Jimma University

Jimma Institute of Technology

School of Graduate Studies

Faculty of Civil and Environmental Engineering

Chair of Hydrology and Hydraulic Engineering

Assessment of Land Use/Land Cover Change Impact on Stream Flow of Weyib River Catchment, Genale Dawa River Basin, Ethiopia

By Asrat Otoro

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

August, 2023

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Main-advisor: Tamene Adugna (Dr. Ing. Professor)

Co-advisor: Abdata Wakjira (MSc.)

August, 2023

Jimma, Ethiopia

DECLARATION

I, the undersigned, declare that this thesis entitled “Assessment of land use/land cover change impact on stream flow of Weyib catchment, Genale Dawa river basin, Ethiopia.” It is my original work and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used in this thesis have been acknowledged.

Candidate Name: Asrat Otoro

Signature: ____________

Date: ____/____/______

APPROVAL

As Master's Research Advisors, we hereby certify that we have read and evaluated this MSc. Thesis prepared under our guidance by **Asrat Otoro** entitled: "Assessment of land use/land cover change impact on stream flow of Weyib catchment, Genale Dawa river basin, Ethiopia."

We recommend that it can be submitted as fulfilling the MSc. Thesis requirements.

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DEDICATION

This thesis is dedicated to my family and my lovely friends.

ACKNOWLEDGMENT

First of all, I would like to praise ‘The Almighty GOD’ who enabled me to begin and accomplish this work commendably. I would like to express my emphatic gratitude to my main-advisor, Tamene Adugna (Dr. Ing. Professor) and my co-advisor, Mr. Abdata Wakjira (MSc.) for their constant follow-up and providing fruitful advices on the successful completion of my Thesis. My heartfelt thanks to be for governmental organizations of National Meteorology Agency of Ethiopia, Ministry of Water, Energy, Irrigation and Electricity, and Ethiopian Mapping Authority for offering all the necessary hydro-meteorological and spatial data, which were vital to my work. My sincere gratitude goes to Jimma University for giving the chance to me to study MSc program in hydraulic engineering and Konta Zone Administration for sponsoring of my study. Finally yet importantly, I would like to give my deepest appreciations and acknowledgements to my helpful family, relatives and friends for their never-ending concern, support and encouragement.

ABSTRACT

Globally, there has been a lot of research on land use/land cover (LULC) change, which has profound effects on both natural and human systems. In this study, Weyib watershed historical LULC changes, as well as their impacts on stream flow was assessed using Soil and Water Assessment Tool (SWAT). Spatial data (Digital Elevation Model (DEM), Soil Maps, Landsat images) and Hydro-meteorological data (Stream flow and Weather data) were input data used in this study. The DEM, soil map, and LULC map of the watershed were prepared by using Arc Geographic Information System (ArcGIS) 10.4.1 software. The LULC classification and its accuracy assessment were carried out by using Earth Resources Data Analysis System (ERDAS) imagine 2015. The investigation of changes in LULC within the watershed was implemented using satellite images (2002 and 2020). The LULC classification results indicated that, the expansion of agricultural land by 11.54% and urban areas by 3.73%. Grassland, water bodies, forests and shrub land were decreased by 6.83%, 1.09%, 2.45% and 4.98% respectively due to socioeconomic development, population growth and pressures for agricultural land needs. Using the two years (2002 and 2020) LULC maps for hydrological simulation, the SWAT model was set up and run. Then, sensitivity analysis was completed on a monthly basis using 15 flow parameters and only 8 parameters were identified as influencing the stream flow. The model calibration and validation were done from 1992 to 2002 and from 2003 to 2008 respectively and the simulation was compared with the observed data. The result showed a good match of simulation with observation with coefficient of determination (R^2) 0.94 and 0.98 and Nash-Sutcliff efficiency (NSE) 0.69 and 0.72 for calibration and validation respectively. The mean wet monthly stream flow increased by 37.49% (from 31.66m^3 /s in 2002 to 43.53m^3 /s in 2020) and the mean dry monthly stream flow decreased by 31.10% (from 18.10m^3/s in 2002 to 12.31m^3/s in 2020). Generally, the study result indicated stream flow during the wet season increased whereas during the dry season decreased because of increment of agricultural and urban area, and reduction in forest, shrub land, water body and grassland result on variation of surface runoff and ground water flow.

Key words*: ERDAS Imagine, Land Use/Land Cover, Stream Flow SWAT model, Weyib watershed.*

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ACRONYMS

AOI	Area of Interest
ArcGIS	Arc Geographic Information System
ARS	Agricultural Research Service
DEM	Digital Elevation Model
ERDAS	Earth Resources Data Analysis System
ETM	Enhanced Thematic Mapper
FAO	Food and Agriculture Organization
GIS	Geographic Information System
HRU	Hydrologic Response Unit
LULC	Land Use/Land Cover
m.a.s.l	Meters above sea level
MSS	Multi-Spectral Scanner
MWIE	Ministry of Water, Irrigation and Electricity
NMSA	National Meteorological Service Agency
NSE	Nash and Sutcliffe simulation Efficiency
OLI-TIRS	Operational Land Imager and Thermal Infrared Sensor
R^2	Coefficient of Determination
RS	Remote Sensing
SUFI	Sequential Uncertainty Fitting
SWAT	Soil and Water Assessment Tool
SWAT-CUP	Soil and Water Assessment Tool Calibration and Uncertainty Programs
TM	Thematic Mapper
UNESCO	United Nations Educational, Scientific and Cultural Organization
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WGEN	Weather Generator

CHAPTER ONE

1. INTRODUCTION

1.1.Background

Understanding the hydrological response of a watershed to land use/land cover (LULC) change is imperative for water resources management planning (Gashaw *et al*., 2018). The long-term management of the earth's surface, including changes in LULC is a crucial environmental concern that humanity must handle (Germer *et al*., 2009). LULC change in addition to ecosystem instability are key causes of global environmental change with potentially severe consequences for human livelihoods (Koneti *et al*., 2018a). Hence, hydrology and biodiversity responses are all affected by these changes. According to Gassman *et al*., (2007) between 39 and 50 percent of terrestrial ecosystems have been changed as a result of anthropogenic activity, like land use/land cover, soils, geomorphology, agricultural practice and population expansion.

Socioeconomic development, population growth and pressures for agricultural land are the key drivers of LULC changes (Tewabe & Fentahun, 2020). Like the rest of the world, East Africa is not an exception to these processes. East Africa's agriculture is predominantly rain-fed making rural livelihoods and food security extremely vulnerable to changes in water resources (Nyssen *et al*., 2004). LULC modifications in this region have led to the loss of natural forests to human settlements, urban centers, farmlands and grazing pastures (Guzha *et al*., 2018). LULC change initiated by the interaction between demographic and socioeconomic changes as well as biophysical conditions is one of the main driving forces on global and local environmental changes. Hence, it exerts multidimensional consequences on essential Earth’s ecosystem functions and services at local, regional and global scales.

In Ethiopia, LULC change is mainly dominated by the conversion of natural vegetation cover to use for agriculture activities (Negese, 2021). LULC changes are highly pronounced in developing countries that are characterized by agriculture based economy and rapidly increasing human populations caused by several natural and human driving forces. Natural effects such as climate change are only over a long period, the effects of human activities are immediate and often direct. From human factors, population growth is the most essential in Ethiopia as it is common in developing countries (Odongo, 2009).

More than 85% of the population in Ethiopia lives in rural areas and directly depends on the land for its livelihood which insight that the demands for land are increasing as the population increases (Aneseyee *et al*., 2020). The increase in population number put pressure on water resources. The LULC changes due to population increment that impact water resources are an expansion of agricultural activities and urbanization (Gorgoglione *et al*., 2020). Tillage of the land and clearing of forests can change infiltration and runoff characteristics, which affect ground water recharge, water yield and evapotranspiration (Liu *et al*., 2009).

According to Serur & Sarma (2016) evaluation of the Arc SWAT model in simulating catchment hydrology of Weyib river provided better understanding of SWAT model set-up, sensitive parameters that influence the model output, and hydrologic processes of the catchment. Since the researcher conducted only the performance evaluation of SWAT model in the Weyib watershed, I have been studied LULC change impact in Weyib watershed stream flow. According to Dechasa *et al*., (2019) the assessment of biophysical characteristics of Weyib watershed gives awareness one how to significantly describe the basic features and to use them as an input for different activities to be conducted inside the watershed. The result exhibit that this watershed does have moderate climatic condition, which is very suitable for massive agricultural production. Nevertheless, the author did not included the temporal LULC change and its impact in the watershed hydrology, so, I have conducted my study in the LULC change impact in the Weyib watershed streamflow.

According to Aredo & Hatiye, (2021) LULC changes are mainly generated by human influences on the environment and water resources in Shaya catchment, the natural environment and the hydrologic cycle equally respond to such perturbations. The combination of population growth and LULC changes has altered the stream flow of the Chemoga watershed, Abay river basin (Kassie *et al*., 2020). The impact of LULC changes on stream flow of the Wabe watershed, Omo Gibe basin was shown the impact of LULC changes on the monthly stream flow basis and the differences was assessed at the watershed outlet. Seasonal variability of watershed mean monthly stream flow at the outlet were increased as a result of an increase of agricultural land.

According to Rahman *et al*., (2012) land use/land cover change detection by aim of ERDAS Imagine shows the transformation of rural land into urban land uses leads to increase in impermeable surfaces at North-West District of Delhi watershed.

The assessment of impacts of land use changes on the hydrology in the Ketar watershed, Lake Ziway catchment applying SWAT model showed that change in hydrological process because of change in LULC (Rao, 2015). Hence, the increase in surface runoff is possible as the result of higher surface runoff contribution from cultivated areas.

1.2. Statement of the Problem

LULC changes are associated with changes in population number and rate of increase according to studies conducted in tropical regions utilizing time-series remotely sensed data. According to Urgesa *et al.*, (2016) the global population will grow from 6.8 billion in 2009 to around 9.2 billion in 2050. LULC change drivers differ across developed and developing countries, according to several researchers. Large-scale farming and urban growth are considered the primary causes of LULC changes in developed countries. Rapid economic development in India has intensified the changes in natural land cover and thus affects the availability of water resources (Samal & Gedam, 2021).

Ethiopia is a developing country with a population that has exploded in recent decades (Urgesa *et al.*, 2016). The main occupation of the rural population is mixed farming about 85 percent of the rural population relies on rain-fed agriculture for their livelihood Land practice and LULC changes in the country are a result of agricultural operations and population expansion. Since the drivers of LULC change and land management activities vary from place to place, the nature of LULC dynamics varies greatly from nation to country.

The conversion of natural vegetation cover to use for agriculture activities dominates land use/land cover change in Ethiopia (Negese, 2021). Thus, changes in land use/land cover played a significant impact in affecting hydrological processes such as increased surface runoff volumes, reduced infiltration, and decreased groundwater recharge. LULC changes are intimately linked to hydrological processes. In recent years, the country has paid more attention to the spatial and temporal changes in land use/land cover as well as their effects on hydrological processes.

The Weyib River catchment is a Multi-purpose River upon which diverse water resource schemes are involved in the flow of the river. The schemes comprise many current and future planned irrigation systems, visiting the attractions and fish agricultural at the distinct parts of the river (Hailemariam *et al*., 2016). Weyib watershed is very favorable for broad agricultural production, according to current biophysical features analysis (Dechasa *et al*., 2019). Because of the watershed high agricultural suitability, agricultural land demand rises with time resulting in LULC variations in the sub-basin catchment. The fast-growing population and the density of livestock in the Subbasin, lack of awareness of the watershed management strategies and agricultural practices on the land resources, resulting in forest clearing and overgrazing (Desalegn *et al*., 2014).

1.3. Research Questions

1. What is the change in LULC of Weyib River catchment?
2. How does the LULC change affect the Weyib catchment stream flow?

1.4. Objective of the Study

1.4.1. General Objective of the Study

To assess the impact of LULC change on the streamflow of the Weyib watershed.

1.4.2. Specific Objective of the Study

1. To investigate the temporal LULC change for two specified years.
2. To quantify the impact of land use/land cover changes on the streamflow of the Weyib River catchment.

1.5. Scope of the Study

It is desirable to limit the scope of the problem of the study to come to a manageable objective. This study was investigated the impact land use/land cover change on stream flow of Weyib watershed. The land use/land cover of watershed was identified and map of land use/land cover was prepared. Using SWAT model, the stream flow was estimated and its impact in the watershed was evaluated.

1.6. Significance of the Study

This study would be made an effort how to assess impact of LULC change on stream flow in the watershed and to differentiate LULC change drivers and cause, to identify LULC change and its impact on stream flow of watershed for researchers and stockholders.

Understanding of LULC change impact on stream flow is essential to enable local governments and policymakers to create and implement effective and suitable response plans and knowledge of how land use/land cover changes influence watershed stream flow.

In general, this research is expected to aid concerned sectors in the planning, development and management of water resource projects in the study area, as well as serve as a resource for individuals interested in additional research in relevant fields and areas of study. Therefore, for planners to develop policies and limit the negative consequences of future LULC changes for sustainable management of resources. Thus, assessing LULC fluctuations within a watershed is crucial for evaluating the amount stream flow variation of watershed.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Land Use/Land Cover Change

Internationally, land use/land cover change is as old as human kind, however, the current rate of change is not the same as what was at the beginning (Gebreslassie, 2014). A dramatic increase in the rate of change has been seen in the past few centuries. Most of the registered LULC changes were the result of the practices done to satisfy the immediate needs of a human being (Basanna, 2013). The rapid LULC changes exert detrimental and adverse impacts on the environment and livelihood human health and welfare, food security and industrial developments are dependent on adequate supplies of suitable water; however, water resources are finite in space and time and are affected by many parameters (Rao, 2015). Establishing LULC changes play an essential role in the studies of regional, local and global environmental change.

Land use/land cover are distinctive, closely associated characteristics of the Earth's surface and prominently derived from human activities (Thanapakpawin *et al.*, 2007). Land cover demonstrates the terrain features on the Earth's surface while land use reflects the utilization of available land by human beings i.e. built environment or human use of landscapes. Land cover refers to how the Earth's surface is covered by forests, wetlands, impervious surfaces, agricultural and other types of landform and water bodies. Land use refers to how human use the landscape, whether for development, conservation or mixed uses. Land use includes recreation areas, wildlife habitats, agricultural land and built up area.

Land Use/Land Cover change analysis is one of the most useful methodologies to understand how the land was used in the past years, what types of detections are to be expected in the future, as well as the driving forces and processes behind these changes (Kenea *et al.*, 2021). The land cover is directly observable in the field and by remote sensing images (Alemu, 2021). Hydrological effects of land use/land cover change manifested in many ways and at different spatial and temporal scales. Most obvious are the immediate and direct effects on the quantity and quality of the catchment stream flow. LULC change is the most significant factor driving hydrologic changes on stream flow variability.

2.2. LULC Change Studies in Ethiopia (previous studies)

Land use land cover (LULC) changes are highly exhibited in developing countries, as they are characterized by an agriculture based economy and a rapidly growing population (Kenea *et al.*, 2021). Understanding how LULC changes influence watershed hydrology will enable local governments and policymakers to formulate and implement effective and appropriate response strategies to minimize the undesirable effects of future LULC change and sustain the local socio-economic situation. In Ethiopia, LULC changes are inherently spatial and dynamic with high spatiotemporal variability resulted from complex human and environmental interactions (Yesuph & Dagnew, 2019). Current extents, rates and intensities of LULC changes are driving unprecedented changes in ecosystems functions and environmental processes.

LULC changes in Ethiopia were initiated by the interaction of various demographic, socioeconomic, institutional and biophysical factors (Shuma, 2015). Population pressure, widespread, agricultural expansion, expansion of settlement, rural poverty, inadequate management of common property resources (Negese, 2021). Thus, land contract insecurity due to institutional and policy reforms and demand for fuelwood and construction materials were recognized as the major drivers of LULC change in the country. In Ethiopia, LULC changes were registered at the local level, which enhances the changes at the national level (Gebreslassie, 2014). Most of these changes were from the natural forest to agricultural land and were due to human intervention in the natural resources of the landscape.

2.3. Land Use/Land Cover Change Impact on Hydrology

Water resources management is an important and integrated approach that includes all of the hydrological components and their linkages with one another (Koneti *et al.*, 2018b). It is very important to understand and quantify the hydrological components for the efficient planning and management of the water resources. Human modifications such as LULC change bring extreme changes to the hydrological variations. Hence, the LULC changes have a great role in influencing the hydrological cycle and assessing the hydrological components of a river basin and the impact of LULC for its efficient management of water resources is very important. In hydrologic modeling, LULC information is of great importance, as it helps to determine model variables and parameters that account for runoff (Krause *et al.*, 2005).

To determine the effects of LULC on the various processes of the earth system, an understanding of past LULC practices and current LULC patterns is required (Fathian *et al*., 2016). Water on earth exists in a space called the hydrosphere and lithosphere, circulating and forming the hydrologic cycle. The cycle has no beginning and no ending and can be affected by different factors (Kidanewold *et al*., 2014). Among those factors, manmade activities, land use/land cover change can affect hydrological processes such as infiltration, runoff and groundwater recharge.

2.4. Remote Sensing on LULC Classification

Remote Sensing (RS) is defined as the science of obtaining information about an object, area or phenomenon through the analysis of data acquiring by a device that is not contact with the object, area, or phenomenon under investigation (Devi *et al*., 2015). It provides a large amount of data about the earth surface for detailed analysis and change detection with the help of sensors. Most of the data inputs to the hydrological model SWAT are directly or indirectly extracted from remotely sensed data. Some of the important data used in the hydrological modeling that are obtained from remote sensing includes Digital Elevation Model (DEM), soil map, land sat images and LULC maps.

2.4.1. Landsat images

In the study of the impacts of LULC change on hydrological responses of catchment, remote sensing images are required and can be processed by computers to produce LULC map. In water resource engineering, the mapping of LULC map in a wide area catchment, remotely sensed images plays a paramount role (Gilbertson *et al*., 2017). The long archive period of Landsat images offers researchers a chance to gain insights into past trends, which are important when monitoring LULC changes.

Landsat images are used to solve problems of having inadequate information on the quality and quantity of resources, especially in developing countries (Zhe Zhu, 2006). Furthermore, studies, which cover larger areas, can be costly if commercial satellite images are used; however, the free access to Landsat images offers opportunities to researchers who cannot afford commercial satellite images because of the higher prices. This solves the problem of many resource constrained researchers as these images can be accessed free of charge.

Landsat images are constantly improving due to new generations of satellites being launched with new and improved sensors. The improvements are mainly defined by the richness in spectral, spatial, radiometric and temporal resolution. Landsat MSS images have a spatial resolution of 60 m, a radiometric resolution of 6 bits and spectral resolution of four bands and Landsat TM, ETM+ and OLI have spatial resolutions of 30 m (Ahmed *et al.*, 2022) Landsat TM, ETM+ and OLI have a radiometric resolution of 8 bits, 9 bits and 12 bits respectively. With respect to spectral resolution, Landsat TM has seven bands and ETM+ has eight bands.

2.4.2. Application of ERDAS imagine on LULC classification

Earth Resources Data Analysis System (ERDAS) Imagine software performs the classification of an image for identification of terrestrial features based on the spectral analysis. ERDAS Imagine software package is a simple and useful tool for visualizing and manipulating geographic imaging data (AL Kinani, 2015). ERDAS Imagine was one of the first commercial software packages to offer the graphical geospatial data modelling tool model maker for workflow.

The next generation of spatial modeler was released in ERDAS Imagine. Spatial model editor had a modern interface and new modern graphic elements. The editor provided a real time preview of results, incorporating geo media vector and grid operators. Since changes in the LULC are dynamic and continuous, LULC classification by ERDAS plays a vital role in planning and supervising the utilization of the natural resources based on the gradual increase in the human demands in the current ecosystem (Chepkochei, 2011).

The classification and identification of the changes in LULC by using ERDAS Imagine in a given catchment is mandatory to assess the impact of LULC changes on catchment stream flow. Accuracy assessment is an essential step after image classification. After generating the classified images, the accuracy of the classified images should be determined using the ERDAS Imagine software (Vivekananda *et al.*, 2021).

2.5. Hydrologic Models

Hydrologic modeling is commonly used to simulate runoff and subsequent stream flow from watersheds (Yuan *et al.*, 2015). Stream flow estimations may be used for a variety of purposes, such as the design of hydraulic structures, the prediction of flood stages, and ecological restoration design (Salunkhe *et al.*, 2013).

While useful for understanding the overall system, a simulation model is a simplification of the actual watershed. The nature of the model and the simplification involved in model formulation partially determine model applicability to both common and advanced hydrologic modeling tasks. Modeling the effect of temporal variability of land resources and basin characteristics on stream flow requires the use of distributed or semi-distributed hydrologic models (Khakbaz *et al*., 2012).

Hydrologic modeling has proved to be a very important tool that can be applied to understand and explain the effects of LULC change on the hydrologic response of the watershed (Jr & Whittaker, 2008). Hydrological models are mathematical descriptions of components of the hydrologic cycle (Ye *et al*., 2008). They have been developed for many different reasons and therefore, have many different forms. Hydrological models are in general designed to get a better understanding of the hydrologic processes in a watershed and how changes in the watershed occurred as a phenomenon, and for hydrologic prediction. They are also providing valuable information for studying the potential impacts of changes in land use/land cover.

There are many classifications of hydrologic models deterministic versus stochastic, lumped versus distributed. Based on the process description, the hydrological models can be classified into three main categories (Daggupati *et al*., 2015).

Lumped Models: The basin is solely evaluated at the outlet since the parameters of lumped hydrologic models do not vary spatially within the basin; hence, the response of each sub-basin is not explicitly taken into account.

Lumped models are frequently expanded to address challenge hydrologic issues that may be beyond their scope. The LULC study used to distinguish how well lumped and distributed models can examine a typical watershed development problem (Younis & Ammar, 2018). The parameters typically involve some degree of empiricism and frequently do not accurately describe the physical characteristics of hydrologic processes. Typically, these models cannot represent event-scale processes. These models can produce just as accurate simulations as complex physically based models if the focus is only on discharge prediction.

Distributed Models: Distributed models completely permit parameter variations in space at the user-selected resolution.

The goal of the distributed model technique is to combine information on the spatial distribution of factors along with computer tools to assess how this distribution affects the behavior of simulated precipitation runoff (Khakbaz *et al.*, 2012). The distributed model claims that it performs equally or better than the lumped model, especially for extremely variable basin characteristics.

Semi-Distributed Models: Ideally, semi-distributed hydrologic models offer spatially relevant water resources management options in addition to streamflow simulations that are superior to lumped. The spatial distribution of model parameters raises issues related to calibration approach and parameter identification (De Lavenne *et al.*, 2016). Through dividing the basin into a few smaller sub-basins, semi-distributed model parameters are partially permitted to vary in space. The fundamental benefit of these models is that they require fewer input data than fully distributed models and have a structure that is more physically based than lumped models and SWAT is considered a semi-distributed model.

2.5.1. Hydrological Model Selection Criteria

Hydrologic model must correctly reflect changes in land use and agricultural management and their effects on stream flow and with characterized important hydrologic modeling performance like computational efficiency; high spatial detail; readily available inputs; continuous-time representation; the ability to simulate land management scenarios; and the ability to provide reasonable results (Fukunaga *et al.*, 2015). Determining the model to use for a watershed in any modeling session is a problem in many hydrological investigations.

When selecting a model, the modeler's are not solely reliant on its predictive performance but will also take into account the modeler's preference and familiarity in using particular models, the aim of the modeling task, the time available to develop, apply a model and the level of accuracy required. In addition to these issues, significant attention is also paid to the performance of the model when applied to a specific catchment (Serur & Sarma, 2018). Assessing the relative performance of competing models can be difficult given the limited data that are often available. Numerous criteria can be utilized to select the best hydrologic model. Because, each project has its own set of objectives and needs, these criteria are always project specific. Furthermore, several criteria, such as a personal taste for graphical user interface, computer operating system, input out management system and structure are user dependent.

2.5.2. SWAT Model Development and Interface

A SWAT interface compatible with ArcGIS was released at the 2006 Potsdam conference by R. Srinivasan (Williams *et al.*, 2008). The SWAT model is a physically based, watershed-scale model operating on a daily time step. It was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land uses and management conditions over long periods.

Arc SWAT has been extensively used to investigate water resource problems for a range of scales and environmental conditions across the globe. It also contributes to understand complex ecosystems as well as water availability, water quality, climate change and agricultural production issues across the world. Several tools have been developed to enhance the application and development of the SWAT modeling effort. ArcGIS have been successfully integrated with the SWAT model to collect, manipulate, visualize and analyze the inputs and outputs. ArcGIS interface is a key tool in driving the widespread adoption of the SWAT model (Dile *et al.*, 2016).

2.5.3. Application of Hydrological Model SWAT

There is an imperative need to address Earth's water resource situation by developing durable socio-political and economic strategies to promote sustainable water resource use (Yin *et al.*, 2017). The known linkages between water (quantity and quality) and LULC must be addressed in the quest for sustainability. Land use planning on watershed management affects various physical processes that directly affect the environment and ecosystems and it provides a framework for integrating knowledge and perspectives on social and natural sciences into planning, policy and decision-making (Anaba *et al.*, 2017).

Computer based hydrologic models are essential tools for water resource planning, development and management because they enable long-term simulations of the effects of watershed processes and management activities. Hydrologic model must have important characteristics to simulate different land management scenarios, able to produce realistic findings, accurately reflect changes in LULC and how they affect stream flow. The implementation of this models often requires the integration of GIS, remote sensing and multiple databases for the development of the model input parameters analysis and visualization of the simulation results (Fukunaga *et al.*, 2015).

2.6. SWAT Calibration and Uncertainty Procedures (SWAT-CUP)

Distributed watershed models support more and more decision-making in LULC change and calibration and uncertainty analysis should be performed on these models (Resources *et al*., 2016). Different programs are introduced to perform parameter calibration and uncertainty analysis. One of the programs being used at the moment by several researchers is SWAT-CUP. Since SWAT-CUP is in the public domain, it is possible to link any calibration, uncertainty or sensitivity to SWAT.

SWAT-CUP link the Markov Chain Monte Carlo (MCMC), Sequential Uncertainty Fitting (SUF2), Parameter Solution (Parasol), Generalized Likelihood Uncertainty Estimation (GLUE) and Parasol techniques to SWAT modeling (Abbaspour *et al*., 2010). SWAT-CUP makes possible for SWAT models to undergo sensitivity analysis, calibration, validation and uncertainty analysis. SUF2 method determines uncertainty through the sequential and fitting process in which iteration and unknown parameter estimates are achieved before the final estimate.

2.6.1. Parameter Sensitivity Analysis

In SWAT modeling, process based input parameters must be kept within a reasonable uncertainty range (Shawul *et al*., 2013). Finding the most sensitive parameters for a particular watershed is the first stage in the calibration and validation process in SWAT simulation. Sensitivity analysis is the process of determining how quickly model output parameters change in response to changes in model inputs. It is necessary to identify key parameters and the parameter precision required for calibration through sensitivity analysis and this is the first step helps to determine the predominant processes for the component of interest.

In SWAT simulation, two types of sensitivity analysis are generally performed: local (by changing values one at a time) and global (allowing all parameter values to change) (Healy & Essaid, 2012). The two analyses, however, may yield different results. The sensitivity of one parameter often depends on the value of other related parameters; hence, the problem with the one-at-a-time analysis is that the correct values of other parameters that are fixed are never known. The disadvantage of the global sensitivity analysis is that it needs a large number of simulations. Both procedures, however, provide insight into the sensitivity of the parameters and are necessary steps in model calibration (Asl-Rousta *et al.*, 2018).

2.6.2. SWAT Model Calibration and Validation

Calibration is an effort to better parameterize a model to a given set of local conditions, thereby reducing the prediction uncertainty (Narsimlu *et al*., 2015). Calibration is to measure the agreement between the simulated and the observed (typically gauged streamflow) data by evaluating one or more objective functions. Model calibration is performed by carefully selecting values for model input parameters (within their respective un-certainty ranges) by comparing model predictions (output) for a given set of assumed conditions with observed data for the same conditions. Calibration is an important step for the applicability of hydrological models as different parameter sets could produce similar results.

The final step in SWAT simulation of stream flow of watershed is validation for the component of interest (Moriasi *et al*., 2015). Model validation is the process of demonstrating that a given site specific model is capable of making sufficiently accurate simulations, although sufficiently accurate can vary based on project goals. Validation involves running a model using parameters that were determined during the calibration process, and comparing the predictions to observed data not used in the calibration.

2.6.3. Model Performance Evaluation

To assess the effectiveness of the model offer standards for model evaluation that quantify the accuracy of watershed modeling (Zhu & Li, 2014). The measured and simulated data were compared statistically and visually for evaluation. The graphical approach provided an initial overview and the statistical criteria used to evaluate the performance of the model. The ratio of the square of the difference between the observed and simulated values and the variance of the observations is a deviation from the unit that is described by the Nash and Sutcliffe simulation Efficiency (NSE) (Wu & Johnston, 2007). The coefficients have values ranging from minus infinity to one, with one denoting full agreement between the simulated and observed data. The lesser fit between the simulated and observed data is indicated by a smaller NSE value. The average of the observational data offers a better fit to the data than the simulated data, which can be seen as a negative value of the NSE.

The percent bias (PBIS) stated as a percentage describes the tendency of the simulated data to be greater or smaller than the observed data. Zero is the ideal PBIAS value and low numbers show that the model simulation is successful (Ngondo *et al*., 2022).

Positive numbers show the model tendency to underestimate, whereas negative values show the model's tendency to overestimate. Coefficient of determination (R^2) indicates the linear relationship between simulated and observed data and it ranges from zero (poor) to one (good) (Kiros *et a*l., 2015). By comparing simulated and observed variables, hydrologic model behavior and performance are frequently assessed and discussed. At the catchment outflow, comparisons between simulated and observed streamflow are common.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Descriptions of the Study Area

3.1.1. Location

Weyib watershed is found in the southeastern part of Ethiopia and it is located between 7°0'-7°20' N latitudes and 39°20'-40°40' E longitudes. It has a total basin area of 4152.68 km^2. The Weyib River originates from the northerly sides of the Bale Mountains and first flows generally northeastwards then flows east and southeastwards for the remainder of its course (Abdulkerim *et al*., 2016). It initiates from an elevation of 4356 m (m.a.s.l) in the Bale Mountains extreme points to an elevation of 1441 m at the outlet. Finally, it joins with Genale and Dawa Rivers near the Ethiopia-Somalia border to strengthen its journey to the Somali lowlands (Dechasa *et al*., 2019).

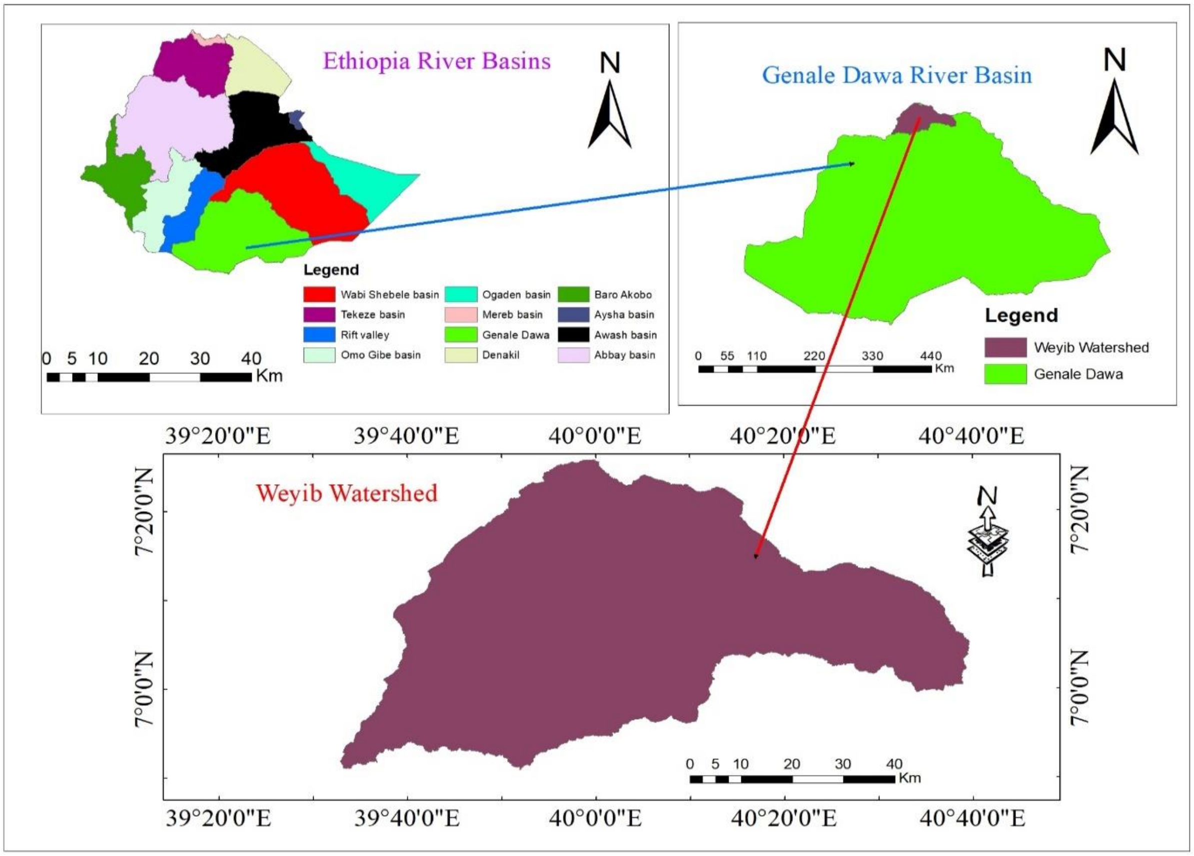

Figure 3-1: Location of the study area

3.1.2. The Climate of the Study Area

The five climatic zones are indicated by the conventional categorization system, which is the most widely used classification scheme (Roth & Lemann, 2016). The system classifies as Wurch (cold climate, altitude>3000m), Dega (temperate climate, altitude 2500-3000m), Woina Dega (warm climate, altitude 1500-2500m), Kola (hot and arid climate, altitude<1500m) and Bereha (hot and hyper-arid climate) (Duan *et al.*, 2019).

Since the Weyib watershed is found between the elevation of 4356m high altitude and 1441m low altitude, the watershed comprises all climatic zones classified as conventional. In the Weyib watershed, rainfall is distributed differently in low land areas compared to higher altitudes in mountainous areas. The average rainfall of the study area ranges from 874.99mm to 1391.34 mm and a mean of 1133.16mm per annum and the mean annual rain fall data of watershed were shown in tabular form in appendix-1. The mean annual maximum and minimum temperature of the study area is 22.69°C and 7.53°C respectively. The study area has a 16.20°C average annual maximum temperature and 13.92°C minimum temperature and the whole temperature data values were shown in appendix-2.

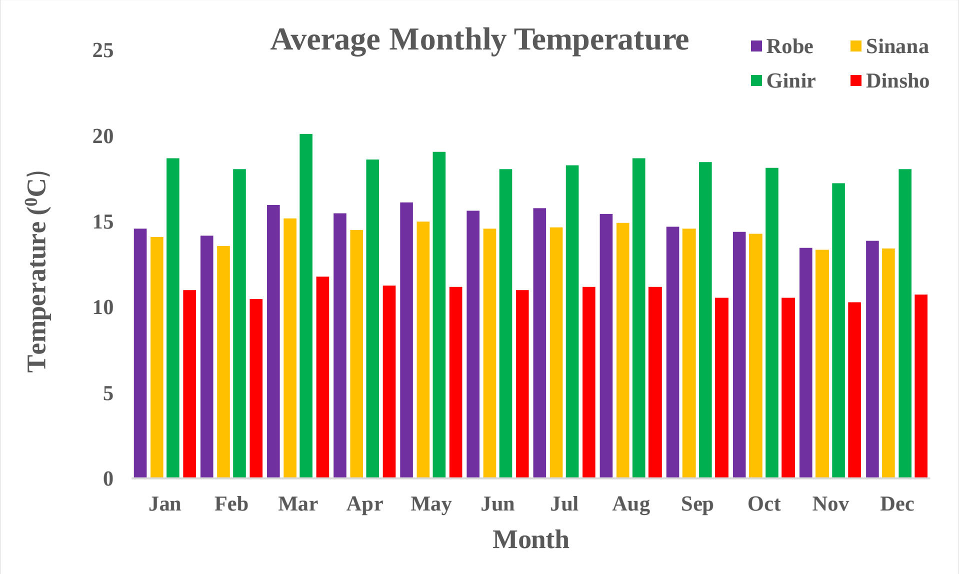

Figure 3-2: Average monthly temperature of all stations (1990-2020)

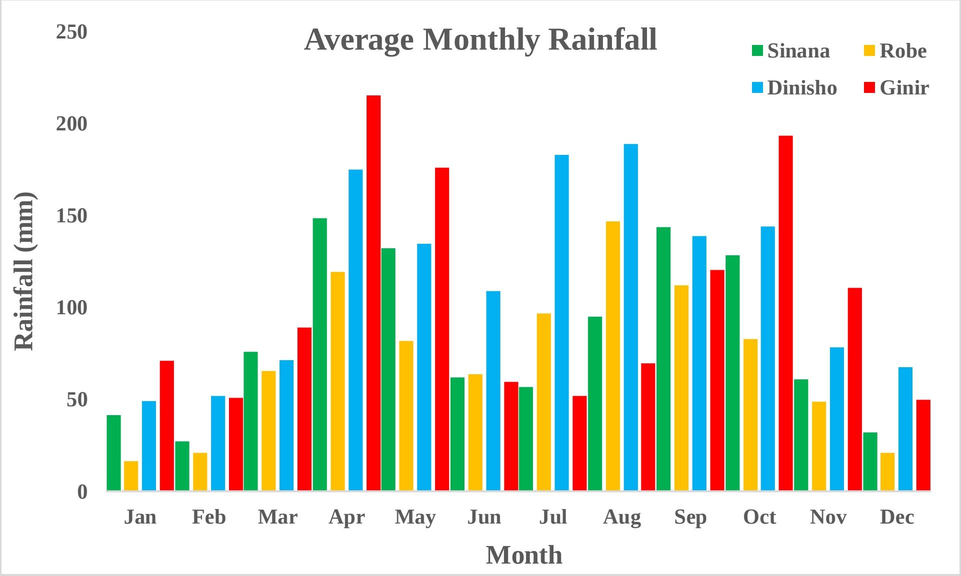

Figure 3-3: Average monthly rainfall of selected stations (1990-2020)

3.1.3. Land Use/Land Cover (LULC)

The LULC is one of the important spatial data that characterizes the catchment (Use *et al.*, 2018). This parameter is dynamic as LULC may change both spatially and temporally. Land use/land cover have a major impact on runoff generation of the watershed (West & Nile, 2019). Therefore, LULC classification is mandatory to assess the impact of land use/land cover change on the stream flow. The dominant land use in the Weyib watershed is agriculture (Serur & Sarma, 2018). The watershed is intensively cultivated, different crops are grown and the watershed provides water for domestic (rural and urban water supply) and agriculture sectors. The LULC classes of 2002 and 2020 over the study area was shown in the figure 4.3.

3.1.4. The Soil of the Study Area

In the investigation of the effects of change in land use/land cover on watershed hydrological components, soil data plays an important role. One of the key inputs to the SWAT model of the watershed is information on the soil characteristics. The soil data needed can be divided into physical and chemical characteristics. This consist of properties such as available water content, soil texture, hydraulic conductivity, bulk density and organic carbon content for different layers of each soil type. They play a great role in determining the movement of water and air within the hydrologic response units (HRU).

The study area, soil raster data set and the relevant soil data were obtained from the Ministry of Water, Irrigation, and Energy (MWIE) based on FAO/UNESCO soil classification system.

3.2. Software and Materials used

The Soil and Water Assessment Tool (SWAT) model was used for the hydrologic simulation. It is a semi-distributed model that can be used to simulate the effects of land management practices on water, sediment, nutrients and other factors at the scale of a watershed. It needs specific input data, such as meteorological, hydrological and spatial data. The spatial data were processed using a geographic information system, which also served as the SWAT model interface.

Table 3.1: Software used

No.	Software	Use
1	Arc SWAT	To delineate watershed boundaries and model watershed hydrological parameters
2	ERDAS Image 2015	Image classification and accuracy evaluation for Landsat images processing
3	SWAT_CUP 12	To assess the sensitivity, calibrate, validate, and verify the results of the SWAT
4	ArcGIS10.4.1	To prepare a map and organize spatial data
5	XLSTAT 2016	To complete the gaps in hydrological and meteorological data
6	Google Earth Pro	To impart and take current watershed information
7	Excel spread sheet	Data preparation for pre and post-processing.
8	WGEN	To prepare weather data for the SWAT database

Table 3.2: Types of data, use and source of data

No.	Data type	Use of data	Source of data
1	DEM	To delineate catchments and estimate its characteristics	Ethiopian Mapping Authority
2	Meteorological data	Precipitation, Maximum and minimum Temperature, Solar Radiation, Wind Speed and Relative humidity	NMSA
3	Soil data	To incorporate the soil map into the user's soil database in the SWAT model	Ethiopian Mapping Authority
4	Hydrological data	Stream flow of the watershed for calibration and validation	MWIE
5	Landsat images	To processing of LULC classification	USGS Website
6	LULC data	To incorporate the LULC map into the SWAT crop database with the SWAT model	By classifying

3.3.Methodology

The general study process was depicted in figure 3.4 below from data collection to comparison of simulation outcomes.

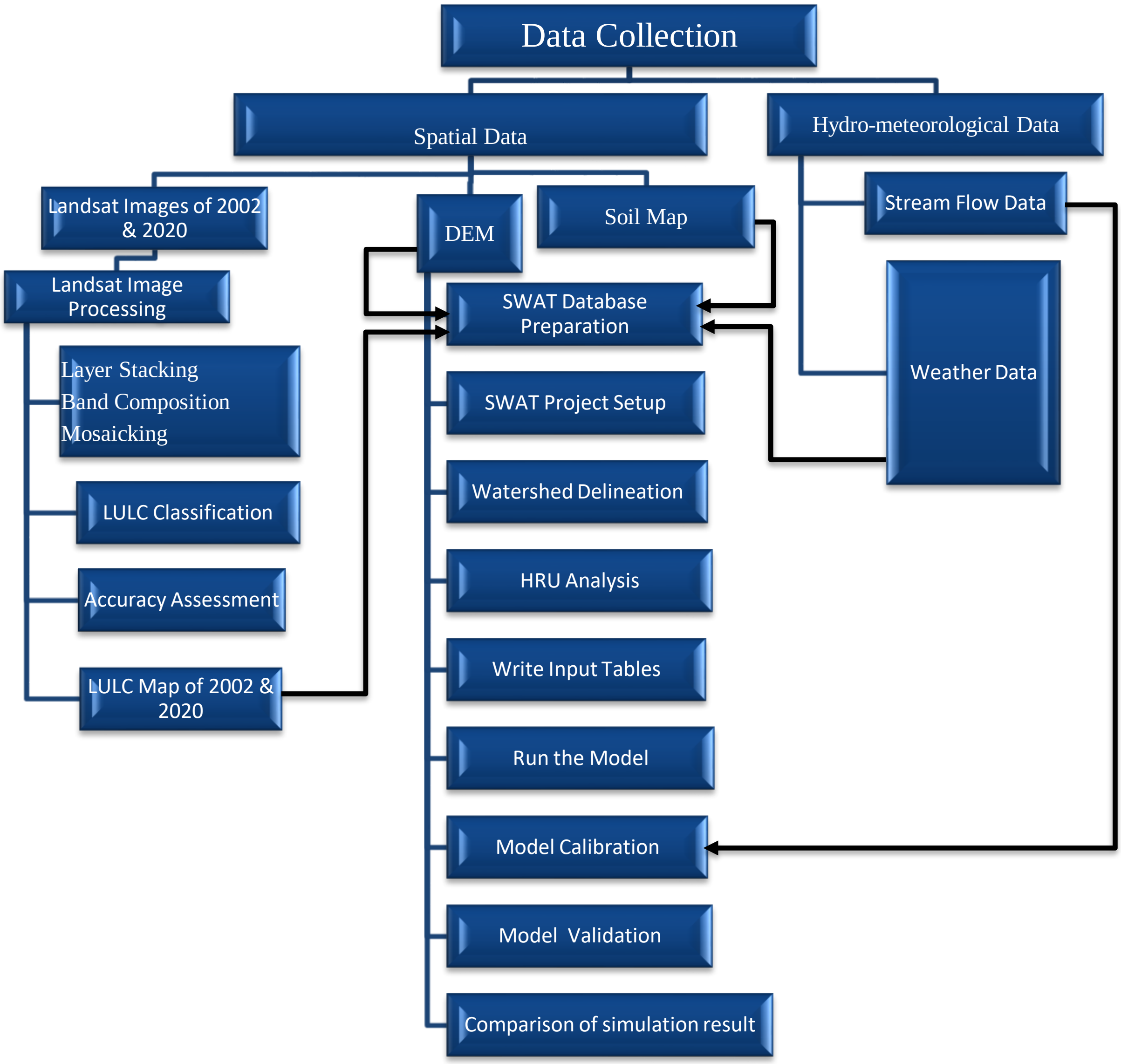

Figure 3-4: Framework of the Study

3.4. Data Collection and Analysis

3.4.1. Spatial Data

Digital Elevation Model (DEM): The SWAT uses the DEM as one of the input variables to divide the watershed into various sub-basins and to define the drainage pattern of the watershed, stream length and slope and width of channels of the watershed. DEM explain homogeneous regions and the distribution of terrain components that contribute to the spectral response (Galata *et al*., 2020). To delineate the SWAT watershed, the Ethiopia river basin DEM was clipped to form the Weyib Watershed DEM 30*30m. The raw data was then processed and projected to UTM Zone 37N.

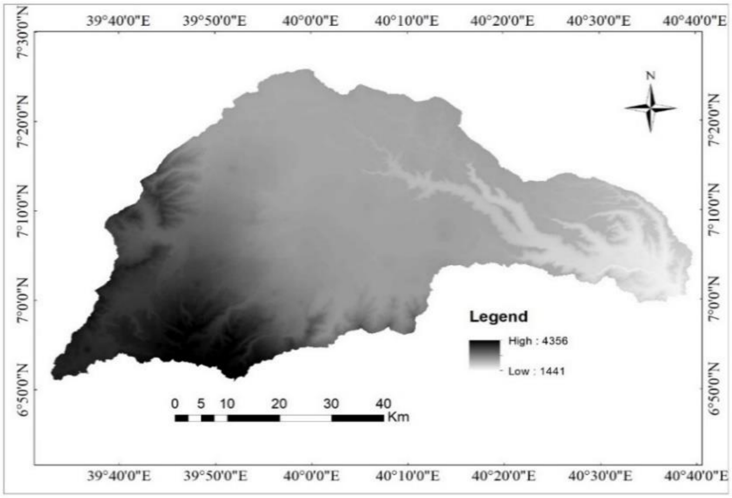

Figure 3-5: DEM of Weyib watershed

Soil Map Preparation: One of the key elements influencing watershed response to stream flow is soil characteristics. Soil with its physical and chemical properties is needed as input data for the SWAT model. A user soil database was created and added to the SWAT user soil databases to link the soil map with the SWAT model. The Weyib watershed soil map comprises 7 major soil groups (Chromic Cambisols, Chromic Luvisols, Eutric Cambisols, Eutric Vertisols, Haplic Nitisols, Humic Nitisols and Lithic Leptosols) were identified from FAO/UNESCO soil classification system and the most part of watershed area is dominated by Eutric Vertisols.

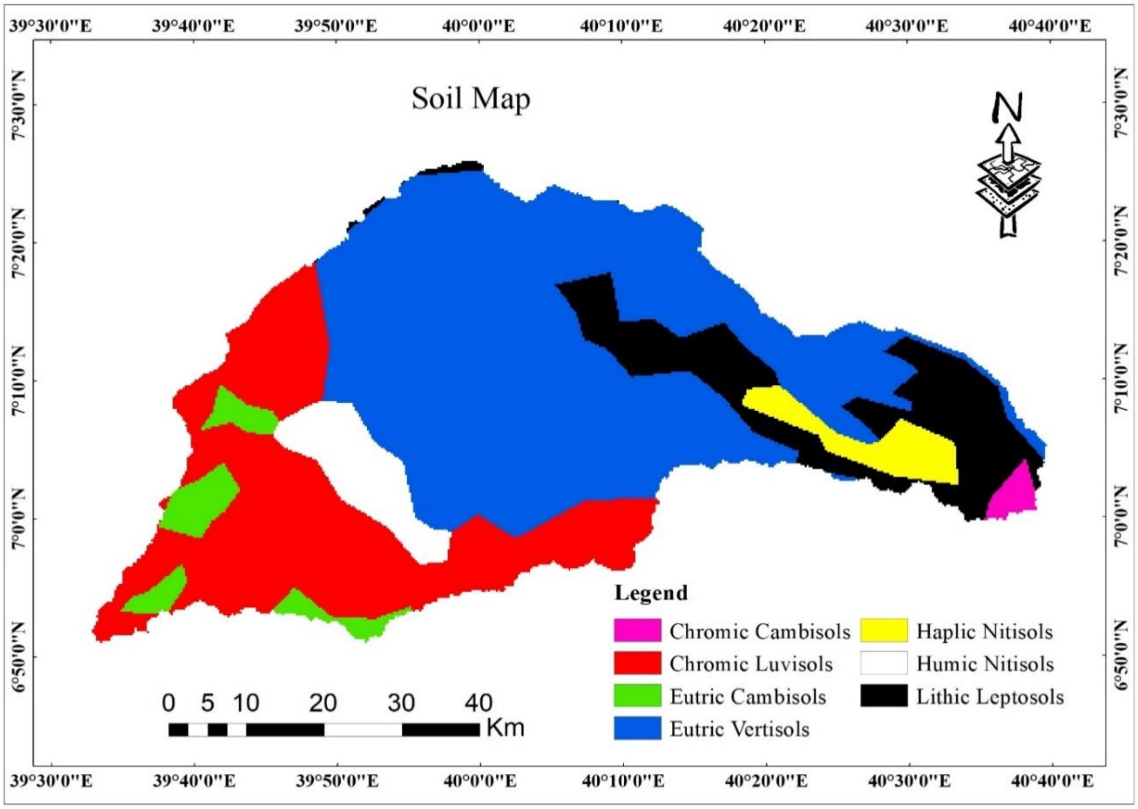

Figure 3-6: Soil map of the Weyib watershed

Table 3.3: Soil group distribution in the Weyib watershed

S/N	**Soil Classification**	**SNAM**	**Area (km^2)**	**Area (%)**
1	Chromic Cambisols	CHCAMBISOLS	29.36	0.72
2	Chromic Luvisols	CHLUVISOLS	1036.66	24.96
3	Eutric Cambisols	EUCAMBISOLS	148.54	3.58
4	Eutric Vertisols	EUVERTISOLS	2124.54	51.16
5	Haplic Nitisols	HPNITISOLS	121.77	2.93
6	Humic Nitisols	HUNITISOLS	187.30	4.51
7	Lithic Leptosols	LTLEPTOSOLS	504.18	12.14
	Total		**4152.68**	**100**

Land use/land cover map: The mapping of land use/land cover map in a large area watershed by using remotely sensed data plays a crucial role in the assessment of land use/land cover influence on the water resources.

Landsat Images Processing: Researchers have the opportunity to learn about historical trends that are important for observing changes in land cover because of the lengthy archive duration of Landsat images (Deng *et al*., 2019). Selecting the right Landsat images is crucial, however, due to the particularities of the sensors at a given time and data gaps in the Landsat archives, researchers will encounter several restrictions (Phiri & Morgenroth, 2017).

The quality of the image, particularly for those with no cloud cover was taken into consideration while choosing the Land satellite image date in order to eliminate seasonal variations in land coverage. As a result, the images were nearly cloud-free and taken during the same seasonal period. Every Landsat was georeferenced using the WGS-84 datum and Zone 37N of the UTM.

The two Land satellite image of 2002 and 2020 generated from the Landsat OLI-TIRS and ETM imaginary classification of respective years. The images were processed using the ERDAS Imagine 2015 program, which also performed the satellite image stacking and composition for each band and clip the research area from the images.

During land sat image processing, Landsat-8 and Landsat-7 images were used for mapping the LULC map of the Weyib watershed and the Land sat images of 2002 and 2020 were downloaded from the United States Geological Survey website (https:earthexplorer.usgs.gov) in GeoTIFF file format. The quality of the image had an effect on the selection of the Land sat satellite image dates.

Table 3.4: Characteristics of Landsat satellite images

Spacecraft ID/Sat name	Path/row	pixel Size(XY)	Datum/UTM Zone	Output format	Sensor ID	Date Acquired
Landsat-8	168/55	30m * 30m	WGS 1984/37N	GeoTIFF	OLI-TIRS	18/03/20
Landsat-7	167/55	30m * 30m	WGS 1984/37N	GeoTIFF	ETM	07/02/02

The images were corrected using preprocessing techniques such as layer stacking, mosaicking and band color mixing. Each band stacking and mosaicking satellite image was completed.

The research area was then clipped from the mosaicked images in order to more clearly realize the surface features and to perform color composition on the satellite images. The first step in image stacking was opening the original image in the Viewer in ERDAS Imagine window. The next step was to select Open Raster Layer from the File menu in the Viewer. In the Open File dialogue, the image and signature files of the classified image were opened. Each classification can be viewed selecting opacity of all other signatures.

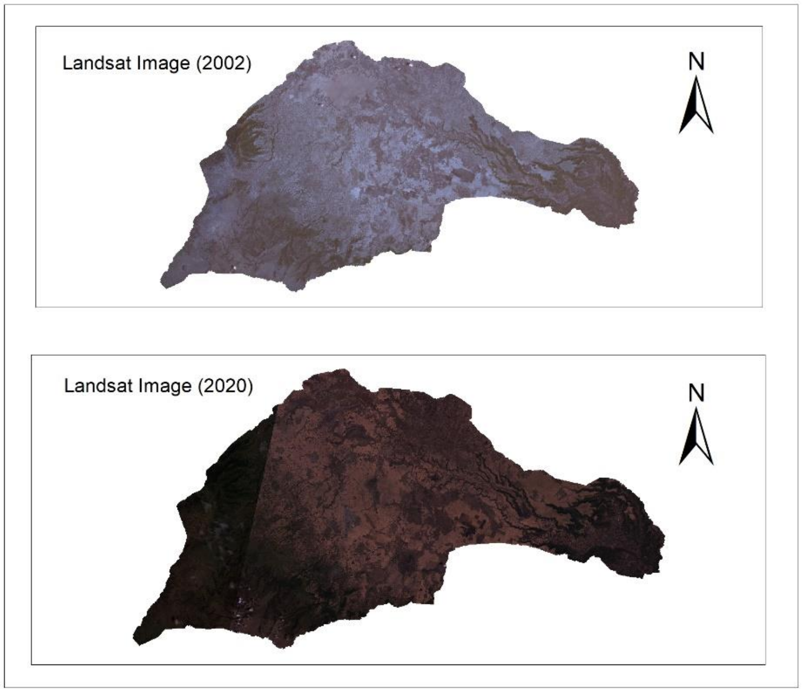

Figure 3-7: The composite bands of satellite images of (2002-2020)

3.4.1.1. Image Classification

The image classification process is the automatic classification of all pixels in a picture into LULC classes or themes (Saha *et al*., 2005). Using image classifiers depends on the type of data being analyzed, the computing power available, and the intended use of the classified data. Unsupervised classification and supervised classification are the two categories under which images can be classified (Gilbertson *et al*., 2017). Unsupervised classification i used to classify the pixels in a data set based solely on statistics (Kassawmar *et al*., 2018). Supervised Classification allows the user to define certain signatures from which the image is classified.

The first step in Supervised Classification was opening the Signatures Editor from the Classifier Menu. After opening the Signature Editor, the image being classified was opened using the Viewer. Once the file was opened in the viewer, we selected the areas that defined the signatures. In order to do this, the Polygon Tool from the Attributes Editor was used. Using the Polygon Tool and by zooming in and out of the image, we selected specific areas of the image where the features were known. Once select an area of known characteristics, then selected class added to the signature editor by using the add signature button, and the signature labeled with the name of the feature. After several features were identified, the signatures were saved as a signature file (*.sig). The image was also saved as an image file (*.img). In order to view, the classified image both the image file and the signature file was opened in the Viewer.

The training sites were selected in agreement with the Land sat Image and Google Earth pro. Finally, the Weyib watershed LULC was classified into six LULC classes.

3.4.1.2. Accuracy Assessment

The accuracy assessment stage is the last step in the classification process for satellite images. Accuracy evaluation involves selecting a sample of sites that are either visited in the field or based on prior research. Then, for the same location, the land use/land cover discovered in the field are compared to those that were mapped in the image. The accuracy assessment statistical error matrix for the full study region can then be derived. The generated error matrix can be used to identify certain land cover types for which mistakes are more than anticipated. The rows of the matrix indicate the number of pixels per class for the classed images, while the columns of the matrix show the number of pixels per class for the reference data. To evaluate the classification, various statistical accuracy metrics, including overall accuracy, user’s accuracy, producer’s accuracy and kappa statistics were produced.

The accuracy of LULC classification can be evaluated by using statistical accuracy measures, including overall accuracy, Producers’ accuracy and Users’ accuracy and Kappa statistics

Overall accuracy: Offers the overall results of the confusion matrix. It is the ratio of the total number of correctly classified pixels (diagonal) to the total a number of reference pixels. **Producers’ accuracy**: Expresses us how well a certain area can be classified and which is the probability of a reference pixels being classified correctly.

It gives only the proportion of correctly classified pixels. It is obtained by dividing the number of correctly classified pixels in the category by the total number of pixels of the category in the reference data (column total).

Users' accuracy: Clarifies the probability that a pixel of the classified image actually corresponds to the class to which it has been assigned. It is the ratio between the total number of pixels correctly belonging to a class (diagonal elements) and the total number of pixels assigned to the same class by the classification procedure (row total).

Kappa statistics: a statistical measure of reliability or consistency between evaluators. It is a discrete multivariate technique used to present map accuracy evaluation result. The image classification of accuracy assessment was carried out using Google Earth pro imageries and existing LULC maps of 310 and 335 testing sample points were collected for the years 2002 and 2020 respectively.

In this study, the Weyib watershed was classified into 6 classes **(**Agriculture, Grass Land, Forest, Built Up area, Water body and Shrub Land) of LULC map data was prepared. The LULC map was linked to the SWAT land use database and coded to the SWAT four-letter codes. The LULC types were therefore made consistent with the input needed by the model after creating the look-up table.

Table 3.5: LULC classes, SWAT database, SWAT name.

LULC	LULC SWAT Database	SWAT Name
Agriculture	Agricultural Land-generic	AGRL
Grass Land	Range Grass	RNGE
Forest Land	Forest- Mixed	FRST
Built-Up area	Residential High Density	URHD
Water Body	Water	WATR
Shrub Land	Shrub land	SHRB

3.4.2.Hydro-Meteorological Data

Weather Data: SWAT water quantity and quality model use the nearest weather station for each sub-basin. One of the key types of input information used by the SWAT model is weather data. Daily data on precipitation, maximum and minimum temperatures, relative humidity, wind speed and solar radiation are among the weather input variables required for SWAT simulation. Data from four meteorological stations in and around the Weyib watershed, including Ginir, Sinana, Robe and Dinsho were collected from the National Meteorological Services Agency (NMSA) and the location of the stations were shown in Figure 3.11 below.

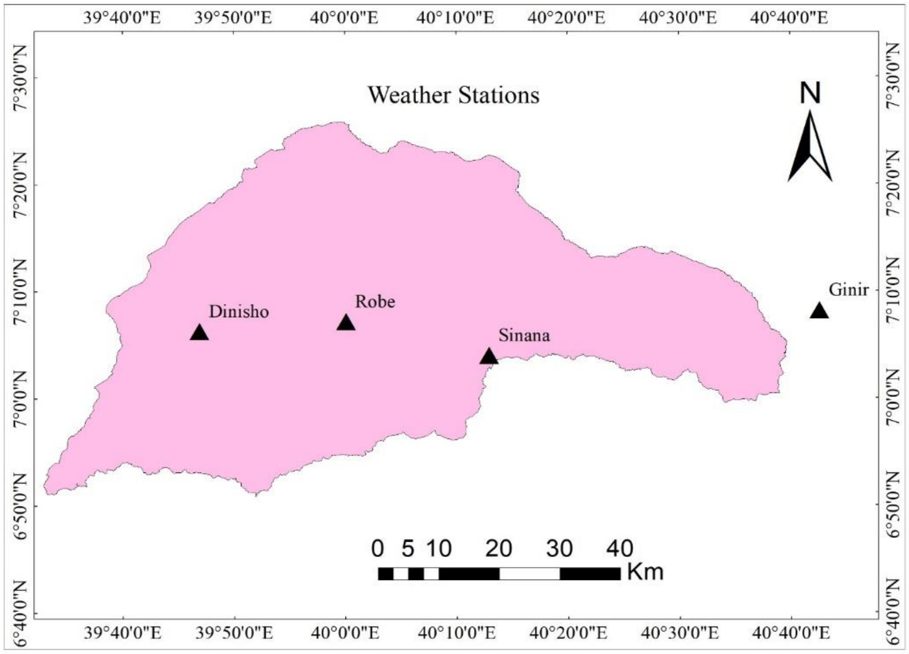

Figure 3-8: Location map of weather stations of Weyib watershed

Stream Flow Data: The measured stream flow data of the Weyib River was needed for the calibration and validation of the model. The daily stream flow data for the year (1990 to 2008) at Tebel gauging station were obtained from the MWIE. According to discharge recorded at Tebel gauging station from 1990 to 2008, the average monthly flow was shown in the Table 3.6. The stream flow has missing value of data and the missing data values were filled using XLSTAT.

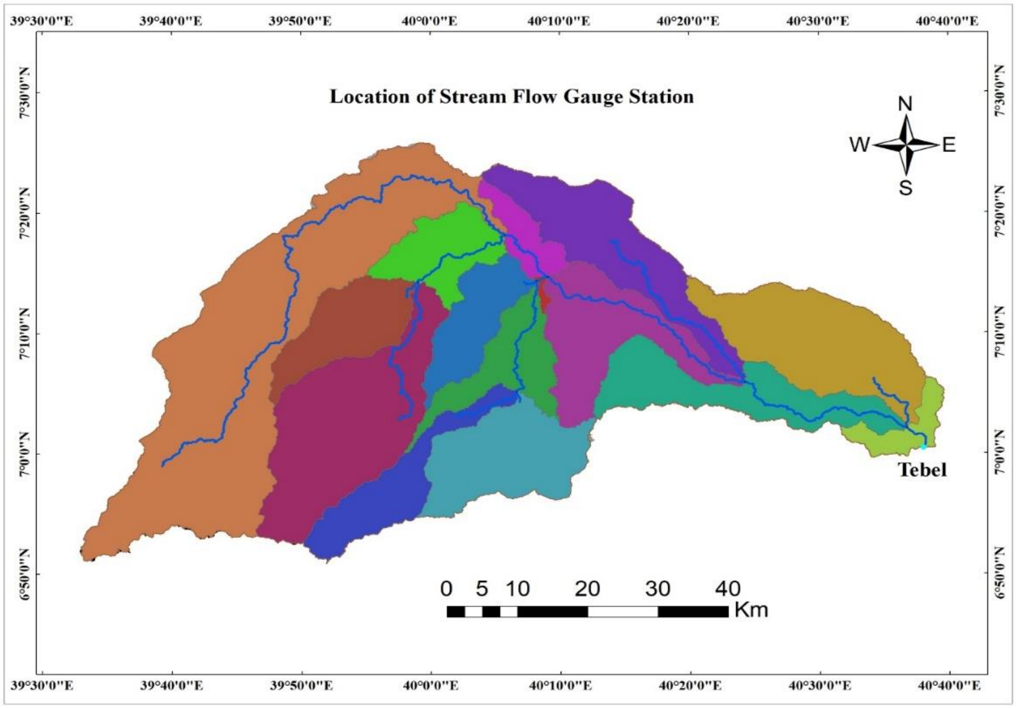

Figure 3-9: Location of Weyib watershed stream flow gauge station

Table 3.6: Mean monthly stream flow of Weyib River (1990 to 2008)

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mean-flow (m^3/s)	2.08	2.7	8.8	32.2	24.4	14.1	25.7	27.07	20.8	17.2	5.13	3.1

Source: Ministry of Water, Irrigation, and Energy of Ethiopia (MWIE)

3.4.2.1.Rainfall Data Quality Analysis

Filling missing rainfall data: The quality of the rainfall data gathered from the stations may vary (Aduna, 2009). For this study, number of weather station data was obtained in and around the Weyib watershed. Among those stations only 4 station data Dinsho, Robe, Ginir and Sinana were selected, due to a fewer missing values in these stations. All of the selected stations missing values were filled up using XLSTAT and the weather generator (WGEN) which was generated and comprised into the SWAT model from a monthly weather parameter.

Consistency Test: The obtained rainfall data of selected stations were examined using the double mass curve approach to determine whether they were constant across the chosen study period and to determine whether the correction was necessary. The recording rain gauge station may have changed throughout the record because it was moved to a new place, an ecosystem such as a forest changed, or observational error started to arise after a specific date. This method is based on the idea that recorded data are consistent if they come from the same parent population. A base station was selected from a selection of a specific number of nearby stations that were all considered suspects until they were checked. The yearly rainfall data for the questionable station and the average annual rainfall for the group of base stations over a long period was organized. The precipitation of station x (doubtful station) can be corrected using the following formula.

$$P_{cx} = P_x\left(\frac{M_c}{M_a}\right) \qquad (3.1)$$

Where P_{cx} corrected precipitation at any time period t at station X, P_x original recorded precipitation at time period t at station X, Mc Corrected slope of the double mass curve, and M_a original slope of the double mass curve

To investigate whether there was inconsistency in gauging stations in the catchment a group of four stations was chosen. Cumulative annual rainfall data of those stations within the Weyib catchment shown in Appendix.1 was used to develop a double mass curve. The cumulative values of the unstable stations were plotted against the cumulative average group using a Microsoft Excel Spreadsheet.

Since the graph was discovered to follow a fairly straight line, the records of these stations did not validate any inconsistent data, indicating that there were no recording issues or exposure to any outside influences during the study period.

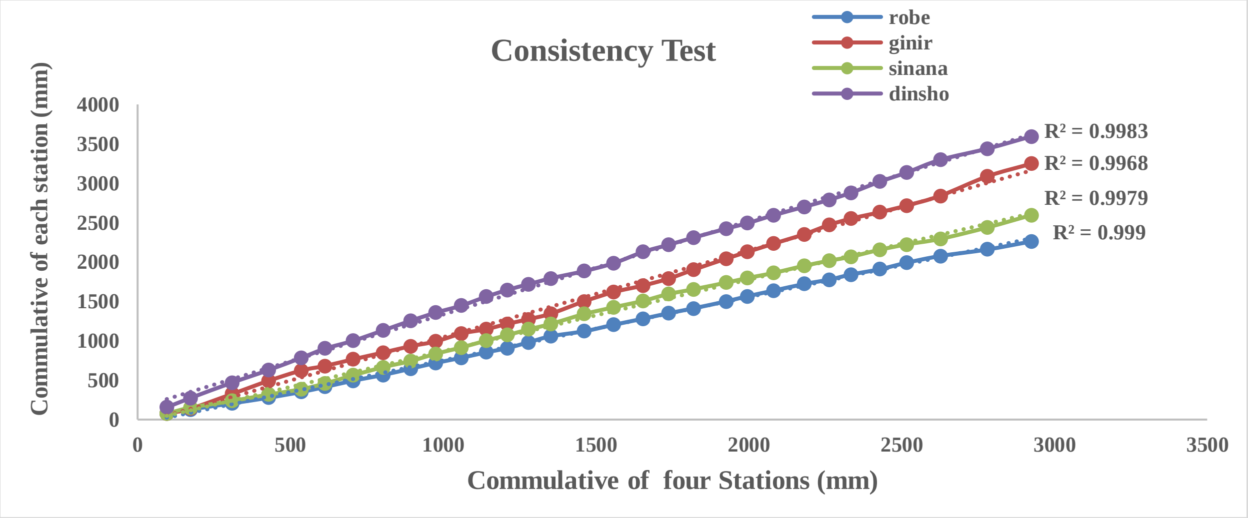

Figure 3-10: Daily annual rainfall consistency test

3.5. Hydrological Modeling with SWAT

SWWAT is a semi-distributed physically-based hydrological model operating on a daily time step and the model is embedded in the ArcGIS interface to simulate on the principle of dividing the watershed into several homogenous sub-basins of hydrologic response units (HRUs) (Chaemiso *et al.*, 2016). Modeling with SWAT procedure includes SWAT project setup, Watershed delineation, HRU Analysis, Write Input Tables, editing SWAT Input and SWAT simulation.

3.5.1. Model Setup

The ArcGIS 10.4.1 software was integrated to include the SWAT model toolbar after it was downloaded from its website. Prior to watershed delineation, ArcGIS10.4.1 software was used to project the soil map, LULC map and DEM to the same projection. The SWAT project was put up to establish the appropriate databases and folders to store all the data before the watershed demarcation.

3.5.2. Watershed Delineation

The process of creating a SWAT model begins with the delineation of a watershed. The watershed and sub-watershed delineation was performed using 30 m resolution DEM data using Arc SWAT model watershed delineator tools. There are five main processes in the watershed delineation process: setting up the DEM, defining the stream, defining the outlet and inlet, choosing and defining the watershed outlets and calculating the Subbasin parameters.

Once, the DEM setup was completed and the location of the outlet was specified on the DEM, the model automatically calculates the flow direction and flow accumulation. Subsequently, stream networks, sub-watersheds, and topographic parameters were calculated using the respective tools. Using a threshold value suggested by the Arc SWAT interface, the Weyib watershed was delineated into 15 sub basins having an estimated total area of 4152.68 km^2 and the watershed outlet was located at the sub basin number 14.

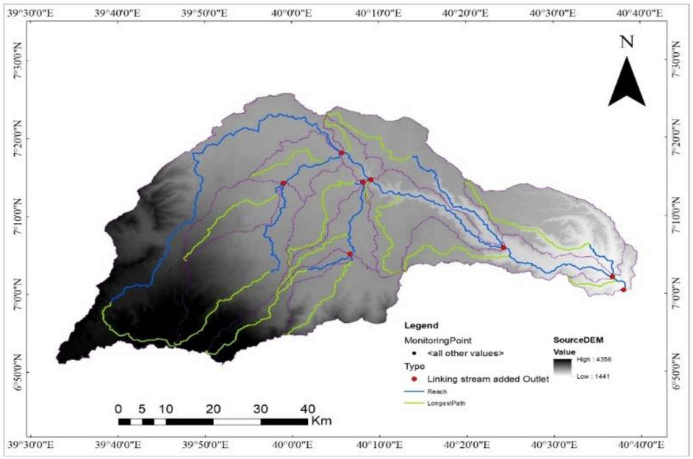

Figure 3-11: Weyib watershed delineation map

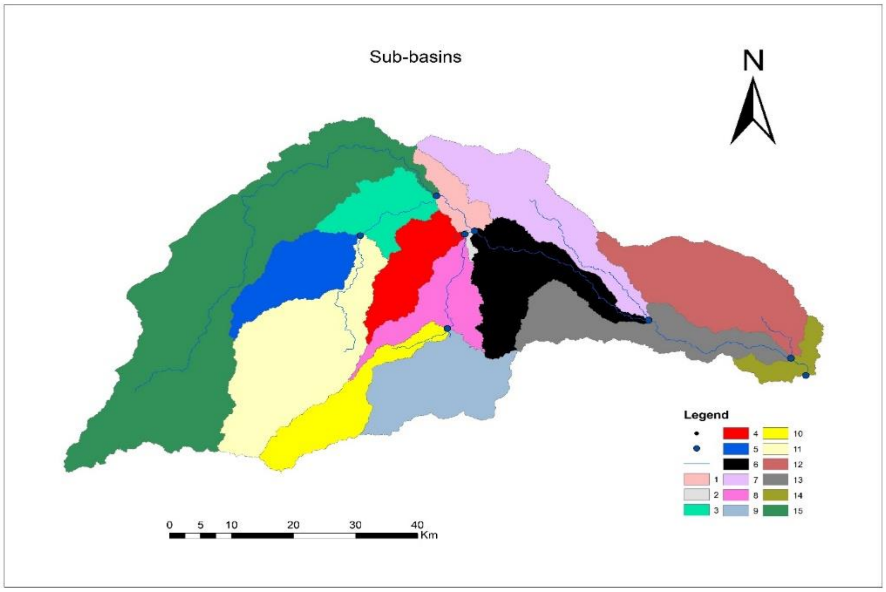

Figure 3-12: Map of Weyib watershed sub-basins

3.5.3. Hydrologic Response Units (HRUs) Definition

The HRUs are regions with uniform land use, soil characteristics and land slope properties. A watershed is divided into sub-basins in the SWAT simulation based on the number of streams. At the HRU level, a large portion of the SWAT simulation takes place, including effects on hydrology, water quality, agricultural management and conservation practices. According to user-specified thresholds for each category, the HRUs are often defined by grouping similar land use, soil type and optionally slope characteristics within a certain sub-basin.

The spatial data required in the HRU definition were the LULC map and soil map, and the slope of the study area. The LULC is used to categorize vegetation types that have an impact on the hydrological process of the area. The soil map is used to identify the physical and chemical characteristics of various soils that have a major role in the hydrological process of an area.

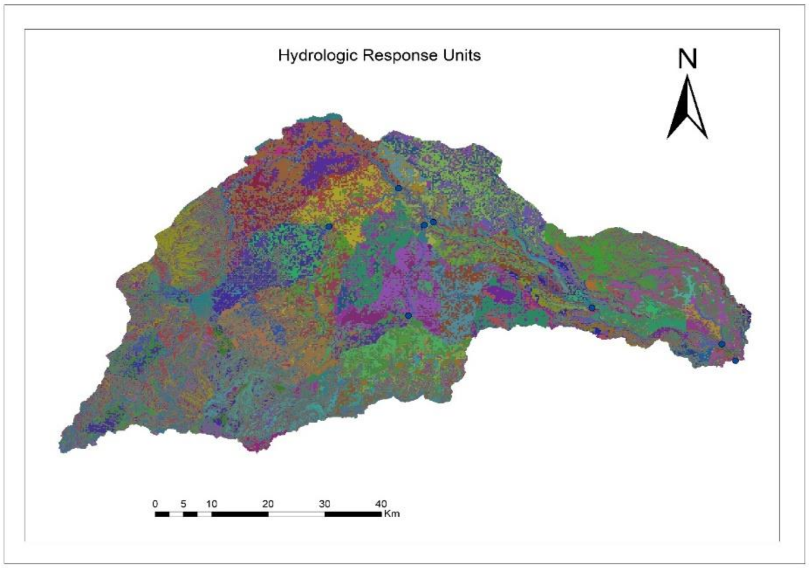

Figure 3-13: Hydrologic Response Units of Weyib Watershed

Slope classification was carried out based on the elevation range of the DEM used during watershed delineation. The slope values of the watershed were reclassified in percent. It was reclassified into three classes as shown in Table 3.8. The manual suggestion of a 0 % land use threshold, 5 % soil threshold and 5 % slope threshold was applied for modeling. The LULC and soil maps and slope were overlaid to create a total number of 394 and 401 HRUs with unique land use, soil and slope class for 2002 and 2020 land use/land cover respectively.

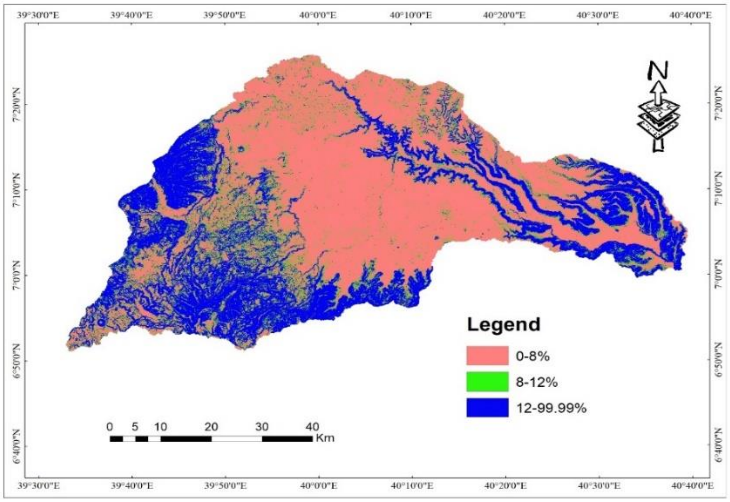

Figure 3-14: Slope Map of Weyib Watershed

Table 3.7: Slope classes and coverage area in the Weyib watershed.

S/N	**Slope range**	**Area (km^2)**	**Area (%)**
1	0-8	2346.67	56.51
2	8-12	360.04	8.67
3	>12	1445.97	34.81
Total		**4152.68**	**99.99**

3.5.4. Weather Data Definition

After HRU analysis, the first command under the Write Input Tables menu item on the Arc SWAT toolbar weather stations was used to import the weather data that would be used in a watershed simulation. With the use of this tool, the current project can load the locations of weather stations and allocate weather information to the sub-watersheds. There is a missing value in the data gathered from the meteorological stations and filled by weather generator. Weather data from the selected stations were used as input to determine the value of the weather generator parameters.

Therefore, for weather generator data definition, the weather generator data file WGEN_user, rainfall data, temperature data, relative humidity data; solar radiation data, and wind speed data were selected and added to the model.

The weather generator parameters were developed to calculate average monthly and average daily precipitation, standard deviation, skew coefficient, probability of a wet day following a dry day and average number of days of precipitation in a month.

3.5.5. Sensitivity Analysis

Sensitivity analysis is the process of identifying the importance of one or more parameters concerning the objective function or model output. Therefore, to minimize the number of parameters that require optimization, sensitivity analysis was performed prior to the calibration and validation process. In the sensitivity process, by using SWAT-CUP, the SWAT simulation results, chosen parameters and the stream flow data were entered to perform the sensitivity analysis.

During sensitivity analysis 15 hydrologic flow-influencing parameters were selected and the calibration process was run with 8 hydrologic flow-influencing flow parameters. Choosing flow parameters is based on available information in literature and compares the observed flow data to simulated output. Therefore, sensitivity analysis was done prior to the calibration process to identify important parameters for model calibration. The average monthly stream flow data of 19 years from 1990 to 2008 of the watershed river discharge were used to compute the sensitivity of the stream flow parameters and out of these 2 years from 1990 to 1991 were set for the model warm-up period.

3.5.6. Model Calibration

After doing a sensitivity analysis, the sensitive parameters were employed for model calibration in order to optimize their values. In this study, manual calibration was first carried out and the SWAT model parameters were modified. The SWAT model was then calibrated using auto-calibration SUFI2. The location of the sub-basin where the observed flow could be compared against simulated output as well as the SWAT simulation that would be used to complete the calibration were both defined in the SWAT-CUP calibration procedure. The stream flow at the outlet of the catchment was used as data for calibration and validation for the SWAT model, the model was calibrated using the measured stream flow data from January 1992 to December 2002 with 2 years' warm-up periods. Then, the desired parameters for optimization of observed data, and methods of calibration were selected.

The calibration was done by adjusting parameters until the simulated and observed values showed good agreement. The model was run using the best parameter output values and the simulations were compared with observed stream flow data using Percent BIAS (PBIAS), Nash and Sutcliffe coefficient of efficiency (NSE) and coefficient of determination (R^2). Both graphical methods and statistical tests are used in model calibration and validation. According to Jayakrishnan *et al*., (2005) it was calibrated until monthly $R^2 > 0.6$ and $NSE > 0.5$. After the completion of calibration, the model was run using the best parameter output values and the simulations were compared with observed stream flow data.

3.5.7. Model Validation

Validation is the process of approving that a certain site-specific model is capable of producing sufficiently accurate simulations and results to differ depending on the project aims. Without making any additional modifications to the parameters, it is used to test the calibrated parameters using a different set of data. Stream flow validation was done using the statistical model performance measure that were used in the calibration procedures (Shawul *et al*., 2013). In this study, the validation was performed to compare the model outputs with an independent data set without making further changes to parameters obtained during the calibration process and the measured stream flow data of Weyib River from 01 January 2003 to 31 December 2008 were used.

3.5.8. Model Performance Evaluation

The act of validating a site-specific model involves demonstrating its capacity to generate simulations that are precise enough to vary depending on the project objectives. It is used to evaluate the calibrated parameters using a different set of data without making any further adjustments to the parameters. The statistical model performance measures used in stream flow validation were:

Coefficient of Determination (R^2): the squared value of the coefficient of correlation and an indicator of the strength of the relationship between the observed and simulated values it is the magnitude linear relationship between the observed and the simulated values. Higher values indicate less error variance and values larger than 0.6 are regarded as acceptable. R^2 ranges from 0 (which is poor) to 1 (which is good) (Jayakrishnan *et al*., 2005).

$$R^2 = \left(\frac{\sum_{n=1}^{n} (O_i - O_{avg})(S_i - S_{avg})}{\sqrt{\sum_{n=1}^{n} (O_i - O_{avg})^2} * \sqrt{\sum_{n=1}^{n} (S_i - S_{avg})^2}} \right)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.2)$$

Where R^2 Coefficient of Determination, Oi observed value, S_i simulated value, S_{avg} average simulated value and O_{avg} average observed value.

Nash-Sutcliffe Efficiency (NSE): defined as one minus the total of the absolute squared differences between the observed values and the simulations, normalized by the variance of the observed values during the investigation period (Jayakrishnan *et al.*, 2005). The NSE measures how well the 1:1 line is fit by the plots of observed versus simulated data. NSE value ranges from negative infinity to one (best). The NSE value of zero denotes poor performance because it shows that the mean observed value is a better predictor than the simulated value. NSE values greater than 0.5 are regarded as acceptable performance, with the simulated value being a stronger predictor than the mean observed value.

$$NSE = 1 - \frac{\sum_{n=1}^{n} (O_i - S_i)^2}{\sum_{n=1}^{n} (O_i - O_{avg})^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.3)$$

Where NSE Nash and Sutcliffe efficiency, O_i observed value, O_{avg} average observed value and S_i simulated value.

Percent Bias (PBIAS): stated as a percentage, describes the propensity of the simulated data to be larger or smaller than the real data. Zero is the ideal PBIAS value and low numbers show that the model simulation is satisfactory. Positive numbers indicate the model's propensity to underestimate, whereas negative values show the model's propensity to overestimate. PBIAS Values up to ±25 are considered acceptable (Kumar *et al.*, 2017).

$$PBIAS = \left(\frac{\sum_{n=1}^{n} (O_i - S_i)}{\sum_{n=1}^{n} (O_i)} * 100 \right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.4)$$

Where PBIAS Percent Bias, O_i observed value and S_i simulated value

Table 3.8: Performance ratings of statistical measures of stream flow

Performance rating	**PBIAS (%)**	**NSE**	**R^2**
Very good	PBIAS < ±10	$0.75 < NSE \leq 1$	$0.7 < R^2 < 1$
Good	$\pm10 \leq PBIAS \leq \pm15$	$0.65 < NSE \leq 0.75$	$0.6 < R^2 < 0.7$
Satisfactory	$\pm15 \leq PBIAS \leq \pm25$	$0.5 < NSE \leq 0.65$	$0.5 < R^2 < 0.6$
Unsatisfactory	$PBIAS \geq \pm25$	$NSE \leq 0.4$	$R^2 < 0.5$

Source:(Moriasi *et al*., 2015)

3.6. Impacts of Land use/land cover change on stream flow

The main goal of this study is to evaluate the impacts of LULC change on stream flow Weyib watershed. According to Dechasa *et al*., (2019) Weyib watershed is recognized as a potential agricultural zone in the southeastern part of Ethiopia. Weyib watershed experienced LULC changes in the period of 2002 to 2020 due to the population growth rate, which lead to resource competition. There was slight urban and high agricultural land expansion in the marginal lands during the study period and these change in LULC influence stream flow.

The study was conducted for two different years from, 2002 to 2020. The two LULC maps, soil, weather and stream flow data values were used to evaluate the impacts of LULC change on stream flow using the SWAT model. The model was calibrated and validated on monthly time steps. The years 2002 and 2020 LULC were used as input variables in the SWAT model to compare output as a result of their differences in LULC change. In Weyib watershed the seasonal steam flow variability due to LULC change was experienced and a comparison was made on stream flow based on the two simulation outputs.

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1. Land Use/Land Cover Classification

Each homogenous land use/land cover should be identified before the investigation of land use/land cover change. LULC maps of the watershed was formed using Landsat images from years 2002 and 2020, which were acquired from the USGS, then six land Use/land cover classes of Weyib watershed were identified in two different years 2002 and 2020 prior to LULC classification. The classified LULC classes are grassland, forests, agricultural, built-up areas, shrub land and water body.

4.2. Accuracy Assessment of LULC Images

The evaluation of accuracy is the last step in the categorization process. Comparing the original LULC image and the categorized land use/land cover image with chosen reference points allowed for an accuracy assessment of the classification. To evaluate classification accuracy, the method of confusion matrix was utilized. The accuracy evaluation of the classified LULC map was derived from the statistical process of the error matrix. Table 4.1 and 4.2 shows the LULC classification accuracy evaluation results in the study periods of 2002 and 2020.

The overall accuracy of the classification using the error (confusion matrix) is 91.93% and 93.73 % respectively. The Kappa statistics of the LULC map for each category was calculated to measure the accuracy and confidence of the results. The Kappa statistics of the LULC classification map results in the periods of 2002 and 2020 was 87.85% and 89.46% respectively. This showed quite good overall accuracy and was accepted for subsequent change and detection analysis.

According to Bahadur *et al*., (2015) the minimum accuracy value for reliable LULC cover classification is 85% and others say the expected accuracy is determined by users. Hence, the LULC classification accuracy assessment result satisfies the minimum accuracy assessment criteria. The user accuracy (error of commission or inclusion) and producers’ (error of omission or exclusion) which are used to evaluate classification accuracy were also calculated. This was carried out after image classification of the two LULC maps from the years 2002 to 2020.

Table 4.1: Confusion matrix for LULC classification of 2002

	FRST	RNGE	SHRB	WATR	URBN	AGRL	Total	Users' Acc. (%)
FRST	**53**	0	0	3	0	0	56	**94.64**
RNGE	0	**54**	1	0	0	3	58	**94.74**
SHRB	5	0	**40**	0	0	0	45	**88.89**
WATR	3	0	0	**22**	0	3	28	**78.57**
URBN	0	2	0	0	**35**	0	37	**94.59**
AGRL	2	1	0	0	2	**81**	86	**94.18**
Total	63	57	41	25	37	87	**310**	
Producers' Acc. (%)	**84.13**	**94.74**	**97.56**	**88.00**	**94.59**	**93.1**		

Table 4.2: Confusion matrix for LULC classification of 2020

	FRST	RNGE	SHRB	WATR	URBN	AGRL	Total	Users' Acc. (%)
FRST	**50**	0	0	3	0	1	54	**92.59**
RNGE	0	**63**	1	1	0	0	65	**96.92**
SHRB	2	1	**44**	0	0	0	47	**93.61**
WATR	2	1	0	**32**	1	0	36	**88.88**
URBN	0	0	2	1	**46**	0	49	**93.87**
AGRL	0	4	1	0	0	**79**	84	**94.04**
Total	54	69	48	37	47	80	**335**	
Producers' Acc. (%)	**92.59**	**91.30**	**91.66**	**86.48**	**97.87**	**98.75**		

4.3. Land use/land cover maps

The LULC maps for the Weyib watershed were grouped into 6 predominant classes: Grass Land, water body, built-up area, agriculture, grassland, Shrub Land and forest. The figure 4.3 indicates the LULC maps for 2002 and 2020 that were generated from Land sat images with supervised classification. According to the study result and data gathered from satellite imaging for the Weyib watershed, the watershed has observed a number of changes in LULC recently. It was simply shown that there is an increase of agricultural land and Urban areas, and decrease of forested areas, shrub land, grassland and water bodies over 19 years due to different human needs and natural events during the study periods.

4.3.1. Land use/land cover map of 2002

The land use/land cover map of 2002 shows that about 21.08% of the Weyib catchment was covered by agricultural land, 25.43% by Grass Land, 17.87% by forest, 23.93% by shrub land, 4.07% by water and 7.63 % by Urban area. Grassland is found in most parts of the watershed.

Table 4.3: Coverage area of LULC classes of 2002

LULC Classes of 2002	**Coverage Area**	
	Area (ha)	**Area %**
Forest	74196.67	17.86
Grass Land	105596.66	25.43
Waterbody	16890.16	4.07
Built-Up area	31688.35	7.63
Shrub Land	99369.26	23.93
Agriculture	87526.94	21.08
Total	**415268.04**	**100**

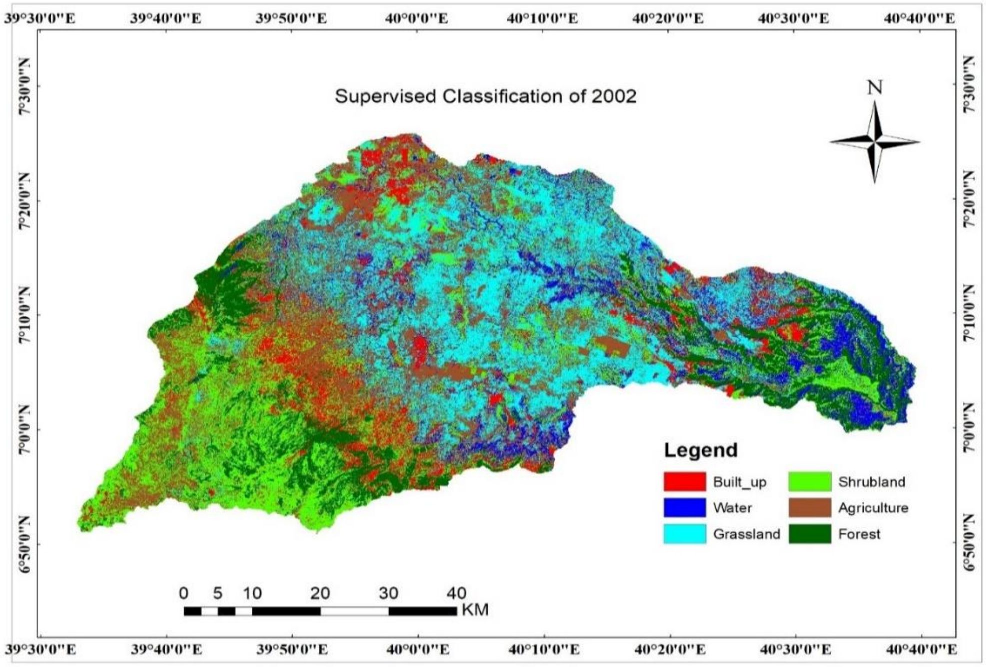

Figure 4.1: Map of LULC Classification of 2002

4.3.2. Land use/land cover map of 2020

The LULC map of 2020 shows that about 32.63% of the Weyib catchment was covered by agricultural land, 18.60% by grassland, 15.42% by forest, 18.95% by shrub land, 11.42% by residential area and 2.98% by water body. The distribution of LULC classes was shown in the table 4.4. During the study period, agriculture and residential area were increased from (21.08% to 32.63%) and (7.63% to 11.42%) by 11.54% and 3.73 % respectively. In addition, shrub land, water body, grassland and forest were decreased by (23.93% to 18.95%), (4.07% to 2.98%), (25.43% to 18.60%) and (17.86% to 15.42%) by 4.98%, 1.09%, 6.83% and 2.45% respectively. Mainly, the grassland was changed into agricultural land and the grassland, agricultural land and shrub land were found in most parts of the watershed.

Table 4.4: Coverage area of LULC classes of 2020

LULC Classes of 2020	**Coverage Area**	
	Area (ha)	**Area %**
Forest	64052.54	15.42
Grass Land	77245.07	18.60
Waterbody	12369.03	2.98
Built-Up area	47433.86	11.42
Shrub Land	78695.60	18.95
Agriculture	135471.94	32.63
Total	**415268.04**	**100**

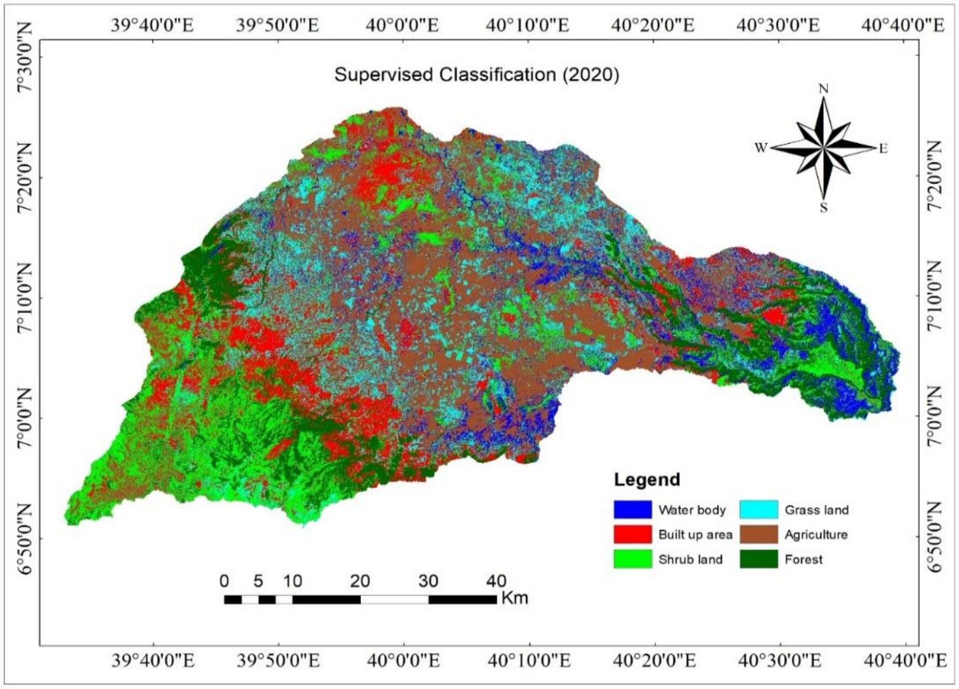

Figure 4.2: Map of LULC Classification of 2020

4.3.3. Land use/land cover change between 2002 and 2020

From the results of the above-mentioned LULC changes, it can be found that agriculture and urban areas have undergone great changes study period. The total area of change of built up and agricultural land from 2002 to 2020 was 15745.51 ha and 47945.00 ha respectively.

The results show that during 2002 to 2020, agricultural area and urbanization increased at the expense of other LULC types. From the results, it was found that agricultural land is the predominant LULC type of the sub basin.

In the past 19 years, the total area of forest cleared between 2002 and 2020 reached 10144.13 ha. This means that about 2.45% of the existing forest coverage in 2002 was cleared. The largest expansion of agriculture and urbanization occurred between 2002 and 2020 was estimated to be 11.54% and 3.73 %, respectively. The results of the study showed that the area of shrub land has decreased from 23.93% in 2002 to 18.95% in 2020. Similarly, grassland decreased from 25.43% in 2002 to 18.60% in 2020 and water bodies decreased from 4.07% in 2002 to 2.98% in 2020.

It was found that the main driving forces of this transition were rapid population growth and urbanization, which led to deforestation, rainfall shortages and human need of farmland. The increasing in population has been driving the increase of agricultural land nationwide (Gyawali *et al*., 2022). From the year 2002 to 2020, the drastic changes in the watershed were the expansion of agriculture and urbanization and the reduction of forests, shrubs, grasslands, and water bodies. This shows that agriculture is expanding on a large scale.

In Ethiopia, population growth has led to agricultural expansion, urbanization, and overgrazing; LULC has undergone tremendous changes in the past few decades (Thanapakpawin *et al*., 2007). Similarly, in the past 19 years, the LULC of Weyib sub basin has undergone major changes. The results show that between 2002 and 2020, the urban area increased significantly. This shows that the LULC of the urban area category has undergone great changes, exerting incredible pressure on non-urban areas, especially agricultural land. Through the construction of residential units, commercial units, road networks, and other impervious surfaces, the rapid expansion of urban areas has led to the continuous expansion of building surfaces in different corners of the towns. The change detection results show that the extent of LULC changes that occurred in shrubs and grasslands was concentrated in agricultural land. These changes indicate that the strengthening of agricultural land is the result of population growth.

The driving force of LULC changes in the basin is essentially related to manmade influences. Rapid population growth, human migration to urban areas are the main drivers of changes in agricultural LULC in the entire watershed.

Population growth has led to a considerable increase in the demand for food and the expansion of agricultural land by affecting the area of uncultivated forestland (Bhat *et al*., 2017). It is speculated that in the socio-economic context of Ethiopia, the impact of human activities, such as agricultural deforestation and the demand for firewood and housing construction, will make a greater contribution to the changes in LULC (Dagnachew *et al*., 2020). Therefore, understanding the causes and consequences of LULC changes is crucial for scholars, decision makers, and water and land managers as it helps to take appropriate actions for future water management.

LULC is a complex and dynamic process that can be caused by many cooperative processes ranging from various natural factors to socio-economic dynamics (Yesuph & Dagnew, 2019). Due to different driving factors, major LULC changes occurred in the study area (reduction of grassland, expansion of farmland and settlements and reduction of shrub land). Population increase seems to be the main driving force of LULC changes, which is mainly manifested by expanding cultivated land at the expense of vegetation cover (Fenta Mekonnen *et al*., 2018). This has led to the expansion of cultivated land, charcoal, fuelwood extraction and other wood products (such as housing construction products related to population growth) as the main direct drivers of the loss of natural vegetation in the study area.

Changes in LULC from non-urban to urban or from forest to agricultural land have resulted in the loss of LULC for many different types of vegetation (Mundhe & Jaybhaye, 2014). Hence, the most serious consequence of changing land use through urbanization and agricultural expansion is the reduction of natural and expansion of agricultural land and the increase of hard surfaces in built up areas This leads to soil erosion and loss of soil biodiversity, which leads to a decline in soil fertility, which in turn reduces agricultural productivity. Changes in LULC are driven by human actions, which in turn drive changes that change the availability of human and livestock products and services (Mishra *et al*., 2014). The environmental consequences that cause LULC changes were increasing agricultural activity, reduction of soil fertility, use of trees for (firewood, charcoal, and construction), settlement and urban expansion.

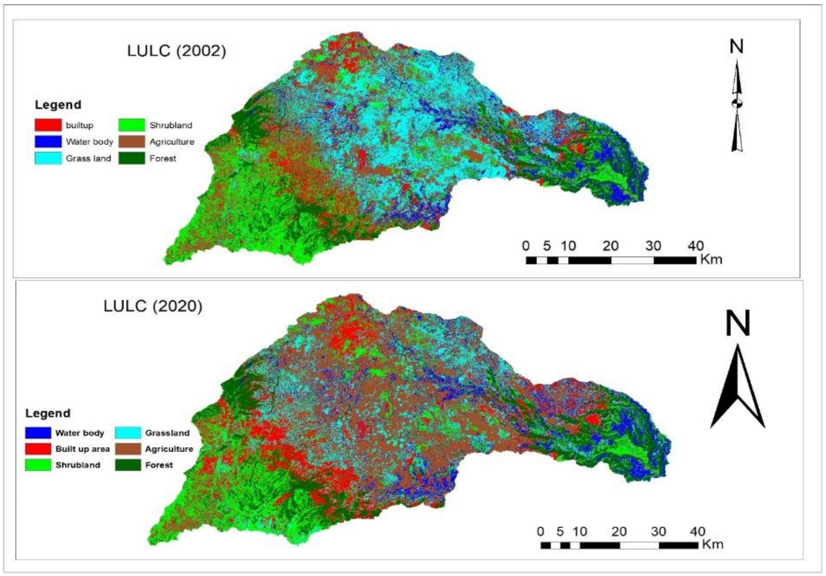

Figure 4.3: Comparison of LULC classes of 2002 and 2020

Table 4.5: Areal change of LULC classes of (2002 to 2020)

LULC Class name	**2002**		**2020**		**Area Changed**	
	Area (ha)	**Area %**	**Area (ha)**	**Area %**	**Area (ha)**	**Area %**
Forest	74196.67	17.86	64052.54	15.42	10144.13	(-)2.45
Grass Land	105596.66	25.43	77245.07	18.60	28351.59	(-)6.83
Waterbody	16890.16	4.07	12369.03	2.98	4521.13	(-)1.09
Built-Up area	31688.35	7.63	47433.86	11.42	15745.51	(+)3.73
Shrub Land	99369.26	23.93	78695.60	18.95	20673.66	(-)4.98
Agriculture	87526.94	21.08	135471.94	32.63	47945.00	(+)11.54
Total	**415268.04**	**100**	**415268.04**	**100**		

4.4. Hydrological Modeling

Hydrological modeling was performed using the SWAT extension for ArcGIS mapping analysis software. The model is a physical based, semi-distributed and operating on daily time step. As a physical based model, in SWAT simulation, a basin is divided into multiple sub basins, which are further divided into one or more HRUs to represent spatial heterogeneity based on the specified threshold percentage of the watershed land use, soil types and topography slope.

The default LULC of the SWAT model was linked to LULC map through the look up table, which was again linked to the LULC Database.

The prepared LULC was given as input to the model data of the SWAT to describe the HRU of the watershed. Each HRU is vertically divided into the surface layer, root zone, shallow aquifer and the deep aquifer layers for the analysis assuming that the groundwater processes incorporated in the model are satisfactory for the current level of analysis. Precipitation, after interception at the canopy layer, reaches the soil surface and a part of it becomes surface runoff and rising up by evapotranspiration. The remaining part infiltrates into the soil layer and adds to the soil moisture storage. The saturated hydraulic conductivity of the soil layer, slope, drainable porosity and the drainable volume of water present in the layer is used to simulate the lateral flow.

Percolation from the soil layer is computed as a function of the drainable volume of water present in the layer. This percolation is added to the shallow and deep groundwater storages.

Water balance in the shallow aquifer is achieved between percolation, deep aquifer recharge, revap (which is the movement of water from the shallow aquifer to the root zone) and groundwater flow. Groundwater flow from each HRU is estimated as a function of the rate of change of water table height and is added to the channel reach at the sub basin outlet. Recharge to the deep aquifer is estimated as a fraction of the total percolation reaching the shallow aquifer.

4.4.1.Sensitivity Analysis of Stream Flow Parameters

Sensitivity analysis seeks to determine how quickly a model output will change in response to changes in watersheds that significantly alter its hydrologic sensitivity. The use of semi-distributed hydrological models has become increasingly popular in both research and operational settings. Many of these models are highly complex and are generally characterized by a multitude of parameters. Due to spatial variability in the processes simulated by these models, the value of many of these parameters may not be exactly known. Further, many of them may not be directly measurable. Therefore, in most model applications, calibration is necessary to estimate model parameter values.

Before applying SUFI-2 for calibration, the most sensitive parameters were selected by running the sensitivity analysis. It is important to identify sensitive parameters for a model to avoid the problems of over parameterization. Model calibration helps to reduce the parameter uncertainty which in turn reduces the uncertainty in the simulated results.

The sensitivity analysis was conducted for the Weyib watershed stream flow to determine the parameters needed to improve simulation results and thus to better understand the behavior of the hydrologic system and to evaluate the applicability of the model. Sensitivity analysis from SUFI-2 provided partial information about the sensitivity of the objective function to model parameters. SUFI-2 is one of the uncertainty analysis programs that is incorporated in an independent program SWAT calibration and Uncertainty Program (SWAT-CUP). That perform uncertainty analysis due to both parameter and model uncertainties. Its main function is to calibrate SWAT and perform validation, sensitivity and uncertainty analysis for a watershed model.

To conduct a sensitivity analysis, certain water related parameters having absolute minimum and maximum ranges in the SWAT model papers were chosen. These hydrologic parameters are related to ground water, runoff and soil process and which influence the stream flow in the watershed. A measure of sensitivity is provided by the sensitivity ranking and T-stat (higher absolute values indicate greater sensitivity) and the significance of the sensitivity is determined by the p values (a value close to zero has more significance).

During sensitivity analysis, 15 flow parameters which may affect stream flow were considered from which only eight 8 parameters were selected to influence in controlling the hydrological processes in the watershed. The remaining parameters 7 were not considered during calibration process, as the model simulation result was not sensitive to these parameters in the watershed. The hydrologic parameters affecting the streamflow were identified through reading a literature review and the range of parameter values were taken directly from the SWAT user's manual which resulted in the identification of 8 parameters used in this study of the measure of sensitivity. The parameters affecting the hydrologic process of the Weyib watershed used in model the Sensitivity analysis were CN2, GW_DELAY, GWQMN, EPCO, REVAPMN, SOL_AWC, GW_REVAP and CH_K2.

Soil Conservation Service (SCS) runoff curve number (CN2) contribute directly to surface runoff generation. The most widely used and popular technique to estimate runoff in watershed is CN2, this method incorporates soil type, watershed condition and LULC density to define coefficient of CN. Thus, it is an empirical equation predicting runoff from rainfall, using a shape parameter based on soil, vegetation, land use, and soil moisture prior to a rainfall event. Groundwater delay (GW_DELAY) is the lag between the time that water exits the soil profile and enters the shallow aquifer. Threshold depth of water in the shallow aquifer required for return flow to occur (GWQMN) affect groundwater flow.

Plant uptake compensation factor (EPCO) form of compensation and that the degree of compensation is principally a function of soil capillarity and the ratio of total effective root length to potential transpiration. Thus, uptake compensation increases as root to leaf area ratios increase, since potential transpiration depends on leaf area. Threshold depth of water in the shallow aquifer for revap to occur (REVAPMN).

Available water capacity of the soil layer (SOL_AWC) represents soil moisture characteristics in the model and estimates the difference between the field capacity and the wilting point. Ground water revap coefficient (GW_REVAP) or the ground water ‘revap’ coefficient controls the water movement from shallow aquifer to the unsaturated soil layers and affect groundwater flow. Effective hydraulic conductivity in main channel alluvium (CH_K2) shows the relationship of the stream with the ground water and directs the water movement from streambed to the subsurface depending on the stream type.

The result of the sensitivity analysis indicated that the most sensitive parameters were the SCS runoff curve number (CN2) with a t-value of 18.8 and p-value of 0.00 to simulate Weyib watershed and the least sensitive was Average slope length (SLSUBBSN) with absolute t-stat value of 0.20 and p-value of 0.90.

Table 4.6: Hydrologic Parameters and their description

S/N	Parameters	Descriptions
1	CN2	SCS runoff curve number (%)
2	GW_DELAY	Groundwater delay (days)
3	GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur (mm)
4	EPCO	Plant uptake compensation factor (dimensionless)
5	REVAPMN	Threshold depth of water in the shallow aquifer for revap to occur (mm)
6	SOL_AWC	Available water capacity of the soil layer
7	CH_K2	Effective hydraulic conductivity in main channel alluvium
8	GW_REVAP	Ground water revap coefficient (dimensionless)

4.4.2.Calibration

With default parameter values, the SWAT simulation of the Weyib watershed displayed poor statistical parameters. Hence, calibration was done for sensitive flow parameters of SWAT with observed average monthly stream flow data. First, some sensitivity flow parameters were adjusted by manual calibration procedure based on the available information in literatures. In this procedure, the values of the parameters were varied iteratively within the allowable ranges until the simulated flow as close as possible to observed stream flow. Then, the manual and automatic calibration on monthly time steps was done for the period of 11years (1992 to 2002).

To attain high NSE, R^2 and low PBIAS values, numerous parameter combinations were made while running flow simulations. This was carried out until the simulated and observed flows were closely matched. The results showed a good correlation between the predicted and observed flows. The calculated NSE indicated that the predicted and the observed discharges have a good correlation and the model was a good in simulating the watershed. The performance criteria indicated that the parameters modified during calibration represented the catchment hydrologic response.

Table 4.7: Parameters used for calibration and their ranking values

Parameters	**Calibration**	
	T-stat	**P-value**
6:V__REVAPMN.gw	-0.29	0.77
3:A__GWQMN.gw	1.28	0.20
7:R__SOL_AWC (..) .sol	-1.50	0.13
5:A__EPCO.hru	-1.58	0.11
8:V__GW_REVAP.gw	-4.58	0.00
2:V__GW_DELAY.gw	5.05	0.00
4:R__SOL_K (..) .sol	11.56	0.00
1:R__CN2.mgt	63.55	0.00

Table 4.8: Parameters used for calibration and their values

S/N	**Parameters**	**Calibration**		
		Value		**Calibrated value**
		Min	**Max**	
1	CN2	-0.2	0.2	0.19
2	GW_DELAY	30	450	441.18
3	GWQMN	0	25	3.72
4	SOL_K	-0.8	0.8	0.13
5	EPCO	0	0.2	0.14
6	REVAPMN	0	10	4.09
7	SOL_AWC	-0.2	0.1	-0.11
8	GW_REVAP	0	0.2	0.02

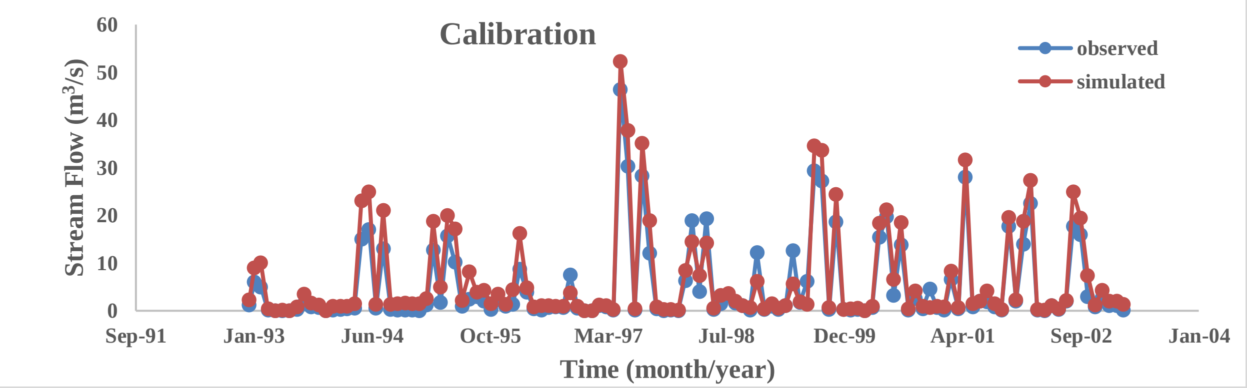

Figure 4.4: Calibration result of average monthly stream flow (1992 to 2002)

4.4.3.Validation

Calibrated parameters were validated for the period of 6 years (2003 to 2008). Validation proves the performance of the model for simulated flows in periods different from the calibration periods, but without any further adjustment in the calibrated parameters. Validation was performed for 6 years from January 1, 2003 to December 31, 2008. The results of model validation showed that the model is capable of forecasting the catchment response. NSE denotes a model ability to forecast the watershed response with a level of acceptable accuracy, however; performance is lower than that for calibration. In this work, the validation findings revealed a better fit than the calibration results and the results proved that the model could accurately replicate the catchment hydrologic response.

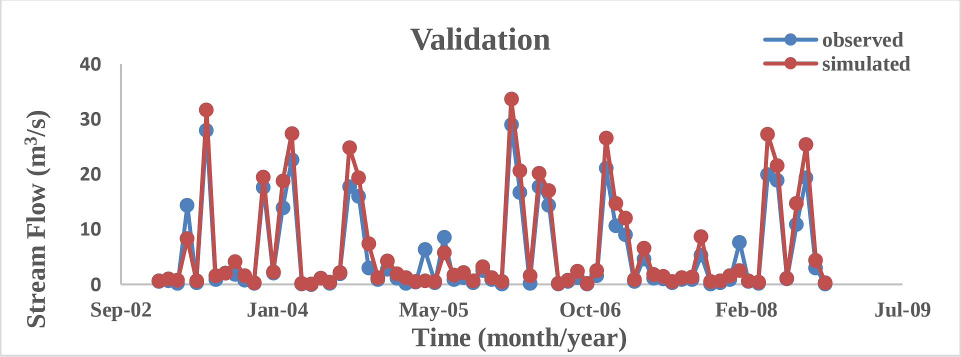

Figure 4.5: Simulated and observed flow in the validation period (2003 to 2008)

In general, both during calibration and validation periods, the graphical and statistical results demonstrated appropriate model performance and the model predicted the value of the stream flow in each month. Due to the rainfall data of Dinsho and Robe stations, which experience more precipitation than the remainder stations and which cover the majority of the watershed, the peak flows during validation appear to be overstated in wet months. This may be due to local rainfall storms that were not well represented by the rainfall data used in the hydrologic simulation because of uneven weather station distribution and some missing data.

The over estimation of the model could be also attributed to uncertainties that might exist in the Weyib watershed, such as surface or subsurface water abstractions for irrigation, water detention, industrial and rural or urban water supply which were unaccounted for in this study due to data limitation and also the quality of observed data may affect.

The statistical results of calibration and validation in different period of time were presented in the table 4.9 below.

Table 4.9: Model calibration and validation performance statistics.

Period of calibration and validation	**Evaluation criteria**		
	R^2	**NSE**	**PBIAS (%)**
Calibration (1992 to 2002)	0.94	0 .69	-14.65
Validation (2003 to 2008)	0.98	0 .72	-13.11

4.5.Impacts of LULC change on stream flow of Weyib watershed

Evaluation of the hydrological responses of the Weyib watershed to LULC change was one of the study crucial components. Therefore, at the catchment outlet, the evaluation was based on stream flow which is significant watershed processes. Changes in LULC can have an impact on this processes. It was done to see how the LULC changed the stream flow between the years 2002 and 2020.

In order to assess the variability of stream flow caused by changes in land use/land cover, SWAT simulation was run using the two land use/land cover maps for the corresponding periods (2002 and 2020). All other input variables were set to be the same except the two land use/land cover maps for both simulations. Stream flow results were provided and match patterns of both land use/land cover. After comparing these results, the watershed's percentages of discharge change during the wet and dry seasons were evaluated and utilized as indicators to estimate the hydrological effects of the changing land use/land cover.

Table 4.10: Mean monthly simulated stream flow of (2002 and 2020)

Dry and Wet months	**LULC of 2002**	**LULC of 2020**	**Change**	**%**
Mean monthly flow of Wet month (m^3/s)	31.66	43.53	(+)11.87	37.49
Mean monthly flow of Dry month (m^3/s)	18.1	12.31	(-)5.79	31.1

The stream flow for both LULC forms were depicted. The findings were then compared and the discharge changed according to the seasonal cycles with the wettest stream flow occurring from June to September and the driest stream flow occurring from October to February to detect the change in stream flow. These seasonal cycles were used as a way to depict the impact of change LULC on stream flow. During the study period, the monthly stream flow is higher during the wet season (June to September) and lower during the dry season (October to February). The mean monthly stream flow for wet months had increased by 37.49% (from 31.66m^3 /s in 2002 to 43.53m^3 /s in 2020). The mean dry monthly flow decreased by 31.10% (from 18.10m^3 /s in 2002 to 12.31m^3 /s in 2020) due to LULC modifications.

Due to the large percentage of impermeable surfaces present in built up regions water percolation and groundwater contribution to stream flow are either blocked or significantly reduced, which allows for an increase in surface runoff as a result of changes in LULC with in the watershed.

Different LULC areas are being forced into settlements and infrastructure due to urban growth, creating closed surfaces that are negatively affecting the precipitation distribution in favor of increased surface runoff which influence stream flow. The expansion of agricultural land because of soil compaction from tillage activities were linked to lower infiltration rates. Generally, the study result indicated stream flow during the wet season increased whereas during the dry season decreased.

According to Rientjes *et al*., (2011) LULC change assessment was through classification analysis of remote sensing based LULC data results of the supervised LULC classification analysis the result indicated that significant decrease in forest cover is mainly due to expansion of agricultural land and increase in stream flow has changed in the Gilgel Abbay catchment LULC change. The study analyzed Hangar watershed hydrological responses to land use/land cover change the result after simulation indicated that stream flow through the study period is increased for wet season whereas, decreased for dry season (Galata *et al*., 2020). An increase of wet season flow may result in flooding, and the reduction of dry season flow may affect water scheme practice. Therefore, this study enables the concerned body to turn the changes in LULC towards increasing vegetation cover so that, surface runoff that contributes to wet season flow would be reduced and infiltration that supply groundwater from which dry season base flow contribution would be increased.

The gradual reduction of water bodies can lead to landscape component (flora, soil, and fauna) degradation, leading to desertification, which in turn leads to health problems, poverty, and loss of biodiversity. Deforestation is one the driving cause of the changes in LULC, which is considered the main cause of changes in hydrological processes such as surface runoff, sediment production, evapotranspiration, groundwater, infiltration, lateral flow, and rainfall interception. The availability of future water resources depends, largely, on land use planning and management in a constantly changing environment. Sustained human behavior continues to modify LULC to meet increased demand, especially due to the significant increase in population and the development of better facilities.

LULC change is a complex source of pressure that threatens the sustainability and management of water resources. The impact of the LULC change pattern on the sub basin connecting coastal areas and highland areas has led to economic, social, political, and environmental problems at the national, regional, and local levels in many countries. LULC changes have serious consequences for the natural environment because LULC is directly related to land condition and leads to environmental changes. Therefore, understanding and paying attention to the existing LULC changes is very important for the policy decision making and regulatory action formulation of future LULC activities.

Changes in LULC not only affect volume of stream flow but also affect the quality of water resources through different mechanisms (Dobarco *et al*., 2019). Changes in LULC, such as the fragmentation and removal of terrestrial landscape, adversely affect the quality of aquatic ecosystems. Freshwater ecosystems are some of the most threatened ecosystems on the planet, facing human and environmental pressures. For example, due to the increasing pressure and scarcity of freshwater resources, the pollution of freshwater resources is attracting global attention. River water quality is affected by rapid urbanization and agricultural chemicals may leak or seep into the soil due to the expansion of farmland, causing pollution of nearby water sources.

A positive correlation between LULC changes and water resource parameters, indicating that LULC changes contribute to water resource changes, and thus, frequent water quality monitoring and LULC planning and management are recommended to control watershed pollution. With the predicted changes in LULC in the Weyib watershed, water resources are expected to continue to be affected; therefore, appropriate actions must be taken to reduce the impact of LULC changes on water resources.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The SWAT model was used in this study to assess the effects of changing land use/land cover on the hydrologic regime of the Weyib watershed. The Weyib watershed land use/land cover classifications were mapped using ERDAS Imagine 2015 throughout the last 19 years, from 2002 to 2020, using satellite imagery. This was done to evaluate classification accuracy of map of LULC classes. Before evaluating the impact of LULC on the hydrologic response of the Weyib watershed, the preparation of hydro meteorological data and spatial data was completed. In the watershed, the SWAT model was calibrated, validated, and its statistical performance was observed. The effects of the LULC modification on stream flow of watershed was assessed.

According to the LULC classification conducted during the study period, the Weyib watershed LULC considerably changed between 2002 and 2020. The study showed that the expansion of agricultural land and built up area. However, the other LULC classes showed reduction during the study period. The grassland decreased due to agricultural expansion in the watershed during the study period. Generally, the change of LULC is due to the population increment, which leads to increase demand for cultivation land.

For sensitivity analysis 15 flow parameters that may affect stream flow were considered from different kinds of literature and only 8 parameters were selected to have an influence in controlling the hydrological processes in the watershed. The statistical results during the calibration and validation period of 2002 and 2020 showed adequate model performance with a good R^2, NSE and PBIAS values. From the statistical parameters, it can be concluded that the SWAT model, using the identified parameters could simulate the watershed hydrologic response for the study area. The impacts of land use/land cover change on stream flow was completed after calibration and validation of the model. The simulated stream flow result showed that the mean wet monthly stream flow increased and the mean dry monthly stream flow decreased during the study period of (2002 to 2020).

The average monthly stream flows increased during the wet season and decreased during the dry season Therefore, the LULC changes caused by urbanization and agricultural intensification have a huge impact on the water resources of the river basin, and should be considered in future water resources management. Changes in LULC plan have an implication on water resources, such as reductions in water production surface runoff, river flow and water quality, and evaporation in the watershed. The future availability of water resources depends mainly on the planning and management of land use in this changing environment. Therefore, it is necessary for water resource managers and land use planners to understand the impact of changes in land use in sub basins on water resources in order to improve future water resource management. Population pressures that lead to urbanization and agricultural expansion through unplanned and inappropriate resource management practices to meet the food security needs of a rapidly growing population cause LULC dynamics.

Agriculture related LULC are unavoidable for developing countries such as Ethiopia whose economies depend on agriculture, as most of their cultivable land is located in large river and lake basin areas. Evidence of LULC changes and drivers of change are essential for future planning projects, as they provide more information about LULC. The results of this study can be used for future hydrological impact assessments in the sub basin to contribute to the sustainability of the water resource management system. This study provides water resources managers and land use planners with valuable information to improve future LULC policies, develop sub watershed management strategies in the context of sustainable water resources and land use planning and management.

5.2. Recommendation

Depending on the results, the following recommendation was made on the Weyib watershed:

- For better calibration and validation and for management purposes, future research should be done considering the different sources of uncertainties like water abstraction and water detention in the basin.
- To improve the performance and result of the model, the weather stations should be uniformly distributed in the watershed in both quality and quantity.
- Further research should be studied in the impact of LULC change and sediment yield on hydrology of watershed.
- Reforestation and land management on upstream of the watershed should be implemented to develop the hydrology.
- The basin stakeholders should optimize management of natural physical land and water resource to avoid future terrible stream flow fluctuations due to significant LULC change, possibly flooding during the wet season and low or dry riverbeds during the dry months.

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APPENDICES

Appendix 1: Annual Rainfall of selected Stations (mm)

Year	**Dinsho**	**Sinana**	**Ginir**	**Robe**
1990	1857.48	907.20	900.58	906.90
1991	1442.10	914.43	772.90	640.41
1992	2328.70	1021.60	2229.22	933.91
1993	1904.44	958.09	1994.08	842.10
1994	1885.30	834.00	1587.30	887.46
1995	1394.45	864.30	692.61	763.10
1996	1174.10	1235.97	994.90	936.40
1997	1605.21	1249.77	1046.30	896.20
1998	1444.80	919.67	952.10	937.24
1999	1240.29	1112.63	725.90	877.60
2000	1085.74	968.84	1208.97	792.80
2001	1342.71	1037.82	659.90	819.10
2002	1039.96	839.00	811.50	648.90
2003	875.50	872.30	713.60	891.40
2004	898.51	838.06	840.60	921.38
2005	1092.03	1497.14	1871.35	752.51
2006	1203.57	1027.60	1417.30	985.40
2007	1726.67	985.43	1001.63	933.45
2008	1073.20	1041.24	1042.11	827.70
2009	1097.89	717.23	1360.70	748.40
2010	1380.20	1024.50	1700.60	1075.24
2011	826.46	693.96	1021.44	769.20
2012	1205.80	775.92	1243.50	855.30
2013	1282.23	1092.14	1450.10	1009.50
2014	1074.90	767.70	1423.28	672.58
2015	1074.49	617.18	951.90	773.27
2016	1679.38	1053.73	969.34	803.70
2017	1386.72	809.90	1009.10	982.90
2018	1944.65	840.71	1491.93	1026.90
2019	1702.09	1751.25	2974.06	999.20
2020	1861.80	1867.30	1909.56	1214.43

Appendix 2: Annual temperature distribution of selected Stations (0c)

Year	**Dinisho**		**Ginir**		**Sinana**		**Robe**	
	Tem max	Tem min	Tem max	Tem min	Tem max	Tem min	Tem max	Tem min
1990	17.81	1.84	23.11	12.96	20.38	8.52	21.20	7.51
1991	18.12	2.09	23.47	13.23	20.84	8.16	21.80	7.73
1992	17.44	2.39	23.06	13.21	20.33	6.50	20.95	7.88
1993	18.27	2.46	23.12	12.68	20.11	7.96	20.84	7.38
1994	17.56	2.22	23.19	12.54	20.67	7.90	21.30	7.58
1995	16.52	2.04	22.73	12.47	20.68	7.80	21.48	7.64
1996	16.21	1.60	23.41	13.64	20.78	7.80	21.30	7.75
1997	16.42	2.32	23.26	12.62	20.72	7.18	21.62	8.17
1998	16.89	5.58	23.54	12.84	20.69	7.12	21.43	8.58
1999	16.80	5.86	23.65	12.52	20.87	7.02	21.01	7.77
2000	16.98	5.86	23.83	12.79	19.68	7.04	21.68	8.00
2001	16.58	5.88	24.35	13.19	21.50	8.22	21.44	8.21
2002	16.49	5.94	24.17	13.35	21.20	8.48	21.90	8.80
2003	16.34	5.93	24.33	13.48	21.50	8.13	21.61	8.83
2004	17.42	5.97	24.34	13.28	21.22	8.65	21.77	8.61
2005	16.64	5.90	23.98	12.84	21.33	7.24	22.03	8.46
2006	16.40	5.94	23.70	13.28	20.91	8.69	21.37	8.81
2007	16.77	5.91	23.79	13.09	20.93	8.08	21.32	8.58
2008	16.81	5.92	24.00	12.56	21.20	7.33	21.45	8.30
2009	16.87	5.91	23.95	12.92	21.81	6.45	22.00	8.85
2010	16.64	5.94	23.50	13.28	21.38	5.68	21.45	8.83
2011	16.89	5.89	24.02	12.77	21.22	2.20	21.92	8.22
2012	17.13	5.94	25.11	13.10	23.11	1.92	22.14	7.77
2013	16.72	5.92	24.41	12.78	22.96	4.06	21.67	7.79
2014	16.69	5.91	23.88	13.06	22.91	7.42	21.73	8.41
2015	17.31	5.89	24.79	13.50	22.86	8.31	22.39	8.45
2016	16.68	5.92	24.29	13.11	22.64	9.12	22.29	8.77
2017	17.32	5.94	24.02	13.02	23.07	8.16	21.99	8.63
2018	15.70	5.92	24.69	12.97	23.32	8.71	21.70	8.46
2019	17.28	5.87	24.32	13.09	21.14	7.80	22.18	8.89
2020	16.86	5.88	23.99	13.37	21.38	8.17	21.73	9.01