The average monthly stream flow data (1990-2013) were used for the Awash- Awash Sub-Basin.

3.4.5 Data preparation and Analysis

The collected and acquired data were analyzed and ready before any use through the procedures below.

3.4.5.1 Filling missing weather data

The goal of any missing data filling technique is the creation of complete data set, which may then be analyzed using complete data inferential methods. A variety of methods exist in the literature for filling missing hydrological data, ranging from simple to complex. For longer and continuous data establishment, a correlation method with the neighboring stations having longer data can be used. The estimation of missing meteorological data can be done through within stations, between stations, or regression-based methods (Allen *et al*., 2001). Short gaps can be filled by simple station methods such as interpolation between available data or moving averages.

In developing countries like Ethiopia where there is a sufficient amount of water resources potential and also a lack of high-quality meteorological data, it expected to have the problem of facing missing meteorological data even though all means were used to escape these missing values from the records (Boke, 2017) and (Presti *et al*., 2010) Some of the causes of the occurrence of these data problem could be the absence of an observer, malfunction of instruments, incorrect measurements, relocation of stations, and loss of records.

The data collected from the National Metrological Service Agency have much-missed data. The missed daily rainfall and temperature data were filled by XLSTAT 2018 program, where multiple linear regressions were used to fill missed daily rainfall data from neighboring stations, and missed maximum and minimum daily temperature data were filled by average multiple imputations.

Some of the average weather data were generated by the weather generator programs (WXGEN) developed by (Williams (1991) for SWAT weather generating station which has full data and solar radiation data which is not available from the Agency of Meteorology was calculated from the available measured sunshine hour's data and average day length data obtained from standard tables.

3.4.5.2 Solar Radiation Estimation from the Measurement of Sunshine Hours

Since the SWAT model needs solar radiation in a day, the sunshine hour data collected from NMSA was converted to solar radiation by using an empirical equation developed by Angstrom (Equation [3.1]). According to World Meteorological Organization (WMO), the sunshine duration is defined as the period during which the direct solar irradiance exceeds a threshold value of 120 W/m2-day or 2.88 KWh/m2-day (Coulibaly, 2007). Solar radiation of a certain period is proportional to sunshine duration. The relation between solar radiation and sunshine duration was first proposed by Angstrom in 1924 (Shuvankar, 2015).

The original Angstrom equation is given by:

$R_s = [a_s + b_s * n/N] * R_a$ -- [3.1]

Where;

R_s Solar or shortwave radiation [$MJm^{-2}\ day^{-1}$],

n actual duration of sunshine [hour],

N maximum possible duration of sunshine or daylight hours [hour],

n/N relative sunshine duration,

R_a extraterritorial radiation [$MJm^{-2} day^{-2}$],

a_s and b_s are regression constant (empirical coefficients), expressing the fraction of extraterritorial radiation reaching the earth on over cast days (n = 0),

$a_s + b_s$ the fraction of extraterritorial radiation reaching the earth on clear days(n=N)

The Angstrom values as and bs will vary. Where no actual solar radiation data are available and no calibration has been carried out for enhanced as and bs parameters; as = 0.25 and bs = 0.50 are recommended.ws = The mean sunrise hour angle for the given month.

Table 3. 5: Emperical equations used to derive solar radiation.

day	Ra	ws	N=24/3.14*ws	n(sunshine)	a	b	n/N	b*n/N	a+b*n/N	RS
1	32.3741	1.51447	11.57556927	8.78178	0.25	0.5	0.758648	0.379324	0.62932	20.3738
2	32.4055	1.5147	11.57729932	8.76267	0.25	0.5	0.756884	0.378442	0.62844	20.365
3	32.4392	1.51494	11.57916872	8.74356	0.25	0.5	0.755111	0.377556	0.62756	20.3574
4	32.4751	1.5152	11.58117638	8.72445	0.25	0.5	0.75333	0.376665	0.62667	20.351
5	32.5132	1.51549	11.58332112	8.70534	0.25	0.5	0.751541	0.375771	0.62577	20.3458
6	32.5534	1.51578	11.58560169	8.68476	0.25	0.5	0.749617	0.374808	0.62481	20.3397
7	32.5958	1.5161	11.58801676	8.66565	0.25	0.5	0.747811	0.373906	0.62391	20.3367
8	32.6402	1.51643	11.59056496	8.64654	0.25	0.5	0.745998	0.372999	0.623	20.3348
9	32.6866	1.51678	11.59324484	8.62743	0.25	0.5	0.744177	0.372089	0.62209	20.334
10	32.735	1.51715	11.59605488	8.60832	0.25	0.5	0.742349	0.371175	0.62117	20.3342

3.4.5.3 Filling missing hydrological data

Before beginning any hydrological analysis, it is essential to make sure that data are complete with no missing values. Missing flow data records for the watershed may be filled by evolving correlation station by scatter plot between the station with lost data and any of the adjacent stations with the same hydrological features and common data points and XLSTAT with various options. XLSTAT proposes a multiple imputation algorithm based on the Markov Chain Monte Carlo (MCMC) approach also called fully conditional specification for this study MCMC imputation technique using the XLSTAT add-ins plugin in Microsoft Excel was used to fill missing hydrological data.

3.4.6 Checking Data consistence and homogeneity

3.4.6.1 Checking consistency of meteorological data

Sometimes a significant change may occur in and around a particular rain gauge station. Such change occurring in a particular year will start affecting the rain gauge data, being reported from a particular station. Before conducting the analysis, the series should be scrutinized for possible errors or inconsistency and for any indication that contravenes basic statistical assumptions. (Hamed and Rao, 2000). To detect such inconsistency and to correct and adjust the reported rainfall values, a technique called the double mass curve method is generally accepted. A double mass curve is a graphical method for identifying and adjusting inconsistency in a station record by comparing its time trend with those of adjacent stations. Consistency of time series data analyzed based on the theory that a plot of two cumulative quantities that are measured for the same period should be a straight line and their proportionality remain unchanged which is represented by the slope. If the conditions relevant to the recording of a rain gauge station have undergone a significant change during the period of record, inconsistency would arise in the rainfall data of that station. This inconsistency can be differentiated from the time the significant change took place. If a significant change in the regime of the curve is observed, it should be corrected by using the following equation. The stations used in this study have not undergone a significant change during the baseline period (1990-2019) (Figure 3.6) of the study.

$PCX = PX^* Mc/Mx$ --- [3.2]

Where:

Pcx is corrected precipitation at any period,

Px is originally recorded precipitation at period,

Mc is corrected slope of the double mass curve and

Mx is the original slope of the double mass curve.

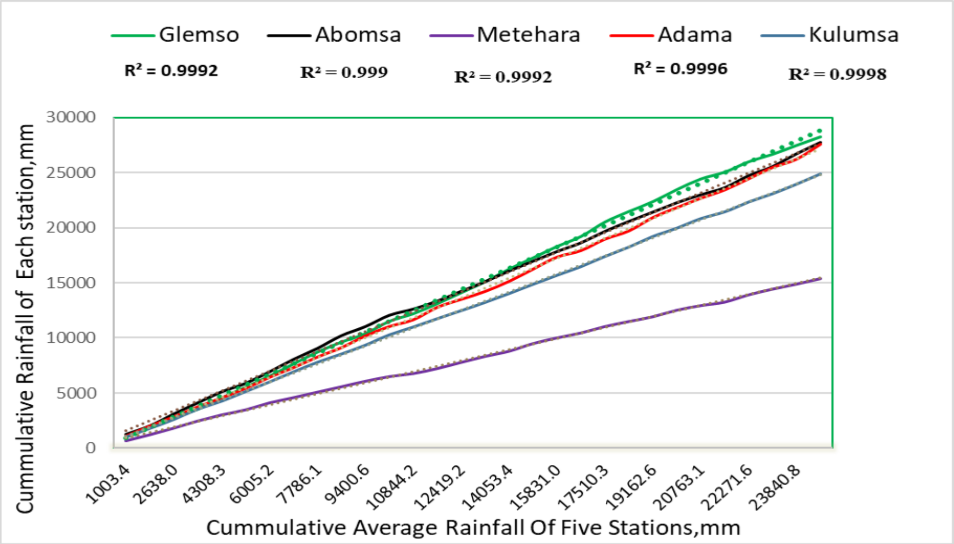

Figure 3. 6: Double mass curve of five stations of the study area.

3.4.6.2 Homogeneity test

To detect possible errors checking the station for data quality using the appropriate method is crucial. Homogeneity analysis is used to detect a change in the statistical property of the time series data which is caused by either natural or man-made. These include alteration to include and relocation of the observing station. The recommended method to apply homogeneity has been tested concerning neighboring stations.

For this study, the RAINBOW method was used to check the homogeneity of data which was based on evaluating the maximum and the range of the cumulative deviations from the mean. The rainfall and flow stations used in this study are homogeneous at 90%, 95%and 99% probability (Appendix H). The homogeneity of the data of a time series is tested shown as below in figure 3.7.

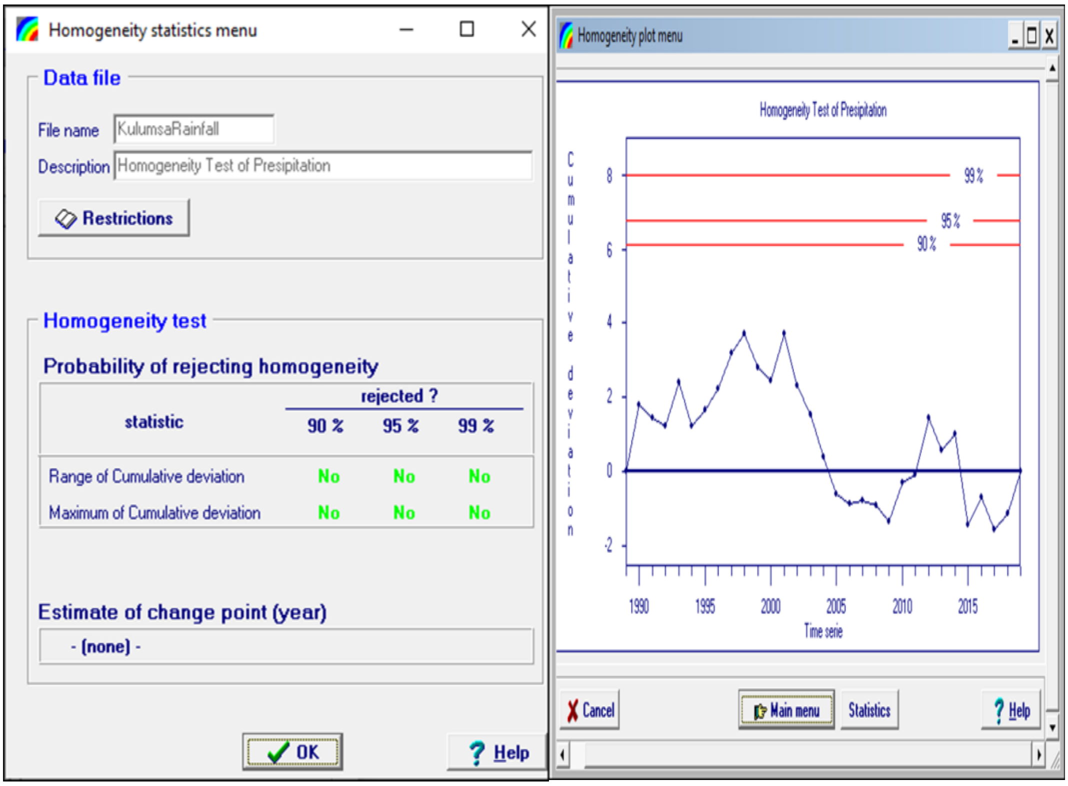

Figure 3. 7: Homogeneity test of data using RAINBOW

3.5 Materials/tools

For this particular study, different materials and tools were used. Some of the materials that were used were; laptop computers, notebooks, and other stationary materials.

Tools like; -

i. Arc-GIS 10.4.1 to obtain hydrological and physical parameters and spatial information of the catchments of the study area.
ii. Soil and Water Assessment Tool (SWAT) software;-To delineate watershed and simulate hydrological parameters of the watershed.
iii. ERDAS software; - For Landsat image process, image classification, and accuracy assessment.
iv. PCP STAT; - To calculate statistical parameters of daily precipitation data used in the weather generator.
v. Dew02; - designed to calculate the average daily dew point temperature per month.
vi. SWAT-CUP; - To calibrate and validate SWAT output.
vii. XLSTAT 2018; - For filling of missed data.

3.6. SWAT Model description

The Soil and Water Assessment Tool (SWAT) model was developed by US Department of Agriculture-Agriculture Research Service (USDA-ARS). SWAT model is physically based, semi-distributed, and can continuously simulate stream flow, sediment yield, nutrient, pesticides and agricultural management in watersheds with varying soils, land use and management conditions over long periods of time (Neitsch, *et al.*, 2011).Based on their topographic situation the model spatially divides the entire watershed into smaller sub basins. The sub basins are divided further into hydrologic response units (HRUs), which consists homogeneous soil type, land use and slope with in watershed.

3.6.1.Hydrological components of SWAT model

The Simulation of the hydrology of a watershed is separated into two divisions. One is the land phase of the hydrological cycle that controls the amount of water, sediment, nutrient and pesticide loadings to the main channel in each sub basin. The second one is routing phase of the hydrologic cycle that can be defined as the movement of water, sediments, nutrients and organic chemicals through the channel network of the watershed to the outlet. In the SWAT model the water balance is the backbone of the hydrologic simulation in a watershed.

SWt = SWo + Σ (Rday−Qsurf−Ea−Wsweep−Qgw) -------------------------------[3.3]

Where; SWt is the final soil water content (mm H2O), SW0 is the initial soil water content on day i (mm H2O), t is the time (days), Rday is the amount of precipitation on day i (mm H2O), Qsurf is the amount of surface runoff on day i (mm H2O), Ea is the amount of evapotranspiration on day i (mm H2O), Wseep is the amount of water entering the vadose zone from the soil profile on day i (mm H2O), and Qgw is the amount of return flow on day i (mm H2O).

3.6.2.Surface Runoff

Surface runoff is a flow that occurs along a sloping surface and it occurs whenever the rate of water application to the ground surface exceeds the rate of infiltration. It is the major component of the hydrologic cycle.

SWAT provides two methods for estimating surface runoff: the SCS curve number procedure (USDASCS, 1972) and the (Green& Ampt infiltration method,1911).Using daily or sub daily rainfall, SWAT simulates surface runoff volumes and peak runoff rates for each HRU. The SCS curve number used (G SCS, 1972) has the following computational formula (Neitsch, 2005):

$$\mathrm{Qsuf} = \frac{(\mathrm{Rday}-\mathrm{Ia})2}{\mathrm{Rday}-\mathrm{Ia}-\mathrm{S}} \text{ --3.4}$$

Where, Qsurf is the accumulated runoff or rainfall excess (mm H2O), Rday is the rainfall depth for the day (mm H2O), I_a is the initial abstractions which includes surface storage, interception and infiltration prior to runoff (mm H2O), and S is the retention parameter (mm H2O). The retention parameter varies spatially due to changes in soils, land use, management and slope and temporally due to changes in soil water content. The retention parameter is defined as:

$$\mathrm{S} = 25.4 * \frac{100}{\mathrm{CN}} - 10 \text{---3.5}$$

Where CN is the curve number for the day and it is a function of land use, soil permeability and antecedent soil water condition. Commonly Ia is approximated by 0.2S and the above equation rewritten as follow.

$$\text{Qsurf} = \frac{(\text{Rday}-0.2\text{S})2}{\text{Rday}+0.8\text{S}} \text{---3.6}$$

3.7. SWAT model setup

Arc SWAT is an extension of the SWAT model that runs within ArcGIS. It provides a graphical user interface that allows for GIS data to be easily formulated for use in SWAT model simulations. Arc SWAT breaks pre-processing into three main steps: watershed delineation, hydraulic response unit (HRU) analysis, and weather data definition with that of sensitivity analysis and calibration.

To understand how each section works within the modeling process, it is important to understand the conceptual framework of each step, as well as what data are used and how they are integrated into Arc SWAT. There for the major steps of Arc SWAT pre-processing are covered in-depth as follows:

3.7.1 Watershed Delineation

SWAT uses digital elevation model (DEM) data to automatically delineate the watershed into several hydrological connected sub-watersheds as a hydrological model, the starting point of the SWAT database creation is the watershed definition. The watershed delineation consists of streams definition, outlets inlets definition, and calculation of the sub-basin parameters. Before going in hand with spatial input data (i.e. the soil, LULC map, and DEM) were projected into the same projection called UTM Zone 37N, which projection parameters for Ethiopia. A watershed was partitioned into several sub-basins, for modeling purposes. The watershed delineation process includes five major steps, DEM setup, stream definition, outlet and inlet definition, watershed outlets selection, and definition and calculation of sub-basin parameters. During the stream definition phase, the flow direction is computed for each cell in the DEM raster to determine the water destination in it (Shuvankar, 2015). For the stream definition, the threshold based on the stream definition option was used to define the minimum size of the sub-basins.

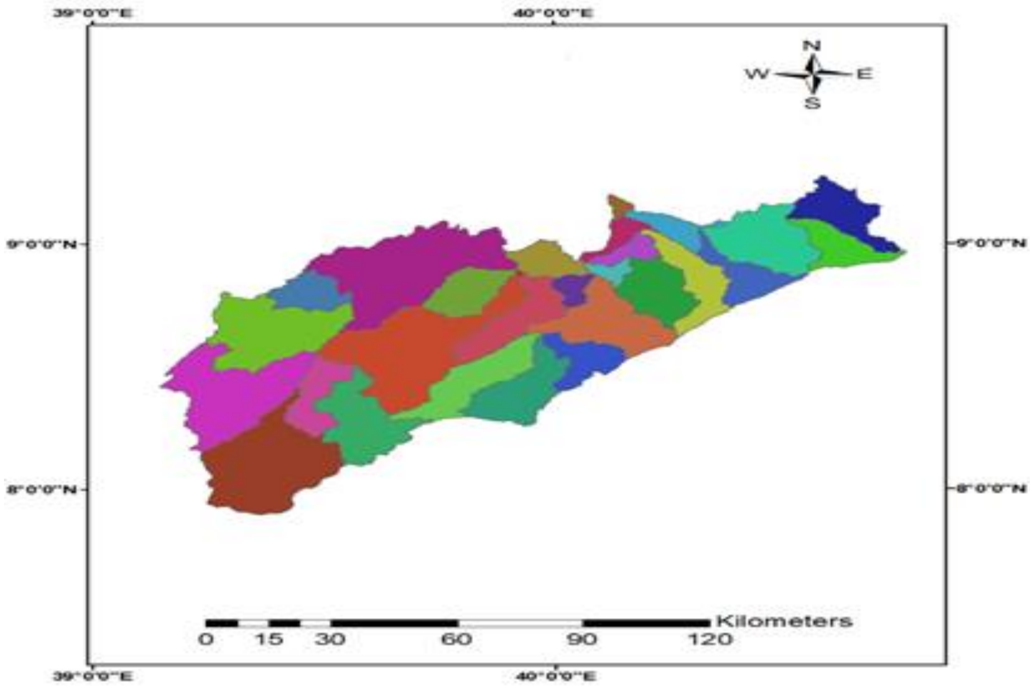

Figure 3. 8: The delineated watershed sub-basins by SWAT

3.7.2 Hydrological Response Units (HRUs)

The HRU is the smallest unit in the SWAT model and it is used to simulate processes such as rainfall, infiltration, plant dynamics, and erosion, nutrient cycling, leaching of pesticides (Neitch *et al*., 2011). SWAT model used spatial data such as land use, soil, and slope to create different Hydrologic Response Units (HRUs) analysis system, which are the unique combinations of land use soil and slope type within each sub-basin. The multiple scenarios that account for 5% land use, 10% soil, and 10% slope threshold combination give a better estimation of stream flow. As the percentage of land use, slope, and soil threshold increases, the actual evapotranspiration decreases due to eliminated land-use classes (Vilaysane *et al*., 2015). Hence, the Awash-Awash sub- basin results in 370,392,420 HRUs for 1990,2000 and 2019 years respectively in the whole basin. Categorizing sub-basins into HRUs increases accuracy and provides a much better physical description ((Mtalo *et al*., 2012).The land use and soil classifications for the model are slightly different than those used in many readily available datasets and therefore the land use and soil data were reclassified into SWAT land use and soil classes before running the simulation. Definition and reclassification of Land use dataset, the definition of soil dataset, reclassification of soil and slope layers and of land use, soil and slope layer were done during

Hydrologic Response Unit analysis.The prepared soil layers classified LULC and slope layers and delineated Watershed by Arc SWAT were overlapped 100%.

3.7.3 Importing input data

The write input tables menu contains items that allow building database files containing the information needed to generate default input for SWAT. Weather data to be used in a watershed simulation was imported once the HRU distribution has been defined. The periods of the measured weather data, which was obtained from the National Meteorology Service Agency of Ethiopia (NMSA), differed from station to station. In this study, all the weather stations or the weather data definition locations were prepared in text format and loaded. To deal with the weather data, it should be stored in a specific tabular and supportive file format of Arc SWAT. In this case, they were stored in DBF format which is read by the Arc SWAT interface. The geographical coordinate names of the weather stations of the study area were introduced into the Arc SWAT database. The data has provided the most representative precipitation and temperature data available. Then the climatic input variables are imported together with their weather location.

3.7.4 SWAT Simulation

SWAT simulation run was carried out on the 1990-2019 climates. The run output data was imported to the database and the simulation results were saved in different files of SWAT output. It is used for SWAT model calibration since most of the observations of the watershed's behavior are obtained by measuring these parameters.

3.8 Model Sensitivity analysis, Calibration, and Validation

3.8.1 Sensitivity Analysis

Several parameters affect complex hydrological modeling. Most of the values of these parameters are not exactly known. Therefore, sensitivity analysis as an instrument for the assessment of the input parameters concerning their impact on model output is useful not only for model development but also for model validation and reduction of uncertainty (Kassa, 2009). The global sensitivity analysis approach which considers the sensitivity of one parameter concerning other parameters under consideration was used to determine the sensitive parameters in this study.

The sensitivity analysis was performed on 20 SWAT parameters (APPENDIX-A,Table-1), and the most sensitive parameters were identified using the Global sensitivity analysis method in SWAT-CUP SUFI2, by following SWAT-CUP user manual.(Abbaspour, 2015) . Parameters for sensitivity analysis were selected by reviewing previously used calibration parameters and documentation from SWAT manuals.

A complete preprocessing of the required input for the SWAT - CUP (SUFI2) model, flow simulation was performed for twenty-three years of recording period of 1990 - 2013. The higher the value of the Index, the higher will be the influence on the runoff and sediment yield generation. (SWAT- CUP) version 5.1.6 with SUFI2 was applied to calibrate, validate, and assess model uncertainty. The most sensitive parameters were identified using the Global sensitivity analysis method in SWAT-CUP SUFI2. SWAT-CUP is a public domain computer program for the calibration of SWAT models. A t-stat provides a measure of sensitivity (larger in absolute value are more sensitive), whereas p- values the significance of the sensitivity, a value close to zero is more significant (Abbaspour, 2015).

3.8.2 Model Calibration

Soil and Water Assessment Tool-Calibration and Uncertainty Programs (SWAT-CUP) is an automated calibration model which provides a link between the input/output of a calibration program and the model. It is a generic interface that was developed for calibrating the SWAT model (Komlavi, 2015). SWAT-CUP (calibration and Uncertainty Programs) was used for calibration and uncertainty analysis on streamflow parameters. SUFI-2 algorithm was used in this analysis for the calibration of the streamflow for the monthly SWAT run. The total available monthly discharges at the gauge station were from the 1990 – 2013-year simulation period, however, the data were split into a calibration period of 1990-2006 and a validation period of 2007-2013 using the daily streamflow observation data from gauging stations within the study area. For a better parameterization of the SWAT model and to reduce the model output uncertainty (Gashaw *et al*., 2018) a longer calibration period was used.

The auto-calibration tool in SWAT – CUP can be run in the SUFI-2, GLUE, Parasol, Mc, and Paso. For this study, the SUFI-2 option was selected (Abbaspour, 2007). This method was chosen for its applicability to both simple and complex hydrological models. SWAT-CUP simulation was specified for performing the auto-calibration and the location of the sub-basin where observed data could be compared against simulated output. Then, the desired parameters for optimization and observed data file were selected. Hence, 10 flow parameters were considered in the calibration process.

3.8.3 Model Validation

To utilize the calibrated model for estimating the effectiveness of future potential management practices, the model was tested against an independent set of measured data. This testing of a model on an independent set of data set is commonly referred to as model validation. As the model predictive capability was demonstrated as being reasonable in both the calibration and validation phases, the model was used for future predictions under different management scenarios (Neitsch *et al*., 2005). Flow validation was carried out at a station similar to the calibration. The statistical criteria (R^2, NSE, and PBIAS) used during the calibration procedure were also checked here to make sure that the simulated values are still within the accuracy limits. The validation period was covered 2007-2013.

3.9 Model Performance Evaluation

To evaluate the model simulation outputs relative to the observed data, model performance evaluation is necessary. The accuracy, consistency, and adaptability performance of the model must be evaluated (Goswami *et al*., 2005) The analysis uses four commonly used goodness-of-fit tests:

1. Coefficient of Determination [R^2]

The coefficient of determination denoted R^2, provides a measure of how well-observed outcomes observed desperation is explained by the prediction. A value of zero means no correlation at all, whereas one means the prediction is equal to that of the observation (Moriasi *et al.*, 2007).

$$R^2 = \left[\frac{\sum_{t=1}^{n}(\, Q^{obs} - Q^{obs\ mean})(Q^{simu} - Q^{simu\ mean})}{(\sum_{t=1}^{n}(Q^{obs} - Q^{obs\ mean})^2 * (\sum_{t=1}^{n}(\, Q^{simu} - Q^{simu\ mean})^2}\right]^2 - - - - - [3.7]$$

Where:

n is umber of observed data points,

R^2 is the coefficient of determination,

Q^{obs} is the observed flow (m^3/s),

$Q^{obs\ mean}$ is the mean of observed flow (m^3/s),

Q^{simu} is the simulated flow ((m^3/s),

$Q^{simu\ mean}$ is the mean of simulated flow (m^3/s).

2. Nash-Sutcliffe coefficient (NSE)

The Nash-Sutcliffe coefficient measures the efficiency of the model by relating the goodness of fit of the model to the variance of the measured data, Nash-Sutcliffe efficiencies can range from −∞ to 1. An efficiency of 1 corresponds to a perfect match of simulated discharge to the observed data. An efficiency of 0 indicates that the model predictions are as accurate as of the mean of the observed data, whereas an efficiency less than zero (−∞ < NSE < 0) occurs when the observed mean is a better predictor than the model (Nash and Sutcliffe , 1970).

The formula for Nash Sutcliffe (NS) is:

$$\mathrm{NSE} = 1 - \left[\frac{\sqrt{\sum_{t=1}^{n}(\ Q_i^{obs} - Q_i^{simu})^2}}{\sqrt{\sum_{t=1}^{n}(\ Q_i^{obs} - Q\ obs^{mean})^2}}\right] - - - - - - - - - - - - - - [3.8]$$

Where:

NSE is Nash-Sutcliffe coefficient,

Q^{obs} is the observed flow (m^3/s),

$Q^{\ mean}$ is the mean of observed flow (m^3/s),

Q^{simu} is the simulated flow ((m^3/s),

n is a number of observed data points.

3. Percent bias (PBIAS)

Percent bias (PBIAS): describes measures the average tendency of the simulated data to be larger or smaller than their observed counterparts (Gupta *et al*., 1999) which is expressed as a percentage. Their observed data equivalents, being the optimum value zero, while, low magnitude values indicate accurate model simulation. Positive values imply model underestimation bias, and a negative value indicates model overestimation bias (Gupta *et al*., 1999).

$$\frac{PBIAS = 100(\sum Yi - \sum Xi)}{\sum Xi} \text{ ------------------------ } [3.9]$$

Where: Xi is measured value, Yi is simulated value

Table 3. 6: Performance ratings of recommended statistics for monthly Streamflow

Performance rating	R^2	NSE	PBIAS
Very good	0.75-1	0.75-1	<10%
Good	0.65-0.75	0.65-0.75	10%-15%
Satisfactory	0.5-0.65	0.5-0.65	15-25%
Unsatisfactory	<0.6	<0.5	>25%

Source: (Van Liew et al.,2003)

3.10 Conceptual frameworks of the study

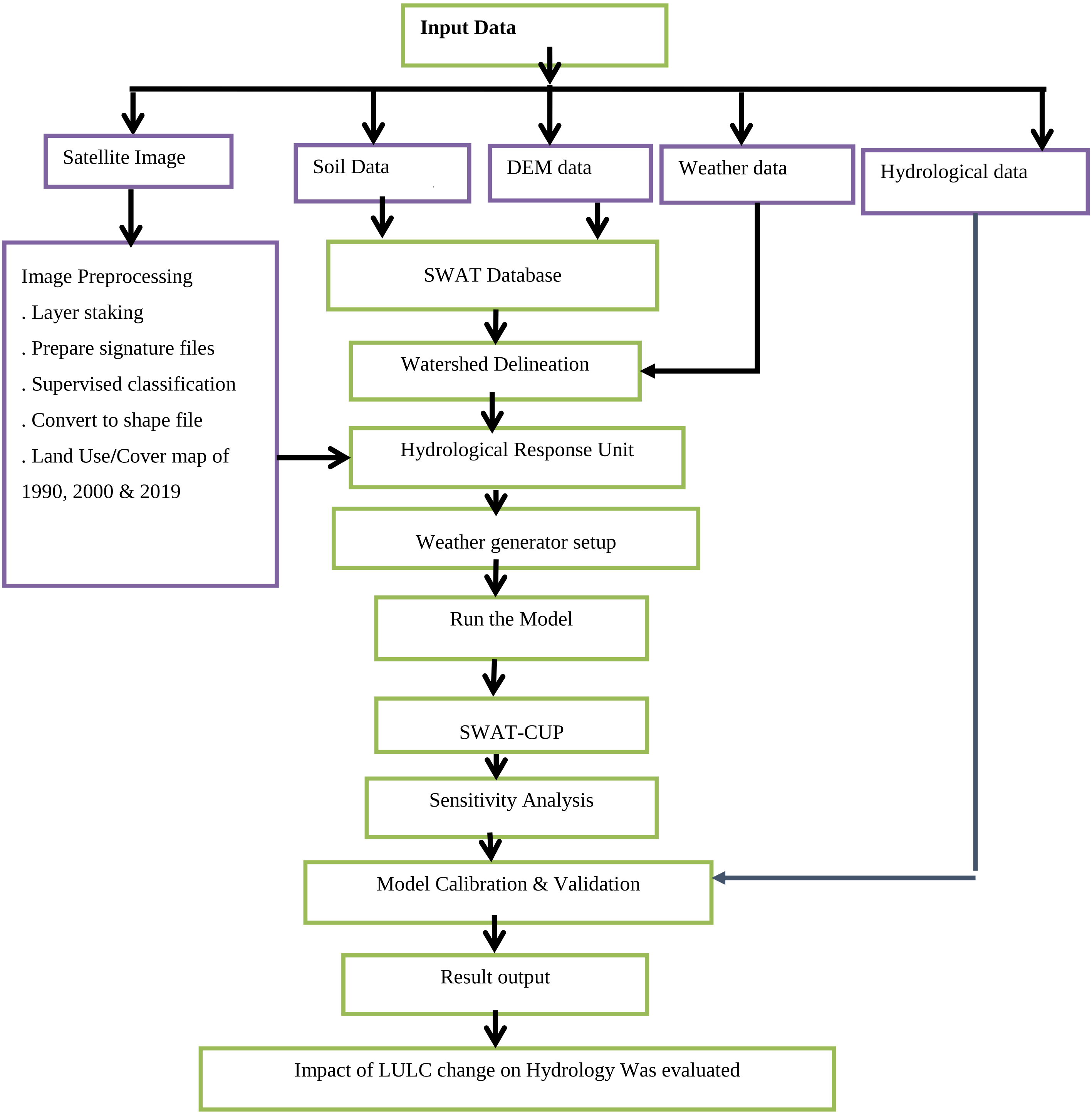

Figure 3. 9: Conceptual frameworks of the study.

4. RESULTS AND DISCUSSIONS

4.1 Land use/land cover Classification accuracy assessment

Accuracy assessment is used to control the correctness of the classified image. In this study, the accuracy assessment is performed for the period 1990, 2000, and 2019 respectively by using visual/ spatial comparison by linking the view with the collected training site and Google earth. The resulting error matrix is shown in Table 4.1 below. The overall accuracy of the classification was 98%, 97%, and 97.6% for the period 1990, 2000, and 2019 respectively. A Kappa coefficient of above 0.80 was also obtained for the three classified images. Therefore, the validation data set indicated a very good agreement of the classified image with the ground truths. The accuracy report of the three classified images is shown in (Table 4.1) in Appendix: A table 2 and 3).

a) Confusion matrix calculations.

1. Overall accuracy; - is used to indicate the accuracy of the entire classification. It is calculated by dividing the total number of correctly classified pixels (diagonals) by the total No of reference pixels multiplied by a hundred.

Overall accuracy= $\frac{\text{total number of correctly classified pixels (diagonals)}}{\text{total No of reference pixels}} * 100 - -[4.1]$

Overall accuracy = $\frac{35+45+22+7+25+52+41}{235} * 100$

=.97*100 =97%

2. Producer's accuracy (PA); - tells how well a definite area can be classified. It is calculated for each land use and the land cover type and obtained by dividing the number of correctly classified pixels of certain land use and land cover type by the total number of pixels of the same land use and land cover type in the reference data or found by dividing the number of correctly classified pixels of certain land use and land cover type by the column total pixels of the same land use and land cover type.

PA= $\frac{\text{number of correctly classified pixels of a certain land use and land cover type}}{\text{total number of pixels of the same land use and land cover type in the reference data}} * 100 \ldots .[4.2]$

In this study producer's accuracy range was from 80 % to 100 %.

3. User accuracy; - User accuracy is also denoted as Commission Error. Commission error occurs when pixels linked with a class are incorrectly identified as other classes, or from wrongly separating a single class into two or more classes. Commission error is calculated by dividing the number of pixels not correctly classified for each class in the classification (row) by the total number of pixels for that class in the classification (row total). In this study users' accuracy ranged from 96 % to 100 %.

4. Kappa co-efficient of agreement; - Cohen's kappa coefficient is a chance-adjusted measure that was established and has often been used and adopted as a standard measure of classification accuracy. The kappa coefficient states the proportionate reduction in error generated by a classification process compared with the error of a completely random classification or unsupervised classification. (Monserud, 1990) (Rientjes *et al.*, 2011) reported that a kappa value of < 40 % is poor, 40-55 % fair, 55-70% good, 70-85 % very good and >85% excellent. According to this range the overall kappa coefficient for this given study period which (> 97 %) is grouped under excellent

$$\textbf{Kappa Coefficient} = \frac{N(\sum_{i=1}^{r} Xii) - (\sum_{i=1}^{r}(X_{i+}X_{+i})}{N^2 - \sum_{i=1}^{r}(X_{i+}X_{+i})} * 100 \; ----------- \quad [4.3]$$

Where r =number of rows in the error matrix

Xii =number of observations in row i and column i (on the major diagonal)

Xi+=total of observations in row i

X+i =total of observations in column i

N =total number of observations included in the matrix

Overall Kappa Coefficient = $\frac{53815-9453}{235^2-9453}$ =97%

Table 4. 1: Accuracy assessment of classified LULC of Awash-Awash sub-basin in 1990 (Appendix-A, table 2- 3 for 2000 and 2019 respectively)

1990	**REFERENCE**									
CLASSIFIED DATA		FRST	RNGB	URBN	WATR	BARR	AGRI	GRAS	Total	UA%
	FRST	37	0	0	0	0	0	0	37	100
	RNGB	0	45	0	0	0	1	0	46	97.826
	URBN	0	0	22	0	0	0	0	22	100
	WATR	0	0	0	7	0	0	0	7	100
	BARR	0	0	1	0	25	0	0	26	96.154
	AGRL	0	1	0	0	0	52	1	54	96.296
	PAST	0	0	0	0	0	1	41	42	97.619
	Total	37	47	23	7	25	54	42	234	
	PA(%)	100	95.745	95.652	100	100	96.3	97.619		OA%=98

UA: user accuracy, PA: producer accuracy, OA: overall accuracy

4.1.2 Land use/land cover maps

The Landsat images of the Watershed area were pre-processed and classified using ground truth data. The LULC states of the Awash-Awash watershed through the 1990 to 2019 periods are shown in (Figures 4.1, 4.2, and 4.3) below.

4.1.2.1 Land use land Cover Map of 1990

According to maximum likelihood classification of 1990 land sat satellite image; the land cover classes (Figure 4.1 and Table 4.2) of Awash-Awash sub-basin showed that about 12.84 % by forest, 23.11 % by Rangeland, 0.14% by settlement (Urban), 0.29 % by Waterbody, 25.70% by Bare land 3.25 % by cultivated land and 34.67 % of the sub-basin catchment was covered by Grass Land. The distribution of land cover class as is shown below in the tabular and graphical form. Rangeland is found in most parts of the watershed.

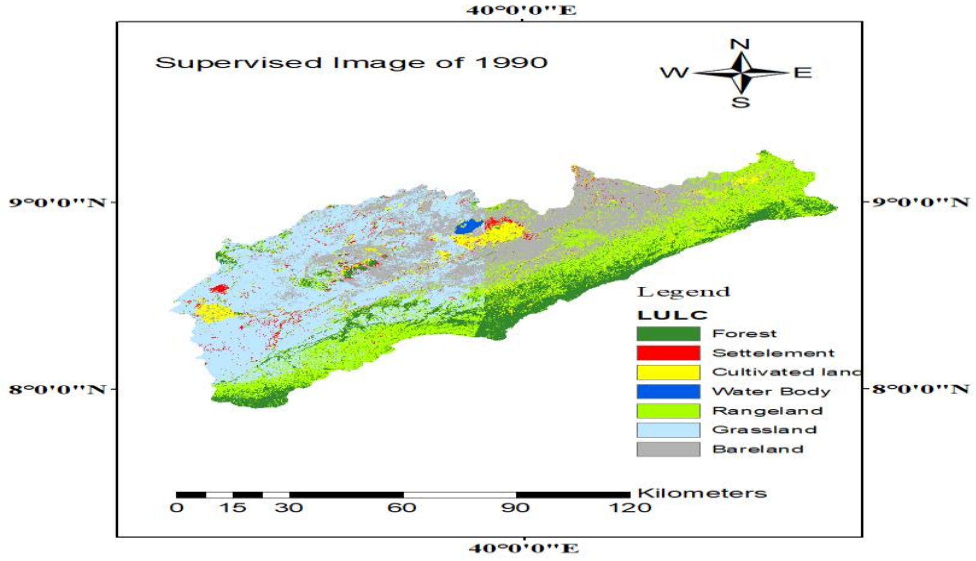

Figure 4. 1: Land use/land cover map of the study area in 1990

4.1.2.2 Land use Land Cover Map of 2000

The maximum likelihood classification of 2000 land sat satellite images showed that the land cover classes (Figure 4.2 and Table 4.2). The percentage coverage of forest land covered some 5.36% while, Rangeland, Settlement, waterbody, Bare land, cultivated and Grassland covered 23.01%, 2.76%, 0.33%, 29.16%, 10.53%, and 28.85% respectively.

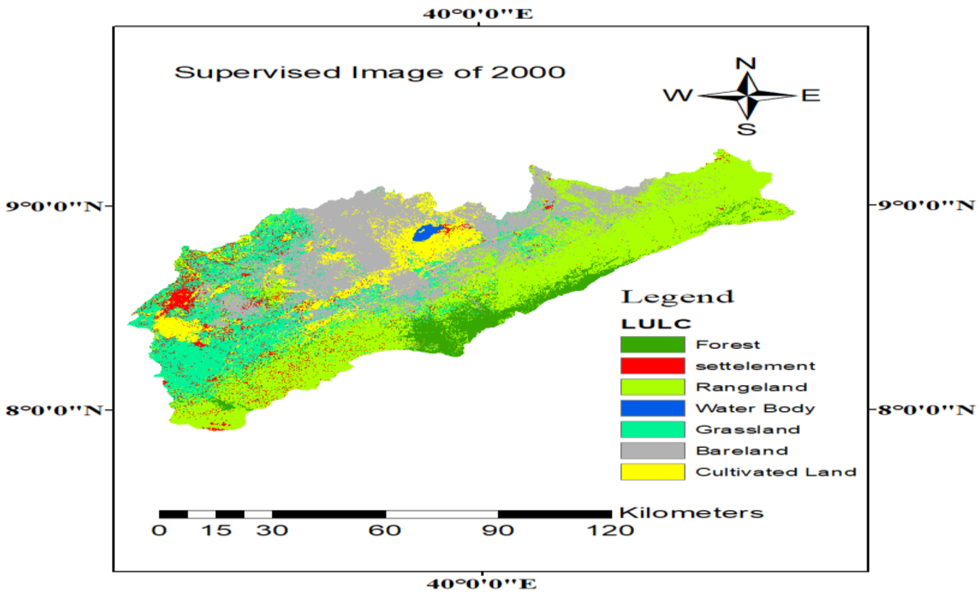

Figure 4. 2: Land use land cover map of Awash-Awash sub-basin for the year 2000

4.1.2.3 Land use Land Cover Map of 2019

The maximum likelihood classification of 2019 land sat satellite images showed that the land cover classes (Figure 4.3 and Table 4.2). The percentage coverage of forest land covered some 3.62% while, Rangeland, Settlement, waterbody, Bare land, cultivated and Grassland covered 17.6%, 3.33%,0.31%, 37.16%,13.12%, and 24.85% respectively.

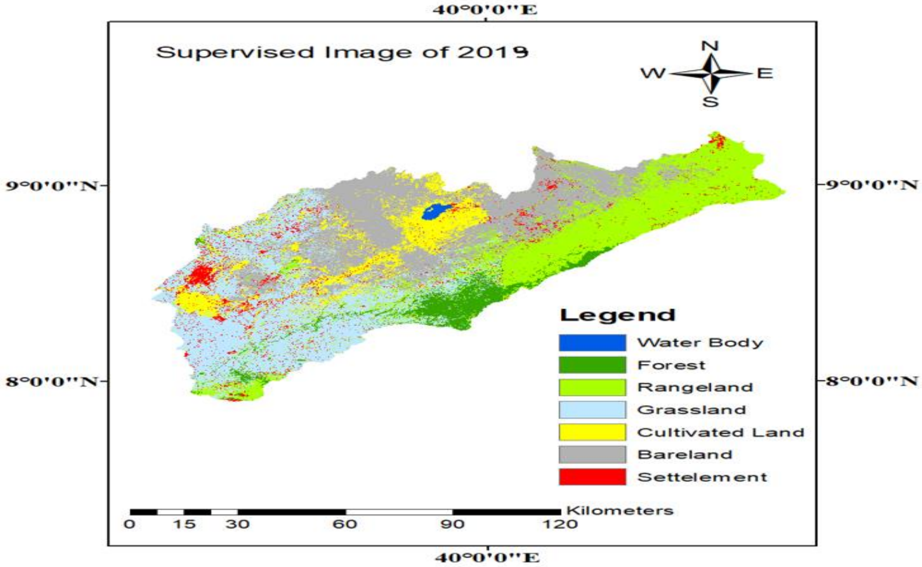

Figure 4. 3: Land use land cover map of Awash-Awash sub-basin for the year 2019

4.1.3. Land use/land cover change

During 1990–2019, a significant amount of LULC changes occurred in the watershed. For example, cultivated land increased from 3.25% in 1990 to 10.53% in 2000, to 13.12% in 2019 periods. Correspondingly, the extent of built-up area was increased between 1990 and 2000 periods (0.14 to 2.76%), and the increment continued in 2019 (3.33%). Conversely, areas covered by forest decreased from 12.84% in 1990 to 5.36% in 2000, to 3.62% in 2019. Similarly, the extent of Range Land, grasslands, and Waterbodies were reduced throughout the 1990, 2000, and 2019 periods (Figure 4.1, 4.2, and 4.3).

Table 4. 2: LULC types and percentage area coverage of 1990 to 2019

Land-use type	Area (1990)		Area (2000)		Area (2019)	
	Ha	%	Ha	%	Ha	%
Forest	147886.61	12.84	61727.04	5.36	41747.24	3.62
Range Land	266225.85	23.11	269790.61	23.01	202740.55	17.60
Built-Up Area	1640.57	0.14	31793.41	2.76	38347.20	3.33
Water	3338.45	0.29	3798.23	0.33	3608.81	0.31
Bare Land	296066.50	25.70	335924.68	29.16	428051.19	37.16
Cultivated Land	37395.26	3.25	116528.40	10.53	151112.11	13.12
Grassland	399354.12	34.67	332344.99	28.85	286300.28	24.85
Total	1151907.36	100.00	1151907.36	100	1151907.36	100

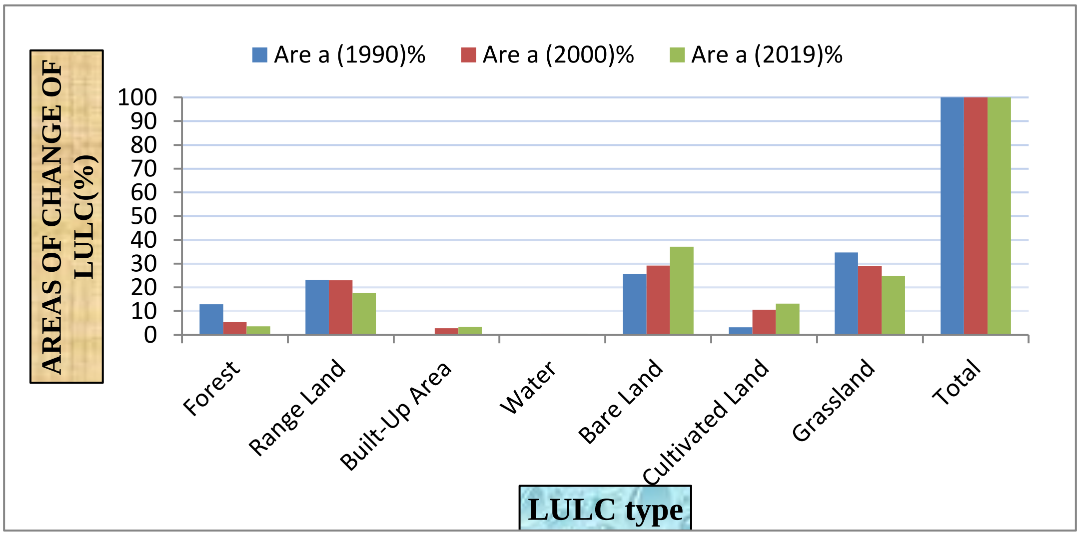

Figure 4. 4: Areas of land use /land cover change in 1990, 2000 and 2019

4.1.4. LULC change analysis

Land use/Land cover supervised classification image was carried out to describe the study area for three reference years of 1990, 2000, and 2019. The settlement land and the built-up area were rapid increment during 1990–2000 and 2000–2019 periods were observed because due to an increase in population growth so that residential Woreda towns were expanded.Cultivated Land and settlement areas continually increased for all the years under review. The area of cultivated land , Built-Up, bare land and water body has increased by 9.87 %,3.19%,11.46% and by 0.02 between 1990 and 2019 respectively.The expansion of cultivated and settlement land was converted from grassland, Rangeland, and forest land. Similar assessment results were worked in different places of Ethiopian regions. (Denboba, 2005) It Was shown 75 % of the Shumba catchment in the southwestern part of Ethiopia was converted to cultivated land and settlement from other land use/cover between the periods of 1967 to 2001. Similar outcomes were also reported by (Zeleke & Hurni, 2001) 99 % of the forest covers were converted to agricultural land in the Dembecha area in the northern part of the country between 1957 and 1995. This growth of cultivated land, settlement, and bare land was problems increase in impervious area in the watershed, these direct impacts on high runoff generation and frequent flood occurrence that means, most rainfalls converted to runoff by decreasing soil infiltration capacity. According (Haregeweyn *et al.*, 2015) relatively high runoff rate on degraded and cultivable land is attributed to decrease surface coarseness, which increases flow velocity and decreases infiltration.

The annual expansion rate (ha/yr.) of Cultivated land, the built-up, and Bare land area were increased until 2019 (Table 4.2).Contrarily, forest, rangeland, and grassland experienced a reduction in converge throughout the study periods and water bodies showed fluctuation (Table 4.2). The Forest land continually decreased by 9.22% between 1990 and 2019.Range Land and the Grassland decreased by 5.51% and 9.82% between 1990 and 2019 respectively.

In the Awash-Awash sub-basin, the core reasons for a reduction in forest cover were the change of forest into open rangeland and agricultural land. The conversion from the forest into rangeland was mainly due to settlements and charcoal production. The cleared area was immediately converted to settlements and farmland. further forest cover decline was observed and reported in several parts of Ethiopia studies like (Dessie & Kleman, 2007) there was reported a relative forest decline from 16% to 2.8% in the Wondo Genet catchment in the period 1972-2000. The areas at which occupied by pastoralists were exposed to massive Livestock grassing pressure accumulated over several seasons so the grassland Area were highly declined and changed to bare land. Grasses dominate the herbaceous vegetation in arid and semi-arid African rangelands, but these rangelands are often highly degraded due to heavy grazing by pastoral communities (Abule *et al*., 2005); (Angassa & Oba, 2007).

Table 4. 3:Analysis of LULC change between 1990-2000, 2000-2019 and 1990-2019

Land-use type	1990	2000	2019	Land use change detection (in %)		
	Coverage(%)	Coverage(%)	Coverage(%)	1990-2000	2000-2019	1990-2019
Forest	12.84	5.36	3.62	-7.48	-1.74	-9.22
Range Land	23.11	23.01	17.6	-0.1	-5.41	-5.51
Built-Up Area	0.14	2.76	3.33	2.62	0.57	3.19
Water	0.29	0.33	0.31	0.04	-0.02	0.02
Bare Land	25.7	29.16	37.16	3.46	8	11.46
Cultivated Land	3.25	10.53	13.12	7.28	2.59	9.87
Grassland	34.67	28.85	24.85	-5.82	-4	-9.82

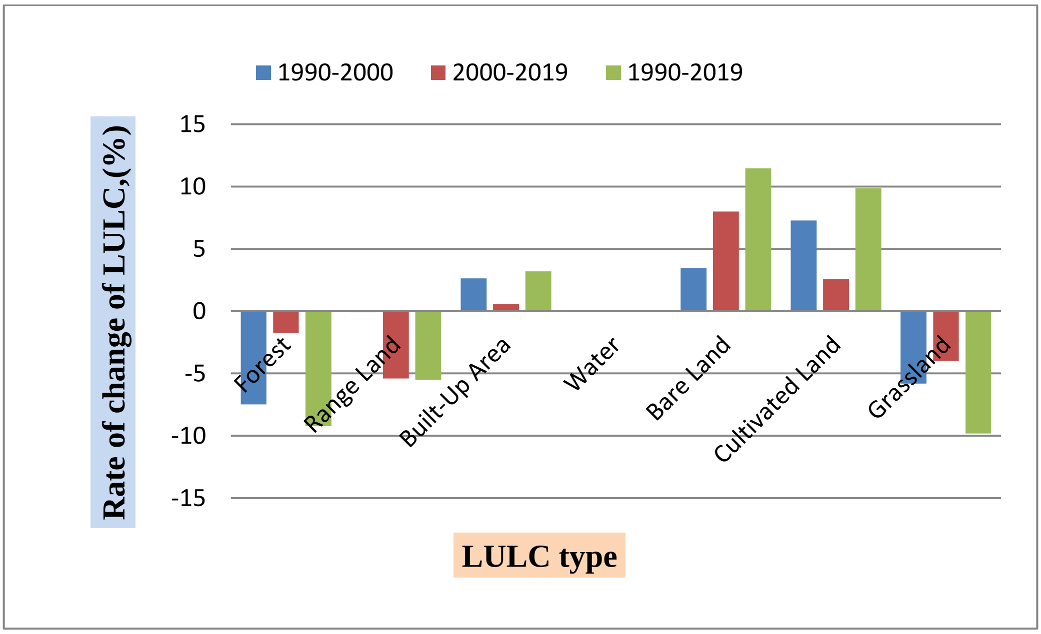

Figure 4. 5: The analysis of Land use/land cover changes through 1990 to 2019

4.2. Performance Evaluation of the SWAT Model

4.2.1. Sensitivity Analysis

The sensitivity analysis aims to estimate the rate of change in the output of a model concerning changes in watersheds that result in a clear difference in hydrologic sensitivity Because of the involvement of a wide range of data and parameters in the simulation process, calibration of outputs of big hydrological models like SWAT was quite a bulky task (Shimelash *et al*., 2018). Therefore, sensitivity analysis minimizes the number of parameters to be used in the calibration and/or validation iteration and shortens the time required for it by identifying the most sensitive parameters largely controlling the performance of the simulated process (Zeray *et al*., 2006).

For this analysis, 20 parameters were considered and only 10 parameters were identified to have significant influence in controlling the streamflow in the watershed. The most sensitive parameters were identified using the Global sensitivity analysis method in SWAT-CUP SUFI2. After set-up the SWAT-CUP model and connecting with the SWAT-2012 model and incorporating all input parameters simulations were carried out and sensitivity analysis was run for the period 1990-2013 and the most sensitive parameters were selected as shown in table 4.4 below.

Table 4. 4: The most sensitive Parameters in the study area

Rank	Flow Parameters	Min. and max. range	t-stat value	p-value	Fitted value
1	CN2	-0.25 to 0.25	-6.4226	0.0030	-0.2050
2	ALPHA_BNK	0 to 1	-2.1316	0.1000	0.766667
3	ESCO	0 to 1	0.1914	0.8574	0.566667
4	EPCO	0 to 1	0.5175	0.6320	0.766667
5	SOL_K	-0.5 to 0.5	-3.4177	0.0268	0.200000
6	ALPHA_BF	0 to 1	-1.1501	0.3141	0.100000
7	RCHRG_DP	0 to 0.2	-0.9034	0.4173	0.18
8	GW_REVAP	0.02 to 0.2	-0.0587	0.9559	0.11
9	GW_DELAY	30 to 450	-0.839	0.4486	184
10	GWQMN	0 to 2	3.9885	0.0162	0.733333

A t-test and p-values

The t-stat is the coefficient of a parameter divided by its standard error. It is a measure of the accuracy with which the regression coefficient is measured. If a coefficient is larger compared to its standard error, then it is probably different from 0 and the parameter is sensitive. The p-value for each term tests the null hypothesis that the coefficient is equivalent to zero (no effect). A low p-value (< 0.05) indicates that you can reject the null hypothesis. In other words, a predictor that has a low p-value is likely to be a meaningful addition to your model because changes in the predictor's value are related to changes in the response variable. Conversely, a larger p-value suggests that changes in the predictor are not associated with changes in the response. So that parameter is not very sensitive. A p-value of < 0.05 is the generally accepted point at which to reject the null hypothesis (i.e., the coefficient of that parameter is different from 0). Finally, the ten most sensitive parameters were selected for calibration and validation processes

4.2.2. Flow Calibration using SUFI-2 Algorithm

The model generated output using model input parameters which were kept within a realistic uncertainty range (Arnold *et al.*, 2012). Therefore, to have the physical knowledge of the watershed, calibration was carried out using SWAT–CUP (SWAT-Calibration and Uncertainty Programs) through Sequential Uncertainty Fitting-2 (SUFI-2). The SWAT model output was calibrated using 16 years of measured streamflow data (1990-2006). The obtained R^2, NSE and PBIAS value during calibration were (0.81, 0.78, 0.82), (0.68, 0.65, 0.74) and (-20.1,-21.5,-14) to 1990, 2000, and 2019 respectively. The graphical comparison of observed and simulated flow during calibration are shown in Figures 4.5 and 4.6 the remains are described in appendix C for the corresponding years of study.

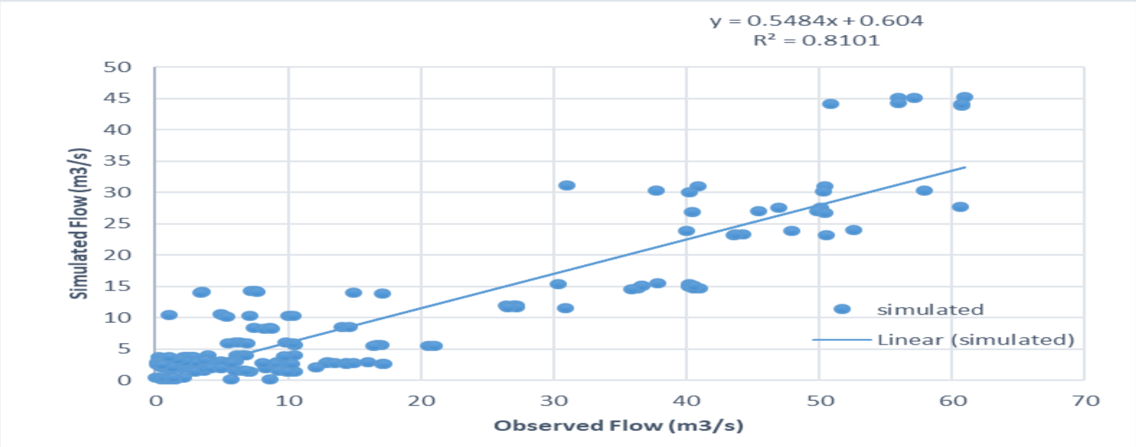

Figure 4. 6: Scatter plot of observed and simulated flow during Calibration for 1990

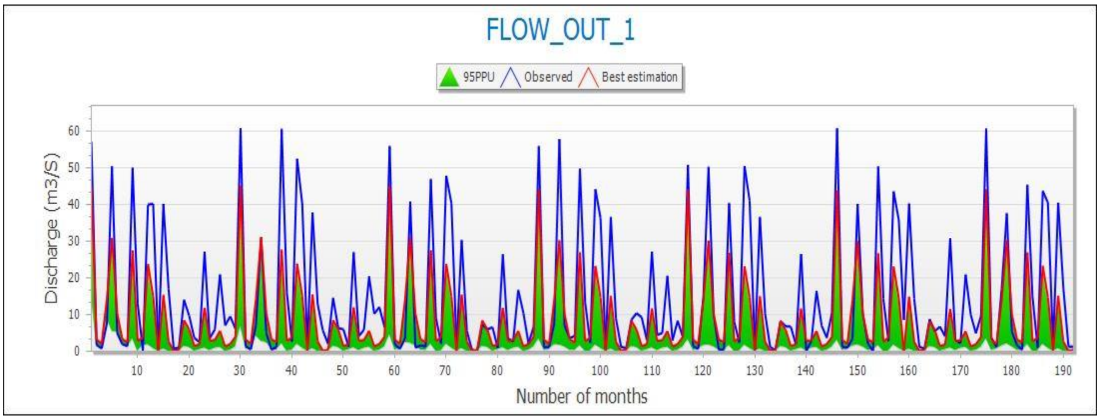

Figure 4. 7: The result of calibration for average monthly stream flows for 1990

4.2.3. Flow Validation using SUFI-2 algorithm

After calibration, the model with calibrated parameters was validated by using an independent set of measured flow data which were not used during model calibration. Flow validation was carried out from 2007 to 2013 without further adjustment of the parameters of flows used in calibration. For the catchment with longtime series split sample test is involved (Shimelash M. *et al*., 2018) for which one part is used to calibrate the model, and the second part is used for testing (validating) if calibrated parameters produced simulations that satisfy goodness-of-fit tests. The obtained R^2, NSE and PBIAS value during validation were (0.84, 0.78, 0.79), (0.76, 0.62, 0.64) and (-12.8,-16.7,-18.5) to 1990, 2000 and 2019 respectively.

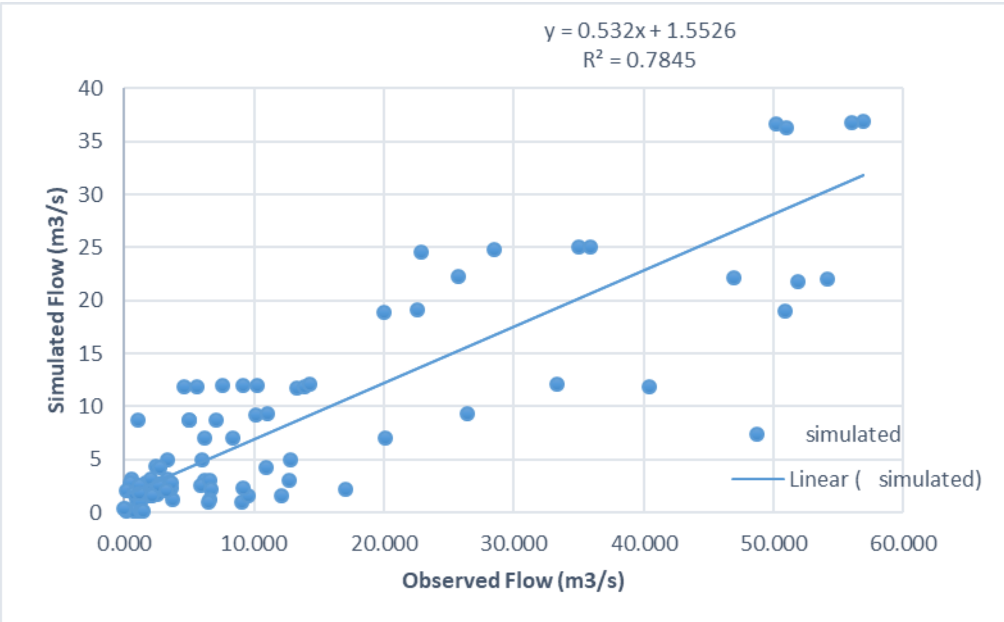

Figure 4. 8: Scatter plot of observed and simulated flow during Validation for 1990

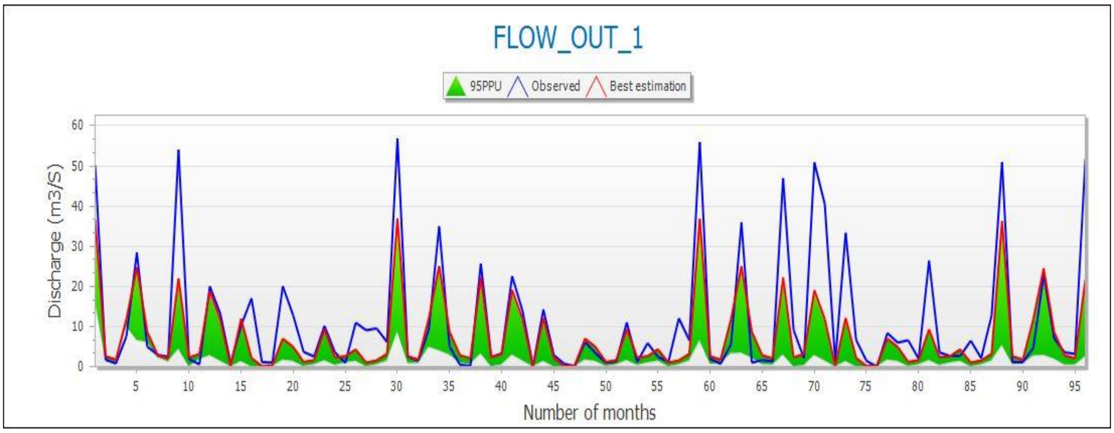

Figure 4. 9: The result of Validation for average monthly stream flows for 1990

4.2.4. Model performance evaluation

Based on the performance ratings of R^2, NSE, and PBIAS (Table 3.6). The SWAT-CUP model performance was effective and had good results. Hence, SWAT-CUP could perform effective prediction of hydrological simulation of Awash- Awash watershed.

Table 4. 5: Summarized results of calibration and validation performance of SWAT model

Results	Year	Evaluation Criteria		
		R^2	NSE	PBIAS
Calibration	1990	0. 81	0.68	-20.1
	2000	0.78	0.65	-21.5
	2019	0.82	0.74	-14
Validation	1990	0.84	0. 76	-12.8
	2000	0.78	0.62	-16.7
	2019	0.79	0.64	-18.5

4.3.The impacts of LULC change on Stream Flow

One of the most main things of the study was to assess the impact of land use and land cover changes on the Awash-Awash sub-basin watershed. The assessment was done in terms of the impact of land use and land cover changes on the seasonal streamflow and variations on the major components of streamflow including surface runoff and groundwater flow during the period (1990-2019). LULC is a significant characteristic in the runoff process that affects infiltration, erosion, and evapotranspiration.The month November, December & January were considered as a dry period, and months

July, August, and September were also taken as the wet period for identifying the change of streamflow. The comparison of simulated streamflow for the LULC of the three periods is briefed in Table 4.6.the mean dry monthly flow decreased by 12.15% (from 10.37 m^3/s in 1990 to 9.11m^3/s in 2000) and reduced by 53.89% (from 9.11 m^3/s in 2000 to 4.20m^3/s in 2019). There are also changes in stream flows in the wet period with an increase of stream flow by 5.01% (from 34.5 m^3/s in 1990 to 36.23 m^3/s in 2000) and increased 8.89%(from 36.23 m^3/s in 2000 to 39.45 m^3/s in 2019) for the first and second periods respectively. The result of the study is Similar with other studies carried out in different parts of the country for instance, by (Baker & Miller, 2013) has shown that there is an increase of stream flow in the wet season and a decrease in the dry season. Similarly, the study by (Tadele and Förch, 2007) in Southern Ethiopia indicated that due to the replacement of natural forest in to farmland and settlements, the mean monthly discharge for wet months had increased while in the dry season decrease.

Table 4. 6: The impacts of LULC of 1990-2000, 2000-2019 and 1900-2019 periods on stream flow.

Season	Annual simulated stream flow (m^3/s)			Change Detection (m^3/s) / (%)		
	1990	2000	2019	1990 – 2000	2000 – 2019	1990 – 2019
Dry period	10.37	9.11	4.20	-1.26 (12.15%)	-4.91 (53.89%)	-6.17 (59.50%)
Wet period	34.50	36.23	39.45	1.73 (5.01%)	3.22 (8.89%)	4.95 (12.54%)

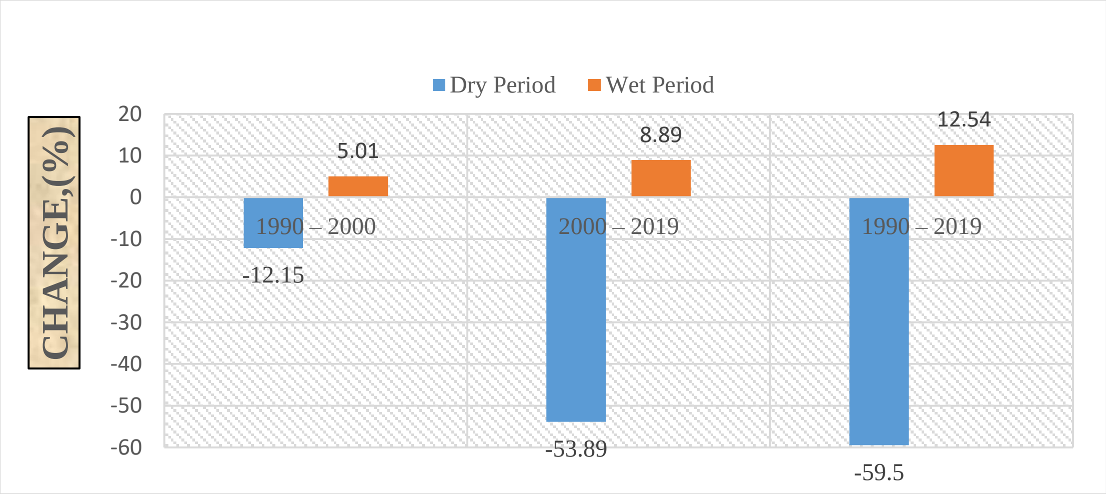

Figure 4. 10: Comparison of simulated stream flow for LULC of 1990-2000, 2000 2019 and 1990-2019 periods

4.4.Impacts of LULC on Hydrological components

Table 4. 7: hydrological components of 1990, 2000 and 2019

Hydrological process	1990	2000	2019	Rate of changes (%)		
				1990-2000	2000-2019	1990-2019
SURQ, mm	202.15	217.38	236.21	7.53	8.66	16.85
LATQ, mm	15.32	14.17	13.04	-7.50	-8.00	-14.88
PERC, mm	240.59	231.23	221.47	-3.88	-4.22	-7.95
AQ recharge, mm	240.57	231.39	218.64	-3.82	-5.51	-9.12
ET, mm	353.8	348.1	341.52	-1.61	-1.89	-3.47
PET, mm	1582.8	1577.34	1571.72	-0.34	-0.36	-0.70
TWYLD, mm	426.38	414.81	401.72	-2.71	-3.16	-5.78
TSL, t/ha	37.34	41.44	46.31	10.98	11.75	24.02

Where, SURQ-Surface runoff, LATQ-Lateral soil flow, PERC-percolation, AQ-aquifer recharge, ET-Evapotranspiration, PET-potential evapotranspiration, TSL–total sediment loading, and TWYLD-total water yield.

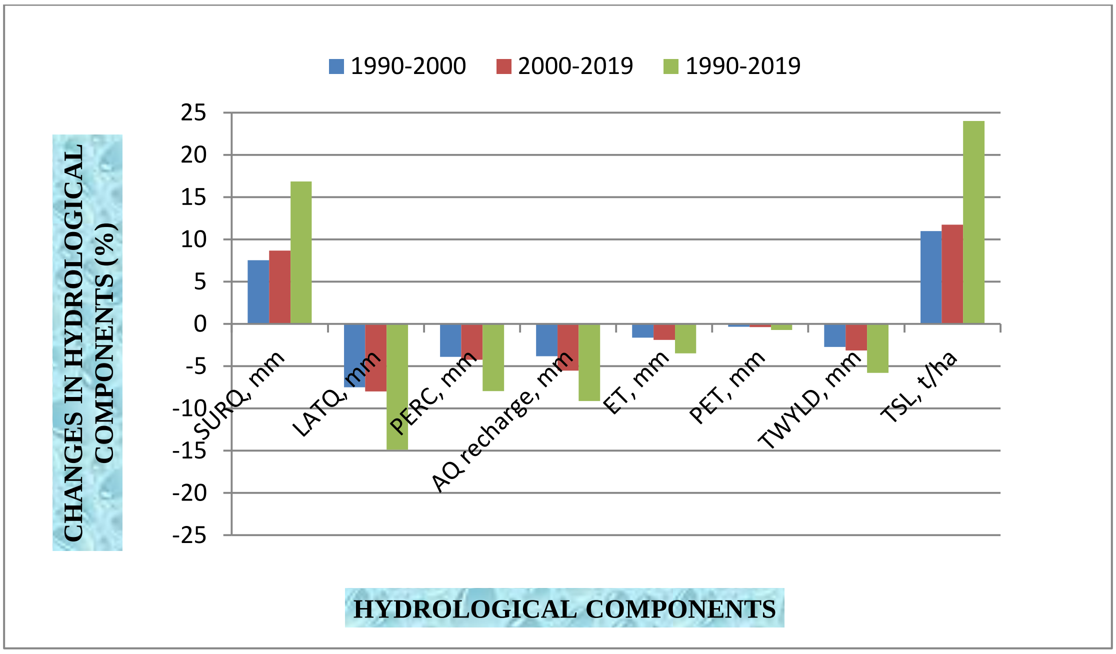

Figure 4. 11: Changes in water balance components for LULC of 1990-2000, 2000-2019 and 1990-2019

Surface runoff of the watershed increased from 202.15mm in 1990 LULC to 217.38mm in 2000 and 236.21mm in 2019 LULC. Lateral soil flow is decreased from

15.32mm in 1990 LULC to 14.17mm in 2000 and 13.04mm in 2019 LULC. percolation is decreased from 240.59 mm in 1990 LULC to 231.23mm in 2000 and to221.47mm in 2019 LULC. Total sediment load is also increased from 37.34 t/ha to 41.44 t/ha and 46.31 t/ha for LULC of 1990, 2000, and 2019 respectively. Such higher sources of sediment in a watershed include un-vegetated stream banks and uncovered soil regions, including deforested areas, and croplands. Changes in land use/cover, streamflow features, and drainage patterns can alter the natural sediment rate. Evapotranspiration is decreased from 353.8 mm in 1990 LULC to 348.10mm in 2000 and 341.52 mm in 2019 LULC. potential evapotranspiration is decreased from 1582.80 mm in 1990 LULC to 1577.34mm in 2000 and 1571.72 mm in 2019 LULC. The result of evapotranspiration and potential evapotranspiration change in small amounts from 1990 to 2019 and shows that the spatial distribution of the significant increases in ET somewhat matches fairly with the areas detected to be covered by forest and agricultural lands. Trees and plants in the forest and agricultural land take up much water for transpiration and photosynthetic purposes. Unlike forest and agriculture, the increase in settlement and bare land decreases the amount of ET.

The total water yield slightly decreased from 426.38 mm in 1990 LULC to 414.81mm in 2000 and 401.72 mm in 2019 LULC. This shows that resulting in decreasing water yield was not due to the change in evapotranspiration and potential evapotranspiration but due to the change of LULC. Whereas, the total aquifer recharge decreased from 240.57mm in 1990 LULC to 231.39mm in 2000 and 218.64mm in 2019 LULC. Total aquifer recharge was decreased due to the reduction of the percolation rate. The fall of percolation out of soil was consistent with that of deep aquifer recharge. These changes were due to the declined in land cover and increased cultivated land, built-up area, and bare land area. Covered land with natural vegetation undergoes reduced surface runoff and infiltration becomes high. For the case of urbanization, land could be paved to take water in and surface runoff increased. The soil in a cultivated area could be easily detached and transported downstream than covered land with vegetation which would be resulted in increased sediment load. Reduction of total aquifer recharge has resulted from increased surface runoff, which reduces infiltration capacity of the soil thereby; percolation of water from the soil to recharge deep aquifer is reduced. According to Abbas (Abbas *et al*., 2010), the change of land use land cover class significantly intensified the surface runoff, soil erosion, land degradation, sedimentation, siltation, drought, migration desertification loss of biodiversity, decrease in productivity and famine.

The expansion of agricultural land, built-up area, and bare land over other land cover results in the increase of surface runoff following rainfall events and causes change in soil moisture condition and groundwater storage. The water infiltrated into the ground to recharge the shallow aquifer is reduced. Therefore, the change in the components of streamflow due to LULC is expected to decrease dry season discharge which mostly comes from base flow (shallow aquifer contribution), and increase discharge during the wet months supplied from surface runoff.

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5. CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The aim of this study was to assess the impact of hydrological response to land use land cover change on awash-awash sub basin over the period (1990-2019) years by considering the land use land cover conditions of 1990, 2000 and 2019's in Awash-Awash sub- basin watershed using satellite data, which classified land use covers map performed on ERDAS Imagine 2015 were integrated with other GIS data and calibrated and validated version of the SWAT_CUP SUFI2 model.

The sensitivity analysis using SWAT model has pointed out 10 most important parameters that control the stream flow of the studied watershed. Model calibration and validation have showed that the SWAT model simulated the flow quite satisfactory. Performance of the model for both the calibration and validation watershed were found to be reasonably good with coefficient of determination (R^2) values of (0.81,0.78 , 0.82) , Nash-Sutcliff coefficients (NSE) values of (0.68,0.65, 0.74) and Percent bias (PBIAS) values of (-20.1,-21.5,-14) for calibration and (R^2) values of (0.84,0.78, 0.79) , (NSE) values (0.76,0.62 , 0.64) and (PBIAS) values of(-12,-16.7,-18.5) for validation in 1990, 2000 and 2019 respectively. Following calibration and validation of the model, impacts of the land use and land cover change on the stream flow was carried out. From the LULC change analysis, it can be concluded that the land use and land cover of Awash-Awash sub- basin watershed for the period of 1990 to 2019 showed significant changed. Forest land, rangeland and grass land decreased from the period 1990 Thus,hapend by the expense of forest land and other land cover types, the cultivated area includes areas for crop cultivation, urbanization and the scatter rural settlement that are closely associated fields dynamically and bar land increased in the period of the study (1990-2019). This might be due to the population pressure has caused a high demand for additional land use in the study area .The result of model for all periods of land use and land cover (1990, 2000 and 2019) indicated that during the wet season, the mean monthly flow increased (by 5.01%, 8.89% and 12.54%) from 1990-2000, 2000-2019 and 1990-2019 respectively . dry season mean monthly flow reduced (by 12.15%, 53.89% and 59.50%) from 1990-2000, 2000-2019 and 1990-2019 respectively.

5.2. Recommendations

Based on the study findings, the following recommendations are made:

- As mitigation measure for prevention of surface runoff and severs erosion, there should be a proper land management practices that encourage afforestation thereby, precipitation during the rainy season could be infiltrated into the ground to supply shallow aquifer (which contribute to base flow during dry months).
- Minimizing grazing lands; apply recommended farming methods (reduce number of tillage's, contour tillage, strip and pasture cropping, intercropping) with communicating concerned agricultural centers and experts.
- Controlling the growth of illegal cutting of trees, burning natural forest and charcoal making without limit, should be given attention to reduce environmental degradation in the study area.
- Further researches like impact of climate change on basin hydrology should be done.

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APPENDIX

APPENDIX-A List of Tables

Table-1 Sensitive parameters with their rang and fitted value

Rank	Parameters	Description	Range value	Fitted value
1	CN2	SCS runoff curve umber	35-98	0.0029
2	ALPHA_BF	Alpha base flow recession constant	0-1	0.31
3	GW_DELAY	Groundwater delay	0-500	41.29
4	GWQMN	Threshold depth of water in the shallow aquifer for return flow to occur	0-5000	1491
5	ESCO	Soil evaporation compensation factor	0-1	0.41
6	EPCO	Plant uptake compensation factor	0-1	0.73
7	RCHRG_DP	Deep aquifer percolation fraction	0-1	0.79
8	GW_REVAP	Groundwater revap coefficient	0.02-0.2	0.16
9	BIOMIX	Biological mixing efficie	0-1	0.14
10	SOL_Z	Depth from soil surface to bottom of layer	0-3500	1023
11	SOL_K	Saturated hydraulic conductivity	0-2000	0.39
12	SOL_AWC	Available water capacity of the soil layer	0-1	0.043875
13	CANMX	Maximum canopy storage	0-2000	57.26
14	SOL_ALB		0-0.25	0.01475
15	CH_K2	Effective hydraulic conductive of main channel	0.01-500	0.1125
16	CH_N2	Manning's "n" value for the main channel	0.01-0.3	0.002
17	SLSUBBSN	Average slope length	10-150	7.325
18	SURLAG	Surface runoff lag time	0.05-24	0.73
19	REVAPMN	Threshold depth of water in the shallow aquifer for "revap" to occur	0-500	16.875
20	SLSOIL	Slope length for lateral subsurface flow	0-150	0.33625

Table 2 Accuracy assessment of classified LULC of Awash-Awash sub-basin in 2000

2000	Reference									
classified data		FRST	RNGB	URBN	WATR	BARR	AGRI	GRAS	Total	UA%
	FRST	28	1	0	0	0	0	1	30	93.333
	RNGB	0	40	0	0	0	1	0	41	97.561
	URBN	0	0	27	0	1	0	0	28	96.429
	WATR	0	0	0	7	0	0	0	7	100
	BARR	0	0	1	0	25	0	0	26	96.154
	AGRL	0	1	0	0	0	48	0	49	97.959
	PAST	0	0	0	0	0	1	41	42	97.619
	Total	28	42	28	7	26	50	42	223	
	PA(%)	100	95.238	96.429	100	96.15	96	97.619		**OA%=97**

UA: user accuracy, PA: producer accuracy, OA: over all accuracy

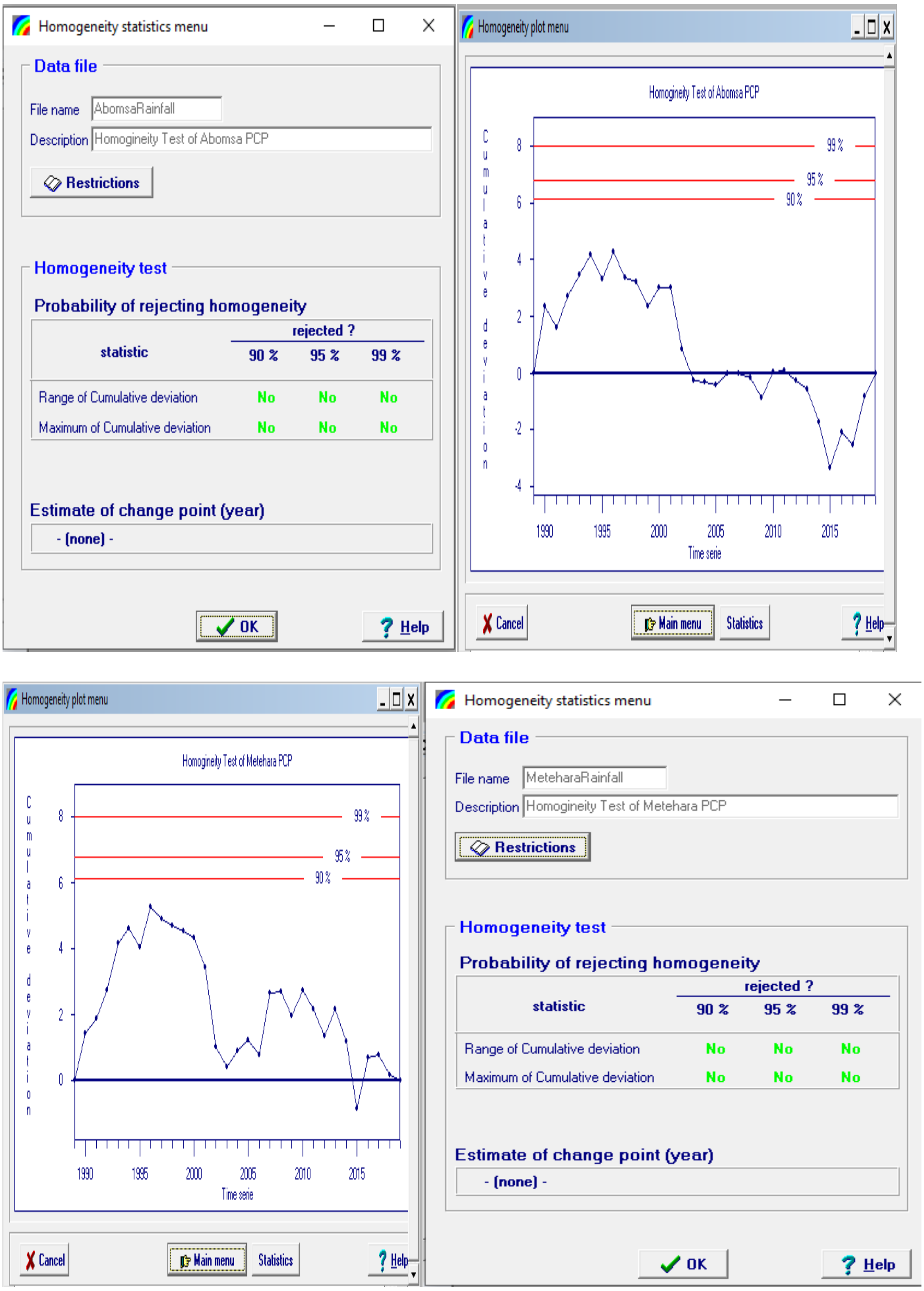
Table 3 Accuracy assessment of classified LULC of Awash-Awash sub-basin in 2019

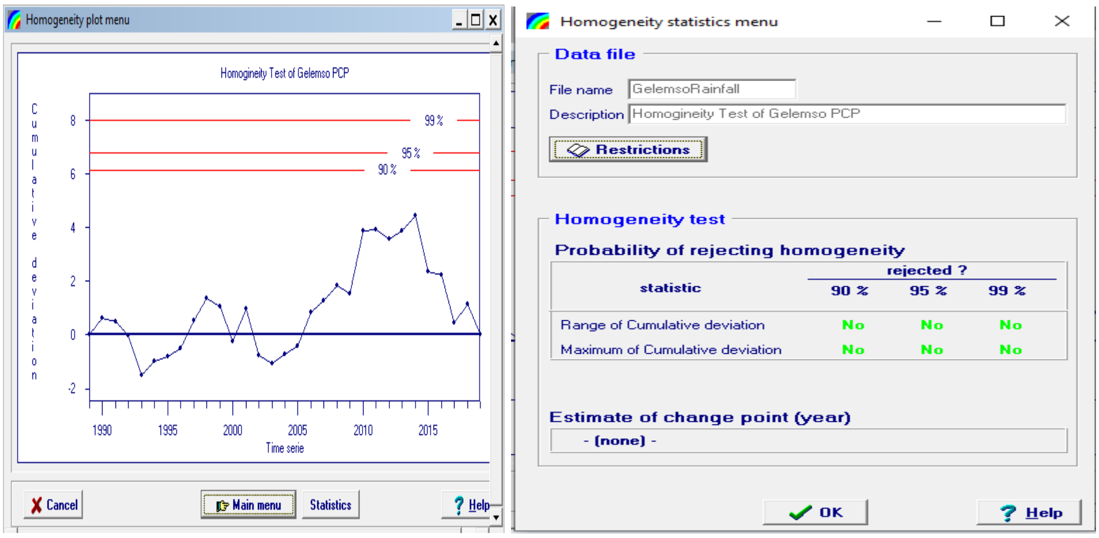
2019	Reference									
classified data		FRST	RNGB	URBN	WATR	BARR	AGRI	GRAS	Total	UA%
	FRST	28	0	0	0	0	0	0	28	100
	RNGB	0	39	0	0	0	0	1	40	97.5
	URBN	0	0	27	0	1	0	0	28	96.429
	WATR	0	0	0	6	0	0	0	6	100
	BARR	0	0	1	0	25	0	0	26	96.154
	AGRL	1	1	0	0	0	48	0	50	96
	PAST	0	0	0	0	0	1	41	42	97.619
	Total	29	40	28	6	26	49	42	220	
	PA(%)	96.6	97.5	96.429	100	96.15	97.96	97.619		**OA%=97.6**

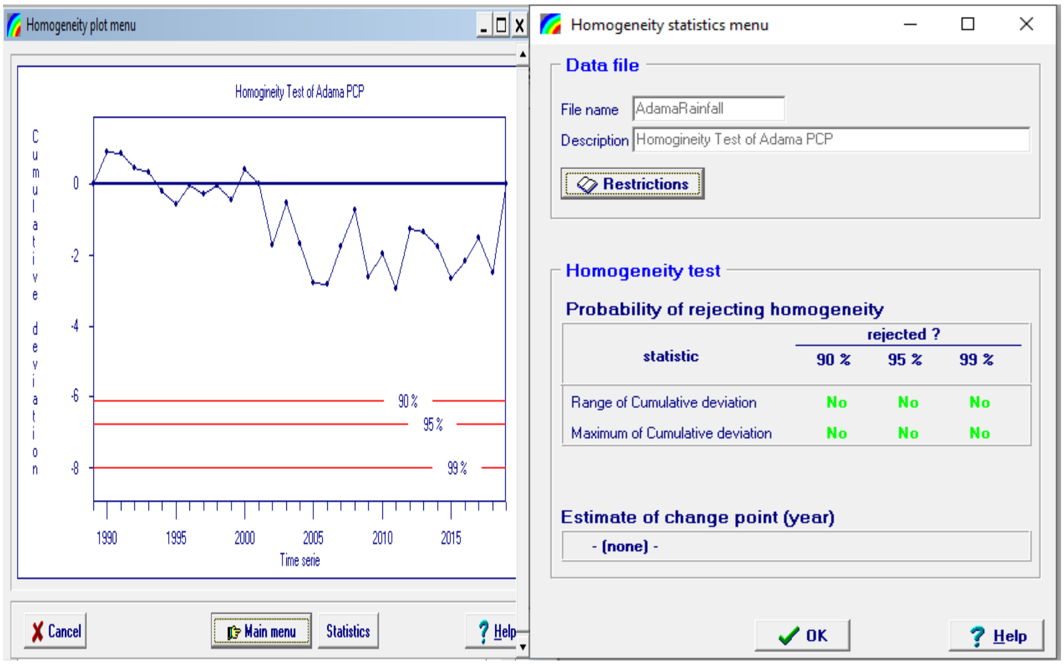
UA: user accuracy, PA: producer accuracy, OA: over all accuracy

APPENDIX-B List of Figurs

Figure-1 Homogeneity test using RAINBOW

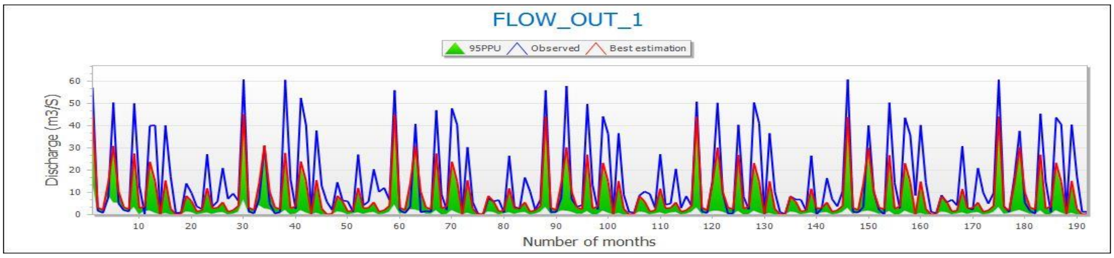



Homogeneity plot menu
Homogineity Test of Gelemso PCP
Cumulative deviation
99 %
95 %
90 %
Time serie
Cancel
Main menu
Statistics
Help
Homogeneity statistics menu
Data file
File name
GelemsoRainfall
Description
Homogineity Test of Gelemso PCP
Restrictions
Homogeneity test
Probability of rejecting homogeneity
rejected ?
statistic
90 % 95 % 99 %
Range of Cumulative deviation No No No
Maximum of Cumulative deviation No No No
Estimate of change point (year)
- (none) -
OK
Help

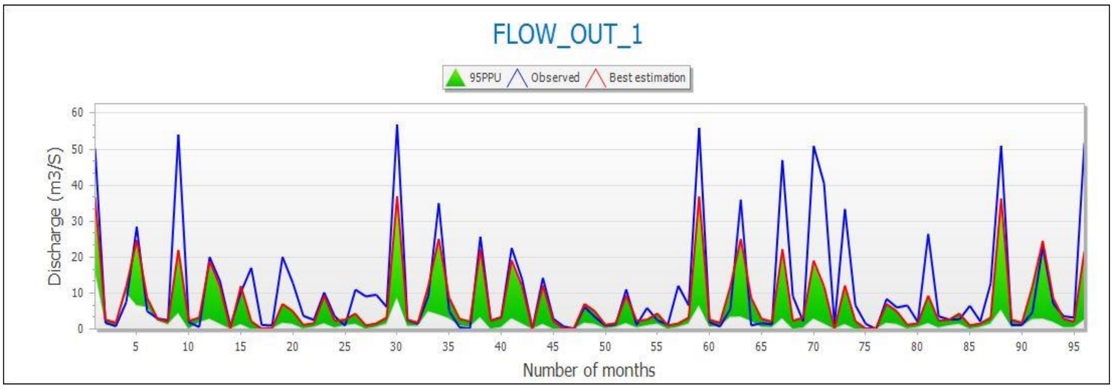

Homogeneity plot menu
Homogineity Test of Adama PCP
Cumulative deviation
90 %
95 %
99 %
Time serie
Cancel
Main menu
Statistics
Help
Homogeneity statistics menu
Data file
File name
AdamaRainfall
Description
Homogineity Test of Adama PCP
Restrictions
Homogeneity test
Probability of rejecting homogeneity
rejected ?
statistic
90 % 95 % 99 %
Range of Cumulative deviation No No No
Maximum of Cumulative deviation No No No
Estimate of change point (year)
- (none) -
OK
Help

APPENDIX C: Calibration and Validation Results.

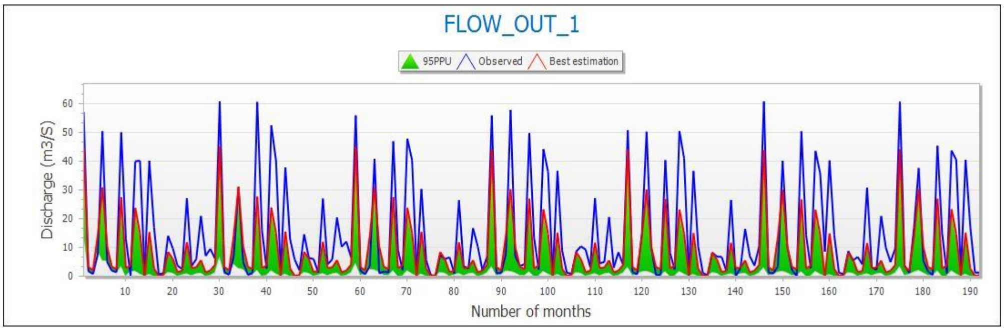
Calibrated Graph for LULC of 2000



Validation graph for LULC of 2000



Calibrated Graph for LULC of 2019



Validation graph for LULC of 2019