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SCHOOL OF GRADUATE STUDIES JIMMA UNIVERSITY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

CHAIR OF HYDROLOGY AND HYDRAULIC ENGINEERING

EVALUATION OF LAND USE AND LAND COVER CHANGE IMPACTS ON STREAM FLOW ; IN CASE OF TEMSA WATERSHED,ABBAY RIVER BASIN,ETHIOPIA USING SOIL AND WATER ASSESSMENT TOOL

Thesis submitted to the school of Graduate studies of Jimma University, Jimma Institute of Technology, Hydrology and Hydraulic Engineering Chair for partial fulfillment of the requirements for the degree of masters of Science in Hydraulic Engineering

By; - Bikila Gedefa

October 28, 2019
Jimma, Ethiopia

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By; - Bikila Gedefa

Advisor; Mamuye .Busier (Assistant Professor)

Co_Advisor; Mr. Abebe Chala (M.sc)

October 28, 2019
Jimma, Ethiopia

DECLARATION

I, the undersigned, declare that this thesis entitled: "**Evaluation of land use and land cover change impacts on stream flow: in Case of Temsa watershed, abbay river basin, Ethiopia, using soil and water assessment tool**" 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 duly acknowledged.

Candidate:
Bikila Gedefa
Signature _____________

As Master's Research Advisors, we hereby certify that we have read and evaluated this MSc Thesis prepared under our guidance by **Bikila Gedefa** entitled: Evaluation of land use and land cover change impacts on stream flow: in Case of Temsa watershed, abbay river basin, Ethiopia using soil and water assessment tool

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

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ABSTRACT

The land use land cover were the major factors alters flow regime. Many studies evaluate impacts of land use land cover change on flow regime and understanding influence of it on river flow regimes was important for sustainable watershed management. An imbalance of natural resources due to human intervention brings an impact of one on another especially in developing countries. In the last 21 years Temsa watershed experienced land use/land cover change. The main objective of this study is to evaluate the Land Use change impacts on the stream flow of Temsa watershed. Specifically, the study analyzed the present land covers that have taken place in the watershed and its effect on the Stream flow responses of the watershed. Geographic Information system was integrated with the Soil and water assessment tool model to carry out the study. Arc GIS10.4.1 and ERDAS imagine2015 were used to process soil raster data set and prepare land use/cover map from Land sat image acquired in 1997 and 2018 respectively. Land use classification was performed using a supervised classification system and accuracy assessment was done using a confusion matrix. Using the two land use/cover map Soil and water assessment tool model was set up and run and the default simulation was compared with the observed data. Then sensitivity analysis was made on a monthly basis using 16 flow parameters whereas only five parameters were identified as influencing the flow. The model calibration was done from 1998 to 2010 and the validation period from 2011 to 2017. The calibration and validation results showed a good match of simulation with observation, with Nash-Sutcliff efficiency 0.73 & 0.82 coefficients of determination and 0.78 & 0.81 for calibration and validation respectively. The result showed that the mean wet monthly flow increased by 33.15% (*from 30.166m3/s in1998 to 49.358m3/s in 2017), the mean short rain monthly flow increased by 9,086 %(from 15.023m3/sec in 1998 to 16.388m3/se in 2017) and the mean dry monthly flow decreased by 49.01% (from 16.2351m3/s in 1998 to 15.745m3/s in 2017). Generally, the study result indicated flow during wet season increased whereas during dry season decreased. The surface runoff contribution increased whereas ground water contribution decreased from 1997 to 2018 as a result of the expansion of agricultural and settlement areas. The study results showed a change in flow with change in land use/cover. The land use land cover changes scenarios were also developed by analyzing the impacts of land cover changes to the hydrological responses were modified or changed.*

KEYWORDS: *Land Use Change, Runoff, Statistical Parameters, SWAT-CUP, SWAT Model*

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ACRONYM

DEM	Digital Elevation Model
ETM+	Enhanced Thematic Mapper plus
FAO	Food and Agricultural Organization of United Nations
GIS	Geographic Information System
GLUE	Generalized Likelihood Uncertainty Estimation
GPS	Global position system
HEC-HMS	Hydraulic engineering center hydrologic modeling system
HRU	Hydrological response unit
LU/LCC	Land Use/Land Cover change
MCMC	Markov Chain Monte Carlo
MOWIE	Ministry of water, irrigation and energy
NMAE	National Meteorology Agency of Ethiopia.
NSE	Nash and Sutcliffe simulation efficiency
OLI_TIRS	Operational land image &Thermal Infrared sensor
PARASOL	Parameter solution
PBIAS	Percent bias
R2	Coefficient of Determination
RMSE	Root mean square error
SCS	Soil conservation service
SUFI2	Sequential Uncertainty Fitting Ver_2
SWAT CUP	Soil &Water Assessment Tool calibration &uncertainty program
USGS	United states Geological Survey
UTM	Universal Transversal Mercator
MOFED	Ministry of Finance and Economic Development

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

The term land use and land cover are often confused and used in appropriately. Land use can be defined as a series of activities undertaken to produce one/more goods/services. Hence, land use is based function, the purpose for which the land is being used (FAO, 1197). (IPCC, 2001) defined the term land use to cover the entire range of direct management activities that affect agricultural soils, result in land use change alter forest management, or affect the long term storage of carbon containing products. All such activities are implicitly human induced. Example of land uses are agriculture, forestry, recreation, etc.

Land cover is the observed physical cover, as seen from the ground or through remote sensing, including the vegetation (natural or planted) and human construction (buildings, roads, etc.) which cover the earth's surface (FAO, 1997).water, ice or sand surface are examples of land cover. Land cover maps provide information to help mangers best understand the current land scape, assess urban growth, model water quality issues, predict and assess impacts from floods and storms surges, track wetland losses and potential impacts from sea level rise, prioritize areas for conservation efforts and compare land cover changes with effects in the environment or to connections in socioeconomic changes such as increasing population (www.htt;//ocean service. Noaa.gov/land use, 2009).

The globally, land use/land cove (LU/LC) change was as old as human kinds (Turner, et al., 1993). Understanding the influence of LULCC on river flow regimes was important for sustainable catchment management (Pokhrel, 2018). Land use/land cover change (LULCC) were one of the major factors that alter the flow regime. Many studies worldwide evaluate the impacts of LULCC on the flow regime. Global forces become the main determinants of land-use change, as they amplify or attenuate local factors. LU/LC change has a major driver of biodiversity loss and affects climate change response, ecosystem structure and functioning, water and energy balance, and agro-ecological potential(El-Sadek and Irvem, 2014) (Kiersch and Tognetti, 2002). Adequate information on LU/LC require on global, national, and local scales. Land cover change was a very important issue in terms of the global context and their responses to environmental and socio-economic drivers. In the East Africa, nearly 13 million hectares of the original forest was lost over a 20 year period, and the remaining forest is fragment and continually under threat (Nyssen *et al.*, 2010). The dynamic of these factors was currently affecting the environment in unbalancing way including watershed hydrology. Therefore, it was very important to understand the functioning of the watershed and their hydrological response under different historical land use and climate change scenario conditions and the water resources development of the basin requires judicious planning for the protection of the fragile ecosystem (Kiggundu *et al.*, 2018).

The Land was a subset of natural resources like water and vegetation on the earth. An imbalance among these natural resources due to human intervention brings an impact of one on another. Especially in the fast-changing developing countries, it was a scientific challenge to predict land-use changes and their effects on water availability and erosion rates. To address these issues, catchment models were dealing with land-use dynamics. An attempt has been made by (Damtew Tufa et al , 2014) to study the land use/land cover changes that occur in watersheds and their effects on the hydrological system of a river basin.

The Conversion of land to feed and shelter the growing human enterprise has been one of the primary modes for human modification of the global environment. Over the coming decades, the expansion and intensification of agriculture, growth of urban areas, and extraction of timber and other natural resources would likely accelerate to satisfy demands of increasing numbers of people at higher standards of living (Gashaw *et al.*, 2017).

The Land use /land cover changes were found to be the most evident indicator of these human footprints and the greatest driver of biodiversity loss and other land degradation forms (Alemu *et al.*, 2015). The disturbance of the land through these human activities has wide-ranging and long-term consequences that affect important ecosystem processes and services (Wu *et al.*, 2013). The collective impact of land use/ land cover changes in the stream flow is a subject of concern to both developing and developed nations, as it affects sustainable development (Akhter, 2006). The Poor use of land especially in developing countries has led to huge proportions of land being degraded, reduction in food production and it was now a threat to livelihood. The Rapid urbanization, predominantly in developing worlds, was one of the critical issues and visible anthropogenic forces that has brought so many changes in the urban landscape and land cover patterns around the globe (Wijesekara *et al.*, 2010).

In Ethiopia, deforestation was one of the major processes of LULC change. Fuel wood collection, timber extraction, commercial agriculture and charcoal production were the primary direct drivers. Indirect drivers were population growth, essential for commodities, governance and economic growth (Solomon, et al., 2018). The LU/LC change was a major challenge impact on the agricultural development process and the implementation of the country's main development strategies, such as the Growth and Transformation Plan developed by Ministry of Finance and Economic Development and the 2011 Climate Resilient Green Economy strategy (MoFED, 2010).

Although the empirical knowledge of land use is obvious; it is difficult to quantify these consequences. Different methodologies have been implemented in an attempt to fill deficiencies of knowledge, but no general and creditable model has been established yet to predict the impact of LU/LCC on stream flow (Abbas *et al.*, 2015). It is important to understand the hydrology of the watershed particularly the physical processes occurring and the controlling factors within the watersheds. Studying the hydrological processes reacting to changes in land cover give valuable insights into how the river flow will respond to these changes. The river flow is known to be an integrated indicator of the entire watershed processes. Besides the projection of watershed hydrology on different land use/cover dynamics, are used to prioritize options for water resources planning and management for future watershed management.

The study was conducted for the Temsa sub-basin, South-Western Ethiopia, which is highly prone to changes imposing an impact on hydrological processes. Excessive land degradation due to increasing population density within the watershed has created environmental changes, economic and social effects, all resulting in degradation of raw water in the Sub-basin. The Temsa watershed was a watershed area located in the Abay River basin exposure to LU/LC change. The LU/LC Changes in land use have potential impacts on water resources, yet quantifying these impacts remain among the more challenging problems in hydrology. Hence, understanding the impact of land use/cover change enhances the water users and managers to allocate and use the available water resources in supporting the dominant agriculture-based economic and social developments. It is also used to implement techniques that control water yields, including rainfall, temperature and stream flows and, finally, to optimize the resources.

In this study a physically-based watershed model, SWAT model was applied to the Temsa watershed for evaluating the land use/land cover change impact in sub-basin hydrology and effects of future land use/land cover changes in the watershed. The Soil and Water Assessment Tool (SWAT) could be applied to watersheds to assess stream flow discharge and other impacts (Moriasi *et al.*, 2007). The semi-distributed Soil and Water Assessment Tool (SWAT2012) is a hydrologic simulation model integrated with ArcGIS used in this study.

1.2 Statement of the Problem

Human activities have modified the environment over the years. Urbanization, agriculture lumbering, mining and other land uses have substantially altered the earth's surface. Land use and the resultant change in land cover have significant effects on ecological, environmental and hydrologic systems and processes. An understanding of past and present land cover change, together with analysis of potential future change, is necessary for proper management. Ethiopian Higher Land of Sub basin was one of densely populated with an annual growth rate of 2.3 % (CSA, 2008). The fast-growing population and the density of livestock in the Sub-basin, lack of awareness of the watershed management strategies and agricultural practices on the land resources, resulting in forest clearing and overgrazing. (Tesfaye *et al.*, 2014).

The Temsa watershed have flow variation due to LULC change that impact on stream flow since the hydrological processes are sensitive to land use land cover change. The watershed is undergoing land use change due to intensive cultivation and urbanization as a result of population growth which has an impact on hydrologic response of the sub basin. The conversion of forest land into agricultural activities and urbanization has a great influence on LU/LC of the Sub basin as well as on the Stream flow. Specifically this study can initiate to understand and evaluate the impact of LULC (Vegetation cover reduction) on the stream flow, which helps finally for a better use, and management of the natural resources. This changes cause different problem in existing hydrological conditions. Change in land use type of certain area like increasing the percentage of impervious was increased volume of surface runoff, decrease time of concentration which makes several distractions by generating higher amount of runoff as well as decrease the amount of water percolated in to the ground. This in turn decreases the amount of water to be recharged in to the ground, and finally imbalances over all hydrological condition of watershed. Such and other issues should be evaluated deeply to know how land uses affect different hydrological process. The land use land cover change has significantly impacts on natural resource, socio economic and environmental system.

1.3 Objectives of the Study

1.3.1 General Objective

The General objective of the study is to evaluate the land use land cover change impacts on stream flow in case of Temsa watershed, abbay River basin, Ethiopia by using SWAT model.

1.3.2 Specific Objectives

Specific objective includes:-

i. To Prepare Land Use Maps for the study Area.
ii. To evaluate the impacts of the LU/LC change on the stream flow of the Temsa watershed.
iii. To evaluate performance of SWAT Model for stream flow prediction.

1.4 Research Question

The Temsa sub basin study will try to address the following question;-

i. What is the extent of land use/land cover change in the study area during the past years?
ii. What are the impacts of the land use /land cover change on the stream flow of the watershed?
iii. How SWAT Model performs for stream flow evaluation in the Temsa Watershed?

1.5 The Significance of the study

This study will attempt to check the performances and suitability of the SWAT model for the evaluation of LULCC impact in the Temsa watershed. However, to evaluate the effect of land use land cover change in stream flow is important to have an understanding of the land use land cover pattern and the hydrological process of the watershed. Understanding the types and impacts of land use land cover is an essential indicator for resource base analysis and development of effective and appropriate response strategies for sustainable management of natural resources in the country in general and in the study area in particular. Moreover, the study presents a method to evaluate land use land cover change and its impacts on surface runoff. This was achieved through a method that combines the hydrological model (SWAT) to simulate the hydrological processes, GIS and remote sensing techniques to analyze the land use land cover change.

Therefore, understanding how LU/LCC influence on the hydrologic condition of the watershed is needed for planners to formulate policies, to minimize the undesirable effects of future land cover changes for sustainable management of resources. Among thus, evaluating LU/LC changes within a watershed is an important component of monitoring watershed quality. Therefore, estimating and understanding the impact of LU/LCC on stream flow is important to accurately evaluate the type and direction of changes occurring within the watershed.

1.6 Scope of the Study

Moreover, the study presents a method to evaluate land use land cover change and its impact on surface runoff. This was achieved through a method that combines the hydrological model (SWAT) to simulate the hydrological processes, GIS and remote sensing techniques to analyze the land use land cover change. The study will cover LULC changes and its impacts on stream flow for Temsa watershed using SWAT and GIS software and remote sensing techniques to analyze the land use land cover change. The scope of this study will be limited to evaluate the impacts of the land use/land cover change effect on the hydrological process as well as land-use change in stream flow in the Temsa watershed.

CHAPTER TWO

LITERATURE REVIEW

2.1 Definition of Land Use and Land Cover Changes

Land cover refers to the physical and biophysical characteristics or state of Earth's surface and immediate, captured in the distribution of vegetation, water, desert, ice and other physical features of the land, including those created solely by human activities e.g., settlements(Mengistu, 2009). Land cover has gone under continuous change for millennia. This change has occurred through the use of fire for game hunting and clearance of covers of land for agriculture and livestock production, since the advent of plant and animal domestication. Land use change is any physical or biological change attributable to management including conversion of grazing to cropping, pollution and land degradation, vegetation removal, and conversion to nonagricultural uses (Yang *et al.*, 2009).

According to (Gebrie and Gebremariam, 2016) the most of the earth's surface is already modified, except those areas that are peripheral in location or are fairly inaccessible. One of the most significant global challenges in this century relates to management of the transformation of the earth's surface occurring through changes in LULC(Kassa *et al.*, 2018) changes that affect the character of the land cover without changing its overall classification. Definition of land use in this way establishes a direct link between land cover and the actions of people in their environment (Kiersch and Tognetti, 2002).This is because human's production demands cannot be fulfilled without modification and/or conversion of land covers. Land use land cover can be defined as how land is utilized. For example, residential and industrial land use would be considered one type of developed land use. Land cover is slightly different. A park could be forest, in this land use is a park and land cover is a forest. Land use refers to the intended use or management of the land cover type by human beings (De Sherbinin, 2002). Thus, land use involves both the manner in which the biophysical attributes of land are manipulated and intent underlining that manipulation, which are more subtle changes that affect the character of the land cover without changing its overall classification. Definition of land use in this way establishes a direct link between land cover and the actions of people in their environment (Briassoulis, 2000).

Land is a subset of the natural resources like water and vegetation on the earth. An imbalance among these natural resources due to human intervention brings an impact of one on another. The changes in Land use/land cover (LU/LC) patterns become important issues these days, considering global dynamics and their responses to environmental and socio-economic drivers. Especially in fast changing developing countries, it is a scientific challenge to predict land use changes and their effects on water availability, flood risk and erosion rates. Rapid socio-economic development drives land use change. To address these issues, catchment models are to deal with land use dynamics. Land use changes are altering the hydrologic system and have potentially large impacts on water resources (Kebenei, 2017).

There is an urgent need for technologies and models that can quantify the impact of land use change and management practices in an organized manner. The change in land use controls the water yields of surface streams and groundwater aquifers and thus the amount of water available for both ecosystem function and human use. The consequences of all of types of land changes have profound impacts on water quality. Land use change and management plays a significant role in water quality and quantity and there is a great need to integrate land change science, hydrology and water resources management in future (Hari, et al., 2014).

Globally, expansions of cropland and pasture land at the cost of forest, natural grassland and savannas were observed during the period of 1770–1990 and 1700–1990, respectively (Tang *et al.*, 2005). However, the direction of LULC change was not uniform across the world. LULC dynamics is an important landscape process capable of altering the fluxes of water, contaminants, and energy. Mainly caused by humans, impact of land use on water resources availability is high. Degraded watersheds tend to accelerate overland flow reducing soil moisture and base flow recharge and increasing sediment detachment and transport. Various studies used land cover mapping tools and methods to understand land use changes, inventory of forest and natural resources, as well as understand the changes in the hydrologic behavior of watersheds (Melesse, 2016)**.**

Land is a subset of the natural resources like water and vegetation on the earth. Over utilization of land resources have caused numerous forms of degradation such as loss of biodiversity, deforestation, land and water degradation(Zabaleta .et al, 2013). It is estimated that, about 83% of the global terrestrial land surface has been affected by the activities of humans and 60% of the ecosystem degraded over the past half century. The modification of the terrestrial surface of the earth is generally referred as land use land cover change (Orkodjo, 2014).

Generally, agriculture is found to be the major driver of land cover change in tropical regions. Over the past 50 years in East Africa, there has been expansion of agriculture at the expense of grazing land (Githui.et al, 2009). Before 1950, semiarid and sub humid areas were predominantly pastoral with scattered settlement and cultivation but from then onwards, there has been a significant transformation of grazing land to mixed crop-livestock agriculture. Understanding the mechanisms leading to LULC changes in the past is crucial to understand the current changes and predict future.

2.1.1 Land Use land cover change

Land use land cover (LULC) is an essential component of the terrestrial ecosystem, influencing various fundamental characteristics and processes such as the hydrological cycle, geomorphological processes, land productivity and animal species (George .et al, 2011). Rainfall and land use/land cover are the important parameter of run-off estimation by hydrological modelling. Different types of land surface parameters have been extracted by studies have shown that changes in catchment hydrology occur mainly due to alterations in interception, infiltration, evapotranspiration and groundwater recharge which are linked to LULC changes from(Abbulu et al, 2014). Assessing the impacts of LULC changes on hydrology therefore, remains an important step in watershed management strategies inclusive of water resources planning and conservation measures. According to(Chaemiso et al, 2016) the impact of land use land cover change may be felt across a wide spectrum of environmental systems including the atmosphere, hydrology, geomorphology and ecology. Land use changes are a key factor for altering hydrological response, and understanding its impacts can help to develop a sustainable and pragmatic strategy in order to preserve a watershed (Pokhrel, 2018).

The land use/land cover change and rainfall have a significant influence on the hydrological response of the river basins. The run-off characteristics are changing naturally due to reduction of initial abstraction that increases the run-off volume. Therefore, it is necessary to quantify the changes in the run-off characteristics of a catchment under the influence of changed land use/land cover. Poor use of land especially in developing countries has led to huge proportions of land being degraded, reduction in food production and it is now a threat to livelihood

(Nyssen *et al.*, 2010). Rapid urbanization, predominantly in developing worlds, is one of the critical issues and visible anthropogenic force that has brought so much changes in urban landscape and land cover pattern around the globe.

Land use land cover change is a crucial environmental change which has several impacts on human livelihoods. Management of earth's natural resources remains a critical environmental challenge that society must address because misuse of available resources may lead to severe threat causing scarcity of water resources(Salim et al, 2016). Natural life is mainly supported by major resources i.e. water and soil, which play crucial roles in the natural ecosystems. Freshwater which moves from upstream to downstream is mainly supplied by the watersheds. The water quality reaching the downstream is being degraded due to the changes that are occurring in land use land cover. Changes in land use land cover mainly drive the changes in watershed hydrology. Deforestation, conversion of vegetation lands to agriculture may increase the economic development but it also affects the environmental status of the society (Venkatesh and Ramesh, 2018).

According to (Fenta Mekonnen et al., 2018) reported that vegetation cover increase evapotranspiration and decrease in the mean annual river flow. In other word, increasing forest cover would substantially reduce sediment yield and modulate stream flow. Therefore, land cover changes interfere with the land phase of hydrologic cycle. The competing processes may result in either increased or reduced dry season flows. Effects on dry season flows are likely to be very site specific. As indicated in (Haregeweyn et al., 2017), the fast growing of population and the density of livestock in the basin resulted in forest clearing and overgrazing. In addition, more mountainous and steeper slopes are cultivated, in many cases without protective measures against land erosion and degradation. Hence, outlining the relationship between land use and the hydrological condition of the area enables us to know how the quantity of water flowing to the reservoir is changed with the change of land use. The agricultural based economy and rapidly increasing human population are the main cause of land use-Land cover change in the developing countries and Resource scarcity is also the main cause of Land use-cover change and largely driven by the decision of the people, population growth, declining household farm size and income (Zhang et al, 2008).

In many parts of the highlands of Ethiopia, agriculture has gradually expanded from gently sloping land into the steeper slopes of the neighboring mountains. According to many literatures, population that has been steadily increasing at a growth rate of 2.67 % per year during the past five decades is the major cause for this expansion. In some areas, expansions of cultivation, commonly into steeper slopes and marginal areas, may have been done without appropriate soil and water conservation measures. Despite this increase, the agricultural productivity is lagging behind the population growth rate. For instance, in the past four decades, areas in the Blue Nile basin have undergone dramatic LULC changes, with the result that almost all land units have been converted into cultivated land (Roth *et al.*, 2018). The results from (Assefa M.et al, 2012) area, for example, show that the natural forest cover declined from 27 % in 1957 to 2 % in 1982 and 0.3 % in 1995, whereas cultivated land increased from 39 % in 1957 to 70 % in 1982 and 77 % in 1995.

2.2 Interaction of Land use Land Cover Change and Hydrology

Land use land cover change (LULCC) is one of the major factors that alters the flow regime. Many studies worldwide have evaluated the impacts of LULCC on the flow regime(Siraj et al, 2018). Understanding the influence of LULCC on river flow regimes is important for sustainable catchment management. LULCC can change base flow, and annual mean discharge. Deforestation and conversion to arable land or grassland are usually accompanied by an increase in surface runoff or total discharge(Erena and Worku, 2019).

Land use land cover are key variables in managing the most of the hydrological models for large and even smaller river catchments. A study conducted (Kidane *et al.*, 2019) revealed that land use land cover changes (e.g., change of forestland to agricultural land or built area) have a serious effect on the rate of surface runoff, groundwater recharge, erosion. Since land use change has a significant and profound effect on water quality and quantity, there is an urgent need to understand the interaction between land use change, hydrology and water resources management. Several studies have discovered that deforestation or afforestation can cause decrease or increase in the total water yield. This has been detected in catchments with wide-ranging area spreading from a smaller than 1 km2 to more than 1000 km2 (Mutayoba *et al.*, 2018).

Land use changes are a key factor for altering Stream flow response, and understanding its impacts can help to develop a sustainable and pragmatic strategy in order to preserve a watershed. Water on earth exists in a space circulates and forming hydrologic cycle. The cycle has no beginning and no ending and can be affected by different factors. Among those factors, manmade activities, and land use land cover change can affect hydrological processes such as infiltration, runoff and groundwater recharges. Different studies indicate that land use land cover change have an impact on Stream flow components. (Haile E. and M., 2012) concluded that the decrease of forest land and grass land was accompanied by the increase in agricultural and built up areas and this change in land use land cover increased surface run off during wet seasons and reduced base flow during the dry seasons. (Gebrie and Gebremariam, 2016) Concluded that the land use land cover change have a great influence on stream flow especially during wet season than dry season. Cultivation of land exerts a major influence on the relationship between surface and subsurface flow. According to data from long term observations done in paired catchments, in the forest zone of Central Russia (El-Sadek and Irvem, 2014) Surface runoff is extremely limited under grass or forest vegetation compared with agricultural land.

Land use planning and management are closely related to the sustainability of water resources as changes of land use are linked with amount of water through relevant hydrological processes. Land use Land cover directly impact the amount of evaporation, groundwater infiltration and overland runoff that occurs during and after precipitation events(Githui et al, 2009). The effect of the land cover changes and best management practices (BMPs) has impact on the stream flow of the watershed by changing the magnitude of surface runoff and ground water flow. The response of Stream flow to land use/cover change is an integrated in ecosystem, and may affect the overall healthy functions of a watershed and its ecosystems (Hernandez *et al.*, 2000).

Land use land cover (LULC) changes, particularly caused by human activities-for example deforestation to clear land for agriculture, are considered to be the most important factor in global environmental change, exerting effects possibly greater than those of other global changes(Chakilu and Moges, 2017).According to (Jemberie.et al, 2016) Have argued that Land use land cover change have an impact on stream flow of the watershed on basin. The land use/land cover change and rainfall have a significant influence on the stream flow response of the river basins. The run-off characteristics are changing naturally due to reduction of initial abstraction that increases the run-off volume. Therefore, it is necessary to quantify the changes in the run-off characteristics of a catchment under the influence of changed land use/land cover from (Khare *et al.*, 2017).

(Abbulu .et al, 2014) Argued that one of the parameters that affect the volume of water flowing in a watershed is land-use land-cover of the watershed area. Having investigated the influence of human induced abstractions and its impact on the stream flow of the basin, it is also important to investigate of land-use/land-cover changes within the basin and their impacts on the hydrological regime. Hence, investigating the relationship between land-use/land-cover and the hydrological condition (runoff volume, peak runoff rate) of the area enables us to know how the quantity of water flowing to the reservoir is changed with the change of land use. As a result, the need for scientific research that establishes the impact of land-use changes on stream flow is essential.

Land-Use/Land-Cover Change (LULCC) can be driven by multiple forces; demographic trends, national policies, and macroeconomic activities which in turn have significant impact on hydrologic system both at a basin and regional scales (Wijesekara *et al.*, 2010). However, Intensity of change may vary spatially as well as temporally due to the distribution and characteristic of population across the landscape. To visualize the future effects of LULCCs on river flow, it is important to have an understanding of the effects of historic land use changes on the watershed hydrological system; because of direct and powerful linkages exist among spatially distributed watershed properties and watershed processes from (Hernandez *et al.*, 2000).

Stream flows are sensitive to land use change i.e. minor change in land use causes major changes to stream flows. Numerous studies have been conducted to investigate the impact of LULC change on stream flows ranging from small watersheds to large river basins which ended up exhibiting the causes for stream flow changes is due to conversion of forest land to agricultural lands. Increase in settlements, deforestation, expansion of agricultural area and intensive grazing yields high runoff yield. These changes enlarge the quantity, velocity and intensity of runoff (Alemu *et al.*, 2015).

Assessing impacts of Land use Land cover (LULC) changes on stream flow is the basis for watershed management and ecological restoration. The assessment usually includes evaluation of spatial patterns of hydrological consequences to different LULC maps, comparison of basin values of simulated hydrological components to LULC changes at the basin scale, and examination of temporal responses in channel discharge with changes in LULC. However, most studies do not quantify contributions of change for individual LULC to different hydrological responses. Without accurate quantification, the impacts of changes for some LULC classes on hydrologic components may be exaggerated or understated, or even misinterpreted(Hernandez *et al.*, 2000).

One of the forms of this resource degradation is believed to follow from land cover changes which results in disturbance of stream flow regimes of watersheds. The basis will lead to the condition of land under little vegetative cover is subject to high surface runoff amounts, low infiltration rate and reduced groundwater recharge. This eventually, leads to lowering of water tables and intermittence of once-perennial streams (Lemann *et al.*, 2018). Consequently, the study on land use land cover change is needed to explore how land use land cover change influences watershed hydrology. Besides, detecting and simulating the effects of land use land cover change on catchment hydrological process requires a new, strategic and improved procedure to conserve the catchment based on the hydrological sensitivity as a result of land use change at sub watershed(Takala.et al, 2016)

2.3 Effects of Land Use Land Cover Change

In the coming years extreme floods are expected to be more frequent and devastating due to the effects of expansion of urbanization that increases the generation of surface runoff. The rainfall-runoff relationships show that an increase in surface runoff is a point of concern in many catchments around the world. Surface runoff is governed by various factors such as land use land cover, river network, morphology and topography (Guzha *et al.*, 2018). However, the main reasons for the increase of surface runoff are resulted from anthropogenic activities such as deforestation, overgrazing and urbanization. The decrease in vegetation cover leads to a decrease in interception and modification of the physical soil structure which reduces the infiltration capacity (Kondoh.et al, 2018)

The need of producing more food and maintaining ecosystem services were undermining the environment by altering the availability of different biophysical resources. The strong relationship between land use land cover from these systems has contributed great concern to the basic planet characteristics and process. Productivity of the land, diversity of plant and animal species, hydrological cycles, ecological and environmental conditions are some of the anxieties. This was basically depending on the fact that, land use change is the proximate cause of the land cover change(Wakjira T.et al, 2016).

Expansion and intensification of agricultural lands, development of urban areas and the need of extracting timber and other products are accelerating over time to meet the needs of an increasing population. Under such circumstance, handling the land and water resources in achieving high productivity would be difficult to be realized without degrading the resources. This results in the land use land cover change leading to a decreased availability of the products and services of the livelihood (Melesse, et al., 2012).

Land cover change, especially deforestation, not only facilitates the physical removal of soil but also accelerates the deterioration of the basic soil properties (Gebremariam.et al, 2016). The formation and advancement of gully erosion are common effects of soil erosion. Gully development in the Umbulo catchment was extended from upslope to the middle and lower slopes at the same pace as the rate of forest reduction from the catchment, indicating the influence of land cover change for the formation of soil erosion, since vegetation was providing soil protection(Kidane *et al.*, 2019).

2.4 Land Use Land Cover Change Studies in Ethiopia (Previous Study)

In Ethiopia, land use can be seen from the perspective of human activities such as agriculture, forestry, building construction, and recently, industrialization which has led to increased human population within urban areas and depopulation of rural areas(Kassa *et al.*, 2018). The driving forces behind land use pattern include all factors that influences human activity, including local culture (food preferences), economics (demand for specific products, financial incentive), environmental condition (soil quality, terrain and moisture). Studies that have been carried out at different parts of Ethiopia indicated that croplands have expanded at the expense of natural vegetation, including forests and shrub lands(Tang *et al.*, 2005).

Land use land cover changes have negative consequences on livestock production due to loss of the country's grazing land, change in hydrological system(Tesfaye *et al.*, 2014), soil erosion, ecosystem degradation and biodiversity loss. However, most of the empirical evidences indicated that land use land cover changes and socioeconomic dynamics have a strong relationship. As population increases the need for cultivated land, grazing land, fuel wood, settlement areas also increase to meet the growing demand for food and energy, and livestock population. Thus, population pressure, lack of awareness and weak management are considered as the major causes for the deforestation and degradation of natural resources in Ethiopia. Land cover dynamics in particular, deforestation has become a global concern, as its implications for human livelihood systems are immense. Land use change is largely driven by the decision of the people and population growth, declining household farm size and income. Whereas natural effect such as climate change are felt only over a long period of time, the effect of human activities are immediate and often radical. Land use land cover is a biophysical characteristic that have strong interrelation between atmosphere and ground surface hydrologic cycle. Its impact is direct on water resources on the ground (Fenta Mekonnen *et al.*, 2018).

In Ethiopia, land is used for agricultural purposes, for construction of buildings and roads and extra purposes. In the country most of the land is used for subsistence farming. With the population growth and slow technological adoption which can increase production, there is deforestation for more production which means conversion of forest to agricultural land and expansion of urban settlements. The researchers conducted by different researchers in different parts of the country indicate that there were LU/LC changes in the country. For instance (George .et al, 2011) identified that decrease of natural vegetation and expansion of agricultural land cover over a period of 41 years in Tigray, northern part of Ethiopia. The other research indicated that the expansion and intensification of agricultural land is due to population growth (Alemu *et al.*, 2015) in the semiarid of Central Rift Valley of Ethiopia and (Welde and Gebremariam, 2017) Concluded that LU/LC dynamics in the Central Rift Valley Region of Ethiopia was due to population pressure which caused agricultural expansion in to marginal land and more sever land degradation(George and Western, 2011).

According to (Tolera, 2018) indicated that farm lands and settlements has expanded which was mostly associated with the decrease in forest in Hare watershed Southern Rift Valley Lakes Basin and deforestation was due to rapid population growth. In Ethiopia, land use can be seen from the perspective of human activities such as agriculture, forestry, building construction, and recently, industrialization which has led to increased human population within urban areas and depopulation of rural areas (Kumar .et al, 2013). The driving forces behind land use pattern include all factors that influences human activity, including local culture (food preferences), economics (demand for specific products, financial incentive), environmental condition (soil quality, terrain and moisture). Studies that have been carried out at different parts of Ethiopia indicated that croplands have expanded, at the expense of natural vegetation, including forests and shrub lands (Brooks and Neary, 2008). Land use land cover changes have negative consequences on livestock production (Roth *et al.*, 2018) due to loss of the country's grazing land, change in hydrological system ((Getahun and HAJ, 2015), soil erosion, ecosystem degradation and biodiversity loss. However, most of the empirical evidences indicated that land use and land cover changes and socioeconomic dynamics have a strong relationship. As population increases the need for cultivated land, grazing land, fuel wood, settlement areas also increase to meet the growing demand for food and energy, and livestock population. Thus, population pressure, lack of awareness and weak management are considered as the major causes for the deforestation and degradation of natural resources in Ethiopia(Tufa and Abbulu, 2014).

(Haile,E. and Assefa .M., 2012) reported that the mean wet monthly stream flow was increased by 39% and dry average monthly flow decreased by 46% for 2011 land cover as compared to 1985 land cover due to LULC change on Angereb watershed in Ethiopia. (Geremew, 2013) found that LULC change affected the stream flow of Gilgel Abbay watershed, Ethiopia. The mean monthly stream flow for wet months had increased by value 16.26 m3/s while the dry season had decreased by 5.41 m3/s during the year 1986 to 2001 due to the LULC change. Therefore, providing a scientific understanding of how LULC change affects the watershed hydrology is very important. LULC change is also one of the fundamental environmental problems in Ethiopia (Gashaw *et al.*, 2017). There was a rapid expansion of cultivated land at the expense of forest lands mostly in the highlands of the country (Welde and Gebremariam, 2017). In the northern highlands of Ethiopia, there are few remnant forests, which are found in sacred and inaccessible places and cultivation is stretched to the steepest areas where access is naturally restricted (Elias *et al.*, 2019).

2.4.1 Land Use Land Cover Change Studies in Abbay Basin

Most of the water used in the lowlands between Ethiopia and the Mediterranean Sea originates in the Ethiopian Highlands. The Blue Nile basin alone contributes 60%–70% of the water in the River Nile flowing through Sudan and Egypt(Khare *et al.*, 2017). In Sudan and Egypt, up to 95% of the water used is blue water from the Nile (Gashaw *et al.*, 2017). By contrast, in the headwaters, until recently, more than 95% of the agricultural area was rained, thus using almost exclusively green water(Taye *et al.*, 2019). Driving forces, such as economic development and population growth, are increasing the demand for water along the entire length of the Nile for food and energy production, and domestic and industrial use. New dams and intensification of agriculture are changing the temporal and spatial use of blue and green water along the Nile, affecting drainage ratios and water availability. Knowledge about the characteristics of different catchments and each watershed's hydrological response is essential to predict the influences of, for example, land use change on future spatial and temporal water availability for up- and downstream stakeholders. Agricultural production contributes to about 43% of the growth development program, 80% of employment, and 75% of export in Ethiopia (MOFE, 2011.). Meanwhile, ~80% of the population in the country lives in the highlands (CSA, 2011).

In Ethiopia, the type of farming system, land use, amount of rainfall and soil type is determined by elevation. In previous empirical studies (Teferi, et al., 2013) conducted in the Upper Blue Nile River Basin where the study site is situated major land use land cover (LULC) types were identified. Several studies attempted to understand the effect of LULC change on biophysical processes; however, limited studies accounted dynamic nature of land use change (Taye *et al.*, 2019). However, land use has generally not fallen in line with the scientific LCC guidelines in Ethiopia. For instance, cultivation for annual crop production was practiced on lands which need to be reserved for other purposes including animal husbandry, forestry and other non-cultivation activities. The existence of the problem has also been proved by studies conducted in the north-western highlands of the country. These studies showed as subsistence crop production has expanded into ecologically marginal areas. This kind of unscientific conversion can adversely affect the erodibility of soil and observed erosion rates, hydrology, biodiversity, ecosystem services and climate through its influence on the surface energy budget(Jemberie, Gebrie and Gebremariam, 2016). Consequently, soil erosion, siltation and water scarcity emerged as major problems for agriculture in the region. The findings of these environmental studies emphasized the need to conduct LCC evaluation to inform land-use policy (Tatedaw.*et al.,* 2018).

2.5 Application of Remote Sensing on LULCC

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(Dwarakish and Ganasri, 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) and land cover maps. Some of the application of remote sensing technology in mapping and studying of the land use/land cover changes are: map and classify the land use and land cover; assess the spatial arrangement of land use and land cover; allow analysis of time-series images used to analyze landscape history; report and analyze results of inventories including inputs to Geographic Information System (GIS) and provide a basis for model building. Land use land cover is changing rapidly in most parts of the world. In such situation, accurate and meaningful data is highly essential for planning and decision making. Remote sensing is particularly attractive for the land cover data among the different sources.

(Griensven et al., 2012) reported that in 1970"s satellite remote sensing techniques have started to be used as a modern tool to detect and monitor land cover change at various scales with useful results. William et al., 1991 showed that the information of land use and land cover change which is extracted from remotely sensed data is vital for updating land cover maps and management monitoring of natural resource phenomena on earth surface. The importance of land cover mapping is to show the land cover changes in the watershed area and to divide the land use and land cover in different classes of land use and land cover. For this purpose, remotely sensed imagery play a great role in obtaining information on both temporal and spatial distribution of watershed areas and changes over time (Fenta Mekonnen et al., 2018). To monitor the rapid changes of land cover, to classify the types of land cover, and to obtain timely land cover information, multi temporal remotely sensed images are considered effective data sources.

2.6 Classification of Hydrological Model

Hydrologic modeling has proved to be very important tool that can be applied to understand and explain the effects of LU/LC change on hydrologic response of a catchment (George and Western, 2011). Hydrological models are mathematical descriptions of components of the hydrologic cycle. They have been developed for many different reasons and therefore have many different forms. However, hydrological models are in general designed to get a better understanding of the hydrologic processes in a watershed and of how changes in the watershed may these phenomena and for hydrologic prediction. They are also providing valuable information for studying potential impacts of changes in land use and land cover. There are many classification of hydrologic models, deterministic versus stochastic, lumped versus distributed and etc. On the basis of process description, the hydrological models can be classified in to three main categories (Truong.et al, 2018).

Lumped models; - Parameters of lumped hydrologic models do not vary spatially within the basin and thus, basin response is evaluated only at the outlet, without explicitly accounting for the response of individual sub basins. The parameters often do not represent physical features of hydrologic processes and usually involve certain degree of empiricism. These models are not usually applicable to event scale processes. If the interest is primary in the discharge prediction only, then these models can provide just as good simulations as complex physically based models(Schilling et al., 2009).

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

Semi distributed models: - Parameters of semi distributed models are partially allowed to vary in space by dividing the basin in to a number of smaller sub basins. The main advantage of these models is that their structure is more physically based than the structure of lumped models and need less input data than fully distributed models. SWAT and HEC-HMS are considered as semi distributed models.

2.6.1 Hydrological Model Selection Criteria

There are many criteria which can be uses for choosing the right hydrologic model. These criteria always project dependent, since every project has its own specific requirements and needs. Further, some criteria are user dependent, such as the personal preference for graphical user interface (GUI), computer operating system, input out management system and structure. SWAT model is a semi distributed; time continuous watershed simulator operating on daily time step. It is developed for assessing the impact of management and climate on water supplies, sediment and agricultural chemical yields in watersheds and larger river basins. The model is physically based and allows simulation of a high level of spatial detail by dividing the watershed into a large number of sub watersheds. The major components of SWAT include hydrology, weather, erosion, plant growth, nutrients, pesticides, land management and stream routing. The program is provided with an interface in Arc GIS for the definition of watershed hydrologic features and storage as well as the organization and manipulation of the related spatial and tabular data. (Moriasi *et al.*, 2007).

SWAT model has been applied in agricultural watersheds and have been successfully calibrated and validated in many areas of the world. The studies indicated that the SWAT model is capable of simulating hydrologic process from complex and data poor watershed with reasonable model performance statistical values. According to (Aduah.et al, 2017) was used SWAT models to predict water balance and water yield of a catchment. It was suggested that, SWAT model could be a promising tool to predict water balance and water yield in sustainable management of water resource. (Getahun and HAJ, 2015) Was applied SWAT model on reported that, the overall model performance was satisfactory. Similarly, (Roth *et al.*, 2018) also applied SWAT model to evaluate surface runoff generation and soil erosion rates for a small watershed in Ethiopia, and recommended that, the SWAT model provides a useful tool for soil erosion assessment from watersheds and facilitates planning for a sustainable land management. The above literature review indicated that the SWAT model is capable of simulating hydrological process with reasonable accuracy and can be applied to large and complex watersheds.

2.6.2 SWAT Development and Interface

SWAT model is a semi distributed; time continuous watershed simulator operating on daily time step (Hernandez *et al.*, 2000). It is developed for assessing the impact of management and climate on water supplies, sediment and agricultural chemical yields in watersheds and larger river basins. The model is physically based and allows simulation of a high level of spatial detail by dividing the watershed into a large number of sub watersheds. The major components of SWAT include hydrology, weather, erosion, plant growth, nutrients, pesticides, land management and stream routing. The program is provided with an interface in Arc GIS (Barsi.et al, 2012) for the definition of watershed hydrologic features and storage as well as the organization and manipulation of the related spatial and tabular data.

2.6.3 Application of Hydrological Model (SWAT)

SWAT model has been applied in agricultural watersheds and have been successfully calibrated and validated in many areas of the world. The studies indicated that the SWAT model is capable of simulating hydrologic process from complex and data poor watershed with reasonable model performance statistical values. (Neitsch *et al.*, 2002) was applied the SWAT model in modeling of Pangari River (Tanzania) to evaluate the applicability of the model in complex and data poor watershed. (Jewitt .et al , 2017) was used SWAT models to predict water balance and water yield of a catchment area in Nigeria. It was suggested that, SWAT model could be a promising tool to predict water balance and water yield in sustainable management of water resource. (Getahun, 2015) was applied SWAT model on Lake Tana Reservoir Water Balance and reported that, the overall model performance was satisfactory. Similarly,(Roth *et al.*, 2018) also applied SWAT model to evaluate surface runoff generation and soil erosion rates for a small watershed (Keleta Watershed) in the Awash River basin, Ethiopia, and recommended that, the SWAT model provides a useful tool for soil erosion assessment from watersheds and facilitates planning for a sustainable land management. (Srinivasarao.et al, 2014) was applied SWAT model for hydrological modeling of Katar watershed, Lake Ziway catchment and recommended the use of SWAT model for further future research. The above literature review indicated that the SWAT model is capable of simulating hydrological process with reasonable accuracy and can be applied to large and complex watersheds.

2.6.4 SWAT Calibration and Uncertainty Procedures (SWAT-CUP)

Distributed watershed models are increasingly being used to support decision making in land use change. These models should pass through a careful calibration and uncertainty analysis. Large scale distributed models are difficult to calibrate and to interpreter the calibration because of large model uncertainty, input uncertainty and parameter non uniqueness. To perform parameter calibration and uncertainty analysis different programs are introduced. SWAT-CUP is one of the program which is currently used by different researchers. SWAT-CUP is a public domain and any calibration, uncertainty or sensitivity can be linked to SWAT. The program links Generalized Likelihood Uncertainty Estimation (GLUE), Parameter Solution (ParaSol), Sequential Uncertainty Fitting (SUFI2) and Markov Chain Monte Carlo (MCMC) procedures to SWAT process in which iteration and unknown parameter estimates are achieved before the final estimates (Abbas *et al.,* 2015). It enables sensitivity analysis, calibration, validation and uncertainty analysis of SWAT models. SUFI method determines uncertainty through the sequential and fitting.

2.6.5 Model Performance Evaluation

For evaluation of model performance, (Taye *et al.*, 2019) describes model evaluation guidelines for quantification of accuracy in watershed modeling. The evaluation was performed by visual and statistical comparison of the measured and simulated data. The graphical method provided an initial overview. The statistical criteria used to evaluate the performance of the model. The Nash and Sutcliffe simulation efficiency (NSE) describes the deviation from the unit of the ratio of the square of the difference between the observed and simulated values and the variance of the observations. The value of the coefficients varies from minus infinity to one with the latter value indicating perfect agreement between the simulated and observed data. A smaller NSE value indicates poorer fit between the simulated and observed data. It is possible to obtain negative value of the NSE indicating that the average of the observational data provides a better fit to the data compared to the simulated data. The percent bias (PBIS) describes the tendency of the simulated data to be greater or smaller than the observed data, expressed as percentage. The optimum PBIAS value is zero and low values indicate that the model simulation is satisfactory. Positive values indicate a tendency of the model to underestimate while negative values are indicative of overestimation. This test is recommended due to its ability to reveal any poor performance of the model. There are no existing standards describing the range of the values of the statistical parameters that would indicate acceptable performance of the model (Pohlert *et al.*, 2007).

Table 2.1 the table reported performance rating for R2, NSE and PBIAS for SWAT model

Modeling phase	R2	NSE	PBIAS	Performance rating
1.Calibration& Validation	0.75<R2≤1.00	0.75<NSE≤1.00	PBIAS≤±10	Very good
2.Calibration & Validation	0.65<R2≤0.75	0.65<NSE≤0.75	±10≤PBIAS±15	Good
3. Calibration & Validation	0.5<R2≤0.65	0.5<NSE≤0.65	±15≤PBIAS±25	Satisfactory

Source; (Griensven *et al.*, 2012)

In General, Model simulation can be judged as satisfactory if NSE>0.50 and RSR≤0.70 and if PBIAS±25 for stream flow.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of study area

The study area of Temsa watershed is located to the South West of Oromia Region and partially in the South Nations and Nationality people of Ethiopia Region and drains to Dedessa Sub basin of Ethiopia. Geographical coordinate of the area is 8°4'54.84"North and 36°44'35.52"(East figure 3.1) below shows in the Abbay River Basin of the main river basin of Ethiopia and the study area map. The topography or elevation of the watershed ranges from 1274 to 3145m above mean sea level. The altitude ranges between 1720m and 2088m above sea level(Wu *et al.*, 2013).

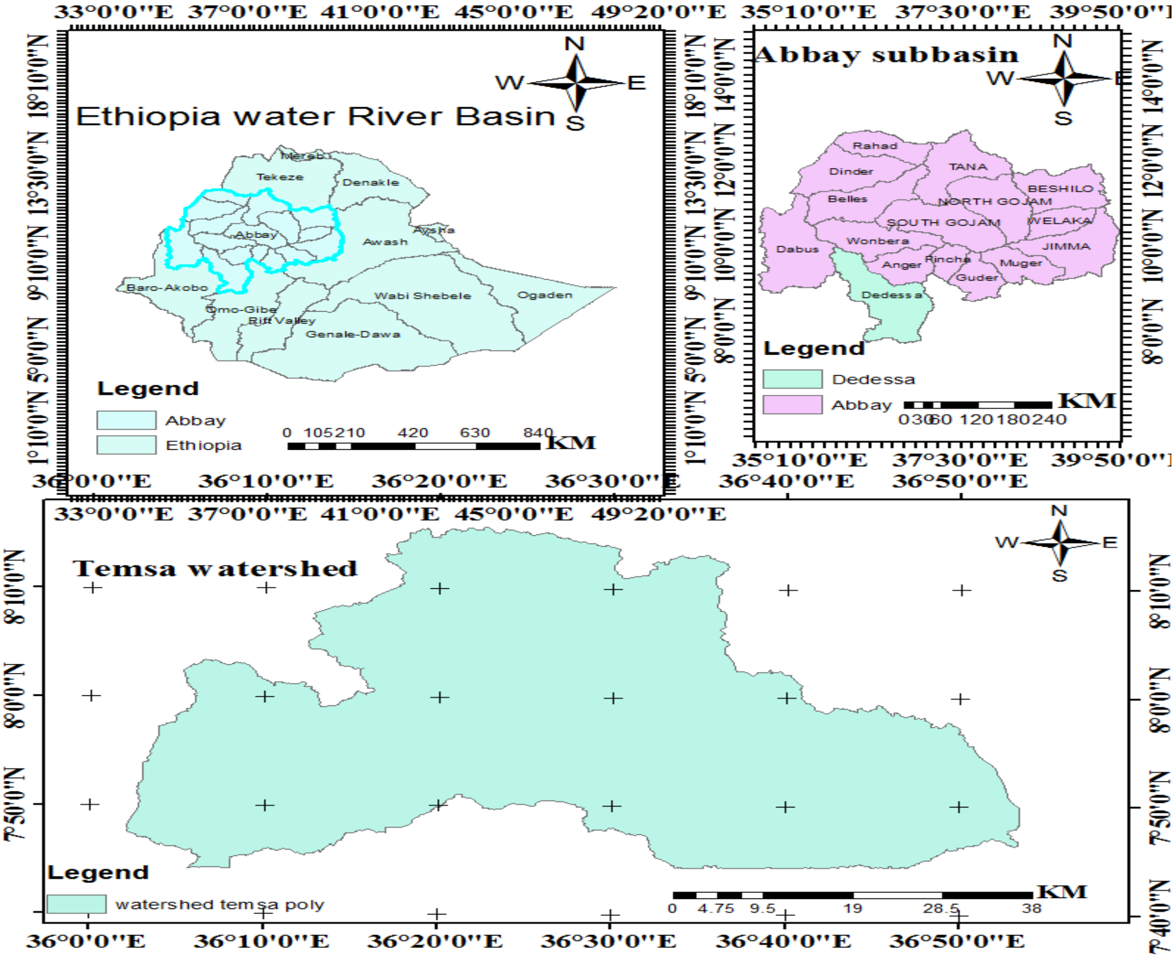


Figure 3. 1 Area of Temsa watershed in abbay river basin

3.1.1 Climate of the Study Area

The majority of the area is characterized by a humid tropical climate with heavy rainfall and the most of the total annual rainfall is received during rainy season called kiremt. The climate of Ethiopia is mainly controlled by seasonal migration of Inter-tropical convergence zone (ITCZ) and its associated atmospheric circulation but the topography has also an effect on the local climate. The most common classification system, traditional classification system mainly relies on altitude and temperature shows the presence of five climatic zones. These are, Wurch (cold climate at more than 3000m altitude), Dega (temperate like climate-highlands with 2500-3000m altitude), Woina Dega (warm at 1500-2500m altitude), Kola (hot and arid type, less than 1500m in altitude), and Bereha (hot and hyper-arid types) climates (NMSA. 2001)(Roth and Lemann, 2016).

Classification with respect to rainfall regimes shows the presence of monomial, bi-modal and diffused pattern of rainfall climates. Consideration of moisture index shows that large portion of the country falls (Lemann *et al.*, 2018). Based on the above classification the climate of Temsa watershed is classified as tropical humid in the highlands that include areas surrounding Gomma Wereda in Jimma Zone and around the headwaters of Buno Bedele Zone watershed including some parts of SNNPE Region in Ethiopia. For the rest, and the greatest part of the watershed, the climate is classified as a tropical sub-humid, intermediate between the tropical humid and the hot arid climate characteristic of the southernmost part of the floodplain towards Dedessa Sub Basin in Abbay River basin(Wu *et al.*, 2013).

3.1.2 Rainfall

The rainfall distribution in the Temsa watershed varies from higher altitudes in the mountainous regions to the low land areas. The monthly rainfall distributions of the study area indicate that June, July, August and September are the wettest season of the months and March, April and May are the short rain season months of the year in all the selected stations. The mean monthly rainfall of the Agaro, Gatira, Jimma and Bedele stations (1995-2017) are shown in (Figure 3-2). The mean annual rainfall (1995-2017) of the study area as shown varies from around 634mm Bedele up to 16610mm for Jimma and mean annual temperature varying from 16.38^{o}c and 37.55^{o}c as show in (Figure 3.3). The precipitation statistical analysis model (Pcp STAT) was used for statistical analyzing of daily precipitation data.

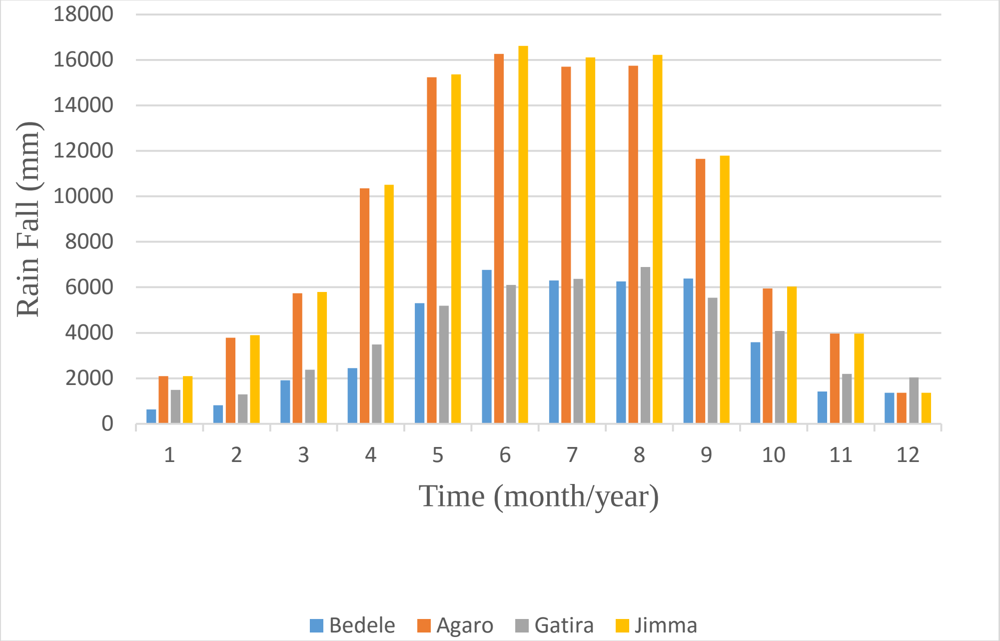
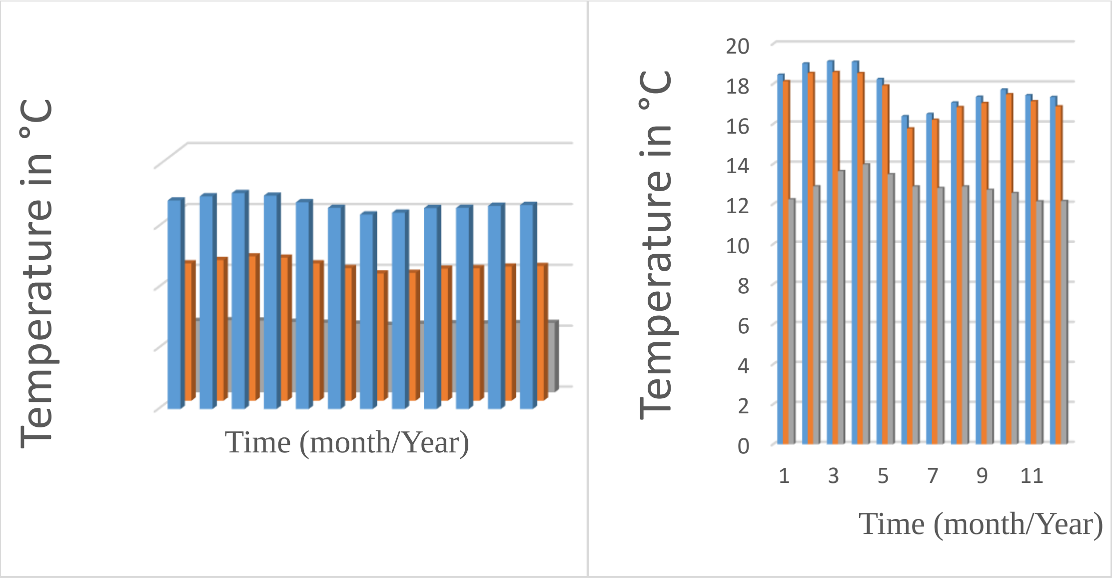


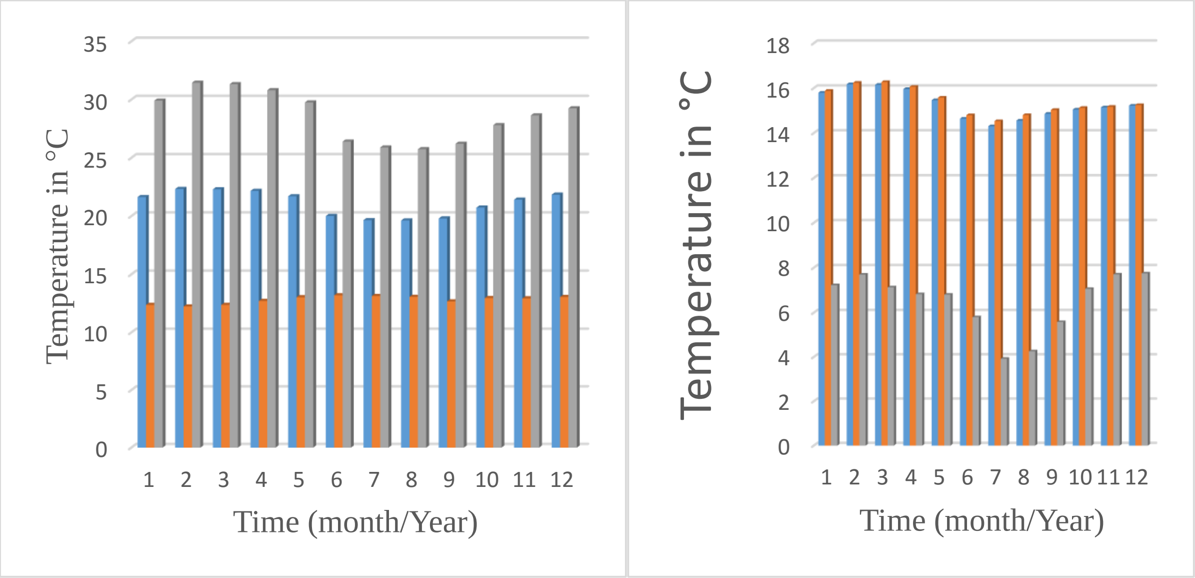
Figure 3. 2 Mean annual rainfall of selected stations (1995-2017)

3.1.3 Temperature

The mean Temperature varies between 11.60ºc and 37.55ºc, respectively. The climate data is among the most prerequisite parameter of SWAT model. This data were collected from Ethiopian National Meteorological Agency. The data collected were based on their homogeneity of the pattern, which can be representative to the Temsa watershed. The meteorological data includes, Precipitation, maximum and minimum temperature for the stations. The collected data covers a period of 1995-2017. The SWAT weather generator model (WGEN) was used to fill missing values in weather data of relative humidity, Temperature maximum and minimum, wind speed and solar radiation. The Penman–Montheith method which utilizes the solar radiation, relative humidity and wind speed data records was employed for estimation of potential evapo transpiration (PET) for this specific study. Meteorological stations also geo-referenced using latitude, longitude, and elevation data. Dew point 02 was used for generating temperature statistical parameters of SWAT database inputs.



A. Comparison of observed monthly temperatures for the period 1995-2017 at Gatira and Bedele station



B. Comparison of observed monthly temperatures for the period 1995-2017 at Agaro and Jimma station

Figure 3. 3 Comparison of observed monthly temperatures for 4 period 1995-2017 station

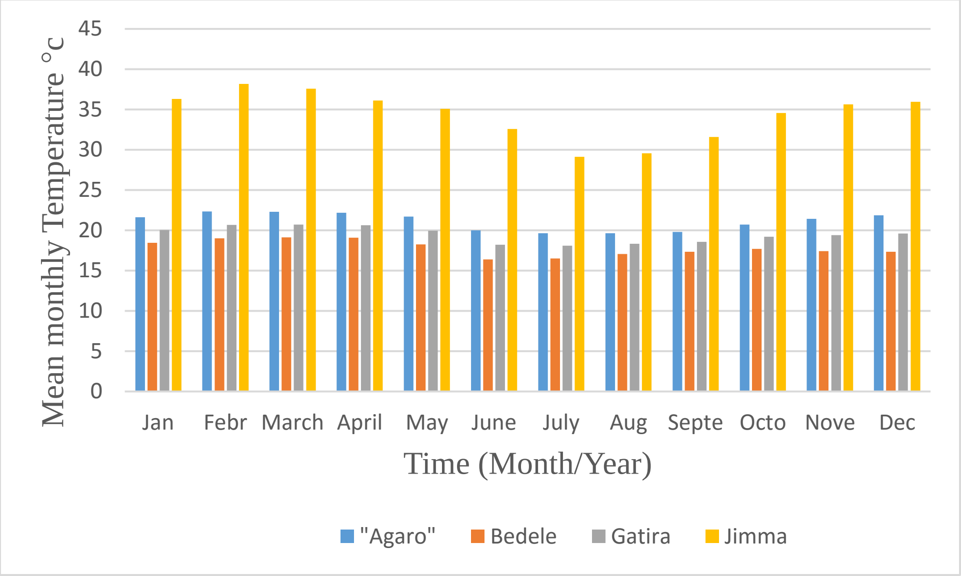


Figure 3. 4 Mean monthly temperature of different station (1995-2017)

3.1.4 Meteorological Data collection and Analysis

The SWAT model needs long years of climate data for the simulation of hydrological processes. For this specific study, the necessary climate data were collected from the National Meteorological Services Agency (NMSA). Among the station in the watershed four meteorological stations have relatively selected with long period of record inside the meteorological variables collected are like Relative humidity, sunshine hours, and wind speed in addition to rainfall, maximum and minimum temperatures. The number of meteorological variables collected varies from station to station depending on the class of the stations. Some stations contain only rainfall data. The other group includes maximum and minimum temperature in addition to rainfall data like Agaro station. There are also stations which contain variables like humidity, sunshine hours, and wind speed in addition to rainfall, maximum temperature and minimum temperature. The first class station Bedele which have all components of climatic variables mentioned above were used as weather generator station. Data of precipitation, maximum and minimum temperatures, sunshine hours, relative humidity, and wind speed were collected from meteorological stations Bedele, Gatira, and Jimma within and around the watershed.

1. Filling missed rainfall data

Some techniques of filling missed rainfall data are simple linear interpolation, arithmetic mean method, XL stat and PCPSTAT, inverse distance and normal ratio method(Firat *et al.*, 2010). For this study excel stat was used to fill the missing data of rainfall and other weather data from nearest stations for other stations since missing data are small . The missing values in all stations were assigned with no data code (-999) which then filled by the weather generator embodied in the SWAT model from monthly weather parameter for Rain fall. Therefore, using different methods, infilling for missed data and extension of short records encountered in the actual data processing activity should be done. The data collected from the meteorological stations have a missing value. Therefore, using weather generator solves such types of problem by generating data from the observed on (Nyssen *et al.*, 2010).The SWAT model requires daily hydro meteorological data from measured data or generated from values using monthly average data over a number of years. In this study measured data were used for all climatic variables. Since the climatic data collected from stations in the Temsa Watershed had missing values, the SWAT weather generator was used to fill the missing parameters. Although complete hydro-meteorological data is a pre-requisite for successful water resource planning and management, significant data sets are usually missing due to interruption of measurements caused by natural and/or human-induced factors cited in (Berndtsson .et al, 2013).

Once water is introduced to the system as precipitation, the available energy, specifically solar radiation, exerts a major control on the movement of water in the land phase of the hydrologic cycle. Since evaporation is the primary water removal mechanism in the watershed, the energy inputs become very important in reproducing or simulating an accurate water balance. Arc SWAT need daily solar radiation but the data acquired from National Meteorological Service Agency (NMSA) is sunshine hour but changed into solar radiation.

2. Checking consistency of selected stations by double mass curve

Numerous factors could affect the consistency of rainfall record at a given station. A time series observational data is relatively consistent and homogeneous if the periodic data are proportional to an appropriate simultaneous period. This proportionality can be tested by double mass analysis in which accumulated rainfall/hydrological data is plotted against the mean value of all neighborhood stations. The double mass curve technique was used to check whether the collected rainfall data from Ethiopian meteorological station were consistent through the selected period of study and reveals if correction was needed. The recording rain gauge station may have undergone change during the period of record as a result of shifting of rain gauge to new location, change due to change in ecosystem such as forest and occurrence of observational error from a certain date. This technique is based on the principle that when each recorded data comes from the same parent population, they are consistent. A group of certain numbers of neighboring stations was chosen as base stations from the vicinity of a doubtful, all stations said as doubt stations unless they are checked ('vedio Lec 9 Double Mass Curve). The data of the annual rainfall of the doubtful station and the average rainfall of the group of base stations covering a long period was arranged in the reverse chronological order (i.e. the latest record as first entry and the old record as the last entry in the list.

The precipitation of station x (doubtful station) can be corrected using the following formula

$$\mathrm{Pcx} = \mathrm{PxMc}/\mathrm{Ma}$$

P_{CX}=Corrected precipitation at any time period t at station X

PX=original recorded precipitation at time period t at station X

Mc=Corrected slope of double mass curve

Ma=original slope double mass curve

To investigate whether there was inconsistency for gauging stations in the watershed a group of four stations were chosen. Cumulative annual rainfall data of those stations within the Temsa watershed were used in this study in developing double mass curve. The cumulative values of the doubtful stations were plotted against the cumulative average group using Microsoft Excel spread sheet.

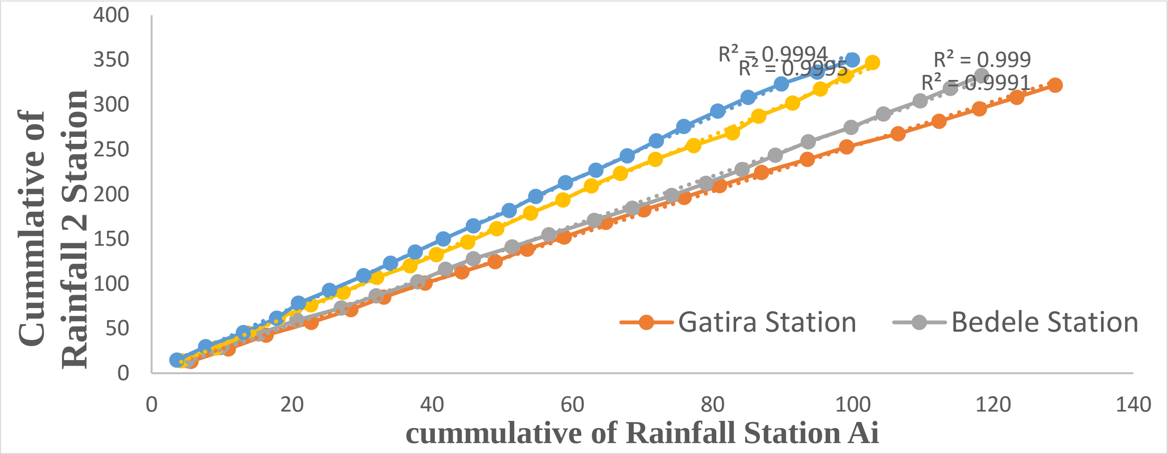


Figure 3. 5 Double mass curve graph for different station data by using (1995-2017) data

The records of these stations did not show inconsistency since the graph was found to follow nearly straight line and therefore, these stations had no recording problems or subjected to any external factors during the study period.

3.1.5 Estimation of Areal Rainfall

Rain gauge represents only point sampling of the areal distribution of a rainfall. In practice, however, hydrological analysis requires knowledge of the rainfall over an area. Station average, Isohyet and Theissen area rainfall estimation are in use to convert the point rainfall value at various stations in to an average value over a catchment(Ramírez, 2010). Among those methods Theissen polygon method is used for this study even though the method is depend on a good network of representative rain gauge.

3.1.5.1 Theissen Polygons

Theissen polygon method is one way of calculating areal precipitation. The method gives weight to satiation data in proportion to space between stations. Lines are drawn between adjacent stations on map. The area of each polygon inside the sub basin area is calculated. This factor is then used as weight of station studies with in that the polygon according to the proportion of the total watershed area that are geographically closed to each of the rain gages, and use in this (Figure 3.7) Thiessen polygon of Temsa watershed.

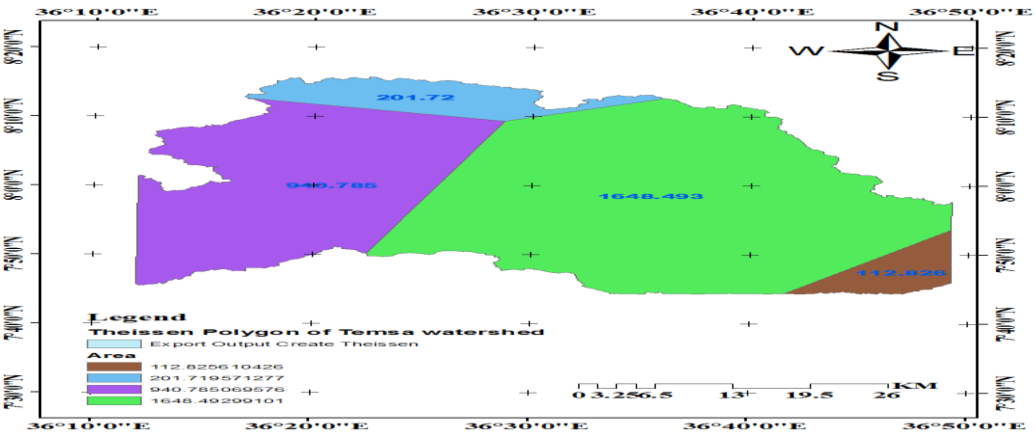


Figure 3. 6 Theissen polygon of Temsa watershed

Theissen polygon is drawn by using Arc view GIS software. After drawing the polygon it is necessary to find percentage of area that each rainfall station represents. To determine mean areal rain fall amount of each station multiplied by area of its polygon and the sum of those products is divided by total area of the watershed. Each polygon area is assumed to be influenced by the rain gauge station inside it, i.e., if P1, P2, P3 ... Pn are the rainfalls at the individual stations, and A1, A2, A3 ... An are the areas of the polygon surrounding these stations, (influence areas) respectively, the average depth of rainfall for the entire basin is given by

$$\mathbf{P}\mathrm{ave} = \sum_{k=0}^{n}\left(\frac{Ai * Pi}{Ai}\right)$$

Where Pave=Areal average rain fall

€Ai=Total area of the sub basin

Table 3.1 Thiessen polygon result for meteorological station

Station name	Area of each polygon (km2)	Elevation (m)	Theissen Mean	Area ratio	Mean Annual Rain fall (mm)	Percentage of area covered
Agaro	1648.40	2030	322.84	0.5677	568.70	56.77
Bedele	201.71	2011	4.83	0.0695	69.47	6.95
Jimma	112.82	1718	1.51	0.04	38.85	3.89
Gatira	940.78	2358	104.97	0.324	323.98	32.40
	2903.71		434.15	1	1001.00	100.00

3.2 Spatial Data Sources

Engineering studies of water resources development and management depends heavily on hydro-meteorological data. SWAT models is data driven and it requires several types of data like topography, land use, soil, hydro-meteorological, and, etc. These data were secondary and collected from various sources and different processes have been carried out to utilize them. These data are weather data that collected from National Meteorological Service Agency (NMSA) of Ethiopia, land use and land cover data acquired from www.usgs Earth Explorer ,Soil data collected from GIS department of ministry of water, irrigation and energy (MOWIE),Stream flow data that gained from the hydrology department of ministry of water, Irrigation and Energy (MOWIE) and Topographic data (DEM) which was acquired from the GIS department of Ministry of Water, Irrigation and Energy (MOWIE).the analysis of collected data carried out before using it. The data were stationary and consistent used to simulate a hydrological system. If it does not fulfill one of the above criteria's, it may result in a big problem that contradicts the actual situation.

3.2.1 Soil Map

Soil data is one of the major input for SWAT model with inclusive and chemical properties. The soil map of the study area was also obtained from Ministry of Water, Irrigation and Energy of Ethiopia. According to Ethiopia Soil classification, five major soil groups were identified in the Temsa sub basin. SWAT model requires soil physical and chemical properties such as soil texture, available water content, hydraulic conductivity, bulk density and organic carbon content for different layers of each soil type. To integrate the soil map with SWAT model, a user soil data base which contains textural and chemical properties of soils was prepared for each soil layers and added to the SWAT user soil data bases. According to the FAO/UNESCO soil classification system the study area comprises of five major soil types, such as Haplic Acrisols, Eutric Vertisols, Haplic Nitisols, Haplic Alisols and Rhodic Nitisols. The soil raster data set was taken from Ethiopian MOWIE. To integrate the soil map with SWAT model, a user soil data base was prepared and added to the SWAT user soil data bases using Arc GIS10.4.1. The soil textural distribution in Temsa watershed is shown as (Figure 3.8).

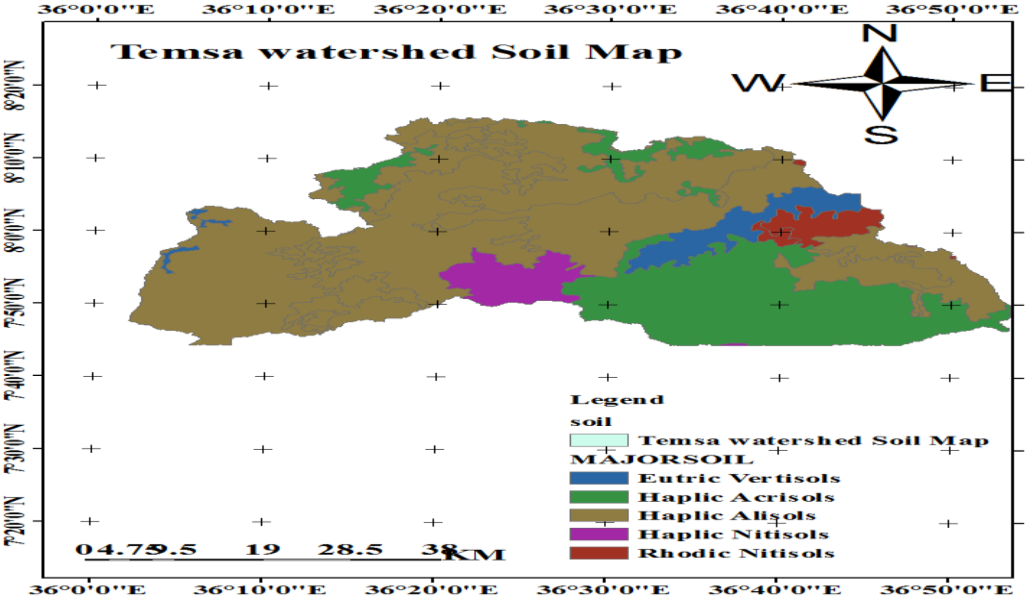


Figure 3. 7 Soil textural distribution in Temsa watershed

3.2.2 Geology

The Geological Study Map data is obtained from Ministry of Water, Irrigation and Energy of Ethiopia. The Temsa watershed which is a sub basin of Dedessa sub basin is dominated by a huge volcano system named as Jima Volcanic shield volcano. It corresponds to the eruptive events that occurred during the early Miocene to Pliocene period and classified in the shield group basalt. The common rock type for this material is basalt with large amount of interbeded lava, volcanic ash and other acidic rocks such as rhyolite and trachyte with rare ignimbrites. Wollaga Basalts, Colluvium and Undifferentiated Lower Complex are also common.

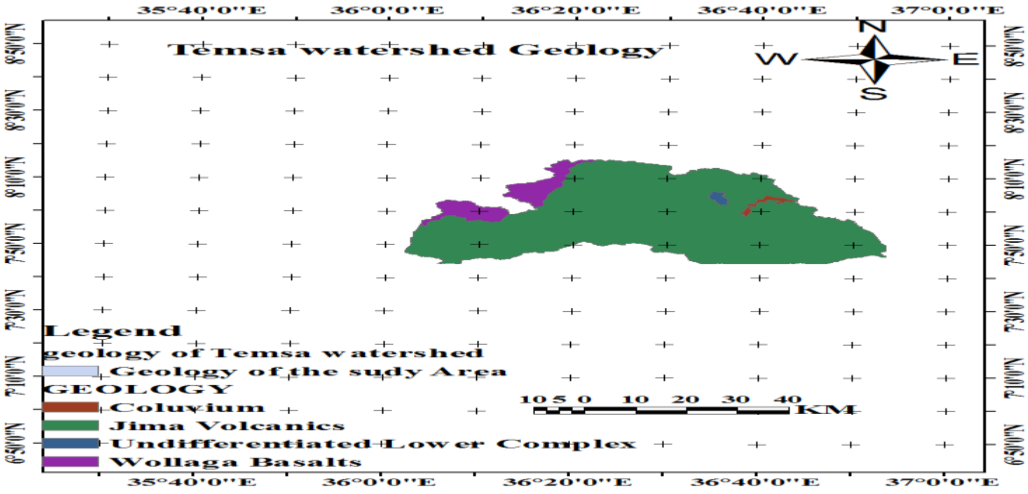


Figure 3. 8 Geology of Study Area

3.2.3 Elevation and Slopes of Watershed from DEM

During the watershed delineation process the topographic parameters such as elevation and slopes of watershed and its sub watershed were generated from the DEM data. The elevation of the watershed ranges from1379m and 3016m above mean sea level.

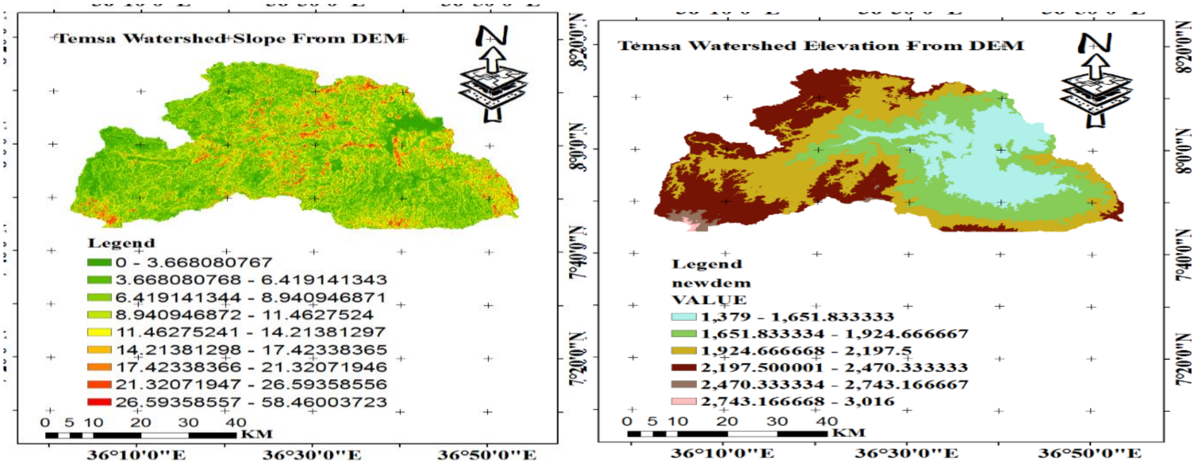


Figure 3.9 Slope and Elevation of study area from DEM

3.2.4 Digital Elevation Model Data

The topography of any point in the watershed can be described by digital elevation model (DEM). The DEM used to delineate the watershed boundary, stream network and create sub basins. For this study the DEM of Ethiopia 30m by 30m resolution was obtained from Ministry of Water, Irrigation and Energy of Ethiopia, department of GIS. Temsa Watershed DEM clipped from Ethio- DEM and used in SWAT watershed delineation. It was projected to UTM Hemisphere North Zone 37 to create overlay with soil and land use raster data set using GIS 10.4.1 and used to generate watershed boundary using SWAT.

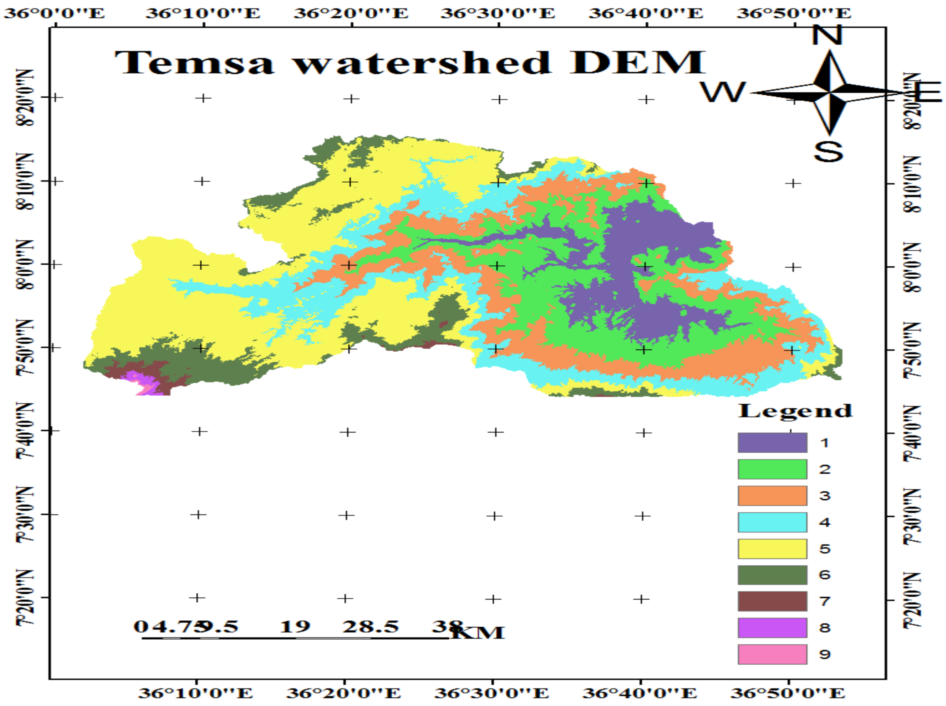


Figure 3.10 Digital Elevation model of clipped by Temsa watershed

To process it and come up with the required outputs, different materials were implemented. Some of the materials used in this study are:-excel stat , statistical software that was used to stack hydro meteorological ,Arc-GIS for spatial data analysis and in conjunction with Arc-SWAT model were used to generate flow in to the required points of interest and ERDAS was used Land use land cover classification. Since the assessment was based on analytical basis, Excel spreadsheet was also used to observe and rearrange the output from the model. For proper implementation of the study, some equipment, materials and software are required for data collection, processing and evaluation. Some of the software and materials required for this study include;

Table 3.2 Material used for the work

Materials	**Its Uses**
ArcGIS10.4	To arrange Spatial data and prepare their Map
Arc SWAT	To delineate watershed and simulate hydrological parameters of watershed
ERDAS Image 2015	For Landsat Image process, image classification and accuracy assessment
PCPSTAT	To calculate statistical parameters of daily precipitation data used in WGN
Dew02	To calculate average daily dew point temperature per month
SWAT CUP	To calibrate and validate SWAT output
XLSAT 2018	For filling of missed data
Google Earth	To provide recent information on watershed LULC
DEM Resolution data 30m	Used input data for Arc-GIS software for catchment delineation and estimation of catchment characteristic
Hydrological data	Stream flow
Meteorological data	Precipitation, Maximum Temperature. Minimum Temperature, Solar Radiation, Wind Speed and Sunshine
Soil data	To integrate the soil map with SWAT model and in user soil database
Excel spread sheet	for pre and post processing etc.,

3.2.5 Land use Land cover data

Land use land cover is one of the main input data of the SWAT model to describe the Hydrological Response Units (HRUs) of the watersheds which affect runoff, evapotranspiration and surface erosion in a watershed. It is also used for comparison of impacts on stream flow of the watershed with in time. The LULC map and all datasets for the years 1997 and 2018 were collected from USGS Earth Explore and USGS GEOTIFF. A lookup table that identifies the SWAT land use code for the different categories of LULC was also prepared so as to relate the grid values to SWAT LULC class. The SWAT model has predefined four letter codes for each land use category (Table 3.3). These codes were used to link or associate the land use map of the study area to SWAT land use databases. Hence, while preparing the lookup-table, the land use types were made compatible with the input needs of the model.

Table 3.3 Land use/cover classification of Temsa watershed as per SWAT

Land Use Cover	Land Use according to SWAT data base	SWAT Code
1.CultivatedLand	Agricultural Close to grown	AGRC
2.ForestLand	Forest mixed	FRST
3.ShrubLand	Range Brush	RNGE
4.GrassLand	Range Grass	RNGB
5.WaterBody	Water	WATR
6.Urban	Urban Residential	URBN

1. Land Sat Images

In the study of the evaluating land use land cover change impacts on stream flow responses of watershed, remote sensing images are required and can be processed by computers to produce land use/cover map. In water resource engineering, the mapping of land use/cover map in a wide area catchment, remotely sensed data plays a paramount role(Szabó et al, 2016). Therefore, in this study Land Sat images were used for mapping LU/LC map of the Temsa watershed.

For this study Land sat images of 1997 and 2018 were downloaded from United States Geological Survey (https:earthexplorer.usgs.gov/) website in GEOTIFF file format. The Selection of the Land sat satellite images data was influenced by the quality of the image especially for those with limited or low cloud cover and also to prevent seasonal variation of vegetation coverage. Therefore, the images were almost cloud free and almost in the same annual season. To avoid a seasonal variation in vegetation pattern and distribution throughout a year, the selection of dates of the acquired data were made as much as possible in the same annual season of the acquired years. In order to view and discriminate the surface features clearly, all the input satellite images were composed using the true color composition and false color composition to identify images provide complete coverage of Temsa sub basin and finally true color composition were used for classification.

Table 3.4 Characteristics of Used Satellite Images

Sensor	Sat Name	Path	Row	Date of Acquisition	Spatial Resolution	Procedure
ETM+	Landsat 7	169	54	1997-02-12	30,15	USGS
OLI&TIFF	Landsat 8	170	54	2018-4-14	30,15	USGS

Each land sat was geo-referenced to WGS_84 datum and Universal Traverse Mercator (UTM) Zone 37N. Preprocessing such as layer stacking and band color combination were carried out in order to Ortho-rectify the images. The images were processed using ERDAS IMAGINE 2015 software. The satellite image of each band stacking was done in ERDAS IMAGINE2015. Then the study area was clipped from the images using ERDAS IMAGINE2015. To better view the surface features clearly and the satellite images were performed color composition. The used bands area 1-5, 7, 8 for ETM+ and 1-7, 9 for OLI&TIFF with spatial resolution of 30,15 in both cases.

Table 3.5 Characteristics of Used Satellite Images for Land Sat 7 &8

Sensor	Bands	Resolution
ETM+	1-5,7	30m
	6	60m
	8	15m
OLI TIRS	1-7,9	30m
	8	15m
	10 &11	100m

(Source Author, 2015)

Because of their low spatial resolution 60m, 100m and 120m were not used for the analysis of LULCC. In the table above, spatial resolution of 15m is used for the panchromatic band 8.

Layer Stacking images - In order to analyze remotely sensed images, the different images representing different bands must be stacked. A layer stack is often used to combine separate image bands into a single multispectral image file. Layer stacking is also commonly used to combine image derivatives with spectral bands for further analysis.

Sub setting an image- can be useful when working with large images. Sub setting is the process of "cropping" or cutting out a portion of an image for further processing. Sub setting of Temsa watershed satellite image was performed using the layer stacked images by the delineated watershed shape file.

2. Image Classification

Image classification is the process of sorting pixels into a finite number of individual classes or categories of data based on their data file values. In remote sensing there are various image classification methods, supervised, unsupervised and hybrid. Unsupervised classification is computer controlled and the limitation is, we can't control computer's selection of pixels into clusters. In supervised image classification system, the user relies on her/his own prior knowledge and skills and can select a group of pixels belongs to a particular land use/land cover. In this system the user should have a good knowledge about the land cover to be studied. Supervised classification is the most common type of land use classification system and depends on prior information about the land use and land cover.

3. Supervised Classification

In this study, analyses of the different LULC classes were performed using supervised classification method. The previous study (Barsi. et al, 2012) were used as a reference for classification number. This was done using the two Land sat satellite images, the Landsat_7 and Land sat_8. The supervised classification was applied after defined area of interest (AOI) which is called training classes. The training sites were selected in agreement with the Land sat Image and Google Earth. In supervised land use classification, defining of training sites, extraction of signature editor and classification of image was performed using Maximum Likelihood classifier.

4. Accuracy Assessment

A vital step in the classification process, whether supervised or unsupervised is the accuracy assessment of the final classification produced(Acharya *et al.*, 2016). This involves identifying a set of sample locations that are visited in the field or using previous studies. The land use land cover found in the field is then compared to that which was mapped in the image for the same location. Then, statistical assessment (using ERRMAT) of accuracy may then be derived for the entire study area.

5. Site Observation

Site observation and field works by GPS was conducted on selected kebeles near Agaro area and near Toba in watershed to get a physical characteristics and land use features of watershed and for ground truth verification of the mapped features and accuracy assessment. Information on these area were obtained through discussion with key informants and data that exist in wereda. Elders who are longtime residents of the areas and guards of forests were selected for the study discussion. During the discussion and interviews, the main focus were to obtain the past and present trends of land use land cover information and the factors contributing to the changes.

Land use/land covers have a major impact on runoff generation of the watershed. Therefore, land use /land cover classification is a mandatory to evaluate the impact of land use/ land cover change on stream flow. The method to evaluate the land use land cover change impact on stream flow can be achieved through integrating GIS, remote sensing, and hydrological models (Figure 4.1 and 4.2). Satellite image have great contribution for preparation of land use land cover of the area.LU/LC information is of critical importance in stream flow as it helps determine model variables that account for the volume, timing, and quality of runoff. A Physically-based distributed hydrological (Arc SWAT) model that allows several different subunits or objects to be defined within a watershed is utilized.

3.3 Hydrological Modeling with SWAT

Arc SWAT version 2012 was downloaded from SWAT website and its toolbar was added to Arc GIS10.4.1 for modeling process. The modeling procedure includes SWAT project setup, Watershed delineation, and HRU Analysis, Write Input Tables, Edit SWAT Input and SWAT simulation.

3.3.1 Soil and Water Assessment Tool Model Setup

A. Watershed Delineation

The first step in creating SWAT model input is delineation of the watershed from a DEM. Inputs entered into the SWAT model were organized to have spatial characteristics. Before going in hand with spatial input data i.e. the soil map, LULC map and the DEM were projected into the same projection called UTM Zone 37N, which is a projection parameters for Ethiopia. The watershed delineation process include five major steps, DEM setup, stream definition, outlet and inlet definition, watershed outlets selection and definition and calculation of sub-basin parameters. For the stream definition the threshold based stream definition option were used to define the minimum size of the sub-basins. The Temsa watershed was delineated with an outlet point at Dabana which is the gauge station and at the out let of watershed. The overall watershed was further classified into sub-basins based on the algorithms provided by the SWAT model. As a consequence these sub-basins influence the level of spatial complexity that is represented in the SWAT model. A sub-basin in SWAT is defined as the hydrologic area contributing to only one stream channel. Stream channels were defined as DEM cells having at least a 3514 km^2 contributing area. After watershed delineation, land use, soil and slope characterization for watershed was performed using commands from the HRU analysis menu on the Arc SWAT Toolbar. These tools were used in loading land use and soil layers of Temsa Watershed into the current project, evaluate slope characteristics and determine the land use/soil/slope class combinations and distributions for the delineated Temsa watershed and each respective sub watershed. The watershed was divided into hydrologic response units (HRU) which have a unique soil and land use combination.

The SWAT2012 model provides three options for defining HRU distribution. The first one is assigning Dominant Land Use, Soils and Slope which create one HRU for each sub basin. The dominant land use, soil and slope class in the sub basin are simulated in the HRU. The second is the Dominant HRU which creates one HRU for each sub basin. The dominant unique combination of land use, soil and slope class in the sub basin is used to simulate the HRU. And the third one is the Multiple HRUs which create multiple HRUs within each sub basin. This option was selected by default. The SWAT user’s manual suggests that a 20% land use threshold, 10% soil threshold and 20% slope threshold are adequate for most modeling application. However, according to suggestion HRU definition with multiple options that account for 10% land use, 20% soil and 10 slope threshold combinations gives a better estimation of runoff (Neitsch *et al.*, 2002). Therefore, for this study, HRU definition with multiple options that accounts for 10% land use, 20% soil and 10% slope threshold combination was used to eliminate minor land use and land covers in sub basin, minor soil within a land use and land cover area and minor slope classes within a soil on specific land use and land cover area. Due to this the Temsa Watershed was divided into 88 HRUs, each has a unique land use and soil combinations.

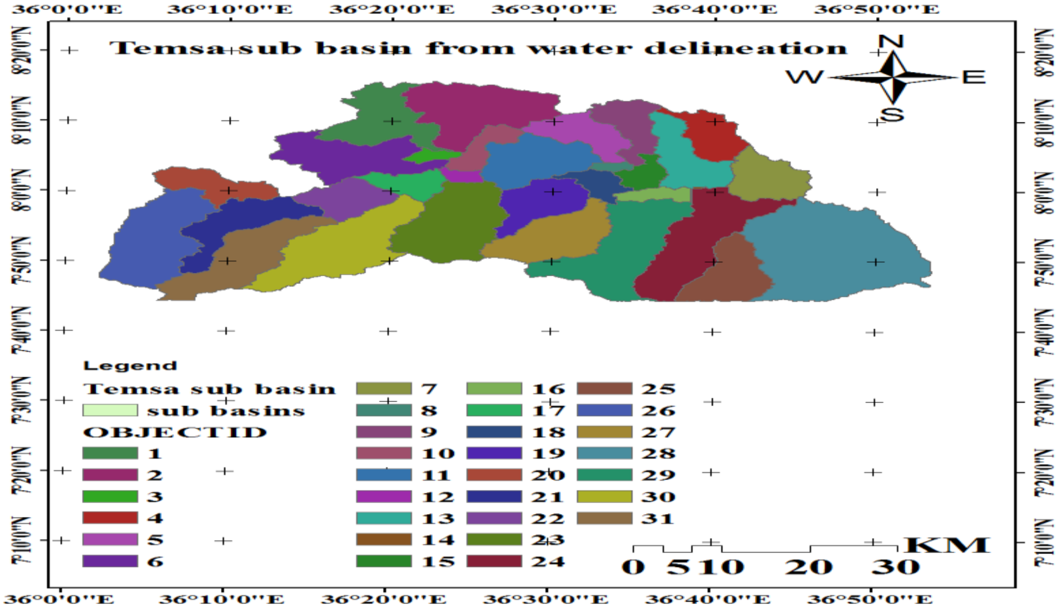


Figure 3.11 Watershed delineation of study by HRU analysis

After HRU analysis the weather data to be used in a watershed simulation was imported using the first command in the Write Input Tables menu item on the Arc SWAT toolbar. This tool helps to load weather station locations into the current project and assign weather data to the sub watersheds. The weather data definition is divided into six tabs: weather generator data, rainfall data, temperature data, solar radiation data, wind speed data and relative humidity data. Weather data of Bedele station was used as an 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 respectively. The weather generator parameters were developed by using excel (pivot table), dew point temperature calculator software, DEW02 and PCP STAT to calculate average monthly precipitation, standard deviation, skew coefficient, probability of a wet day following a dry day and average number of days of precipitation in a month.

B. Hydrological Response Units (HRUs)

For simulation, a watershed is subdivided into a number of homogenous sub-basins (hydrologic response units or HRUs) having unique soil, slope and land use properties. The input information for each sub-basin is grouped into categories of weather; unique areas of land cover, soil, and management within the sub-basin; ponds; groundwater; and the main channel or reach, draining the sub-basin.

The HRU analysis tool in Arc SWAT helps to load land use, soil layers and slope map to the project. The delineated watershed by Arc SWAT and the prepared land use and soil layers were overlapped. HRU analysis in SWAT includes divisions of HRUs by slope classes in addition to land use and soils. The multiple slope option (an option which considers different slope classes for HRU definition) was selected. The LULC, soil and slope map was reclassified in order to correspond with the parameters in the SWAT database. After reclassifying the land use, soil and slope in SWAT database, all these physical properties made to be overlaid for HRU definition.

Write input tables; the input data needed include the Digital Elevation Model (DEM), soil data, land use and weather data and river discharge for prediction of stream flow and calibration purposes.

Soil Data: SWAT model requires different soil textural and physic-chemical properties such as soil texture, available water content, hydraulic conductivity, bulk density and organic carbon content for different layers of each soil type.

Land Use: Land use is one of the most important factors that affect runoff, evapotranspiration and surface erosion in a watershed.

Weather Data: SWAT requires daily meteorological data that could either be read from a measured data set or be generated by a weather generator model. In this research, the weather variables used for driving the simulated stream flow are daily precipitation, minimum and maximum air temperature for the period 1995–2017. These data were obtained from Ethiopian National Meteorological Agency (NMA) for stations located within the watershed.

C. Edit SWAT input: This step of model set up used to modify soil parameters, land use type and slope etc. I was used this step to get simulated stream flow at Temsa watershed after fixing sensitive parameters and their values at Dabana station.

D. SWAT simulation: running the model, sensitivity analysis, calibration and validation was carried out.

3.4 Model Sensitivity Analysis, Calibration and Validation

3.4.1 Sensitivity Analysis

Sensitivity analysis is defined as the process of determining the significance of one or a combination of parameters with respect to the objective function or a model output. Therefore, prior to calibration and validation process, sensitivity analysis was carried out to reduce the number of parameters that needs optimization. A model sensitivity analysis can be help full in understanding which model input are the most important. Sensitivity analysis is a method of identifying the most sensitive parameters that significantly affects the model calibration and validation. Sensitivity analysis describes how model output varies over a range of a given input variable (J.G. Arnold et al, 2011).

When a SWAT simulation is taken place there would be discrepancy between measured data and simulated results. So, to minimize this discrepancy, it is necessary to determine the parameters which are affecting the results and the extent of variation. Hence, to check this, sensitivity analysis is one of SWAT model tool to show the rank and the mean relative sensitivity of parameters identification and this step was ordered to analysis. This appreciably eases the overall calibration and validation process as well as reduces the time required for it. Hence, 16 flow parameters were included for the analysis with values as recommended by other. Up on the completion of sensitivity analysis, the mean relative sensitivity (MRS) values of the parameters were used to rank the parameters, and their category of classification. Two kinds of sensitivity analysis are performed, local (one at a time) and global analysis. The sensitivity of one parameter often depends on the value of other related parameters (Moriasi *et al.,* 2007) which is a problem with local sensitivity analysis. Global analysis requires large number of simulations (Arnold et al, 2012) which can also be a problem. In this research global sensitivity analysis was performed in SUFI-2 prior to calibration and the results were examined. However, in this research the number of simulations used for calibration was 200, which is large enough to get accurate results for global sensitivity analysis. The global sensitivity analysis approach was used in SUFI2 because it takes into account the sensitivity of one parameter relative to the other in order to give their statistical significances. SUFI-2 is superior over other algorithms, because it involves stochastic calibration, where the errors and uncertainties in model are recognized and expressed as ranges accounting for all driving variables.

3.4.2 Calibration

The Calibration is the process whereby model parameters are adjusted to make the model output match with the observed data (Liew, 2008). Therefore, in this study the Stream flow of the model was calibrated at Dabana gauging station in order to make the simulation result more realistic for independent calibration period. The period from 1998 to 2010 was used as a calibration period since the data for this period was representative data.

SWAT-CUP4 was used for calibration and uncertainty analysis on stream flow parameters. It is a public domain computer program for calibration of SWAT models. It links Generalized Likelihood Uncertainty Estimation (GLUE), Parameter Solution (ParaSol), Sequential Uncertainty Fitting, ver. 2 (SUFI-2), Markov Chain Monte Carlo (MCMC) and Particle Swarm Optimization (PSO) procedures to SWAT output files (Pokhrel, 2018). It enables sensitivity analysis, calibration, validation, and uncertainty analysis of a SWAT model. SUFI-2 algorithm (Pokhrel, 2018) was used in this analysis for the calibration of the downstream gauge (Dabana) for the monthly SWAT runs. The Dabana gauge was located in sub-basin 7 of the delineated flow river watershed.

3.4.3 Validation

Validation is described as the process of demonstrating that a given site specific model is capable of making sufficiently accurate simulations, also sufficiently accurate results can vary based on project goals (Moriasi *et al.*, 2007). It is used to test the calibrated parameters with an independent set of data without further changes to the parameters. In this study the validation was performed to compare the model outputs with an independent data set without making further change to parameters obtained during the calibration process. The measured data of average monthly stream flow from 2011-2017 at Near Dabana Gauging station was used for model validation.

3.5 Model Performance Evaluation

There are no universally accepted existing standards describing the range of the values of the statistical parameters that would indicate acceptable performance of the model (Huang *et al.*, 2013). The Model performance was evaluated using objective function namely; Coefficient of determination (R^2), Nash Sutcliffe efficiency (NSE), Root Mean Square Error (RMSE), observation standard deviation ratio (OSDR) for the calibrated and validated SWAT model were compared to the performance statistics rating for monthly time steps proposed by (Asres *et al.*, 2016). But for evaluation of model performance during calibration and validation statistical measures as well as graphical representation at monthly time steps were used. For this research the statistical parameters (NS, PBIAS and R^2) were used for model evaluation for quantification of accuracy in watershed modeling. The coefficient of determination (R^2) describes the proportion of variance in measured data by the model. It indicates the linear relationship between simulated and observed data and ranges from zero (model is poor) to one (model is good). The R^2 is calculated using the following equation.

$$\mathrm{R}^2 = \sum_{k=0}^{n} \left(\frac{\big((Oi - Oi\,mean)(Si - Si\,mean)\big)^2}{(((Oi - Oi\,mean)(Si - Si\,mean))\hat{}0.5)^2} \right)$$

Where: R^2 is coefficient of determination O_i measured value, S_i is simulated values, O_{mean} average measured values, S_{imean} average simulated values.

The Nash and Sutcliffe simulation efficiency (NSE) describes the deviation from the unit of the ratio of the square of the difference between the observed and simulated values and the variance of the observations. The value of the coefficients varies from minus infinity to one with the latter value indicating perfect agreement between the simulated and observed data. A smaller NSE value indicates poorer fit between the simulated and observed data. It is possible to obtain negative value of the NSE indicating that the average of the observational data provides a better fit to the data compared to the simulated data. NSE is recommended and widely used in literature therefore there is a lot of reported values for use as evaluation guidelines. NSE, in a simplified explanation by (Moriasi *et al* 2007) is an indication of how well the plot of observed versus simulated data fits the 1:1 line. NS is computed as shown in the following equation.

$$\mathrm{NSE} = 1 - \sum_{k=0}^{n} \left(\left(\frac{(Oi - Si)^2}{Oi - Simean)^2} \right) \right)$$

The percent bias (PBIS) describes the tendency of the simulated data to be greater or smaller than the observed data, expressed as percentage. The optimum PBIAS value is zero and low values indicate that the model simulation is satisfactory. Positive values indicate a tendency of the model to underestimate while negative values are indicative of overestimation. This test is recommended due to its ability to reveal any poor performance of the model.

$$\mathrm{PBIAS} = \sum_{k=0}^{n} \left(\frac{(Qm - Qs)^1}{Qm^1} \right) {*}100$$

The evaluation was performed by visual and statistical comparison of the measured and simulated data. The graphical method provided an initial overview. The statistical criteria used to evaluate the performance of the model.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Land Use Land Cover Map

Mapping and classifying land use land cover is very important in hydrological study. Before the analysis of land use land cover change each homogeneous land use land cover should be defined. Defining of the land use and land cover of the Temsa watershed was done using remote sensing data and previous studies (Kiggundu *et al.*, 2018)**.** This is done after image classification of the two land use land cover maps (1997 and 2018) using the method maximum likelihood classification of land sat satellite image. The study area of the dominant land use land cover are summarized to six major class namely agricultural land, Forest (deciduous and ever green),Grass Land, Shrub land, Urban and water body.

Table 4.1 Land cover categories of Temsa watershed

Parameters	Definition of parameters
Agricultural Land	Areas in the image that have agricultural crop present
Range Grass Land	Areas covered with grass used for grazing and bare lands that have little grass or no grass cover
Forest Land	Area covered with dense trees which includes mixed forest and plantation forest
Range shrub land	Areas covered with mixed trees on high land areas and every year green
Built up Area	Settlement areas of residential building
water	Areas covered with water

In water resource engineering, the mapping of land use/Land cover map in a wide area catchment, remotely sensed data plays a paramount role. Therefore, in this study Land Sat images were used for mapping LU/LC map of the Temsa watershed. For this study Land sat images of 1997 and 2018 were downloaded from United States Geological Survey (https:earthexplorer.usgs.gov/) website in GEOTIFF file format. The Selection of the Land satellite images date was influenced by the quality of the image especially for those with limited or low cloud cover and also to prevent seasonal variation of vegetation coverage. Therefore, the images were almost cloud free and almost in the same annual season. Each land sat was geo_referenced to WGS_84 datum and Universal Traverse Mercator (UTM) Zone 37N. Preprocessing such as layer stacking and band color combination were carried out in order to Ortho-rectify the images. The images were processed using ERDAS IMAGINE 2015 software.

Table 4.2 Area of LU/LC of Temsa watershed for the study period (1997-2018)

LULC classify categories 1997			2018		2018-1997 change rate of LULC	
LULC class	Area(Ha)	%	Area(Ha)	%	Area(Ha)	%
URBN	1433.75	0.416	4170.316	1.21	2736.566	0.794
RGNE	57901.44	16.80	41978.88	12.18	-15922.60	-4.62
WATR	5080.162	1.474	3618.869	1.06	-1461.29	-0.424
FRST	59417.90	17.24	45873.47	13.31	-13544.40	-3.93
RGNB	90367.60	26.22	49113.22	14.25	-41254.40	-11.97
AGRC	130450.60	37.85	199899.40	58	69448.88	20.15
Total	344651.40	100	344651.20	100.00		

The satellite image of each band stacking was done in ERDAS IMAGINE2015. Then the study area was clipped from the images using ERDAS IMAGINE2015. To better view the surface features clearly and the satellite images were performed color composition.

4.2 LAND USE LAND COVER ANALYSIS

The two-land use cover maps of 1997 and 2018 generated from the land sat ETM+ imaginary Classification (Figure 4.1 and 4.2 respective years). It is easily shown that there is an increase of cultivated land, Urban and decrease of forested areas, shrub land, grassland and water bodies over 21 years.

From the study and data obtained from the satellite imagery for Temsa watershed the Watershed has undergone numerous land use/land cover changes in recent decades. Forest cover decreased markedly between 1997 and 2018 by 3.93%, in the Watershed. The decrease could be attributed to the cutting of trees in the forests for various uses such as firewood and clearing for cultivation and agricultural purposes. The agricultural land increase between 1997 and 2018 by 20.15% at the most part of the watershed. This increase could be linked with high increase population growth. The built up area also changed significantly between 1997 and 2018 by 0.794% due to rapid development of urban centers such as the expansion of the town Agaro, Toba and Bedele at the watershed part. The growth of these urban centers can be attributed to high rate of rural urban migration. Grass cover was found in the most parts of the watershed; especially the northeastern and northwestern part of the watershed; Grass land, Shrub land, and water of the watershed decrease between 1997 and 2018 by 4.62%, 11.97% and 0.42% respectively. The Grass land, Shrub land, and water body including the most of watershed area was transformed in to agricultural land area and used for other uses. Spatial analysis was carried out to describe land use land cover change pattern and overall land use changes with time. This is done after image classification of the two land use land cover maps 1997 and 2018 whose results for each analysis can be expressed as follows:

4.2.1 Land use land Cover Map of 1997

The land cover map of 1997 in (figure 4.1) and the histogram of the land class coverage shows that about 37.85% of the Temsa watershed was covered by agricultural land, 16.80% by Grass Land, 17.24% by forest land, 1.474% by water body, 26.22% by shrub land and 0.416% by settlement (Urban) area. The distribution of land cover class as it is shown in the (figure 4.1). Forest dominantly eastern and southeastern part.

Table 4.3 Area of LU/LC of Temsa Watershed for the Study Period 1997

LULC classify categories 1997			
LULC classes	Area(Ha)	Percentage Area %	LULC Classes
URBN	1433.75	0.416	URBN=Urban
RGNE	57901.44	16.80	RGNE=Range grass land
WATR	5080.162	1.474	WATR=Water body
FRST	59417.90	17.24	FRST= Forest Land
RGNB	90367.60	26.22	RGNB=Range Brush Land
AGRC	130450.00	37.85	AGRC=Agricultural Land
Total	344651.400	100.00	

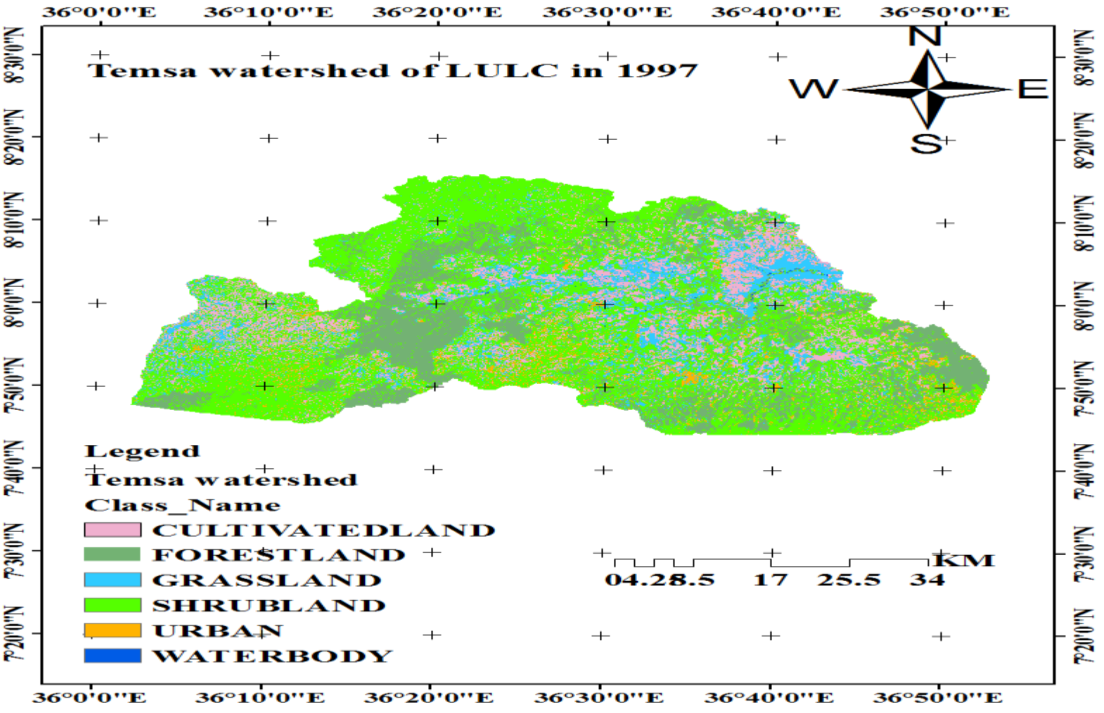


Figure 4.1 Land use land cover map of Temsa catchment in the year 1997

4.2.2 Land use land Cover Map of 2018

The land cover map of 2018 in (figure 4.2) and the histogram of the land class coverage in shows that about 58% of the Temsa watershed was covered by agricultural land, 12.18% by grass land, 13.31% by forest land, 14.25% by shrub land, 1.21% by settlement (urban) area, and 1.06% by water body. Previous studies in other parts of the country also showed similar result. For example, (Roth *et al.*, 2018) showed that 99% of the forest covers changed to agriculture and at Dembecha area in the northern part of the country between 1957 to1995.

(Wakjira T. et al, 2016) reported that the cultivated land increase by 46% while the forest decreased by 2% in Gilgel Abay watershed.

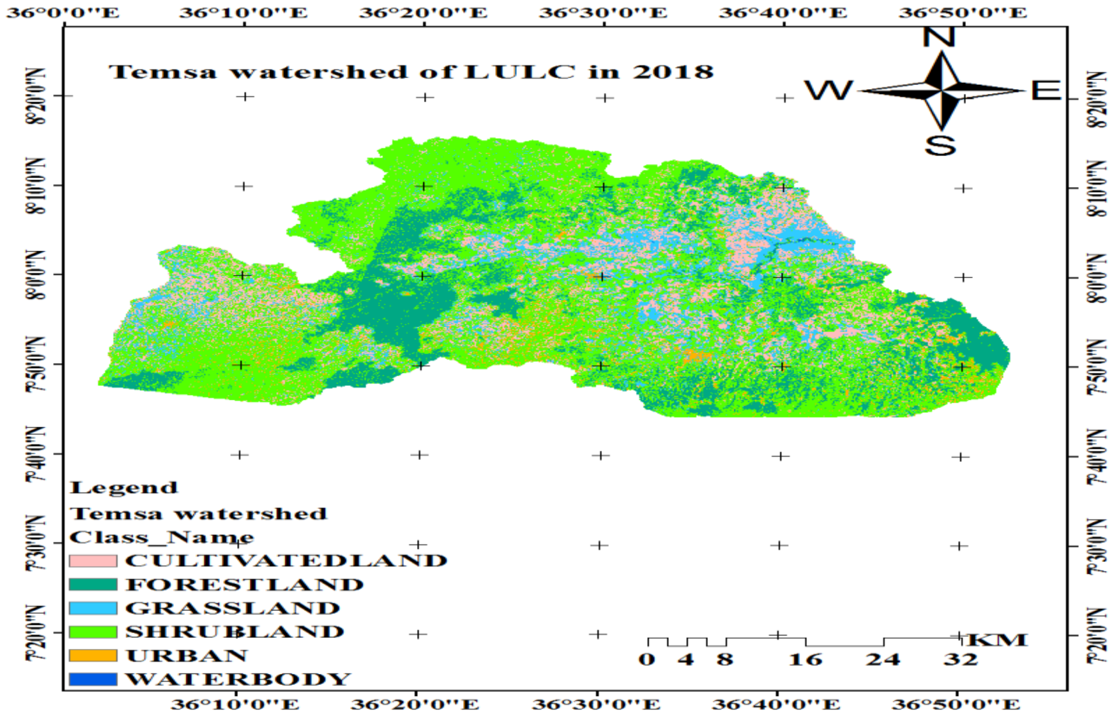


Figure 4.2 Land use land cover map of Temsa watershed in the year 2018

The LULC is an important characteristic in the stream flow process that affects infiltration, erosion, and evapotranspiration. Understanding of the effects historic land use changes have had on river flow is required to understand the future effects of land use land cover on hydrological regimes at a watershed level. Along with these changes, considerable consequences are expected in the hydrological cycles and subsequent effects on water resources(Bauwens.et al, 2009). The SWAT model simulated for the two time periods corresponding to the land use cover of 1997 and 2018.

A comparison of the land covers 1997 and 2018 and average annual stream flows generated using 1997 and 2018 land covers respectively is presented in (Table 4.11). The result indicated that the mean annual surface flow for 2018 land cover and land cover 1997 was increased by 39.50%.

Table 4.4 Parameters from annual simulations for 1997 and 2018 land covers

	LULC Classify categories 2018		LULC classes
LULC classes	Area(Ha)	Percentage%	URBN=Urban
URBN	4170.316	1.21	RGNE=Grass land
RGNE	41978.88	12.18	WATR=water body
WATR	3618.869	1.06	FRST=Forestland
FRST	45873.47	13.31	RGNB=Brush Land
RGNB	49113.22	14.25	AGRC=agricultural Land
AGRC	199899.40	58.00	
Total	344651.20	100.00	

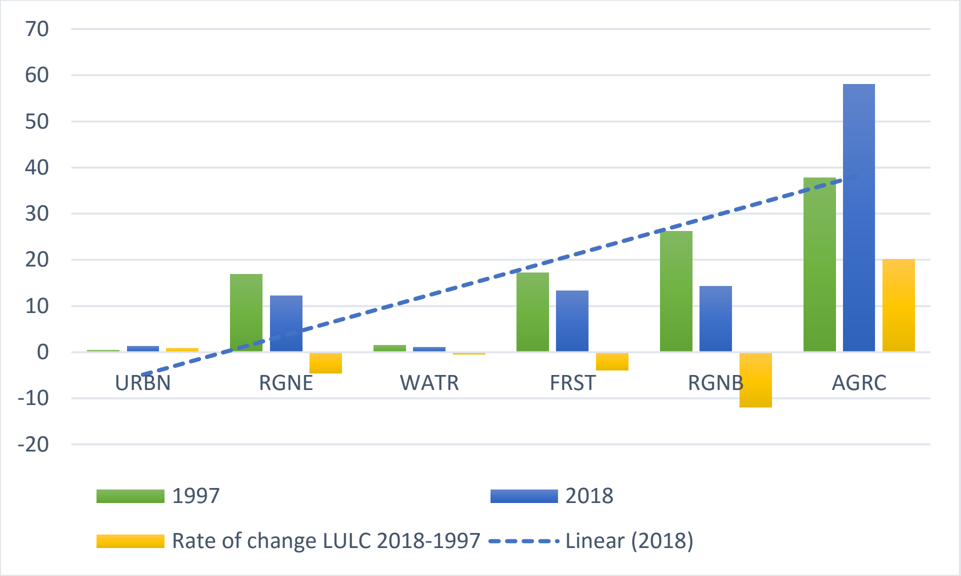


Figure 4.3 Land use land cover distribution of 1997 and 2018

4.2.3 Accuracy Assessment

The land use land cover found in the field is then compared to that which was mapped in the image for the same location. The columns of the matrix indicate the number of pixels per class for the reference data and the rows indicate the number of pixels per class for the classified images. From this statistical accuracy assessment such as, overall accuracy, user’s accuracy and producer’s accuracy were derived to test the classification. The user’s and producer’s accuracy indicate accuracy of individual classes. User’s accuracy is the probability of classified pixels representation of reference data, whereas, producer’s accuracy is the probability of reference data to be correctly classified. In this study classification accuracy assessment was carried out using Google Earth imageries and Existing land cover maps (Guzha *et al.*, 2018). A total of 200 and 163 testing sample points were randomly collected for the year 1997 and 2018 respectively and the result presented in the result and discussion section.

Table 4.5 Confusion Matrix for LU/LC Classification of 1997

Classified Classes								Producer's Accuracy (%)	Kappa coeffici
	URBN	WATR	RGNB	AGRC	RGNE	FRST	Tot		
URBN	**10**	0	0	0	0	0	**10**	**100**	**1.00**
WATR	0	**18**	0	1	0	0	**19**	**94.74**	**0.95**
RGNB	0	0	**20**	1	2	0	**23**	**86.96**	**0.914**
AGRC	0	0	1	**81**	0	2	**84**	**96.43**	**0.96**
RGNE	0	0	3	0	**26**	0	**29**	**89.66**	**0.85**
FRST	0	1	2	2	0	**30**	**35**	**85.71**	**0.85**
Total	10	19	26	85	28	32	**200**		
User's accuracy (%)	**100**	**94.74**	**76.92**	**95.29**	**92.29**	**93.75**		**95.71** Overall accuracy	**0.938**

Table 4.6 Confusion Matrix for LU/LC classification of 2018

Reference Data							2018		
	URBN	WATR	FRST	RGNE	RGNB	AGRC	Row Total	User's accuracy (%)	Kappa Coefficient
URBN	16	0	0	0	0	0	16	100	1.00
WATR	0	15	0	2	0	0	17	88.23	0.854
FRST	0	0	14	0	0	1	15	93.33	0.9097
RGNE	0	0	0	16	0	0	17	94.12	0.923
RGNB	0	0	2	0	13	0	15	86.667	0.899
AGRC	0	1	0	0	0	82	83	98.795	0.984
	16	16	16	17	13	83	**163**	**86.667**	0.899
Producer's accuracy (%)	100	93.75	87.50	100	100	98.79		**92.50** Overall accuracy	**0.9064**

The user's and producer's accuracy indicate accuracy of individual classes. The result presented in the result and discussion section (Table 4.5 and Table 4.6). The overall classification accuracy which is the ration of the total number of correctly classified pixels (diagonal) to total number of reference pixels was shown to be 95.71 and 92.50 for the maps 1997 and 2018 respectively. According to (Anderson, 1976) the minimum accuracy value for reliable land cover classification is 85%. Others say the expected accuracy is determined by users. In this study Table 4.5 & Table 4.6 indicated the classification accuracy assessment according to Anderson and the result satisfies the minimum accuracy assessment criteria. The user's accuracy (error of commission or inclusion) and producers' (error of omission or exclusion) which are used to evaluate classification accuracy were also calculated.

4.3 Hydrological Modeling

4.3.1 Sensitivity Analysis of Stream Flow Parameters

The inclusion of large number of parameters representing different processes in the objective function, in SUFI-2 helps to make the model result enveloping the most of the observations well. For example, (Asres *et al.*, 2016) were used SWAT in Gumera Watershed, Ethiopia for runoff and in calibration they were used two approaches. Fully automated Parameter Solution

(ParaSol) and semi-automated Sequential Uncertainty Fitting 2 (SUFI-2) for the period from 2003 to 2006. They were carried out calibration using seventeen runoff producing parameters AppendixA_2 and concluded that the best performance of SUFI2 and its flexibility over ParaSol and gave higher values for the coefficient of determination and NS coefficient. In this study the t-Stat and P-Values of the parameters were used to rank to the different parameters that may influence the flow and finally to select the ranked values.

Table 4.7 Parameters acquired through Calibration

Parameter Name	t-Stat	P-Value
4:V__GW_REVAP.gw	-0.17	0.87
2:V__ALPHA_BF.gw	0.32	0.75
5:V__ESCO.hru	0.42	0.67
3:V__GW_DELAY.gw	-10.92	0.00
1:R__CN2.mgt	12.52	0.00

The description for the parameter name is explained by AppendixA_1. The model was run on monthly time steps with observed data of the Temsa Watershed at Dabana gauging station. For this analysis 16 parameters were selected based on previous literatures and only 5 parameters were identified to have significant influence in controlling the stream flow in the watershed. Flow parameters that tested for their sensitivity values for monthly time steps are presented as below. The result of sensitivity analysis indicated that five parameters are sensitive to the study area for stream flow, the relative values and rank are present in the (Table 4.7). The time series of discharge at the outlet of the watershed was used as data for calibration and validation for SWAT model, the model was calibrated using the measured stream flow data from 1998 to 2010 with warm up period from 1995 to 1997 and first the sensitive parameters which govern the watershed were obtained and ranked according to their sensitivity (AppendixA_2). The parameters were optimized first using the auto calibration tool, then calibration was done by adjusting parameters until the simulated and observed value showed good agreement. In this process, model parameters varied until recorded flow patterns are accurately simulated. Model calibration of SWAT run can be divided in to several steps. Among these Water balance and stream flow generation are the most important part is also considered. (Kidane *et al.*, 2019) distinguished three types of calibration methods:

A: The manual trial-and-error method,

B: Automatic or numerical parameter optimization method; &

C: A combination of both the above methods

T_Stat provides a measure of sensitivity (large in absolute value area more sensitive) and P-value determined significance of sensitivity of the parameters. P-Value close to zero are more significant. . Upon completion of sensitivity analysis a t_ test was used to identify the relative significance of each parameter. The larger in the absolute value of t_Stat and the smaller of the p_Value, the more the sensitive the parameter. The p_value tests the null hypothesis that the coefficient is equal to zero (no effect). A low p_value less than 0.05 indicate that null hypothesis can be rejected. That mean a predictor that has a low p_value is likely to be a meaningful addition to the model because changes in the predictor's value are related to changes in the response variable. Conversely, a large p_value suggests that changes in the predictor are not associated with changes with the response. So that the parameter is not very sensitive. A p_value of less than 0.05 is a generally accepted point at which to reject the null hypothesis (SWAT_CUP user manual). Based on the above criteria, parameters were selected for calibration process and the results were presented in the result and discussion section. In the sensitivity process, the SWAT simulated text output was copied to the working directory and SWAT_CUP SUFI-2 was used for performing the sensitivity of selected parameters with the default lower and upper parameter bounds.

Appendix A-2 indicates the relative sensitive parameters for monthly flow of stream flow. The parameters affecting hydrologic process of Temsa watershed and used in model calibration were; (GW_REVAP) Ground water Revap coefficient (dimensionless), (R_CN2) SCS runoff curve number, (ALPHA_BF) Base flow alpha factor (days), (V_GW_DELAY) Groundwater delay (days) and (V_ESCO) Soil evaporation compensation factor.

The result of the sensitivity analysis indicated that the most sensitive parameters were (CN2) SCS runoff curve number) with t-value of 12.52 and p-value of 0.00 to simulate Temsa Watershed and the least sensitive was (V_ALPHA_BF) Base flow alpha factor with absolute t-value of 0.32 and p-vale of 0.75. Therefore, the results obtained agreed with the previous research (Srinivasarao. et al, 2014) conducted and taken as a supportive reference for further calibration.

4.3.2 Calibration

SWAT simulated of Temsa watershed with default values of parameters was showed poor statistical parameters. Therefore, after sensitivity analysis, manual calibration and then auto calibration was carried out with SWAT CUP (SUFI-2) on monthly time steps (from 1998-2010). Parameters were varied several times while simulating flows to obtain high NSE, R2 and low PBIAS. This was done until simulated flow closely matched the observed flows. 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 very good in simulating the watershed. The three performance criteria indicated that the parameters modified during calibration represented the catchment hydrologic response. The optimized parameters during calibration were presented in Table 4.7.

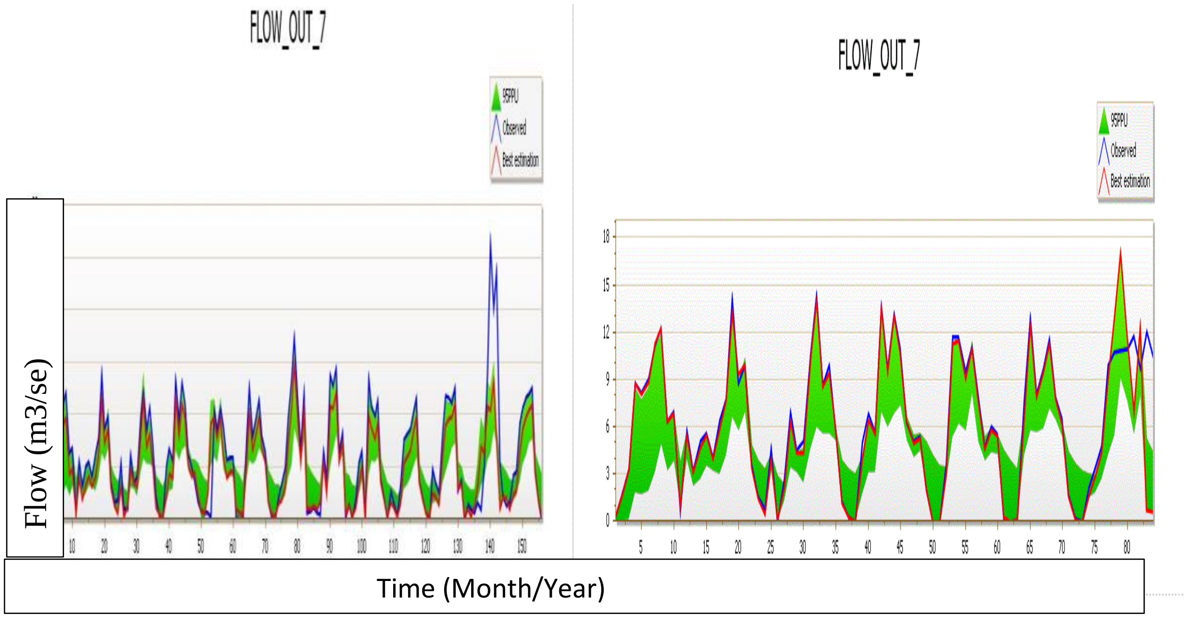


Figure 4.4 Simulated and Observed Discharge for Calibration & validation Period (1998_2017)

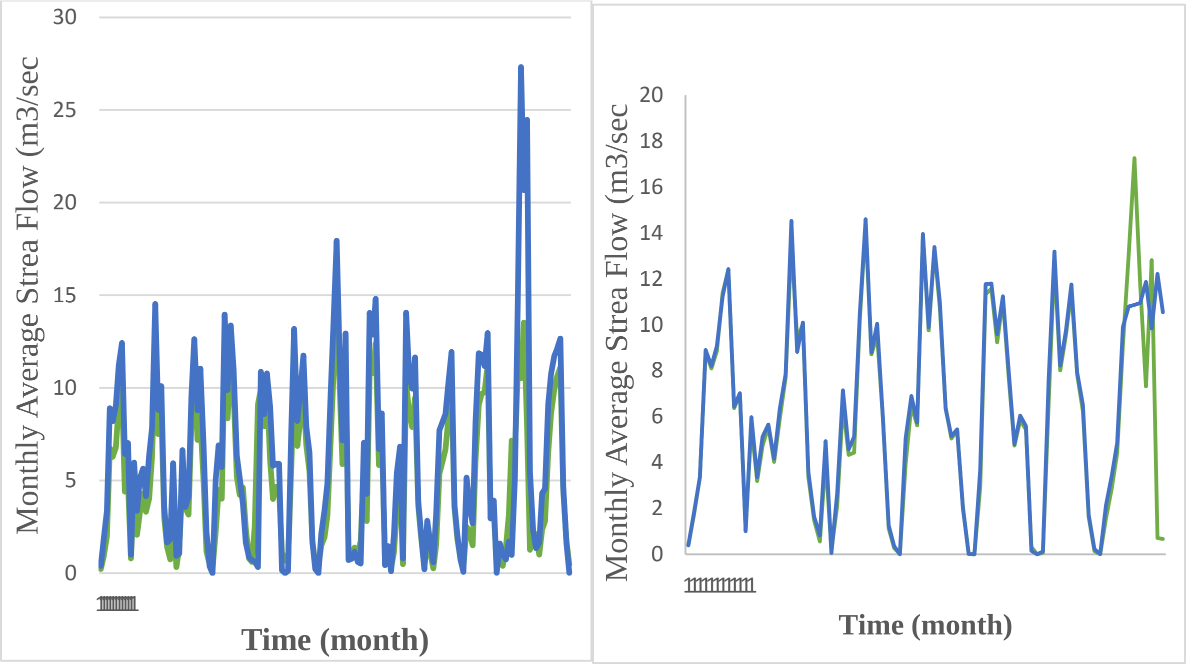


Figure 4.5 Monthly Measured &Simulated Stream flow for calibration & validation (1998 – 2017)

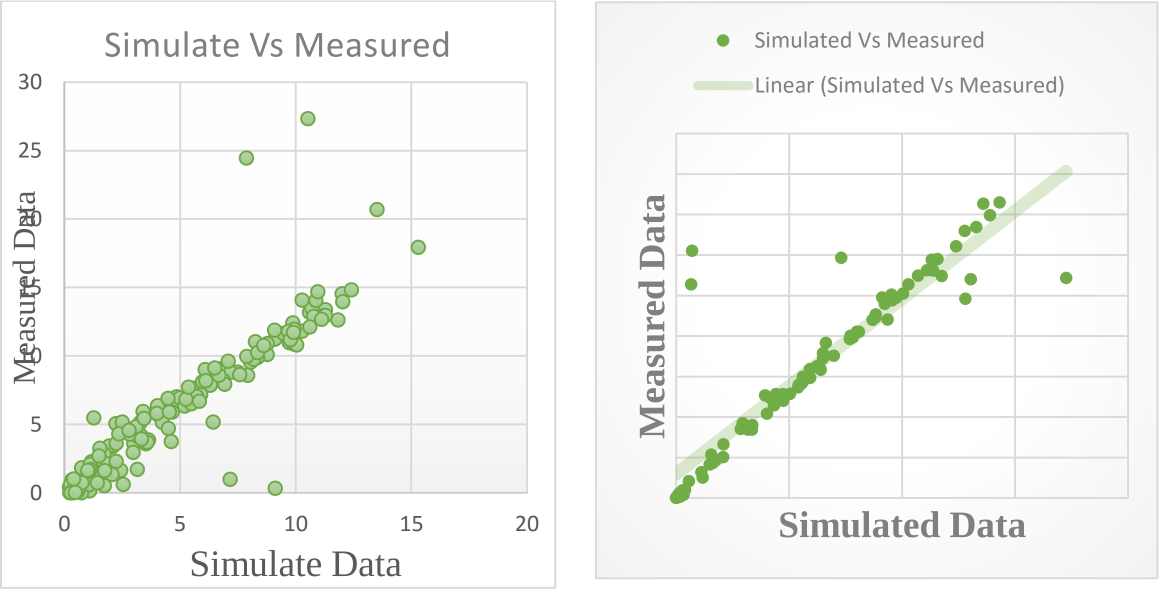


Figure 4.6 Scatter plot of observed Vs simulated stream flow for calibration & validation (1998-2017)

4.3.3 Validation

The Model validation was done for the period 2011 to 2017 and the results indicated that the Model is capable of predicting the watershed response. NSE indicates acceptable accuracy for the model to predict the watershed response. However, performance is lower than that for calibration. This agrees with the case study reported by (Asres *et al.*, 2016). In his work the calibration results showed a better match than validation. Regardless of the low performance during validation, the results indicated that the model could satisfactorily simulate hydrologic response of the watershed.

Generally, the graphical and statistical results both during calibration and validation period showed adequate model performance but the model over predicted the flow in all months except August both in calibration and validation period (Figure 4.4). From Thyiessen polygon area it is indicated that the most parts of the watershed is covered with Agaro and Gatira stations which have higher precipitation as compared to the rest stations. This will lead to over prediction and there may also be inflow to the watershed from other watershed during this month (Figure 3.7). Peak flows seem to be underestimated during validation. 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 stations distribution and some missing data. The over estimation of the model could be also attributed to uncertainties that might be exist in Temsa watershed, such as surface or subsurface water abstractions for water detention and rural or urban water supply which were unaccounted for in this study due to data limitation, and also quality of observed data may affects. Some of basin activities are indicated in appendix A_3. If these uncertainties are considered, the calibrated SWAT model can efficiently predict flow in the Temsa watershed for management purpose. The statistical results of calibration and validation periods are presented (Table 4.8).

Table 4.8 Annually Time Step Calibration and Validation Statistics

Period	Evaluation Criteria			Average Annually Flow(m^3/s)	
	R^2	NS	PBIAS	Simulated	Observed
Calibration(1998_2010)	0.82	0.73	20.2	4.98	6.242
Validation(2011_2017)	0.81	0.78	5.6	6.133	6.496

The model was calibrated and validated using different land use data i.e. land use data for the periods of 1997 and 2018. Similarly the SWAT was run differently using land cover maps (1997 and 2018 maps) while other remaining i.e. weather data. For this research work the measured stream flow data of at Dabana gauging station were manually calibrated from a period of 21 years, which included both the automatic calibration period (from January 1st, 1998 to December 31st, 2010) and the warm up period (from January 1st, 1995 to December 31st, 1997).

In order to utilize the calibrated model for estimating the effectiveness of future potential management practices, the model tested against an independent set of measured data. This testing of a model on an independent set of data set is commonly referred to as model validation. As the model predictive capability was demonstrated as being reasonable in both the calibration and validation phases, the model was used for future predictions under different management scenario. For this research work the measured stream flow data of Temsa watershed at Dabana station from 01 January 2011 to 31 December, 2017 were used for validation.

Different studies that were conducted in the upper Blue Nile basin also showed similar result. For example, (Awulachew *et al.*, 2010) as cited in (Lemann *et al.*, 2018) report that SWAT model showed a good match between measured and simulated flow of Gumara watershed and Lake Tana both in calibration and validation periods. with (SNE = 0.76 and R2= 0.87) and (SNE =0.68 and R2= 0.83), through modeling of the Lake Tana basin, (Dile *et al.*, 2019) respectively. Through modeling of the Temsa watershed indicated that the average monthly flow simulated with SWAT model were reasonably accurate with NSE =0.73, R2=0.82 and PBIAS=20.2 for calibration and NSE = 0.78, R2 = 0.81 and PBIAS=5.6 for validation periods. This indicates that SWAT can give sufficiently reasonable result in the upper Blue Nile basin and hence the model can be used in this similar watershed. The (figure 4.6) shows that the scatter plots of observed and simulated value for both calibration and validation. This shows good linear correlation between observed and simulated values.

4.4 Impacts of Land Use/Land Cover Change on Stream Flow of Temsa watershed

One of the most important parts of the study was to evaluate the Stream flow responses of Temsa Watershed to LU/LC change. Therefore, surface runoff, lateral flow and ground water flow were the most important catchment processes and the evaluation was done depending on these processes at the watershed outlet. These processes can be affected with changing of LU/LC change. It was done to see the stream flow change as a result of LU/LC change during the years of 1997 to 2018.

After calibrating and validating the model using the two land use and land cover maps for their respective periods (1997 and 2018), SWAT2012 was executed using the 1997 and 2018 land use land cover maps for the periods and 1997-2018 while setting all the other set of input variables similar for both simulations in order to evaluate the variability of stream flow due to the land use land cover changes. This gave river discharge outputs that correspond to both land use land cover patterns. These outputs were then compared and percentages of discharge change during the wet, short rain and dry seasons were assessed at watershed and sub-watershed levels and used as indicators to estimate the hydrological effects due to land use and land cover change. Table 4.9 presents the area of watershed in each classified into different sub basin during SWAT run, increase agriculture and settlements land use land cover class and mean monthly wet season, short Rain season and dry season stream flow variability for selected sub-watersheds.

Table 4.9 Seasonal variation of stream flow 1997 and 2018

Year	1997	2018	change
Wet Season (June –September)	30.166	49.358	19.192
Short rain Season (March –May)	15.023	16.388	1.365
Dry Season(October-February)	16.2351	15.745	-0.4901

Table 4.9 presents the monthly mean flows for the seasonal cycle. The model was calibrated and validated using different land use data i.e. land use data for the periods of 1997 and 2018.

Similarly the SWAT was run differently using land cover maps (1997 and 2018 maps) while other remaining variables were kept constant i.e. (change in climate and soil management activities and other land use variables like sediment load) during simulations in order to evaluate the variability of stream flow due to the changes in land use and land cover. This technique presented the flows for both land use and land cover forms. Then, the results were compared and the discharge change during the season cycles, during the wettest months of stream flow were taken as June-September, the shortest Rainy months of the stream flow were taken as March –May and the driest stream flow were in the months of October-February. These were taken as means of estimating the effect of land use land cover change on the stream flow. To assess the effects of LULC change on stream flow, SWAT model was calibrated and validated for stream flow. After calibration and validation of SWAT model, the model was run using the two land use maps (1995-1997 and 2017-2018) while maintaining the other parameters the same i.e. (climate change and soil management activities) to estimate the change of stream flow due to LULC changes. The annual stream flow through study period is increased for wet season (June to September), and short rainy season (March to May) whereas, decreased for dry season (October to February).

The mean monthly stream flow for wet months had increased from 30.166 m3/s to 49.358 m3/s i.e. the mean monthly wet flow increased by 33.15% during wet season (Table 4.9). The mean monthly stream flow for short Rainy months had increased from 15.023 to 16.388m3/sec i.e. the mean flow increased by 9.086% during short Rain season while the dry season decreased 16.2351 m3/s to 15.745 m3/s and mean flow decreased by 3.113% during dry season between the 1997-2018 periods due to the land use land cover changes. Considering wet season of the stream flow by taking June to September, Short Rainy Season of the stream flow by taking (March to May) and dry season stream flow taken as October to February for detecting the change of stream flow the comparison of simulated stream flow for the LULC of the two Periods are summarized as below, For Example, the finding of the study is consistent with other study. The mean monthly discharge for wet months, discharge for short Rainy Season and in the dry season during the 1997-2018 periods due to the LULC changes by graph;-

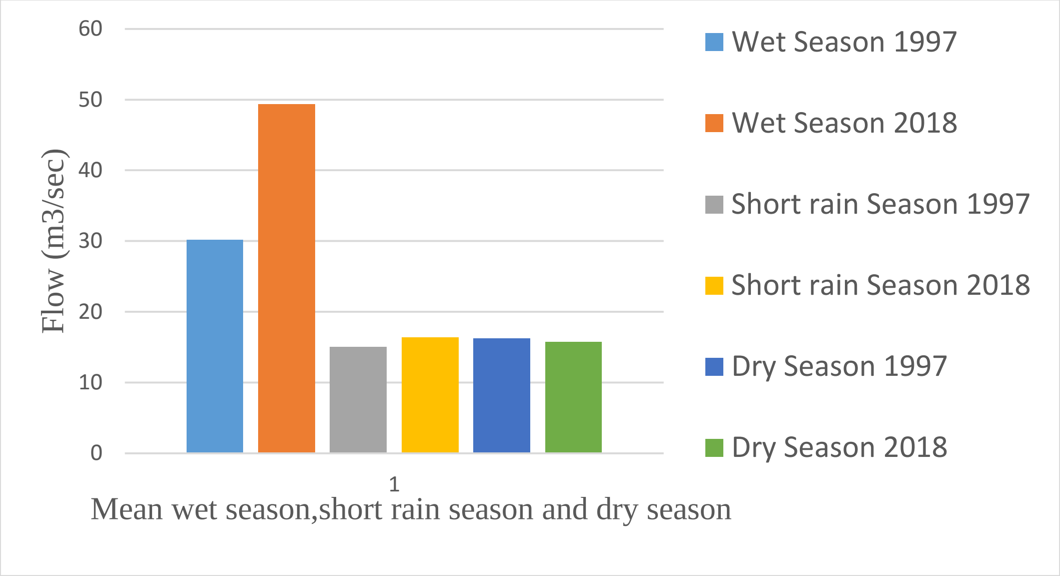


Figure 4.7 simulated mean seasonally monthly flow of Temsa stream flow

The different studies shows in different parts of the country to evaluate the effect of land use land cover change on stream flow. The comparison of simulated stream flow for the LULC of the two Periods are summarized as below, For Example, the finding of the study is consistent with other study. The result of (Mengistu, 2009) in Hare watershed indicated that mean monthly discharge for wet months had increased by 12.5% while in the dry season decreased by 30.5% during the 1999-2004 periods due to the LULC changes.

Table 4.10 presents water balance components as simulated using the land use and land cover map for the two-land use land cover changes. The impacts of different land-use on the water balance components were analyzed at the watershed scale. The results indicated the change in land use land cover maps from the year 1997-2018 as a result of increase in surface runoff by 170.07 mm in the year 2018, while the total water yield has shown to decrease by 7.60mm in the year 2018.

The increase of the surface runoff is due to the fact that built-up areas features have high portion of impervious surfaces which hamper or sturdily decrease in water percolation and groundwater contribution to stream flow and enable an increase in surface runoff. The change of the land use land cover within the watershed causes an increase in runoff, decrease in base flow, increase in sediment deposit on the bank of the river and decrease of the width of the river channel. The cultivation of forest and the demand for agricultural land forced by urban development into settlements and infrastructure forms a sealed surface, which is adversely changing the partitioning of precipitation towards increasing surface runoff and reduced groundwater recharge (Wu *et al.*, 2013).

Table 4.10 monthly simulated surface runoff and ground water flow using LU/LC of 1997 and 2018

Year	SURQ(mm)	GWQ(mm)	Perc Q(mm)	ET(mm)	TSL (T/Ha)
1997	430.94	749.85	753.25	700.90	823.36
2018	601.01(39.465%)	521.28(-30.48%)	523.90(-30.45%)	624.2(-10.94%)	887.28

SURQ: Surface runoff contribution from stream flow from HRU (mm); GWQ: Ground water contribution to stream in watershed on day, month, year (mm); PERCQ: Percolation in watershed (mm); ET: Actual Evapo-transpiration in watershed (mm); SW; WYLD: TSL=Total sediment Loading.

The mean monthly contribution of surface runoff (SURQ) and ground water flow (GW_Q) to the Temsa stream flow due to LULC change is indicated in Table 4.10. As it can be seen from the table the simulated SURQ and GW_Q using land use land cover map of 1997 were 430.94mm and 749.85mm while using land use land cover map of 2018 were 601.01mm and 521.28mm respectively. The surface run off increased from 430.94mm to 601.01mm whereas, the ground water contribution was decreased from 749.85mm to 521.28mm. The variation was associated with the land use/land cover change during the study period. This is attributed to expansion of agricultural land and urbanization over forest evergreen and shrub land that results in the increase of surface runoff following rainfall events and causes variation in soil moisture content and ground water storage. This expansion also results in reduction of water infiltrating into the ground and supplying the shallow aquifer. Therefore, discharge during the dry months (base flow) decreased and discharge during wet month increased. The result indicates that changes in LU/LC can affects infiltration rates, water storage capacity of soils, base flow and runoff the discharge base flow of watershed distribution described according to Appendix A_3.

The base flow values during the dry period was decreased for land use land cover map of 2018 indicating that the degraded watershed could reduce infiltration which can leads to the reduction of base flow. The lowering of infiltration rates were associated with expansion of settlement land (urbanization in the Temsa watershed) due to pavement (impervious or urban areas produce greater volumes of runoff and reduce base flow in stream flow) as well as agricultural land due to soil compaction from tillage activities. In addition, the expansion of agricultural land over forest every green in the upstream of the watershed resulted in the increase of runoff during the wet season. Because crops need less soil moisture as compared to forests.

Different studies have been worldwide conducted to evaluate the impacts of land use/land cover change on stream flow. The study conducted by applying SWAT model to evaluate impacts of land use changes on the hydrology and erosion in the Nile River Basin (Guzha *et al.,* 2018) concluded that decreasing forest cover can cause the risk of increasing frequent flooding. A study conducted on Angereb Watershed (Haile E. et al., 2012) concluded that the wet season flow increased by 39% for the most recent year, while the dry season flow decreased appreciably by 46%. According to this study the reason is due to conversion of forest to agriculture which intern increased surface runoff during wet season and reduced base flow during the dry seasons. The result also indicated that the decrease in forest land and grass land are accompanied by the increase in agricultural and built up areas.

In general from this study the impact of land use/land cover change on hydrological components of Temsa stream flow showed (Figure 4.7) that the base flow and surface runoff have been changed in the study period. The base flow decreased while surface runoff increased as a result of urbanization, agricultural land expansion and decrease of forest evergreen.

The impact of LULC change through sub basin in the study area is similarly influenced by the same problem through the same period in watershed.

Table 4.11 Mean monthly wet, short Rain and dry season stream flow from simulated variability (1997-2018)

Selected sub watersheds	Area (Ha)	Mean monthly flow change (%)		
		Wet season (Jun-Sept)	Short season (Mar-May)	Dry (Oct-Feb.)
4	7313.85	3.567	0.509	-1.668
12	1398.6	0.459	0.066	-0.311
18	3813.66	2.356	0.336	-5.642
21	11992.5	1.860	0.266	-2.383
23	19312.83	5.848	0.835	-9.493
26	20316.6	9.418	1.345	-4.861
	108618.8	24.77	3.54	-26.65

The result on the stream flow variability indicated that mean monthly discharge for wet months had increased by 24.77%, short Rain season increased by 3.54% while in the dry season decreased by 26.65 % during the 1997-2018 periods due to the LUCC. The Stream flow from sub-watersheds where settlement area increased is higher and high agricultural land expansions increased mean monthly increase of stream flow up to 9.42% % (Sub-watershed 26) was observed from wet season and reduction up to 9.49% (sub-watershed 23) during the dry season. On the other hand, sub watershed 12, where farmland expansion was minimum and settlement is relatively small stream flow was increased by 0.46% during wet season and, 0.07% was increased during short Rain season and reduced by 0.31% short rain and dry during seasons respectively.

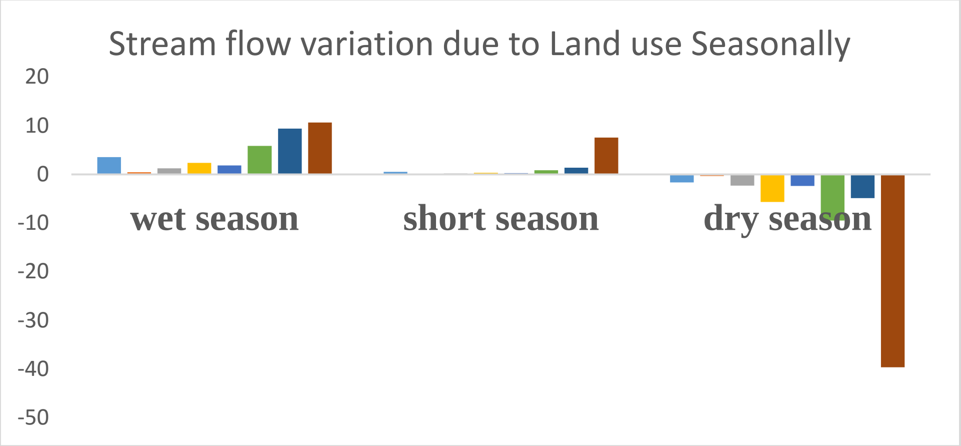


Figure 4.8 mean monthly wet, short rain and dry season stream flow from simulated variability in study area (1997-2018)

When compared, wet season stream flow is less sensitive than dry season flow due to the reason that ground water contribution during the dry season was reduced because of less infiltration that largely caused less vegetation cover.

The highest annual surface runoff was generated in sub basin 26 (AGRC area) in 2018; annual surface runoff 1.88m3/sec and 3.60m3/s were generated during 1997 and 2018 respectively. The percentage change of agriculture in sub basin 26 during 1997 and 2018 increased by 18.70% and 47.006% only in the watershed delineated by SWAT run, the dominated land uses forest land; grass land and shrub land were changed in to urban area and Agricultural Land .The lowest surface flow was generated in sub basin 12, 18 and 21 which are covered by grass land, shrub land and forest land during 1997 and 2018 respectively.

Table 4.12 Surface runoff simulated for selected sub basin part of the study area for LULC of 1997 and 2018

Selected sub watersheds	LULC Classes	Simulated annual average flow in (m3/sec)		
		LULC 1997	LULC 2018	% change b/n LULC 1997 & 2018
4	URBN	0.021	0.0742	5.32
12	RGNE	0.84	0.747	-9.30
18	FRST	0.86	0.747	-11.30
21	RGNB	1.306	0.874	-43.20
23	WATR	0.0734	0.065	-0.84
26	AGRC	1.885	3.557	88.70
		4.985	**6.133**	

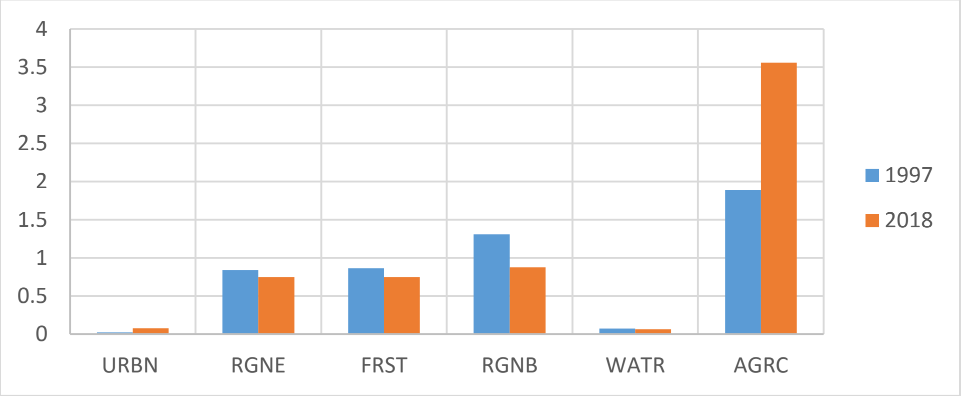


Figure 4.9 Surface runoff simulated of the study area for LU/LC of 1997 & 2018

4.5 Land Use /Land Cover change Scenario Analysis on Hydrological Processes

The three land use/land cover change scenarios are developed to analyze the impacts of land cover changes to the hydrological regime. Base scenario; current land use practices, scenario 1; shrub lands completely changed to forest land and scenario 2; Grass land completely changed to agricultural land.

1. Base Scenario; Current Land Use Practices

It offers reference point or base line data when interpreting the hydrological implication of other management scenarios. This scenario uses the existing land use land cover types to analyze the impacts on hydrological responses. The analyzed result of this scenario shown that, the average minimum monthly stream flow of 4.35mm3/sec February and average maximum stream flow of 73.01mm3/sec occurs during rainy period August (Table 4.13).

2. Scenario 1; Shrub Lands Completely Changed to Forest Land

In this land use scenario more focus is given to the protection of existing forest land from deforestation and the expansion of new forest land by replaced shrub land. The results of this scenario from (Table 4.14) but change of sediment yield, when compared to the base period. The reduction in sediment yield during the wet and short season can be resulted due to other afforestation from the upstream (Table 4.14).

3. Scenario 2; Grass lands completely changed to Agricultural Land

The report released from the Ministry of Finance and Economy and the government policy and strategies on green economy Ethiopian Climate Resilient Green Economy Strategies Plan (CRGE, 2011) shows a 15% expansion of agricultural land and 3% re-forestation work accounts for growth in agricultural sector over the last five years. Grass land conversion to agricultural practices was considered. The result of this scenario shows that stream flow does not significantly differ from the base scenario which is increased by **6.57**mm3/sec annually (Table 4.13) due to agricultural land expansion. However, the trend of the two graphs are similar despite the value difference at each month.

Table 4.13 Average monthly flow of different land use scenario

Month	Base scenario (mm3/sec)	Scenario 1 (mm3/sec)	Scenarion2 (mm3/sec)	Scenario1-base scenario (mm3/sec)	Scenario2base scenario (mm3/sec)
1	5.83	10.45	10.615	4.62	4.785
2	4.35	8.85	8.75	4.5	4.4
3	11.43	20.65	21.12	9.22	9.69
4	32.67	46.02	36.56	13.35	3.89
5	44.56	45.57	54.45	1.01	9.89
6	66.74	67.53	67.65	0.79	0.91
7	66.67	70.1	76.55	3.43	9.88
8	73.01	77.69	73.66	4.68	0.65
9	57.09	77.12	65.54	20.03	8.45
10	44.34	48.69	45.37	4.35	1.03
11	8.72	20.76	15.16	12.04	6.44
12	4.49	5.34	7.5	0.85	3.01
Annually				**6.5725**	**5.252083**

Land use/land cover change is an important characteristics in the runoff process that affect infiltration, interception, erosion and evapotranspiration. This changes cause different problem in existing hydrological conditions. Change in land use type of certain area like scenario 2 grass lands changed to cultivated land will increase volume of surface runoff, decreases time of concentration which makes several distractions by generating higher amount of runoff as well as decreases the amount of water percolated into the ground. This in turn decreases the amount of water to be recharged into the ground, and finally imbalances overall hydrological condition of watershed.

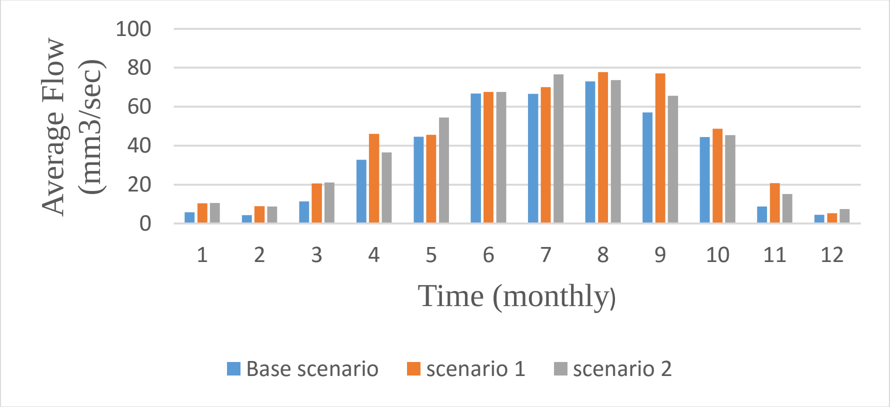


Figure 4.10 Average Monthly Flow Hydrograph of different land use scenarios (bar graph)

Table 4.14 Average annual values of different hydrological component of watershed

scenario	SURFQ (mm)	LATQ (mm)	GWQ (mm)	ET (mm)	PERC (mm)	TLOSS (mm)	WYLD (mm)	Sed.YD (Tone/Ha)
Base scenario	430.94	43.21	523.28	624.20	523.90	3.21	1145.43	823.36
Scenari1	501.01	62.12	649.85	624.20	653.25	3.21	1219.56	803.36
Scenari2	601.01	82.12	449.12	700.90	753.25	6.84	1239.55	887.28

Et-Actual Evapotranspiration from HRU, SW-soil water content, PERC- water that percolates past the root zone during the time step, SURFQ-surface runoff contribution to stream flow during time step, TLOSS-transmission losses, water lost from tributary channels in the HRU, transmission through the bed, GWQ- ground water contribution to stream flow, WYLD (water yields)=SURQ+LATQ+GWQ-TLOSS.

In general, changes in land use types of the area like increasing the percentage of agricultural land increase volume of surface runoff, facilitating soil erosion, decrease the amount of water percolated into the ground. Whereas, increasing the percentage of forest lands in turn increases the amount of water to be recharged into the ground, decrease erosion potential, due to decreased velocity of water which permits a greater decrees of scouring. Therefore, with agricultural expansion and human interaction, hydrological responses are expected to be modified or changed.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

In this study SWAT model was applied to evaluate the land use/land cover changes impacts on Stream flow in Temsa watershed. To do this, satellite images were used to produce the map of the different cover classes of the Temsa watershed using ERDAS IMAGINE2015 during the past twenty one years (1997-2018). This was done to map the land use/cover classes and evaluate classification accuracy. Then, the effects of land cover dynamics on the Stream flow of the watershed were evaluated. The SWAT model was calibrated and validated in the Temsa watershed and Statistical performance of the model was seen. Then, the evaluation of the impacts of land use/cover change on stream flow was done. One of the main aims of this study is to evaluate LU/LCC and its impacts on the watershed hydrological responses.

The preparation of hydro meteorological data and land use/land cover data, sensitivity analysis, calibration, validation and evaluation of model performance were done prior to evaluation of land use/land cover impact on hydrologic response of the Temsa watershed. Processing of soil and DEM data were done using GIS whereas, land use/land cover processing was done using ERDAS IMAGINE2015. From the results the following conclusions were drawn.

The land use /land cover analysis during the study period (1997-2018) indicated a significant change of LU/LC in the Temsa watershed. The study shows the expansion of land area under cultivation by 20.15% and build up area by 0.794% of a total area. But degradation of grass land during the period of 1997 to 2018. Grass land was decreased as a result of urbanization and agricultural expansion in the watershed during the study period. The Forest decreased by 3.93% due to agricultural encroachment to marginal land and expansion of settlement area during the study period and shrub land decreased by 11.97% due to agricultural expansion.

Generally, the change of LU/LC is due to the population increment which leads to increase demand for cultivation land. For global sensitivity analysis using SWAT CUP (SUFI-2) Sixteen (16) flow parameters which may affect stream flow were considered from different literatures and only five (5) parameters were selected to have an influence in controlling the hydrological processes in the watershed. The graphical and statistical results both during calibration and validation period showed adequate model performance with NS and R^2values of 0.73 and 0.82 and R2 0.78 and 0.81 for calibration and validation respectively. The statistical result of model performance assessment also showed that the trend agreements between the calibrated and simulated model was good. The Nash efficiency and coefficient of determination result shown that the model has a good performance. It has also shown the model effectiveness to simulate the stream flow of the watershed.

But the model over predicted the flow in all months except August both in calibration and validation period. The over estimation of the model could be attributed to uncertainties that might be exist in Temsa watershed, such as surface or subsurface water abstractions for different purpose and rural or urban water supply which were unaccounted for in this study due to data limitation, and also quality of observed data. But from the statistical parameters it can be concluded that 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 were done after calibration and validation of the model at the gauging location (Dabana). The result shows that the mean wet monthly flow increased by 33.15% (from 30.166m3/s in1998 to 49.m3/s in 2018), the mean short Rain monthly flow increased by 9.086%(from 15.023m3/sec in 1997 to 16.388m3/sec in 2018) and the mean dry monthly flow decreased by 49.01% (from 16.2351m3/s in 1997 to 15.745m3/s in 2018) during the study period (1998-2017). The mean monthly contribution of surface runoff (SURQ) and ground water flow (GW_Q) to the Temsa stream flow due to LU/LC change indicated a variation with change in LU/LC. The simulated SURQ and GW_Q using land use and land cover map of 1997 were 430.94mm and 749.85mm while using land use and land cover map of 2018 were 601.01mm and 521.28mm respectively. The surface run off increased from 430.94mm to 601.01mm (39.47%) whereas, the ground water contribution was decreased from 749.85mm to 521.28mm (30.48%).

5.2 RECOMMENDATION

Depending on the results of the study the following recommendation was made for the Temsa watershed;

- SWAT model were calibrated using observed flow data at gauging station. In order to improve the model performance, the weather station should be improved both in quality and quantity of the model result the weather stations should be evenly distributed in the watershed.
- It is recommended that for better calibration and validation and for management purpose, future research should be done considering the different sources of uncertainties like water abstraction and water detention in the sub basin.
- Reforestation of marginal land at the upstream of the watershed should be implemented to develop the hydrology
- Further researches like impact of climate change on basin hydrology should be done
- The model simulation in this study considered only land use change effects by assuming all other this constant. But change in climate and soil management activities and other land use variables will also contribute great impact on rain fall process of the watershed.
- Further study need for detail analysis of land cover in the watershed by taking more ground control point and checking the overall accuracy like measuring the amount of conserved soil on each terracing.
- Further researches like land use land cover impacts on sedimentation effects on Temsa watershed shall to be done.
- From the result of land use scenarios, it is recommended that developing Land use planning, protect the water sources like springs, rivers and forests and Soil and Water Conservation (SWC) structure should be considered an integral planning strategy that will help to reduce the amount of soil loss.

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Appendix_A

Appendix A_1 Parameters used in sensitivity Analysis's name

Parameters	Definition
1.CN2	SCS runoff curve number
2.ALPHA_BF	Base flow alpha factor (days)
3.GW_Delay	Ground water delay (days)
4.GW_Revap	Ground water Revap coefficient (dimensionless)
5.ESCO	Soil evaporation compensation factor (dimensionless)
6.CH_N2	Manning's "n" values for the main channel
7.CH_K2	Effective hydraulic conductivity in main channel alluvium (mm/h)
8.ALPHA_BNK	Base flow alpha factor for bank storage
9.SOL_AWC	Available water capacity of the soil layer (mmH_2O/mm Soil)
10.SOL_K	Saturated hydraulic conductivity (mm/h)
11.SOL_BD	Moist bulk density (Mg/m^3)
12.GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur (mm)
13.SLSUBBSN	Average slope length
14.CANMX	Maximum Canopy storage
15.LAT_TTIME	Lateral flow travel time
16.SURLAG	Surface runoff lag coefficient

AppendixA-2 Parameters of sensitivity analysis during calibration

Parameter Name	t-Stat	P-Value
12:V_SLSUBBSN	2.23	0.03
5:V__ESCO.hru	0.32	0.75
9:R__SOL_AWC (.).sol	0.74	0.46
7:V__CH_K2.rte	0.97	0.33
6:V__CH_N2.rte	1.14	0.25
1:R__CN2.mgt	-1.33	0.18
8:V__ALPHA_BNK.rte	-2.09	0.04
4:V__GW_REVAP.gw	2.11	0.04
13:V__GWQMN.gw	-2.23	0.03
11:R__SOL_BD (.).sol	2.33	0.02
10:R__SOL_K (.).sol	2.36	0.02
2:V__ALPHA_BF.gw	2.54	0.01
3:V__GW_DELAY.gw	-16.33	0.00
15:V_SURLAG	-2.13	0.05
14:V_ CANMX	1.23	0.05
16.LAT_TTIME	3.48	0.07

Note; “R_”; relative change to the existing parameter value i.e. the existing value is multiplied by 1+ a given value. And “V_”; the existing parameter value is to be replaced by the given value.

T_stat provides a measure of sensitivity (larger in absolute values are more sensitive); P_values determined the significance of the sensitivity. A value close to zero has more significance

Appendix A_3 Basin Activity

Mon	Rain (mm)	Snow Fall(mm)	SURFQ (mm)	LATQ (mm)	Water yield (mm)	ET(mm)	Sed. Yield (mm)	PET (mm)
1	51.46	0.00	10.60	1.14	31.09	44.40	11.05	105.17
2	46.87	0.00	8.85	0.84	20.46	41.58	10.12	111.28
3	97.51	0.00	20.65	1.49	31.01	58.28	24.24	129.69
4	144.01	0.00	46.02	2.32	59.06	59.39	64.52	100.83
5	216.65	0.00	75.57	4.14	101.00	65.09	105.20	89.35
6	252.27	0.00	89.53	5.49	134.93	63.10	124.31	77.21
7	254.86	0.00	90.10	6.29	158.51	58.47	128.06	69.00
8	269.97	0.00	97.69	6.66	180.78	60.92	141.85	71.23
9	234.26	0.00	77.12	6.17	163.90	62.75	108.09	74.23
10	160.74	0.00	48.69	4.50	130.93	68.95	64.01	96.42
11	86.68	0.00	20.76	2.39	79.60	62.12	26.07	114.03
12	75.40	0.00	15.34	1.77	53.96	55.48	15.74	107.80

Appendix A_4 Annual Rainfall Stations used in developing double mass curve

Year	jimma RF	Gatira RF	Bedele RF	Agaro RF
1995	1313.7	2037.676391	1846.974105	1776.6
1996	1502.1	1965.341533	1735	1678.6
1997	1966.7	1959.837222	2001.6	1497.9
1998	1724.4	2347.169762	1943.474933	1520.7
1999	1143.8	2058.895099	2322.5	1821.7
2000	1621.9	1718.5	1827.8	2008.3
2001	1771.4	2151.1	2165	2018.6
2002	1409.7	1920.3	1449.5	1367.4
2003	1285.3	1740.2	1445.5	1777.4
2004	1468.1	1657.3	2017.917111	1464.2
2005	1559.6	1928.859125	1924.277681	1290.4
2006	1860.1	2173.7	2358.3	1436.1
2007	1390.2	1975.1	1982.4	1285.5
2008	1554.278048	2109.2	2048.654288	1303.6
2009	1575	1845.202316	1776.8	1591.6
2010	1628.590024	2182.721152	1883.277184	1641.3
2011	1518.9	2379.703664	1743.368322	1976.5
2012	1442.9	2054.425148	1709.702073	1355.1
2013	1754.70864	2677.884376	2242.048216	1535.4
2014	1591.646761	2133.415425	1670.938587	1878
2015	1731.726803	2098.599434	1911.254659	1568.2
2016	1869.094839	1963.2	1574.776975	1887.3
2017	1831.59729	2001.573377	1629.368469	2149.2