

ADDIS ABEBA UNIVERSITY
INSTITUTE OF TECHNOLOGY SCHOOL OF GRADUATE STUDIES
DEPARTMENT OF CIVIL ENGINEERING



Impact of Land use Land cover change on Stream flow
(CASE STUDY GILGEL GIBE III)

By: ASSEFA NIGUSSIE GSR2073/07

Advisor: Dr.Ing Yilma Sleshi (PhD)

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Abstract

The population growth and construction of hydropower generation dam caused changes in land cover of the OMO River basin, Gilgel Gibe III sub watershed and this changes have impacted on the stream flow of the watershed by changing the magnitude of stream flow. This study is mainly focusing on the assessment of the impacts of the land cover changes on stream flow through satellite Remote Sensing (RS) and Geographic Information System (GIS) integrated with the SWAT model. ArcGIS used to generate land use and cover maps from Land sat TM,ETM+ and Ls8 acquired, respectively, in 1987,2003 and 2013. The land cover maps were generated using the Maximum Likelihood Algorithm of Supervised Classification. The result of this analysis showed that the cultivated land has expanded, forest land decreased, range grass land decreased and water body has increased during the study period of 1987-2013. Using the three generated land cover maps, three SWAT models set up were run to evaluate the impacts the land use and cover changes on stream flow at the watershed. The performance of the SWAT model was evaluated through sensitivity analysis, calibration, and validation. eleven flow parameters were identified to be sensitive for the stream flow of the study area and used for model calibration. The model calibration was carried out using observed stream flow data from 01 January 1989 to 31 December 2000 and a validation period from 01 January 2002 to 31 December 2007. both the calibration and validation results showed good match between measured and simulated stream flow data with the coefficient of determination (R^2) of 0.72 and Nash-Sutcliffe efficiency (ENS) of 0.67 for the calibration, and R^2 of 0.86 and ENS of 0.6 of the validation period. Because of change in land use land cover mainly decrease in forest land by 24.03 %, increase in cultivated land by 30.146 % and decrease range-grass land by 6.846 % from year 1987 to 2013 stream flow has increased by 37.13 m^3/s , 60.92 m^3/s and 98.05 m^3/s from 1987-2003, 2003-2013 and 1987-2013 Land use Land cover respectively.

Key words: Geographic Information system (GIS), Gilgel Gibe III Watershed, Land use and cover change, Remote sensing, Soil and Water Assessment Tool (SWAT), Surface runoff.

Table of content

Acknowledgment	i
Abstract	ii
List of Figure.....	vi
List of table	vii
1. Introduction	1
1.1 BACKGROUND.....	1
1.2 STATEMENT OF PROBLEM.....	2
1.3 OBJECTIVES.....	2
1.3.1 General objective	2
1.3.2 Specific objectives	2
1.4 RESEARCH QUESTIONS.....	3
1.5 SIGNIFICANCE OF THE STUDY.....	3
2. Literature Review	4
2.1 LAND USE AND LAND COVER.....	4
2.1.1 Land use Land cover changes: definition and concepts.....	4
2.1.2 Land Use and Land Cover changes and the hydrological cycle	6
2.1.3 Effects of Land Use on Hydrology.....	7
2.1.4 Effects of Afforestation and Deforestation on Hydrology.....	7
2.1.5 Land Use Classification Criteria	8
2.1.6 Land Use and Land Cover Change Studies in Ethiopia	8
2.2 IMAGE CLASSIFICATION	9
2.2.1 Supervised Classification	10
2.2.2 Unsupervised Classification	10
2.2.3 Maximum likelihood Classification	12
2.3 HYDROLOGICAL MODEL	12
2.3.1 Model Selection	13
2.3.2 SWAT	15
2.3.3 ERDAS Imagine.....	19
2.3.4 Application of Remote Sensing on LULCC	20

3. Study area and Data	22
3.1 DESCRIPTION OF THE STUDY AREA	22
3.1.1 Location	22
3.1.2 Climate of the study area	26
3.1.3 Topography	27
3.1.4 Soil, Geology and Land cover	28
3.2 DATA COLLECTION AND ANALYSIS.....	28
3.2.1 Meteorological Data collection and analysis	28
3.2.2 Hydrological Data collection and analysis	34
3.2.3 Spatial data collection and analysis	35
4. Methodology.....	39
4.1 GENERAL	39
4.2 OVER ALL FRAME WORK OF THE STUDY.....	39
4.3 IMAGE PRE-PROCESSING.....	40
4.4 IMAGE CLASSIFICATION.....	43
4.5 SWAT MODEL SETUP	44
4.6 MODEL SENSITIVITY ANALYSIS, CALIBRATION AND VALIDATION.....	47
4.7 MODEL PERFORMANCE EVALUATION	49
4.8 EVALUATION OF STREAM FLOW DUE TO LULCC.....	50
4.9 FLOW TRANSFERRING TO THE DAM SITE.....	51
5. Result and discussion.....	52
5.1 LAND USE LAND COVER MAP	52
5.1.1 Land use land Cover Map of 1987.....	52
5.1.2 Land use land Cover Map of 2003.....	54
5.1.3 Land use land Cover Map of 2013.....	55
5.2 SENSITIVITY ANALYSIS.....	58
5.3 MODEL CALIBRATION AND VALIDATION AT ABELTI	60
5.4 EVALUATION OF STREAM FLOW DUE TO LAND USE AND LAND COVER CHANGE	62
5.4.1 Change in the annual Stream Flows.....	62
5.4.2 Change in the Seasonal Stream Flows.....	63
6. Conclusion and recommendation.....	70

6.1 CONCLUSIONS.....	70
6.2 RECOMMENDATIONS.....	72
References	73
Appendices	76

List of Figure

Figure 1 Classification of Hydrologic Models.....	14
Figure 2 hydrological cycle component considered by SWAT model.....	19
Figure 3 Location of study area.....	25
Figure 4 Location of hydro power stations (I,II and III) and selected hydrological station (Abelti).....	27
Figure 5 Selected metrological stations of Gibe III basin.....	30
Figure 6 Monthly average rainfall of selected staions.....	31
Figure 7 Monthly average Maximum temperature of selected stations.....	32
Figure 8 Monthly average Minimum temperature of selected stations.....	32
Figure 9 Homogeneity test for selected meteorological stations.....	33
Figure 10 Double mass curve plot for metrological stations.....	34
Figure 11 Monthly average flow Abelti station.....	35
Figure 12 Digital elevation model of Gilgel gibe III.....	37
Figure 13 Soil map of Gilgel Gibe III.....	39
Figure 14 Conceptual frame work of the study.....	41
Figure 15 Images of land use land cover(path/row:169/54,169/55 and 170/55).....	43
Figure 16 Methodology of Land use map preparation.....	45
Figure 17 land use land cover percentage in the year 1987.....	53
Figure 18 Land use map of Gilgel Gibe III in the year 1987.....	54
Figure 19 land use land cover percentage in the year 2003.....	55
Figure 20 Land use map of Gilgel Gibe III in the year 2003.....	55
Figure 21 land use land cover percentage in the year 2013.....	56
Figure 22 Land use map of Gilgel Gibe III in the year 2013.....	57
Figure 23 Land use Land cover change pattern.....	58
Figure 24 measured & simulated flow hydro graph at Abelti (calibration).....	61
Figure 25 measured & simulated flow hydro graph at Abelti (Validation).....	62
Figure 26 Measured and simulated hydrograph for 1987 land use land cover at Abelti (calibration) (1989-1995).....	57
Figure 27 Measured and simulated hydrograph for 1987 land use land cover at Abelti (Validation)(1996-1998).....	69
Figure 28 Measured and simulated hydrograph for 2003 land use land cover at Abelti (calibration)(1999-2005).....	68

List of table

Table 1. basic future of Gilgel Gibe I hydropower plant (EEPCo,2004).....	22
Table 2. basic feature of gilgel gibe II Hydro power plant (EEPCo,2009).....	23
Table 3. basic feature of gilgel gibe III Hydro power plant (EEPCo,2009)	25
Table 4 Selected metrological stations of Gibe III basin	29
Table 5 Land use/cover classification of Gibe III watershed as per SWAT	37
Table 6 Soil type of the study area and area coverage in the water shade	38
Table 7 Description of Land sat images.....	42
Table 8 The slope classes of the Abelti and Gibe III watershed	45
Table 9 Summary of land use land cover	57
Table 10 calibrated parameters at Abelti sub basin.....	59
Table 11 Sensitivity of the objective function to the model parameters.....	59
Table 12 Comparison of Measured and simulated monthly flow for calibration and validation period at Abelti station	61
Table: 13 Comparisons of Simulated Mean annual Stream flow at Gibe III (1989-2015).	62
Table: 14 Generated stream flow for each land use land cover types for 1987,2003 and 2013 land use land cover.....	63
Table 15 Mean monthly wet and dry month’s stream flow and their variability (1989-2008) at Abelti (after calibration and validation).....	64
Table 16 Mean monthly wet and dry month’s stream flow and their variability (1989-2015) at Gilgel Gibe III.....	64
Table 17 Measured and simulated flow at Abelti for 1987 land use land cover.....	68
Table 18 Measured and simulated flow at Abelti for 2003 land use land cover	68
Table: 19 Change in stream flow for 1987 and 2003 land use land cover at Abelti	68
Table 20 Mean monthly wet and dry months stream flow for 1987 lule and 2003 lule atI Gilgel Gibe III	69

Abbreviation and acronyms

DEM	digital elevation model
ERDAS	earth resource data analysis system
FAO	food agricultural organization
HRU	hydrological response unit
LULC	land use land cover
MoWIE	ministry of water irrigation and energy
a.s.l	above sea level
NMA	national metrological agency
NSE	Nash Sutcliff efficiency
PET	potential evapo transpiration
R ²	Coefficient of determination
SUFI2	Sequential uncertainty
SWAT	Soil and water assessment tool
SWAT-CUP	Soil and water assessment tool- calibration and uncertainty program
SCS	Soil conservation service
WGEN	Weather generator
LiDAR	Light detection and ranging
CN	Curve number
USGS	United State Geological Survey
AVHRR	Advanced Very High Resolution
ETM+	Enhanced thematic mapper
MSS	Multiple Spectral Scanner
TM	Thematic mapper
CAD	Computer Aided Design
GIS	geographical information system
EEPCo	Ethiopia electric power corporation

1. Introduction

1.1 Background

Human health and welfare, food security and industrial Developments are dependent on adequate supplies of suitable water; however, water resources are affected by many parameters. Establishing a relationship among these parameters is the central focus of hydrological modeling from its simple form of unit hydrograph to rather complex models based on fully dynamic flow equations. One of the parameters that affect the quantity of water flowing in a watershed is land use of the watershed area. land use change has an undeniable and significant global, ecological trend which in turn affect the quantity of water. The topography of the Gibe basin in Ethiopia is nutrient depletion. These have a direct effect on the water that draws in the watershed. To visualize the future effects of land use change on river flow, it is important to have an understanding of the effects of historic land use changes on the watershed hydrological system. The dynamic nature of land use arising from an increasing population, expansion of the agricultural sector and climatic change is happening at an alarming rate in Ethiopia. Expansion and intensification of agriculture, growth of urban areas and extraction of timber and other natural resources will likely accelerate over the coming decades to satisfy the demands of an increasing population. The fast growing of population and the density of livestock in the basin resulted in forest clearing and overgrazing.

Hence, outlining the relationship between land use/land cover and the hydrological condition of the area enables us to know how the quantity of water flowing to the reservoir changed with the change of land use. Therefore, the need for scientific research that establishes the impact of land use changes on basin inflow is essential. The knowledge of the influence of land use change on watershed hydrology will enable local governments and policy makers to formulate and implement effective and appropriate response strategies to minimize the undesirable effects of future land use change or modifications.

The main intention of this study is to analyze the effect of land use and land cover changes on the stream flow of the watershed.

Generally, this study can be achieved through the integration of Remote Sensing, Geographic Information System (GIS) and Soil and Water Assessment Tool (SWAT model).

1.2 Statement of problem

Land use and land cover change is an important characteristic in the runoff process that affects infiltration, interception erosion and evapotranspiration. These changes have caused severe stress on forest and water resources in Gibe III-catchment. Due to rapid development in the catchment, is subjected land-use/cover to changes causing the area to form impervious surface. Deforestation, expansion of cultivation and other land use activities can significantly alter the maximum and minimum flows of the river .Although land-use changes in the area are a current phenomenon, the severity of their effects on hydrology of Gibe III catchment might pose serious concern on the future functioning of this fragile resource if urgent action is not taken into consideration. Deforestation, overgrazing of the forest lands and expansion of the agricultural area is activity of the people living in the watershed. The watershed is also facing high erosion by the effects of intense rainfall of the watershed which aggravates the land cover change of the watershed. Uncontrolled soil erosion, Poor land use practices, improper mitigation management systems and land degradation resulting in heavy sediment transport in streams and rivers causes significant reduction of the capacity of Gibe III reservoirs.

This continuous change in land cover has impacted the water balance of the watershed (inflow) by changing the magnitude of the components of stream flow which are surface runoff and ground water flow, which results increasing the extent of the water management problem. Outlining the relationship between LU/LC and hydrological condition of the area enables us to project the possible flood risks management through future development progress for appropriate measure. Therefore, the need for a scientific research is unquestionable. Specifically, this research was addressed estimating the effect of LU/LC changes on the stream flow of Gibe III basin for contribute a lot on the way toward tackling the above problems.

1.3 Objectives

1.3.1 General objective

- The main objective for this study was to Identify the impact of land cover change on stream flow at OMO (Gibe III catchment) river basin.

1.3.2 Specific objectives

- To asses land use and land cover changes of Gibe-III catchment

- To analyze stream flow changes in response to land use/cover change
- To identify the flow sensitive parameters of the watershed
- To evaluate the performance of the hydrological (SWAT) model

1.4 Research questions

- What are the trends of land use/land cover change in the study area?
- How land cover changes significantly affect the stream flow?
- How much SWAT model is applicable to assess land use/land cover impact on stream flow at Ghibe-III catchment?

1.5 Significance of the Study

The land use and land cover change has significantly impacts on natural resource, socio economic and environmental system. however ,to assess the effect of land use land cover change on stream flow it is important to have an understanding of the land use land cover pattern and the hydrological process of the waterside. understanding the types and impacts of land use land cover is essential indicator for resource base analysis and development of effective and appropriate response strategies for sustainable management of natural resources in the country in general and at the study area in particular. Moreover, the study presents a method to quantify land use and land cover change and their impact on 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 analysis the land use land cover change.

2. Literature Review

2.1 Land Use and Land Cover

2.1.1 Land use Land cover changes: definition and concepts

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. Land use refers to the intended use or management of the land cover type by human beings. Thus, land use involves both the manner in which the biophysical attributes of land are manipulated and intent underlining that manipulation (the purpose for which the land is used e.g., agriculture, grazing, etc), which are more subtle changes that affect the character of the land cover without changing its overall classification. Definition of land use in this way establishes a direct link between land cover and the actions of people in their environment (FAO, 1998a).

Land Use and Land Cover Changes (LUCC) is the shift in intent and/or management constitutes land use and land cover. those different types of land use land cover has an impact to increase or decreases stream flow . Increase Crop lands and decrease of forest, results increase of stream flow because of the crop soil moisture demand. Crops need less soil moisture than forests; therefore, the rainfall satisfies the shortage of soil moisture in agricultural lands more quickly than in forests there by generating more runoff when the area under agricultural land is extensive. Hence, this leads to an increases stream flow. Generally, knowing of the impacts of land use and land cover change on the natural resources like water resources depends on an understanding of the past land use practices, current land use and land cover patterns, and projection of future land use and land cover, as affected by population size and distribution, economic development, technology, and other factors.

The land use and land cover change assessment is an important step in planning sustainable land management that can help to minimize agro-biodiversity losses and land degradation, especially in developing countries like Ethiopian. According to the International Geo-sphere Biosphere Program and The International Human Dimension Program (IGBP-IHDP, 1999), land cover refers to the physical and biophysical cover over the surface of earth, including distribution of vegetation, water, bare soil and artificial structures. Land use refers to the intended use or management of the land cover type by human beings such as agriculture, forestry and building construction. Land use and land cover

change (LULCC) is commonly grouped in to two broad categories conversion and modification (Meyer and Turne, 1994).

- I. Conversion refers to a change from one cover or use category to another(e.g. from forest to grassland).
- II. Modification, on the other hand, represents a change within one land use or land cover category (e.g. from rained cultivated area to irrigated cultivated area) due to changes in its physical or functional attributes. These changes in land use and land cover systems have important environmental consequences through their impacts on soil and water, biodiversity, and microclimate (Lambin et al., 2003).

Land cover changes have been influenced by both the increase and decrease of a given population (Lambin et al., 2003). In most developing countries like Ethiopia population growth has been a dominant cause of land use and land cover change than other forces (Sage, 1994). There is a significant statistical correlation between population growth and land cover conversion in most of African, Asian, and Latin American countries (Meyer and Turner, 1994). Due to the increasing demands of food production, agricultural lands are expanding at the expense of natural vegetation and grasslands (Lambin et al., 2003). Land use and land cover characteristics have many connections with hydrological cycle. The land use and land cover type can affect both the infiltration and runoff amount by following the falling of precipitation (Houghton, 1995). Both surface runoff and ground water flow are significantly affected by types of land cover (Abebe, 2005). Surface runoff and Ground water flow are the two components of the stream flow. Surface runoff is mostly contributed directly from rainfall, whereas ground water flow is contributed from infiltrated water. However, the source of stream flow is mostly from surface runoff during the wet months, whereas during the dry months the stream flows from the ground water.

Quite often the study of LUCC is necessitated by the need to know, in quantitative terms, the nature, the extent and the rate at which these changes advance and the problems or impacts they cause. Furthermore, some studies tried to comprehend the effect of changes in upstream land use and land cover, resulting alterations in the movement of water and water availability at the downstream. Increased consciousness of these impacts enhanced their estimating, forecasting and modeling at the regional scales. However, quantifying impacts of LUCC and managements practices at a watershed scale is still complex because of the inherent variability and complex interactions among the different factors. Thus, in order to provide

foundations for effective management of natural resources, an understanding must be built on the variability in time and space of the resources and role of human cultures and institutions in bringing those variations (Thomas, 2001; Awasthi et al., 2002).

Comprehensive knowledge of LUCC is useful for reconstructing past land use and land cover changes and for predicting future changes, and thus may help in elaborating sustainable management practices aimed at preserving essential landscape functions (Hietel et al. 2004). The primary drivers of LUCC and their interrelationship with the hydrological regimes has to be identified to develop projections of future land use and management decision outcomes under a range of economic, environmental, and social scenarios.

Currently, improved understanding of processes of LUCC has led to a shift from a view condemning human impact on the environment as leading mostly to a deterioration of earth system processes to emphasis on the potential for effective utilization of resources and ecological restoration through watershed management. This change reflects an evolution of the research questions, methods, and scientific paradigm (Victor and Ausubel, 2000). As a result, general statements about impacts of LUCC and land-water interactions need to be continuously questioned to determine whether they represent the best available information and whose interests they support in decision-making processes (FAO, 2002; Bewket and Sterk, 2004).

2.1.2 Land Use and Land Cover changes and the hydrological cycle

It is obvious that land cover can affect both the degree of infiltration and runoff following rainfall events, while the degree of land cover can affect rates of evaporation. Land cover has various properties that help to regulate water flows both above and below ground. For example, tree canopy and leaf litter can help reduce the impact of raindrops on the ground, hence reduce soil erosion, while roots hold the soil in place and also absorb water. In the absence of vegetative cover, soil erosion will result and the effects of this phenomenon have been detailed previously. Ethiopia is the water tower of northeastern Africa. However, land cover change can affect the amount of runoff to the downstream countries of the Omo basin, where every main rainy season big floods are reported. The effects of land cover are not only contained within the country, but also on the low-lying countries of

Africa as well. That is why agreements are being signed between Ethiopia and these countries so that Ethiopia takes care of its soil erosion. Land cover change does not only affect the neighboring countries but also the basin itself, within the country, where flooding is a common phenomenon. As a result of this, millions worth of resources are lost nearly every main rainy season. Low level vegetative cover could also affect infiltration and could lead to reduced groundwater levels and therefore the base flow of streams (Dagnachew et al, 2003). specificity of characteristics of each catchment. Much of the present understanding Of land use effects on hydrology is derived from controlled experiments and manipulations of the land surface coupled with observations of hydrological processes, commonly precipitation inputs and stream discharge outputs (De Fries and Eshleman, 2004).

2.1.3 Effects of Land Use on Hydrology

The relationship between land use and hydrology is of greater interest worldwide as it can provide advice for management actions in order to avoid or minimize the negative effects of specific land use activities on the hydrology of a certain region. However, there are still uncertainties on the impact of specific land use practices to different processes of the hydrological cycle due to the complexity under water levels and therefore the base flow of streams (Dagnachew et al, 2003).

2.1.4 Effects of Afforestation and Deforestation on Hydrology

The magnitude of changes on the stream flow due to land use changes varies with catchments and other factors such as climate and human activities. Regarding the impact of deforestation and afforestation on the dry season flow in the tropics, there are conflicting statements and findings. Edwards (1999) in an experiment conducted in Mbeya, observed that the dry season flow was higher from a catchment with traditional small holder cultivation than with forest cover, even on steep slopes. Similar results were observed after deforestation of *Brachy stegia* woodland in Zambia (Mumeka, 1996) and Montane hard wood forest in Taiwan (Hsia and Koh, 1993). In South Africa, afforestation of dry grassland and fynbos scrub land resulted in a highly significant decrease in low flows (Smith and Scott, 1992). Bosch and Hewlett (1982) suggested that forest cutting and removal activities usually cause increases in flood peaks for several years following disturbance, but some authors including Reinhart et al. (1963), Jones and Grant (1996), White head and Robinson (1993) have suggested that these effects can be at least

partially attributed to soil compaction during road and skid trail construction.

2.1.5 Land Use Classification Criteria

A land use and land cover classification system which can effectively employ orbital and high-altitude remote sensor data should meet the following criteria (Anderson, 2005):-

1. Repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another.
2. The classification system should be applicable over extensive areas.
3. The categorization should permit vegetation and other types of land cover.
4. The classification system should be suitable for use with remote sensor data obtained at different times of the year.
5. Effective use of sub categories that can be obtained from ground surveys or from the use of larger scale or enhanced remote sensor data should be possible.
6. Aggregation of categories must be possible.
7. Comparison with future land use data should be possible.
8. Multiple uses of land should be recognized when possible.

2.1.6 Land Use and Land Cover Change Studies in Ethiopia

In Ethiopia, the land is used to grow crops, trees, animals for food, as building sites for houses and roads, or for recreational purposes. Most of the land in the country is being used by smallholders who farm for subsistence. With the rapid population growth and in the absence of agricultural intensification, smallholders require more land to grow crops and earn a living; it results in deforestation and land use conversions from other types of land cover to cropland.

The researches that have been conducted in different parts of Ethiopia have shown that there were considerable land use and land cover changes in the country. Most of these studies indicated that croplands have expanded at the expense of natural vegetation including forests and shrub lands; for example, (Abebe, 2005; Kidanu,2004) in northern part of Ethiopia, (Zelege, 2001) in north western part of Ethiopia,(Kassa, 2003) in north eastern part of Ethiopia. The changes of land use and land cover that occurred from 1971/72 to 2000 in Yerer Mountain and its surrounding results an expansion of cultivated land at the expense of the grasslands (Gebrehiwet, 2004; Hadgu,2008); They identified that decrease of natural vegetation and

expansion of agricultural land over a period of 41 years in Tigray, northern part of Ethiopia. They concluded that population pressure was an important driver for expansion and intensification of agricultural land in recent periods.

To understand how LULC affects and interacts with global earth systems, information is needed on what changes occur, where and when they occur, the rates at which they occur, and the social and physical forces that drive those changes. Human impact on global land cover change, especially in terms of change from forest cover to other land cover, has been one of the important issues on global change research. In the primitive times when there was little human population and low level of economic activity, deforestation was not a problem because the natural regeneration of forest was adequate to cover for any loss of forest by the human beings. However, with the advent of modern civilization and industrialization and the increase in population, the forest loss to meet the ever-growing needs of the population became so huge that it posed a problem for the global environment.

2.2 Image Classification

Image classification is perhaps the most important part of digital image analysis. It is very nice to have a "clear picture" or an image, showing a magnitude of colors illustrating various features of the underlying terrain, but it is quite useless unless to know what the colors mean. Image classification is used to identify and portray, as a unique gray level (or color), the features occurring in an image in terms of the object or type of land cover these features actually represent on the ground. The intent of the image classification process is to categorize all pixels in a digital image into one of several land cover classes, or "themes". This categorized data may then be used to produce thematic maps of the land cover present in an image. Normally, multispectral data are used to perform the classification and, indeed, the spectral pattern present within the data for each pixel is used as the numerical basis for categorization.

Image processing takes a basic understanding of remote sensing and of digital images through the fundamental stages of image processing. It also provides a varied set of cases for application of image processing and introduces a wide range of processing techniques. These form the basis for continued development to advanced level. It is the process of assigning each pixel of an image to a particular group or class.

There are two main classification methods which are supervised classification and unsupervised Classification. Image classification is mostly performed using ERDAS Imagine software. ERDAS Imagine is an image processing software package that allows users to process the geospatial and other imagery as well as vector data. ERDAS can also handle hyper spectral imagery and LiDAR (Light Detection and Ranging) from various sensors. ERDAS also offers a 3D viewing module (Virtual GIS) and a vector module for modeling the native programming language is EML (ERDAS Macro Language). ERDAS is integrated within other GIS and remote sensing applications and the storage format for the imagery can be read in many other applications (*.img files). Leica Geo-systems also purchased ER Mapper to add to their mapping software. Imagine is tightly woven into the GIS fabric more than other image processing software packages and that is the advantage of this package.

2.2.1 Supervised Classification

During supervised classification, the classifier/expertise identifies examples of the information classes (i.e., land cover type) of interest in the image which is called "training sites". The image processing software system is then used to develop a statistical characterization of the reflectance for each information class. This stage is often called "signature analysis" and may involve developing a characterization as simple as the mean or the average of reflectance on each bands, or as complex as detailed analyses of the mean, variances and covariance over all bands. Once a statistical characterization has been achieved for each information class, the image is then classified by examining the reflectance for each pixel and making a decision about which of the signatures it resembles most.

The objective is to extend, or extrapolate information on land cover types for a known area of the image to the unknown areas of the whole image. The image analyst defines a number of training areas for each land cover category. The computer generates spectral signatures based on this information. Typically a maximum likelihood descriptor is used to measure the spread of values around the mean of the class. Each pixel of the image is assigned as far as possible to one of the land cover groups, as defined by the signature.

2.2.2 Unsupervised Classification

Unsupervised classification is a method which examines a large number of unknown pixels and divides into a number of classed based on natural groupings present in the image values. Unlike

supervised classification, unsupervised classification does not require analyst-specified training data. The basic premise is that values within a given cover type should be close together in the measurement space (i.e. have similar gray levels), whereas data in different classes should be comparatively well separated (i.e. have very different gray levels) (Lillesand and Kiefer, 1994; Eastman, 1995).

Unsupervised classification is the simplest technique. Within the image data for the different wavelengths the computer is asked to determine a user-defined number of clusters. Each cluster represents a land cover class or sub-class. The mean digital value for each input band could be represented as a spectral reflectance profile. The cluster represents the spread of values around the mean for the land cover class. After the classification has been completed each class should be examined and assigned a name. It may also be necessary to merge a number of classes into a single category.

The classes that result from unsupervised classification are spectral classes which is based on natural groupings of the image values, the identification of these spectral classes will not be initially known, must compare classified data to some form of reference data (such as larger scale imagery, maps, or site visits) to determine the identity and informational values of the spectral classes (Lillesand and Kiefer, 1994).

An unsupervised approach is useful where no prior ground information exists; is not biased in defining classes; is relatively rapid to compute; and accounts for all cover types in an image. However the process of identifying and merging classes can be time consuming and the statistical description of the spread of values within the cluster is not as good as the maximum likelihood classifier. Conversely the supervised maximum likelihood approach is time consuming when identifying training areas; relatively slow to compute; and can only produce a class map for which there are training areas (Pembury T., 2005).

Unsupervised classification is becoming increasingly popular in agencies involved in long term GIS database maintenance. The reason is that there are now systems that use clustering procedures that are extremely fast and require little in the nature of operational parameters. Thus it is becoming possible to train GIS analysis with only a general familiarity with remote sensing to undertake classifications that meet typical map accuracy standards. With suitable ground truth accuracy assessment procedures, this tool can provide a remarkably rapid means of producing quality land cover data on a continuing basis.

2.2.3 Maximum likelihood Classification

Maximum likelihood Classification is a statistical decision criterion to assist in the classification of overlapping signatures; pixels are assigned to the class of highest probability. The maximum likelihood classifier is considered to give more accurate results than parallelepiped classification however it is much slower due to extra computations. We put the word 'accurate' in quotes because this assumes that classes in the input data have a Gaussian distribution and that signatures were well selected; this is not always a safe assumption.

2.3 Hydrological Model

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 meet one of the two primary objectives.

- ✓ To get a better understanding of the hydrologic processes in a watershed and of how changes in the watershed may these phenomena.
- ✓ For hydrologic prediction (Tadele, 2007). They are also providing valuable information for studying potential impacts of changes in land use and land cover or climate.

On the basis of process description, the hydrological models can be classified in to three main categories (Cunderlik, 2003).

- 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 primarily in the discharge prediction only, then these models can provide just as good simulations as complex physically based models.
- Distributed models:- Parameters of distributed models are fully allowed to vary in space at a resolution usually chosen by the user. Distributed modeling attempts to incorporate data concerning the spatial distribution of parameter variations together with computational algorithms to evaluate the influence of this distribution on simulated precipitation-runoff behavior. Distributed models generally require large amount of

(often unavailable) data. However, the governing physical processes are modeled in detail, and if properly applied, they can provide the highest degree of accuracy.

- Semi-distributed models:-Parameters of semi-distributed (simplified 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 they are less demanding on input data than fully distributed models. SWAT (Arnold, et al., 1993), HECHMS(US-ACE, 2001), HBV (Bergström, 1995), are considered as semi distributed models.

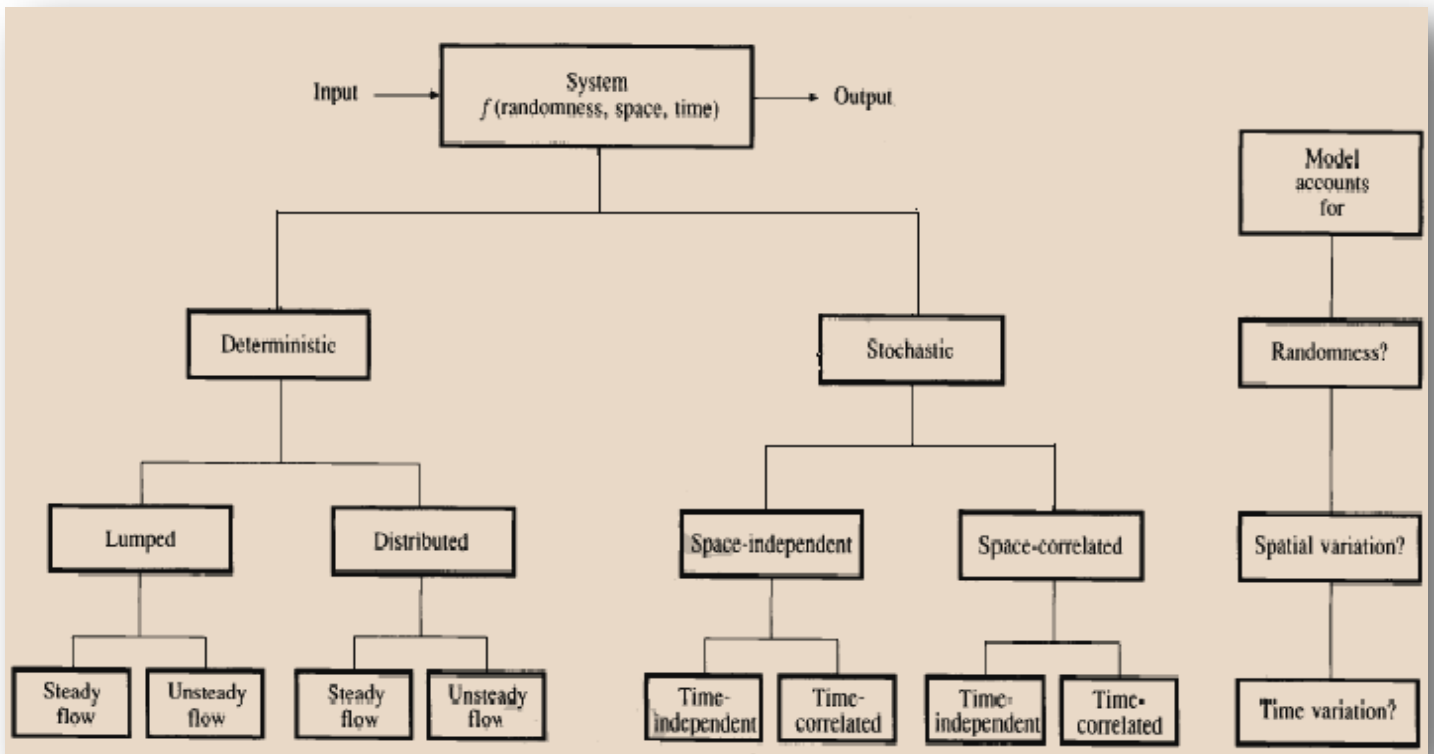


Figure 1. Classification of Hydrologic Models

2.3.1 Model Selection

Hydrological practice would be improved if models were objectively chosen on the basis of making the best use of the information available and following some systematic procedure of selection and verification (Dooge, 1984). The choice of the best model depends to a large extent on the problem. Generally speaking, items that should be considered in the selection process include (Haan et al. 1982):

- (a) The nature of the physical processes involved,
- (b) The use to be made of the model,
- (c) The quality of the data available and
- (d) The decisions that rest on the outcome of the model's use.

Several models may be capable of describing the same process, and, to a great extent, selection of the one to be used depends on a comparison of sampled data and model output. In model selection, decisions that may rest upon the outcome of the model's use must be considered. To a great extent, these decisions will dictate the criteria that should be used to judge the quality of the model's performance. These are rather simplistic examples, but they serve to show the needs of the decision maker, who may not know how to judge the quality of a model's response.

There are different hydrological models that simulate the land use change effects on hydrology and sediment yield of the watershed. Hydrological models have been used for flow forecasting to support reservoir operation, for flood protection, in spillway design studies and for several practical purposes. Some of the hydrological models that are used for hydrological and hydraulic analysis are HBV (Hydrological Byråns Vattenbalansav deleing), SWAT, HEC HMS (Hydrologic Engineering Center's Hydrologic Modeling System), HSPF (Hydrologic Simulation Program Fortran), MIKE SHE (System Hydrologique European) and others. Moreover, with the development of Geographic Information Systems (GIS) and remote sensing techniques, the hydrological models have been more physically based and distributed to enumerate various interactive hydrological processes considering spatial heterogeneity. Hence, the ability of a hydrological model to integrate GIS for hydrologic data development, spatial model layers and interface may be considered as model selection criteria. During this study for the accomplishment of objectives of land use change and impacts on stream flow of Gibe III watershed the following selection criteria's were considered for selecting a type of model to be used:

1. Required model outputs important to the project and therefore to be estimated by the model (Does the model predict the variables required by the project such as peak flow, event volume and hydrograph, long-term sequence of flows?),
2. Hydrologic processes that need to be modeled to estimate the desired outputs adequately (Is the model capable of simulating regulated reservoir operation, snow accumulation and melt, single-event or continuous processes?),

3. Availability of input data (Can all the inputs required by the model be provided within the time and cost constraints of the project?),
4. Price (Does the investment appear to be worthwhile for the objectives of the project?).

Some other criteria's

- **Expertise: What scientific expertise is required to use the model adequately?**
- Technical support: Support available for to set, calibrate and use the model.
- Documentation: What documentation is available about the model, such as user's guides, reference manuals, web pages, newsletters, et
- Ease-of-use: Describes computer-related user-friendliness of the model, taking into account GUI, input-output (I/O) operations, and visualization options
- The model simulates the major hydrological process in the watersheds and It is readily and freely available.

5. Representation should also include the river flow network.

6. The model able to use data from various global databases.

Based on the above selection criteria SWAT model was selected for detail analysis and investigation of land use cover change effects on surface flow of Gibe III watershed.

2.3.2 SWAT

Description of SWAT model

It is the acronym for Soil and Water Assessment Tool which is semi distributed, physically based, time continuous model designed to predict the impact of land management practices on water, sediment, and agricultural chemical yield in large river basins (Arnold et al., 2012) developed by Dr Jeff Arnold for the USDA Agricultural Research Service (ARS). The model is computationally efficient and capable of continuous simulation over long time periods. Major model components include weather, hydrology, soil temperature and properties, plant growth, nutrients, pesticides, bacteria and pathogens, and land management. Among the many advantages of this model are; it has incorporated several environmental processes, it uses readily available inputs, it is user friendly, it is physically based and distributed, and it is computationally efficient to operate on large basins in a reasonable time. Despite the strengths mentioned above SWAT model have some known weaknesses:

- ✓ No routines for concentrated animal feeding operation
- ✓ Simplified stream channel degradation and sediment deposition routines
- ✓ The tile drainage routine of SWAT does not account for the drain spacing and depth of shallow water table
- ✓ The spatial detail required to correctly simulate environmental processes. For example, it is difficult to capture the spatial variability associated with precipitation within watershed.
- ✓ Data files can be difficult to manipulate and can contain several missing records. The model simulations can only be as accurate as the input data.
- ✓ Model does not simulate detailed event-based flood and sediment routing

Inputs entered into the SWAT model are organized to have spatial characteristics. The SWAT model provides three spatial levels: the watershed, the sub-basins, and the hydrologic response units (HRUs). Each level is characterized by a parameter set and input data. The largest spatial level, the watershed, refers to the entire area being represented by the model. The sub-basins refer to subdivisions of the watershed that are connected hydro logically. Sub-basins are then subdivided into HRUs. HRUs are areas within a sub-basin that have the same soil, land use and slope combination. Both sub-basins and HRUs are user defined, providing model users with some control over the resolution considered in the SWAT model (Neitsch et al., 2001a).

Although the SWAT model simulates on a daily time step, the model has options for the output that allow the user to define the output time step (daily, monthly, or annual). Output variables include flow volume, nutrient yields, sediment yield, plant biomass yields and etc. These variables are provided on the sub-basin or HRU spatial level depending on the output time step selected. The output files generated by the SWAT model are created in text and database file formats.

Generally The model uses a digital elevation model (DEM) to delineate the watershed boundary and the watershed is divide into multiple sub water sheds, the sub water shade also subdivided in to hydrologic response units (HRUs) that consist of similar land use, slope, and soil characteristics (Arnold et al., 2012).the HRUs represent percentages of the sub watershed area and are not identified spatially within a SWAT simulation. Alternatively, a watershed can be subdivided into only sub watersheds that are characterized by dominant land use, soil

type, and management. Model outputs include surface runoff, evapotranspiration, groundwater, lateral flow, sediment, nutrient, and pesticide yields.

The SWAT model application can be divided into six steps:

- Data preparation,
- Sub-basin discretization
- HRU definition
- Parameter sensitivity analysis,
- Calibration and validation, and
- Uncertainty analysis

Hydrological modeling using SWAT model requires different procedures. The following are the key procedures necessary for modeling using SWAT.

- Create new SWAT project
- Delineate the designated watershed for modeling,
- Define land use/soil/slope data grids,
- Determine the distribution of HRUs based on the land use and soil data,
- Define rainfall, temperature and other weather data,
- Write the SWAT input files- requires access to data on soil, weather, land cover, plant growth, fertilizer and pesticide use, tillage, and urban activities,
- Edit the input files – if necessary, and
- Setup and run SWAT – requires information on simulation period, PET estimation method and other options view SWAT output.

The land phase of the hydrologic cycle is modeled in SWAT based on the water balance equation (Neitsch, et al, 2005) as follow.

$$SW_t = SW_o + \sum_{i=1}^t (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}) \quad (1)$$

Where, SW_t is the final soil water content (mm), SW_o is the initial water content (mm), t is the time (days), R_{day} is the amount of precipitation on day i (mm), Q_{surf} is the amount of surface runoff on day i (mm), E_a is the amount of evapotranspiration on day i (mm), W_{seep} is the amount of water entering the vadose zone from the soil profile on ,day i (mm), and Q_{gw} is the amount of return flow on day i (mm)

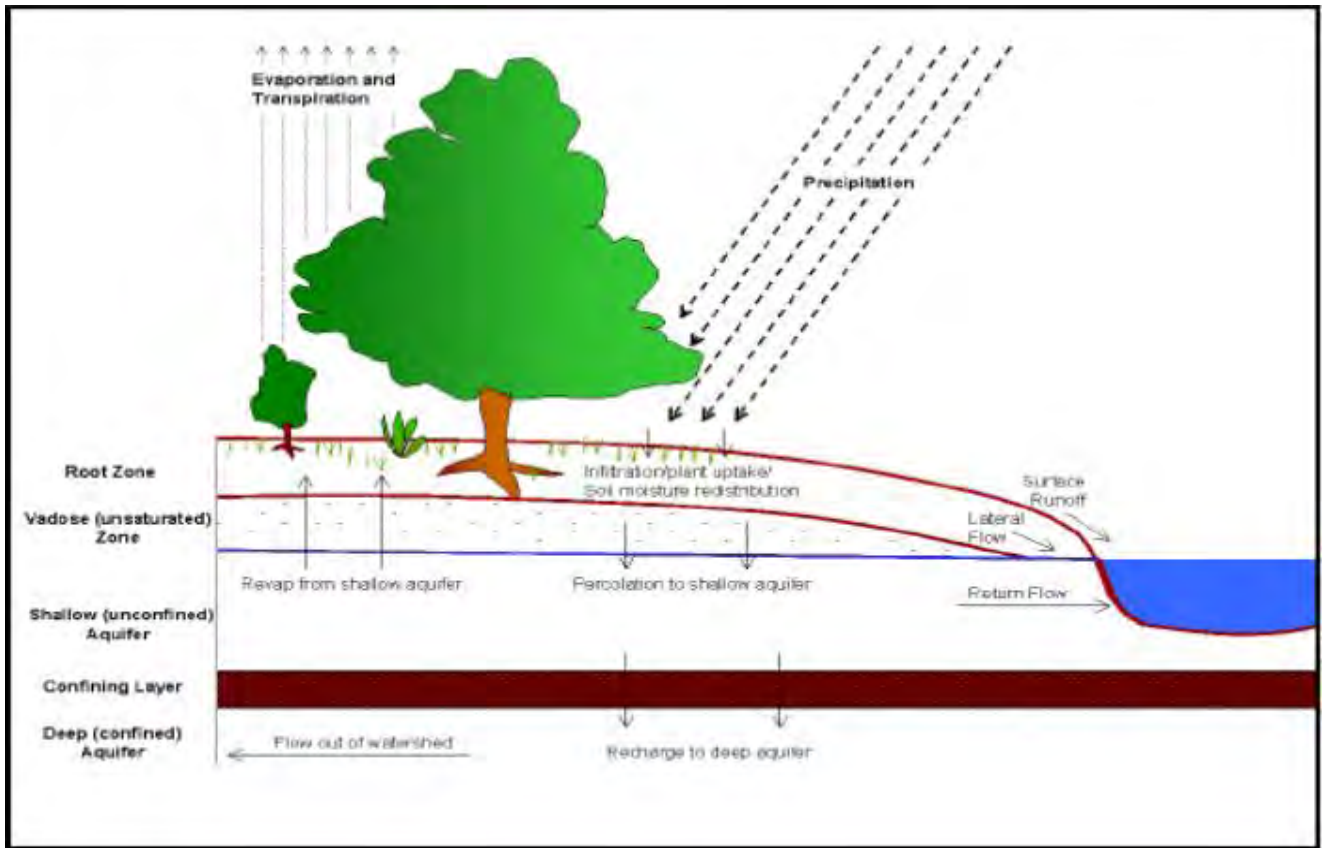


Figure 2. Hydrological cycle component considered by SWAT model(Neitsch et al.,2005).

Surface runoff refers to the portion of rainwater that is not lost to interception, infiltration, and evapotranspiration (Solomon, 2005). Surface runoff occurs whenever the rate of precipitation exceeds the rate of infiltration. SWAT offers two methods for estimating the surface runoff: the Soil Conservation Service (SCS) curve number method (USDA-SCS, 1972) or the Green and Ampt infiltration method (Green and Ampt, 1911). The Green and Ampt method needs sub-daily time step rainfall which made it difficult to be used for this study due to unavailability of sub-daily rainfall data. Therefore, the SCS curve number method was adopted for this study.

The general equation for the SCS curve number method is expressed by equation 2:

$$Q_{surf} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)} \quad (2)$$

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

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

I_a is initial abstraction which includes surface storage, interception

and infiltration prior to runoff (mm water),

S is retention parameter (mm water).

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

$$S = 25.4 * \left(\frac{1000}{CN} - 10 \right) \quad (3)$$

Where, CN is the curve number for the day and its value is the function of land use practice, soil permeability and soil hydrologic group.

The initial abstraction, Ia, is commonly approximated as 0.2S and equation 2 becomes:

$$Q_{\text{surf}} = \frac{(R_{\text{day}} - 0.2S)^2}{(R_{\text{day}} + 0.8S)} \quad (4)$$

For the definition of hydrological groups, the model uses the U.S. Natural Resource Conservation Service (NRCS) classification. The classification defines a hydrological group as a group of soils having similar runoff potential under similar storm and land cover conditions. Thus, soils are classified into four hydrologic groups (A, B, C, and D) based on infiltration which represent high, moderate, slow, and very slow infiltration rates, respectively and for my study the soil types are grouped in A, B and D (Belete Berhanu et al., 2013).

SWAT-CUP (SWAT Calibration and Uncertainty Procedures)

It is a program designed to integrate various calibration/uncertainty analysis programs for SWAT using the same interface. The program can run SUFI2, GLUE, MoMc and Para Sol. The program guides the input files necessary for running a calibration program. Each SWAT-CUP project contains one calibration method and allows running the procedure many times until convergence is reached. It allows saving calibration iterations in the iteration history for later use. SUFI-2 algorithm, in particular, is suitable for calibration and validation of SWAT model because it represents uncertainties of all sources (Yang et al., 2008) and this algorithm was used for this study.

2.3.3 ERDAS Imagine

It is a remote sensing application with raster graphics editor capabilities designed by ERDA, Inc. for geospatial applications. Prior to the ERDAS IMAGINE Suite, Earth Resources Data Analysis System (ERDAS), Inc. developed various different products to process satellite imagery from

Advanced Very High Resolution Radiometer (AVHRR), Landsat, Multiple Spectral Scanner (MSS) and Landsat TM and SPOT imagery into land cover / land use maps, map deforestation. The latest version ERDAS IMAGINE is aimed primarily at geospatial raster data processing and allows the user to prepare, display and enhance digital images for mapping use in Geographic Information Systems (GIS) or in Computer Aided Design (CAD) software. It is a toolbox allowing the user to perform numerous operations on an image and generate an answer to specific geographical questions. By manipulating imagery data values and positions, it is possible to see features that would not normally be visible and to locate geo-positions of features that would otherwise be graphical. The level of brightness or reflectance of light from the surfaces in the image can be helpful with vegetation analysis, prospecting for minerals etc.

2.3.4 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 in contact with the object, area, or phenomenon under investigation (Bawahidi, 2005). It provides a large amount of data about the earth surface for detailed analysis and change detection with the help of sensors.

Most of data inputs to the hydrological (SWAT) model 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 data are digital elevation model (DEM), land cover map, land use map and soil map. Some of the application of remote sensing technology in mapping and studying of the land use and 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), provide a basis for model building.

Land use and land cover is changing rapidly in most parts of the world. In this situation, accurate, meaningful and availability of data is highly essential for planning and decision making. Remote sensing is particularly attractive for the land cover data among the different sources. (Stefanov, 2001) 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, 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 the management of natural resources and monitoring phenomena on the 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 to obtaining information on both temporal trends and spatial distribution of watershed areas and changes over the time dimension for projecting land cover changes but also to support changes impact assessment (Atasoy, 2006). 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.

3. Study area and Data

3.1 Description of the Study Area

3.1.1 Location

The Omo-Gibe River Basin is situated in South-West of Ethiopia, between 4°00'N and 9°22'N latitude, 34°44'E and 38°24'E longitude. Gilgel gibe III watershed covers approximately 79,000 km and It is an enclosed river basin that flows into Lake Turkana in Kenya, which forms its southern boundary. The western watershed of Omo-Gibe basin is the range of hills and mountains that separate it from the Baro-Akobo Basin. The Omo-Gibe River Basin is drained by two major rivers from the highlands, the Gibe River flowing southwards and Gojeb River flowing east wards. The Gibe River rises on the Ethiopian plateau just north of latitude 9° N at an elevation of about 2,200 m a.s.l and the general direction of flow of the river is southwards towards the Omo River/Lake Turkana Trough, a fault feature.

The Gibe River is called the Omo River in its lower valley south and south westwards from its confluence with the Gojeb River. The northern part of the basin has a number of tributaries from the northeast of which the largest are the Walga and Wabe Rivers. The Tuljo and GilgelGibe Rivers are important rivers that drain the main cultivated lands. The three hydropower stations at Omo gibe basin are described as follow.

Gilgel Gibe I

The single plant adopted scheme is a purely hydroelectric project, aimed to increase energy and power supply to the National Grid. It is located on the Gilgel Gibe River, some 260 km Southwest of Addis Ababa and 70 km North East of Jimma in the Oromiya Region with the coordinates of 319344.716 E and 875132.382, UTM WGS 1984 in North Hemisphere Of 37. The catchment area of covers about 4225km² gilgel gibe III. it has an installed capacity of 184 MW. The general future of gilgel gibe I described in table 1

Table 1. basic future of Gilgel Gibe I hydropower plant (EEPCo,2004)

Hydrology		Unit
Catchment area	4225	Km ²
Average annual flow	50.4	m ³ /s
Annual runoff	1578	Mm ³

Reservoir		
Maximum normal water level	1672	m. a.s.l.
Normal operating level	1671	m. a.s.l.
Minimum operating level	1653	m. a.s.l.
Total storage	839	Mm ³
Live Storage	657	Mm ³
Dam		
Rock fill with bituminous upstream facing	1675	
Crest elevation	1675	m. a.s.l.
Maximum height	40	M
Installed capacity	184	MW

Gilgel Gibe II

The Gilgel Gibe II Power station is the second hydroelectric power station on the Omo River. The power station receives water from a tunnel entrance 7°55'27"N 37°23'16"E on the Gilgel Gibe River. It has an installed capacity of 420 MW and was inaugurated on January 14, 2010. Almost two weeks after inauguration, a portion of the head race tunnel collapsed causing the station to shut down; repairs were complete on December 26, 2010.

The Gilgel Gibe II consists of a power station on the Omo River that is fed with water from a headrace tunnel and sluice gate on the Gilgel Gibe River. The headrace tunnel runs 25.8 km under the Fofa Mountain and converts into a penstock with a 500 m (1,600 ft) drop. When the water reaches the power station, it powers four Pelton turbines that operate four 107 MW generators.

The Gibe II plant uses the waters discharged by Gilgel Gibe I and has a gross head of 505 m used by an open air power station of 420 MW installed capacity. This new head is created by a waterway that bypasses about 10 Km of the two rivers (Gilgel Gibe and Omo). The intake is located on the Gilgel Gibe river about 200 m downstream of the Gilgel Gibe I outlet. The waterway crosses the ridge between the Gilgel Gibe valley and the Omo valley by means of 25.8 km of tunnel and 1.2 km of penstocks. The flow discharged by the turbines of Gibe I plant and diverted into the Gibe II intake (EEPCo, 2004). The following table 2 shows the basic features of this hydropower station.

Table 2. basic feature of gilgel gibe II Hydro power plant (EEPCo,2009)

Hydrology		Unit
Catchment area	4304	Km ²

Average flow (receives a regulated flow from Gilgel Gibe I dam)	101.5	m ³ /s
Reservoir		
Max probable flood level(Q= 2325 m ³ /s),corresponding to Max operating level	1437.6	m.a.s.l.
Normal operating level (max retained level)	1431.5	m.a.s.l.
Minimum operating level	1424	m.a.s.l.
Total storage	1.9	Mm ³
WEIR		
Crest Elevation	1439	m.a.s.l.
Max Height (u/s)	49	m
Crest Length	140	m

Gilgel Gibe III

The Gibe III project area is some 400 km South West of Addis Ababa and 150 km South-west of Hawassa. The project is located within the jurisdiction of the Mareka Gana Wereda of the Dawro Zone and Kindo Koyisha Wereda of Sodo zone of the Southern Nations and Nationalities People Regional State . The Gibe III hydropower plant is the third plant of the Gibe cascade developing the hydroelectric potential of the Omo-Gibe river including: Gilgel Gibe or Gibe I operating since 2004 Gibe II currently completed Omo-Gibe IV and Gibe V projects, for hydropower and agricultural uses, currently being planned. The Gibe III project is located with the coordinates of 312,200 E and 757 200 N, UTM WGS 1984 North Hemisphere of 37 dam axis and of the other plants of the Cascade within the Omo river basin. [EEPCO, 2006]

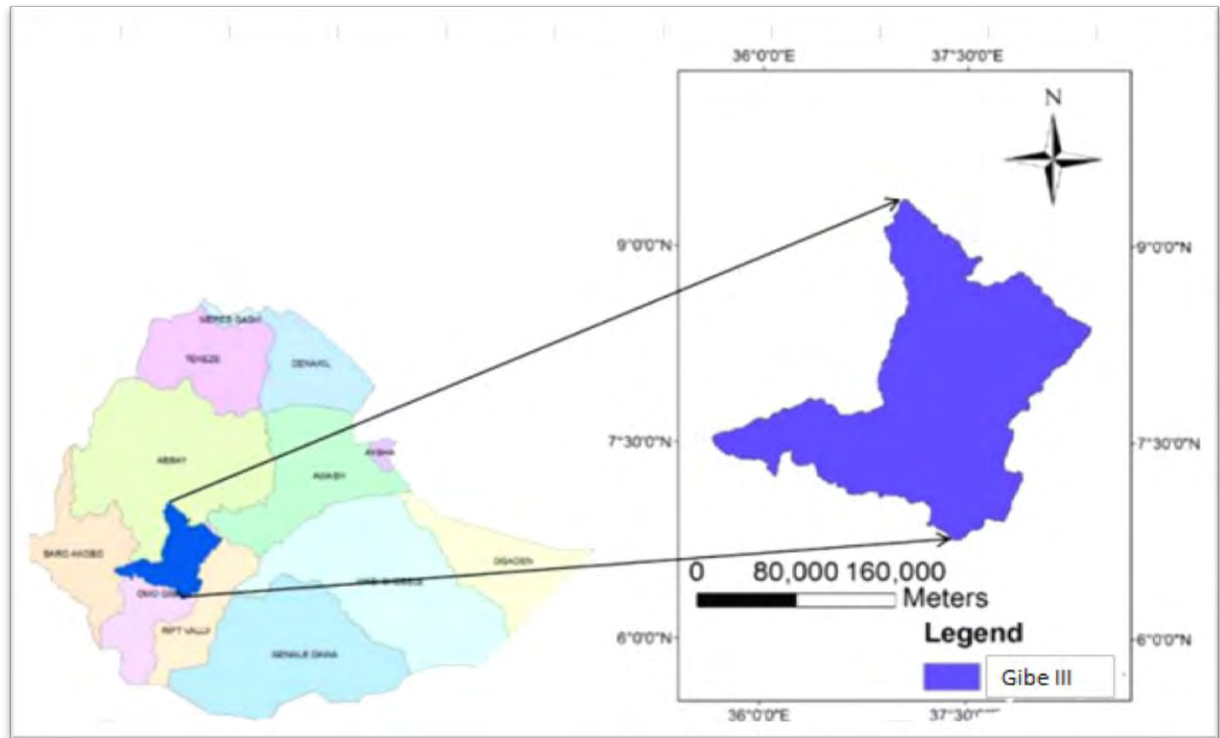


Figure 3. Location of Gilgel Gibe III (Study area)

Table 3. basic feature of gilgel gibe III Hydro power plant (EEPCo,2009)

Hydrology		Unit
Catchment area	34150	Km ²
Average annual runoff	438.2	m ³ /s
Average Annual volume	13820	Mm ³
Reservoir		
Minimum operating level	800	m.a.s.s
Normal operating level	889	m.a.s.s
Maximum water level in the reservoir	892	m.a.s.s
Live storage volume	11750	Mm ³
Surface area at normal operating level	200	Km ²
Dam		
Dam Type	(RCC) dam	
Foundation elevation		m.a.s.s
Height above river bed elevation	231	m
Crest elevation	896	m.a.s.s
Crest length	580	m

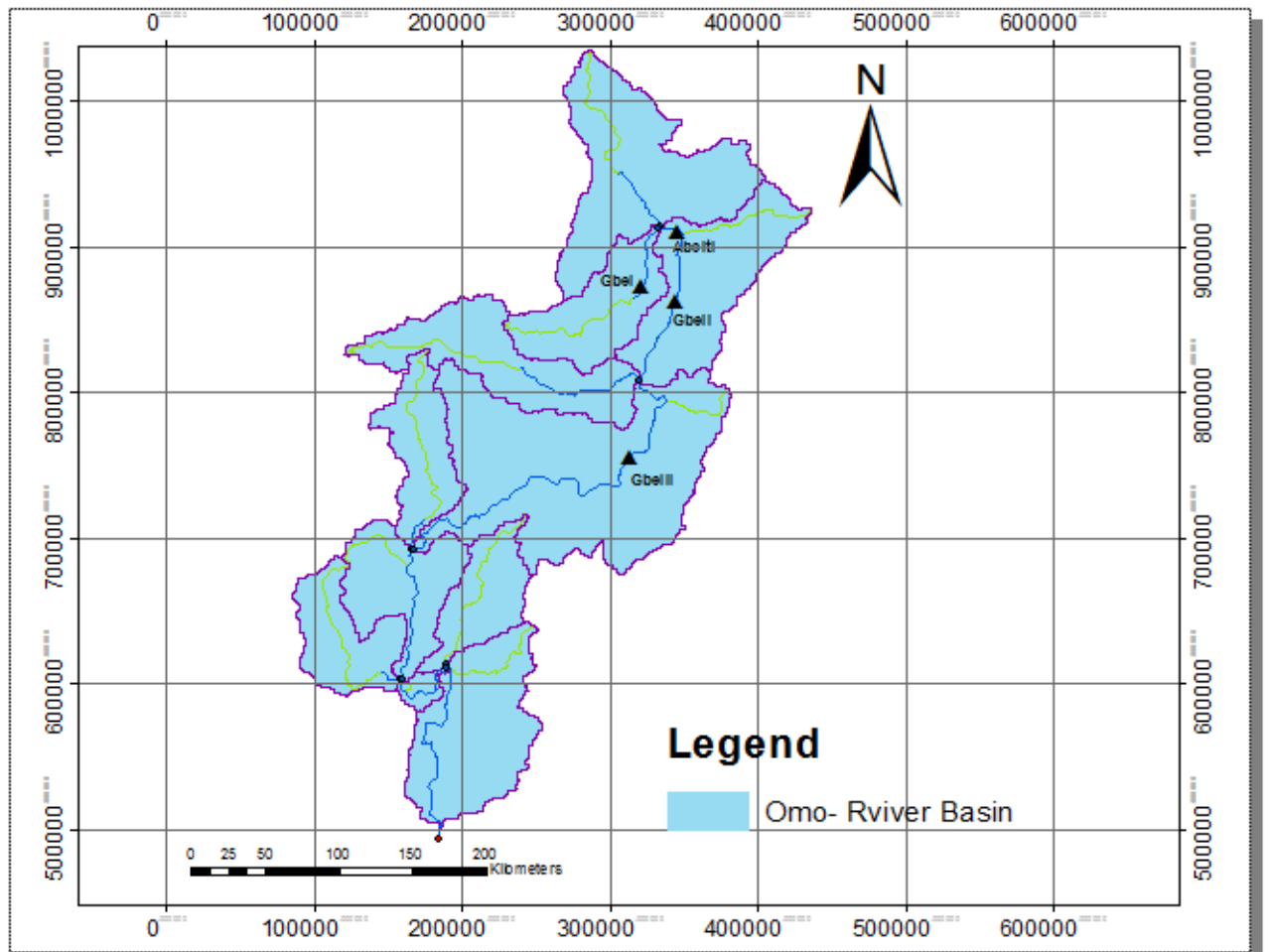


Figure 4. Location of hydro power stations (I,II and III) and selected hydrological station (Abelti)

3.1.2 Climate of the study area

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 traditional climate classification of the country is based on altitude and temperature shows the presence of five climatic zones namely: Wurch (cold climate at more than 3000 m altitude), Dega (temperate like climate-highland with 2500-3000 m altitude), Woina Dega (warm 1500-2500 m altitude), Kola (hot and arid type, less than 1500 m in altitude), and Bereha (hot and hyper-arid type) climate (NMSA,2001).

Based on the above classification the climate of Gilgel Gibe III is classified as tropical humid in the highlands that include areas surrounding Jimma and around the headwaters of Gojeb River. For the rest, and 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 Lake Turkana.

A. Rainfall

Rainfall in Omo-Gibe basin varies from over 1900 mm per annum in the north central areas to less than 300mm per annum in the south. The amount of rainfall decreases throughout the Omo-Gibe catchments with a decrease in elevation. Moreover, the rainfall regime is unimodal for the northern and central parts of the basin and bimodal for south. ITCZ shifts during the year northwards across southern Ethiopia from September to November and southwards from March to May, giving origin to the alternation of a wet (from June to September) and a dry (from December to April) season. (Source: Master Plane Study of Omo Gibe River Basin, 1996)

B. Temperature

The mean annual temperature in Omo-Gibe basin varies from 16⁰C in the highlands of the north to over 30⁰C in the lowlands of the south. The maximum temperature is higher at the southern part of the basin especially at Morka mean annual maximum temperature reaches up to 30.6 ⁰C. There is a little variation in minimum temperature which varies from 9.2⁰C in northern part of the basin example in Gedo to 16⁰C in southern part of the basin at Jinka.

3.1.3 Topography

Elevation of Gibe III water shade ranges between 717m to 3392m. About 50.23% of the watershed is flat (0 to 5% slope steepness), The gently sloping (5 to 15% slope steepness) area covers about 42.13% and (>15 % slope steepness area covers about 7.64 % of the water shade area. The topography of the Omo-Gibe basin as a whole is characterized by its physical variation. The northern two-thirds of the basin has mountainous to hilly terrain cut by deeply incised gorges of the Omo, Gojeb, and Gilgel-Gibe Rivers, while the southern one-third of the basin is a flat alluvial plain punctuated by hilly areas.

The northern and central half of the basin lies at an altitude greater than 1500 m a.s.l with maximum elevation of 3360 m a.s.l (located between Gilgel-Gibe and Gojeb tributaries), and the plains of the lower Omo lies between 400-500 m a.s.l. The head waters of the Great-Gibe River are at an elevation of about 2200 m a.s.l. Although there are some important tributaries from different directions, the general direction of flow of the Gibe River is southwards, towards the Omo River and then to Lake Turkana a fault feature, filled with alluvial and lacustrine sediments

of recent origin associated with the Great Rift Valley. The Gibe river is known as the Omo River in its lower reaches, south-westwards from the confluence with the Gojeb River. This is the reason behind the name Omo-Gibe River Basin. [Richard Woodroof and Associates, 1996]

3.1.4 Soil, Geology and Land cover

In a very broad term, most of the northern catchments of the Omo-Gibe Basin is under extensive cultivation with increased land pressure, meaning the expansion of cultivated areas in to increasingly marginal lands at the expense of forest lands. Deforested areas are now confined to areas too steep and inaccessible to farm. The flatter poorer drained bottom lands of the northern catchments are usually not cultivated but are used for dry season grazing and eucalyptus tree plantations. Wood roof and Associates, 1996]

3.2 Data collection and analysis

Engineering studies of water resources development and management depends heavily on hydro-meteorological data. These data should be stationary, consistent, and homogeneous when they are used to simulate a hydrological system. If it does not fulfill one of the above criteria's, it will result in a big problem that contradicts the actual situation. Therefore ,using different methods, the inconsistency, homogeneity, infilling for missed data and extension of short records encountered in the actual data processing activity should be done.

3.2.1 Meteorological Data collection and analysis

The climate data is among the most prerequisite parameter of SWAT model. This data were collected from Ethiopian National Metrological Agency. The data collected were based on their homogeneity of the pattern, which can be representative to the Gibe III basin. The meteorological data collected includes, Precipitation, maximum and minimum temperature for ten stations as shows below in figure 5 and table 4

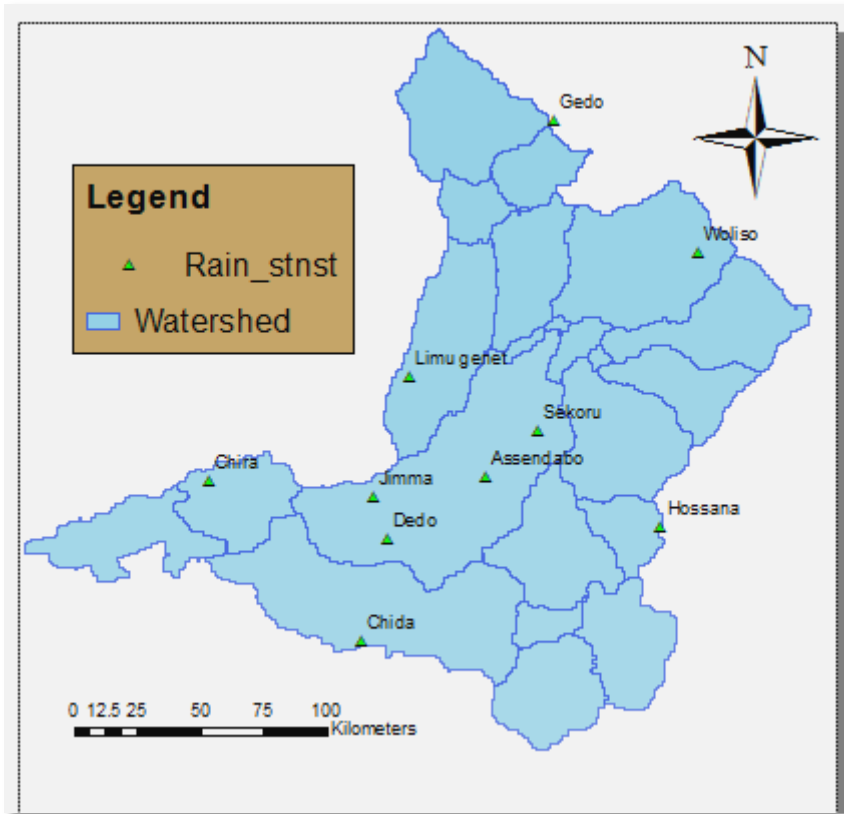


Figure 5. Selected metrological stations of Gibe III basin

Table 4. Selected metrological stations of Gibe III basin

NO	Station name	Latitude	Longitude	Observation period
1	Assendabo	7.750	37.216	1986-2015
2	Weliso	9.000	37.00	1986-2015
3	Chira	7.733	36.23	1986-2015
4	Sekoru	7.916	37.41	1986-2015
5	jima	7.670	36.83	1986-2015
6	gedo	9.050	37.43	1986-2015
7	Hossana	7.570	38.85	1986-2015
8	dedo	7.520	36.87	1986-2015
9	chida	7.159	36.77	1986-2015
10	Limu genet	8.100	36.95	1986-2015

The collected data covers a period of 1986-2015. The SWAT weather generator model (WGEN) was used to fill missing values in weather data of relative humidity, sunshine hour 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. The precipitation statistical analysis model (Pcp STAT) was used for statistical analyzing of daily precipitation data and Dew point 02 was also used for generating temperature statistical parameters of SWAT database inputs. the rainfall variations of the stations are shown in figure 6 below.

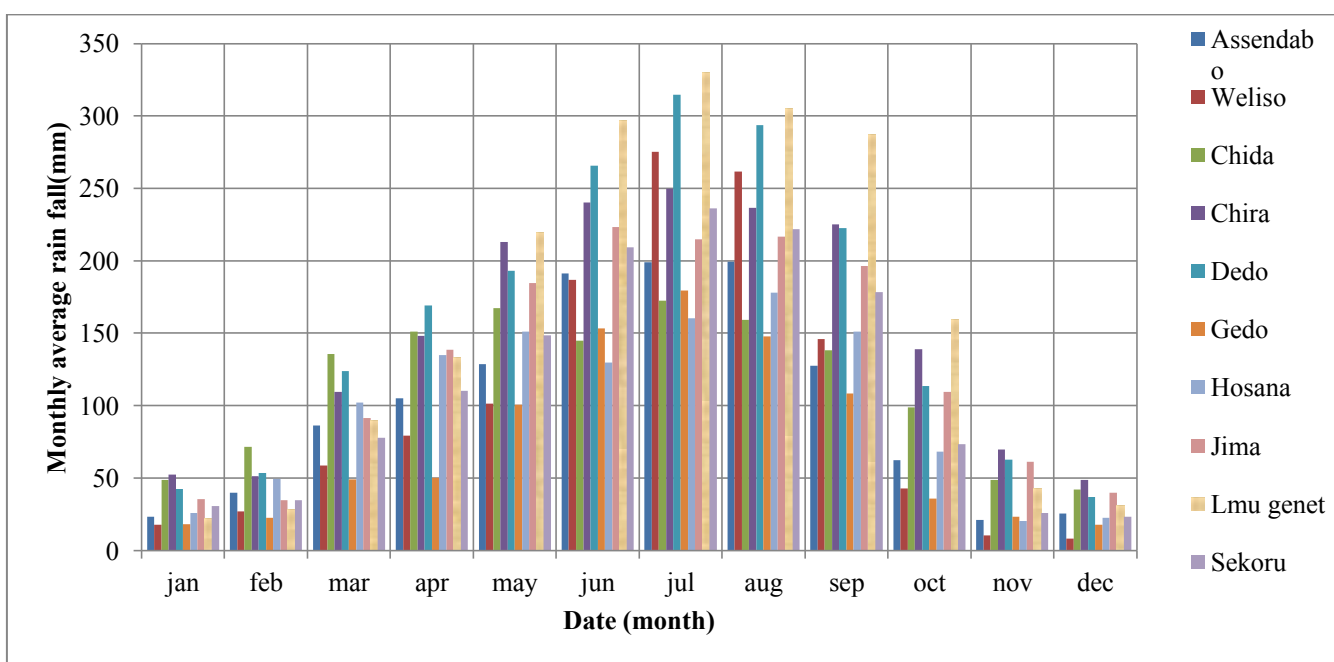


Figure 6. Monthly average rainfall of selected stations (1986-2015)

Maximum and minimum temperature data representing the basin was also collected for ten stations and the average monthly value maximum and minimum temperature of each stations with the study period presented in Figure 7 and Figure 8 respectively.

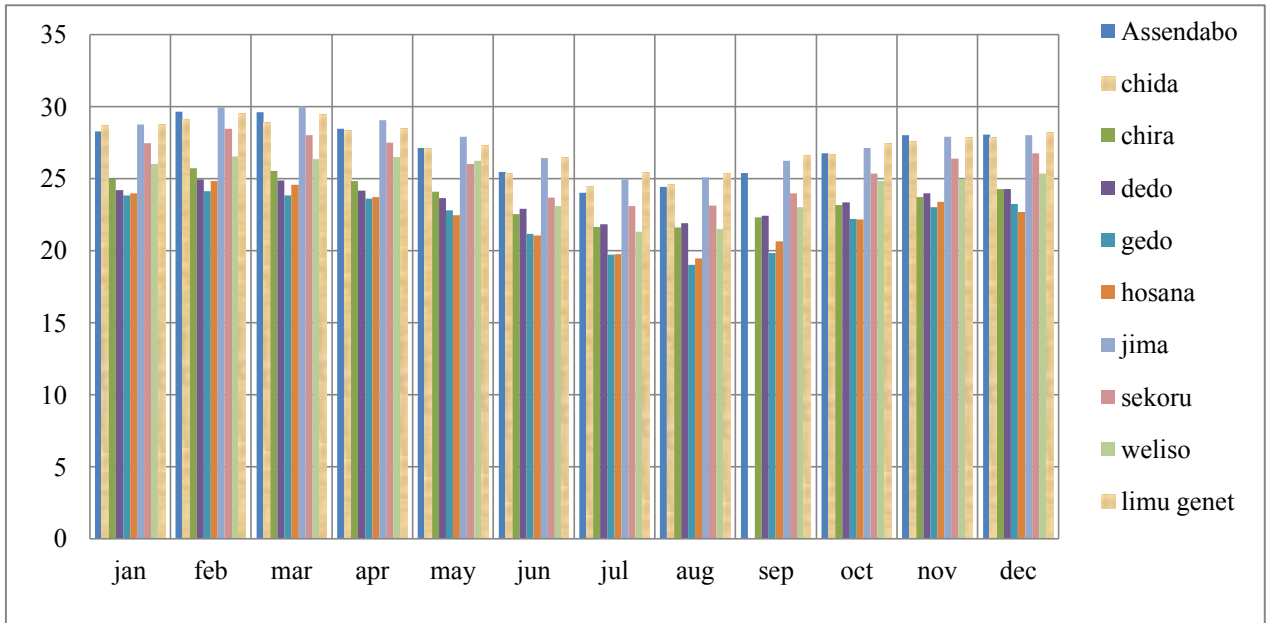


Figure 7. Monthly average Maximum temperature of selected stations (0_C /month)

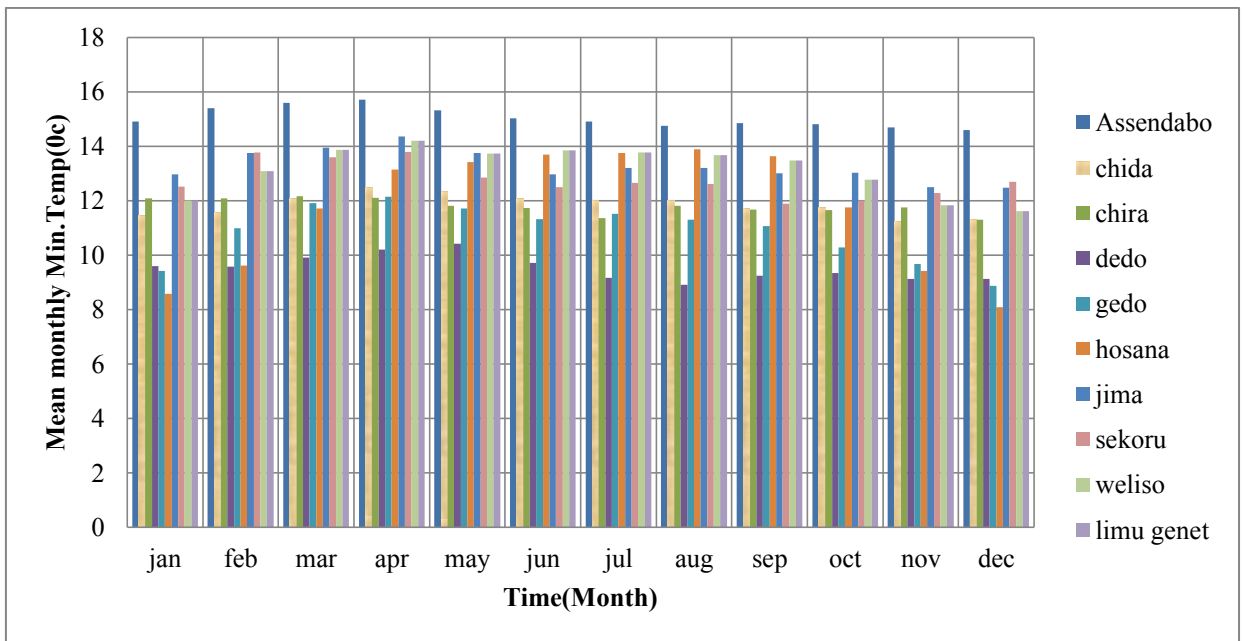


Figure 8. Monthly average Minimum temperature of selected stations (0_C /month)

Before using these data the quality of each data recorded at each station was evaluated using homogeneity test by non-dimensional parameterization and consistency test by double mass curve.

A. Checking homogeneity of stations by non-dimensional parameterization

Homogeneity analysis is used to identify a change in the statistical properties of the time series.

The causes can be either natural or manmade. These include alterations to land use and relocation of the observation station. Therefore, in order to select the representative meteorological station for the analysis of areal rainfall estimation, checking homogeneity of group stations is essential and the homogeneity of the selected gauging stations monthly rainfall records were carried out by non dimensionlization.

$$P_i = \frac{\overline{P_i}}{\overline{P}} \dots \dots \dots (5)$$

P_i =Non dimensional value of precipitation for the month i

$\overline{P_i}$ =over year average monthly precipitation for the station i

\overline{P} =the over years average yearly precipitation of the station

The selected stations are also plotted for comparison with each other; for illustration figure 10 below shows the result of homogeneity analysis and Same-mode and pattern of the stations are observed and hence group stations selected are homogenous.

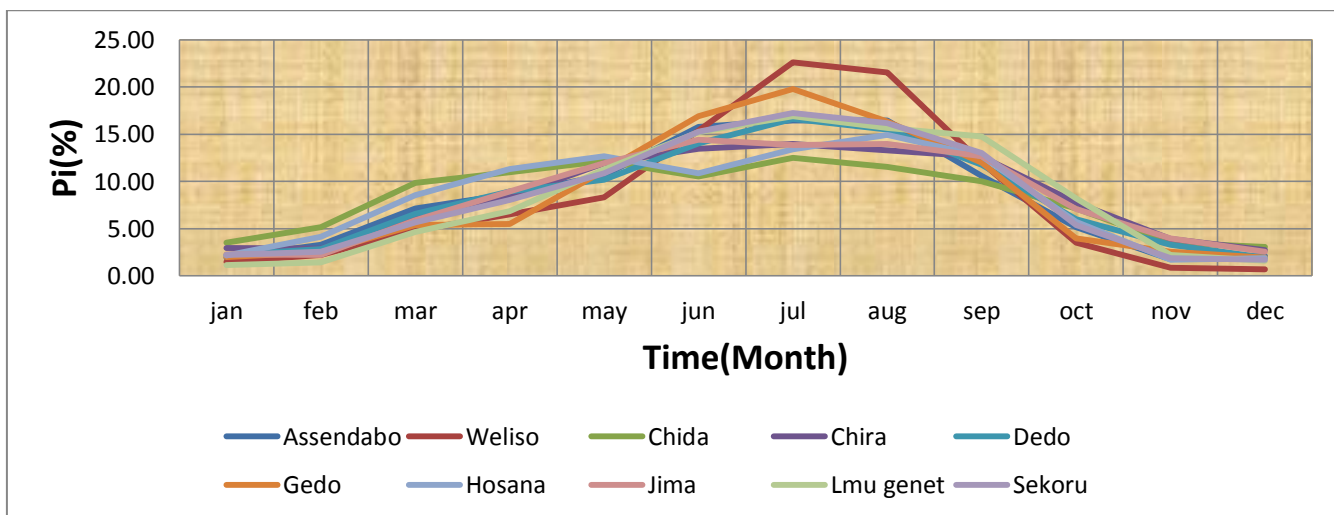


Figure 9. Homogeneity test for selected meteorological stations

B. 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. Double mass curve method helped in determining the best realistic

correlation of stations located near or within watershed. This technique is based on the principle that when each recorded data comes from the same parent population, they are consistent. it

$$\text{should be corrected as } \frac{P_a}{P_d} = \frac{Y/X}{Y^d/X^d} = \frac{\text{Slope of Original line}}{\text{Slope of deviated line}} = \text{correction factor} \dots \dots \dots (6)$$

In which P_a = adjusted amount P_d = deviated amount for the concurrent period for which P_a is desired. Correction was performed when

$$= \frac{\text{Slope of deviated line} - \text{slope of original line}}{\text{slope of deviated line}} * 100 \dots \dots (7) \text{ greater than } 10\% \text{.but for this study}$$

correction was not needed.

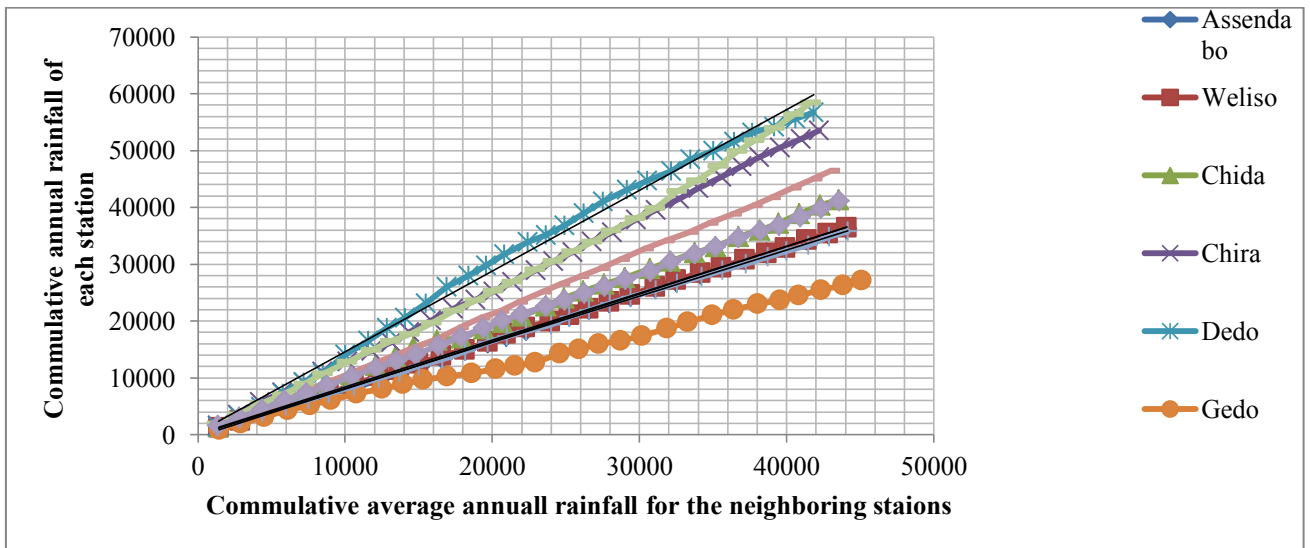


Figure 10. Double mass curve plot for metrological stations

C. filling missed rainfall data by regression

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 Elshorbagy et al.,(2000) as cited in Habtom (2009). Some techniques of filling missed rainfall data are simple linear interpolation, arithmetic mean method, inverse distance and normal ratio method. For this study, arithmetic mean method for one station which have least percentage of missing and regression /excel stat was used to fill the missing data of rainfall and temperature from nearest stations for other stations.

3.2.2 Hydrological Data collection and analysis

Stream flow measurements were used for comparisons against the modeled stream flow in model calibration and validation. daily stream flow data for Gibe III Watershed was collected from Ministry of Water, Irrigation and Energy (MoWIE) for the period off 1986 - 2007 G.C at Abelti station for SWAT simulation result of calibration and validation.

Water resource studies highly depend on stream flow data. These data should be consistent, stationary and homogenous. Monthly stream flow data from a period of 1989-2000 were used for model calibration and from 2002-2007 were used for mode validation. Unlike rainfall, stream flow shows strong serial correlation; the value on one day is closely related to the value on the previous and following days especially during the period of low flow or recession. The runoff generated due to the small rainfall occurs on December to April and heavy rainfall on Jun to September is the main cause of variation of flow in the study area (Source: master plan study of Omo Gibe River Basin).The gauging station have good stream flow records with a small number of missing data in the study baseline.

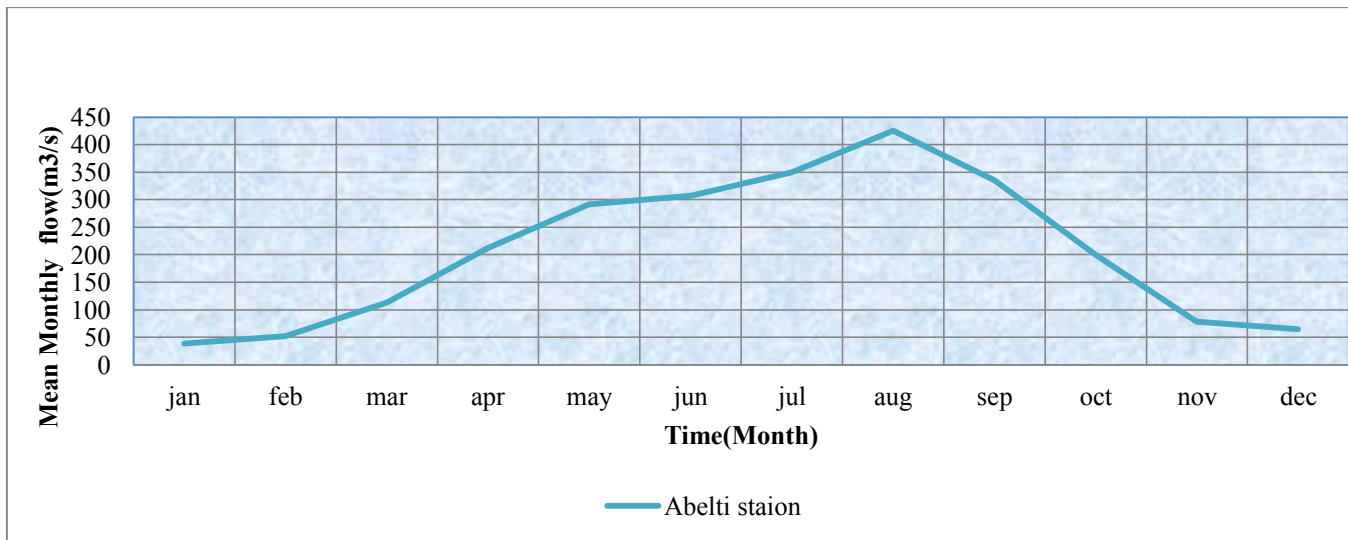


Figure 11. Monthly average flow Abelti station (1989-2007)

3.2.3 Spatial data collection and analysis

The spatial data which are Digital Elevation Model (DEM) was collected from Ministry of Water, Irrigation and Energy (MoWIE). Soil map form (Belete Berhanu et al.,2013) and land use map was produced from satellite images (USGS GLOVIS).

Digital Elevation Model (DEM)

Topography is defined by a DEM that describes the elevation of any point in a given area at a specific spatial resolution. In other words, the DEM is any digital representation of a topographic surface and specifically to a raster or regular grid of spot heights. It is the basic input of the Arc GIS integrated SWAT hydrologic model to delineate the watershed, to extract information about the topography/elevation of the watershed and to analyze the drainage patterns of the land surface terrain. Sub-basin parameters such as slope gradient, slope length of the terrain, and the stream network characteristics were also derived from the DEM. For this study 30m by 30m DEM of Omo basin or 30m by 30m of Ethiopia was collected from Ministry of Water, Irrigation and Energy of Ethiopia. The DEM collected were in different layers which was mosaic ked into one raster data set and further Gibe III watersheds DEM were extracted from this mosaic ked data using Arc GIS 10.3.

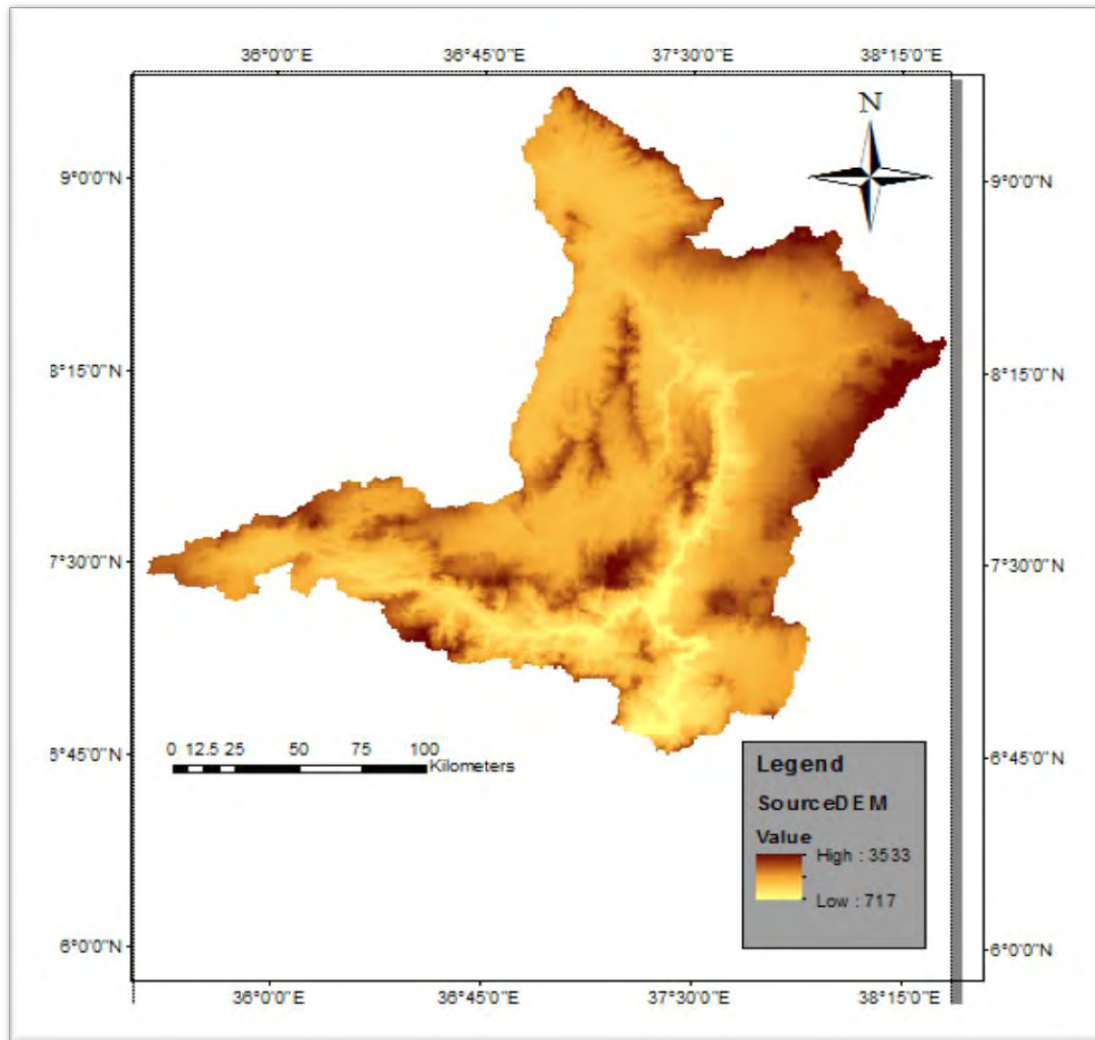


Figure 12. Digital elevation model of Gilgel gibe III

As shown in the above map the elevation of the study area ranges from 717 m to 3553 m a. s. l. This shows that elevation in the watershed is increasing when we go from the dam site to the upper part of the basin.

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, evapo transpiration and surface erosion in a watershed. it is also used for comparison of impacts on stream flow of the catchment with in time. The LULC map and all datasets for the years 1987, 2003 and 2013 were collected from USGS Earth Explore and USGS GLOVIS. 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 5. 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 5. Land use/cover classification of Gibe III watershed as per SWAT

Land use / Land cover	Land use according to SWAT database	SWAT code
Cultivated land	Agricultural land close to grown	AGRC
Dense Forest	Ever green Forest	FRSE
Sparsely vegetated forest	deciduous Forest	FRSD
Grass-wood land	Range-grass	RNGE
Water & marshy land	Water	WATR

Soil Data

Soil data is one of the major input data for the SWAT model with inclusive and chemical properties. seven major soil groups were identified in the watershed of Gilgel Gibe III as indicated Figure 13.

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. These data were obtained from (source:Belete et al,2013) Gis-based hydrological zones and soil geo-database of ethiopea.

To integrate the soil map with SWAT model, a user soil database which contains textural and chemical properties of soils was prepared for each soil layers and added to the SWAT user soil databases using the data management append tool in ArcGIS. The symbol and areal coverage of the soil types are presented in Table 6.

Table 6. Soil type of the study area and area coverage in the water shade.

Soil type	symbol	Swat name	area coverage in the water shade at Abelti (%)	area coverage in the water shade at gibe III (%)
Rendzic Leptosols	LPk	RNLEPTOSOLS	0.01	0.01
Eutric Vertisols	VRe	EUVERTISOLS	23.81	17.16
Humic Nitisols	NTu	HUNITISOLS	25.32	32.70
Chromic Luvisols	LVx	CHLUVISOLS	11.85	8.91
Dystric Vertisols	VRd	DYVERTISOLS	11.70	5.50
Lithic Leptosols	LPq	LTLEPTOSOLS	3.53	15.82
Humic Alisols	ALu	HUALISOLS	23.78	19.91
Total			100	100

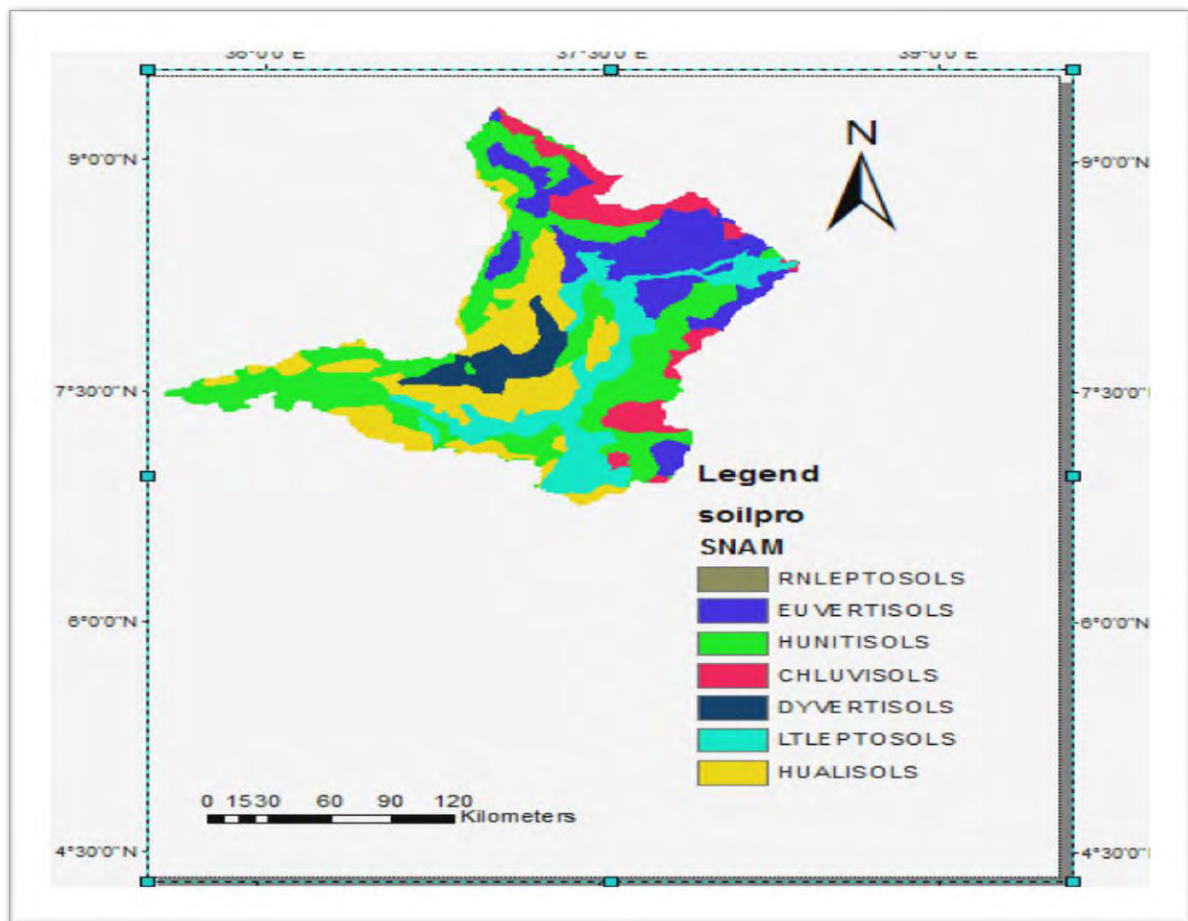


Figure 13. Soil map of Gilgel Gibe III

4. Methodology

4.1 General

SWAT models is data driven and it requires several types of data like topography, land use, soil, hydro-meteorological, reservoir physical data and, etc. These data were secondary and collected from various sources and different processes have been carried out to utilize them. The data should be stationary, consistent, and homogeneous when they are used to simulate a hydrological system. If it does not fulfill one of the above criteria's, it will result in a big problem that contradicts the actual situation. Therefore ,using different methods, the inconsistency, homogeneity, infilling for missed data and extension of short records encountered in the actual data processing activity should be done.

Studies of water resources development and management depends heavily on spatial and temporal hydro-meteorological data. 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.

4.2 Over all frame work of the study

The method to evaluate the impact of land use and land cover change, on hydrological regimes can be achieved through integrating GIS, remote sensing, and hydrological models. Satellite image have great contribution for preparation of land use land cover of the area.

LU/LC information is of critical importance in hydrologic modeling, 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 catchment is utilized. Details of the approach followed are given in figure 14

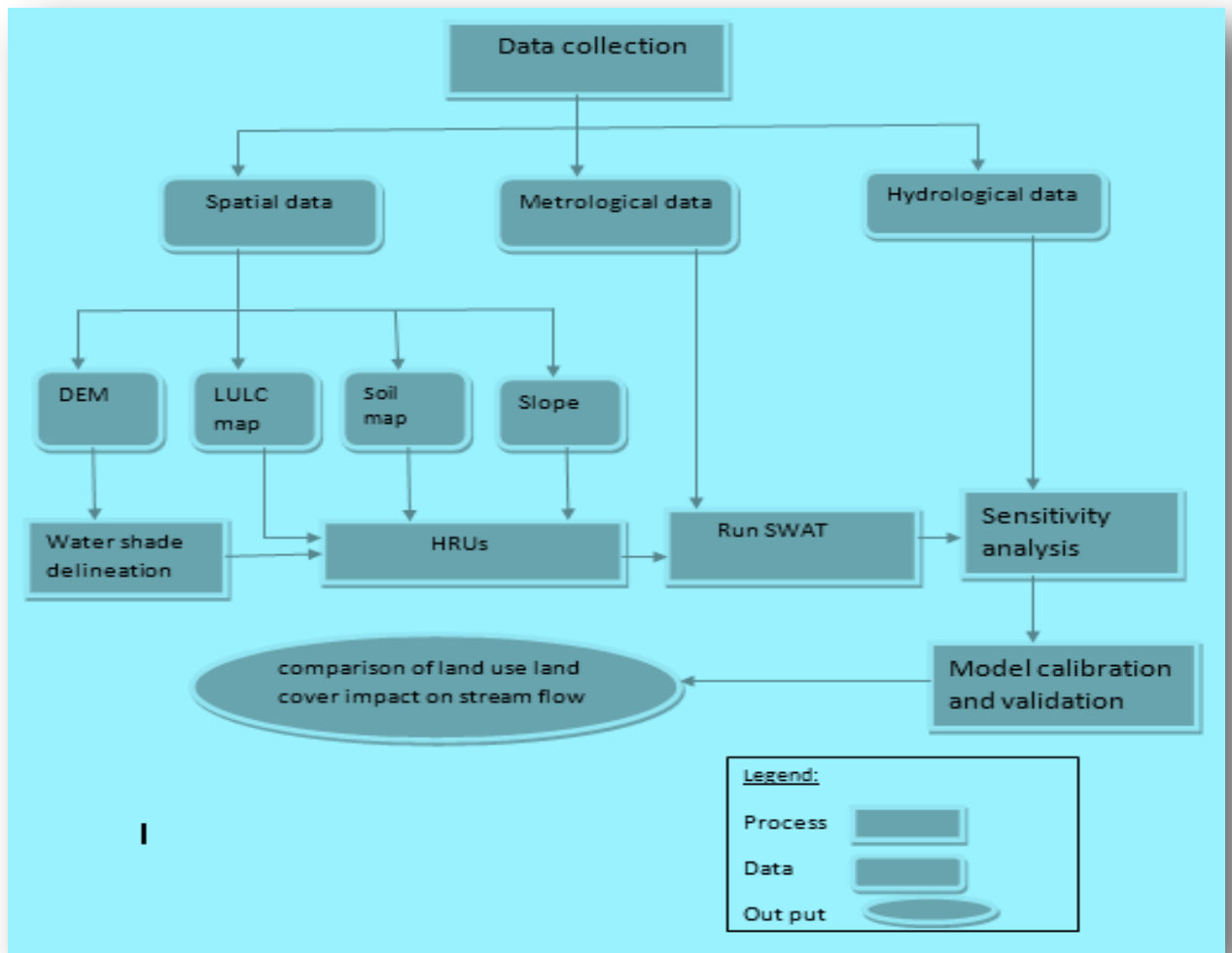


Figure 14. Conceptual frame work of the study

4.3 Image Pre-processing

This study was done using Land sat imageries of seven bands to identify changes in land use and land cover distribution in the Gibe III sub basin over 30 years period from 1986 to 2015. Land sat TM, ETM+ and Ls8 was selected for the period of 1987,2003 and 2013 respectively. 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 Gibe III sub basin and finally true color composition were used for classification.

The image data files were downloaded in zipped files from the <https://www.usgs.gov> United State Geological Survey (USGS) website and extracted to Tiff format files with the path/row of 169/54,169/55 and 170/55.

Layer Stacking images - In order to analyze remotely sensed images, the different images representing different bands must be stacked. This allows different combinations of RGB to be shown in the view. 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 (i.e., layer stack an NDVI image with spectral bands for input to an image classification).

Mosaic an image -since the study area is touch three images ,i.e. path/rows 169/54,169/55 and 170/55 combining those multiple images to single (tied) color balanced and compressed ortho-mosaic imagery was done

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 Gibe III watershed satellite image was performed using the layer stacked images by the delineated watershed shape file.

prominent by raising the quality of images so as to differentiate between different objects or land cover classes. So the techniques of haze reduction and noise reduction were applied on the images for a better understanding of the LULC classes (Lillesand & Kiefer, 1994). ERDAS Imagine 2014 was used for atmospheric correction, haze and noise reduction of the Land sat images.

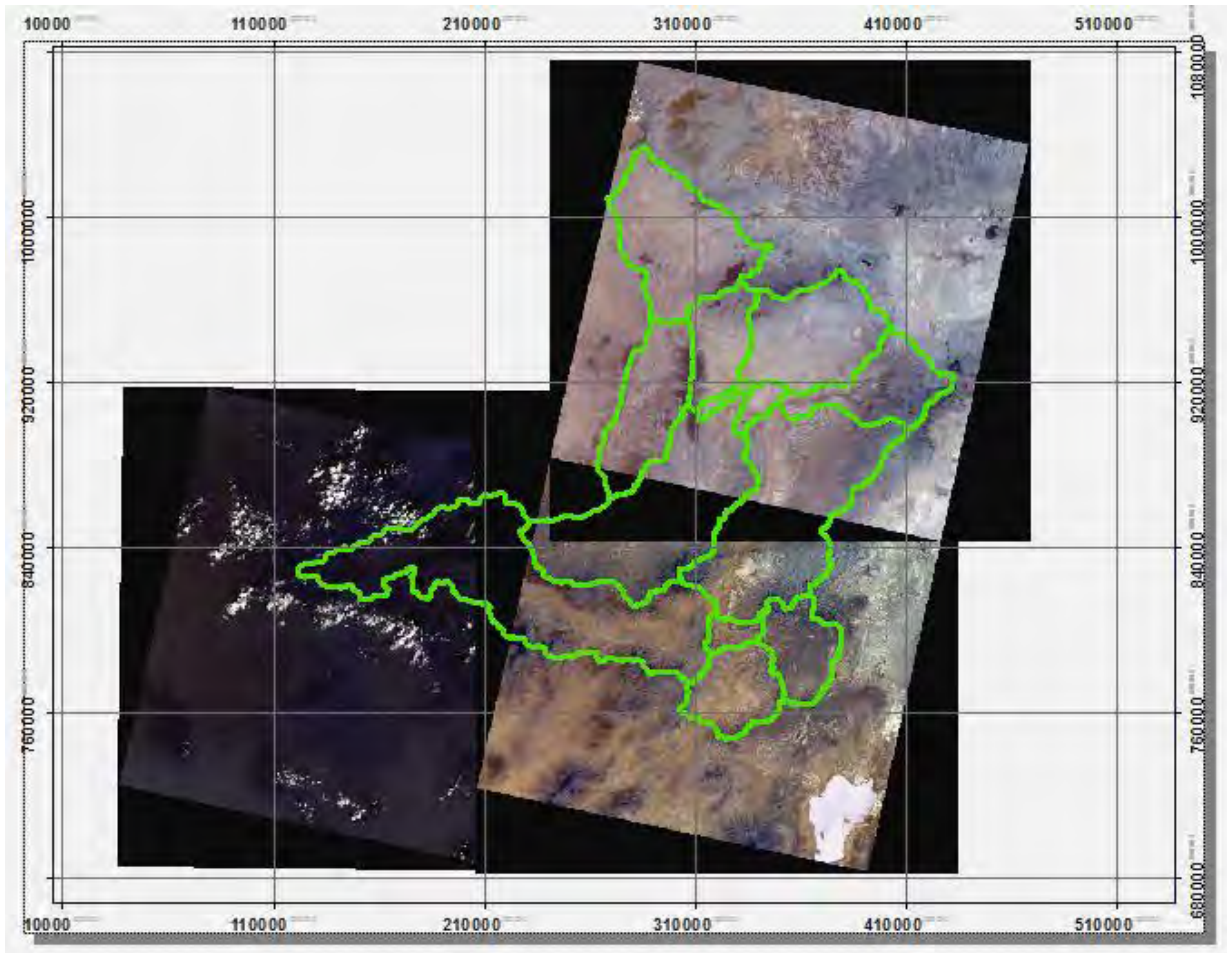


Fig15. Images of land use land cover (path/row:169/54,169/55 and 170/55)

Table 7. Description of land sat images

Sensor(inst rument)	Satellite name	Path	Row	Date of acquisition (day, month and year)	Spatial resolution	producer
TM	Land sat 5	169	54	31/01/1987	30	USGS
		169	55	31/01/1987	30	USGS
		170	55	22/01/1987	30	USGS
ETM+	Land sat 7	169	54	04/02/2003	30	USGS
		169	55	04/02/2003	30	USGS
		170	55	10/01/2003	30	USGS
L _s 8	Land sat 8	169	54	08/12/2013	30	USGS
		169	55	08/12/2013	30	USGS
		170	55	29/11/2013	30	USGS

As the images used in this research were obtained in different time scales, they have haze and dust in different proportions and these camouflages the real changes or may show the same kinds

of land cover classes as different. To overcome these kinds of problems, atmospheric correction methods are used (Berberoglu and Akin, 2009). The radiometric enhancement of images is an important stage of pre-processing. The aim of image enhancement is to make the objects more

4.4 Image Classification

Image classification is the process of assigning of pixels of continuous raster image to the predefined land cover classes. digitization, image rectification, terrain analysis and exporting of an image were performed during land cover classification. The Image rectification process supports the manual input of image pixel or the simple tagging of recognizable points on the image as well as the corresponding locations on a base of previous map layer. Advanced options allow the selection of the rectification method, re sampling scheme, and some control points from goggle earth.

The resulting raster layer can be analyzed and processed just like any other imported layer and can be exported in any one of the supported raster formats. Image classification and enhancement for this study were performed using ERDAS Imagine. ERDAS Imagine was also used for preparation of land use land cover data for SWAT input. This model uses for Data acquisition, image processing and classification of the land use and land cover image of the catchment which is used for further analysis and interpretation of the result. The land sat data image of the catchment which shows the land use land cover for three different years of 1987, 2003 and 2013 were downloaded and used for ERDAS Imagine for further image enhancement, processing and re-classification. Layer staking of the different bands of downloaded satellite images were done for all the data on ERDAS Imagine. then mosaic(groping of multiple images to single imagery) Afterwards, sub setting or extraction of the watersheds satellite image were done for simplification and time saving of image classification on ERDAS Imagine using the watershed's shape files which was derived from delineation.

The main objective of classifying satellite images is to categorize pixel values automatically and transform them directly in to the classes or forms of land use. The previous documents ,the different band combination integrating with Google Earth were taken as a signature defining for supervised classification. A signature level taken was between 25 and 45 for each of the land cover classes over an image.

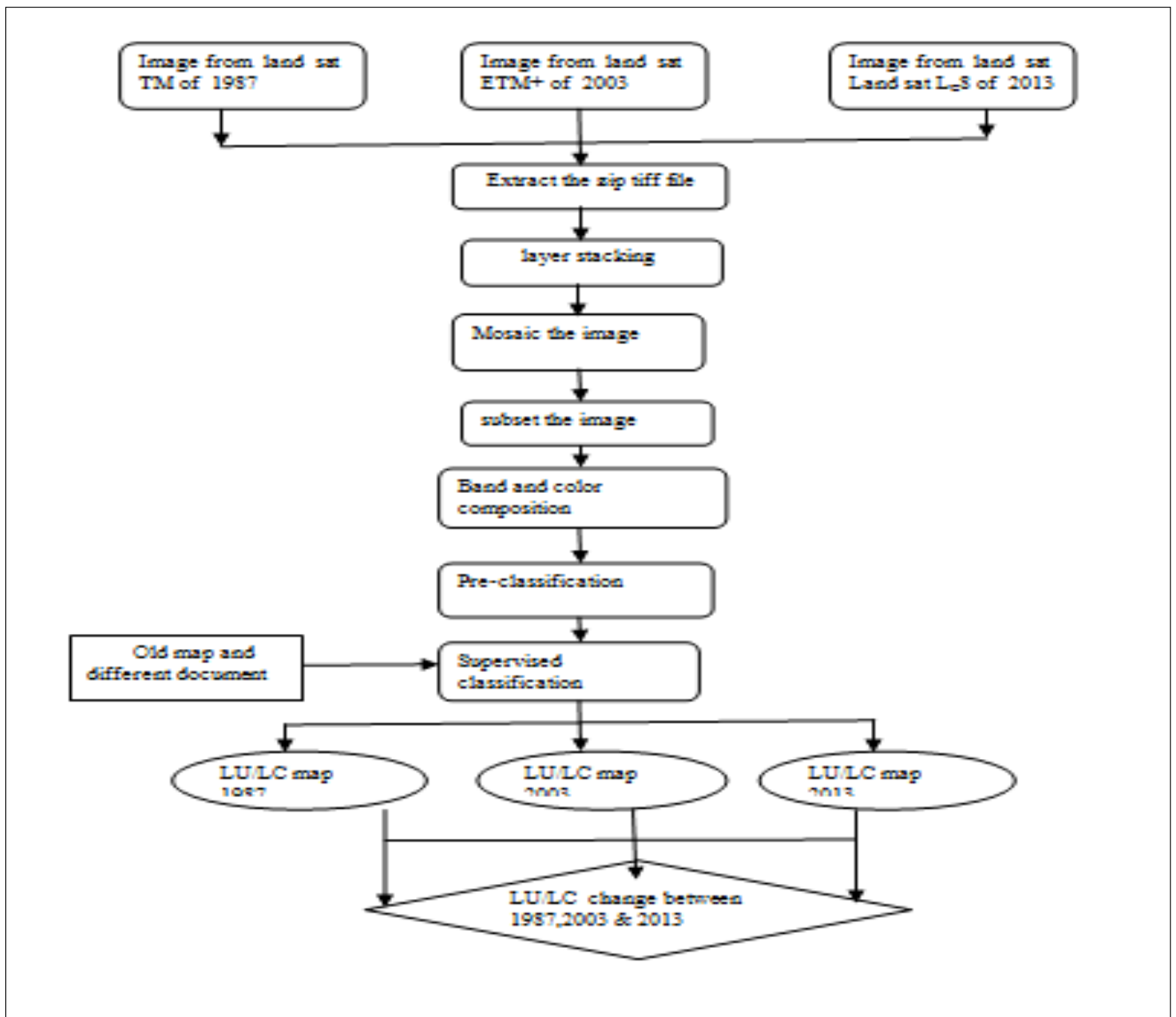


Figure 16 Methodology of Land use map preparation

4.5 SWAT 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 Upper Omo-Gibe(Gibe III) basin was delineated with an outlet point at Abelti which is the gauge station and at the out let of Gibe III. 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 65029.27 hectare contributing area. The contributing area resulted in 9 sub basin for Abelti and 21 sub basins for Gibe III being delineated.

Table 8. The slope classes of the Abelti and Gibe III watershed.

classes	Slope range	Area(Abelti outlet)		Area(Gibe III outlet)	
		ha	%	Ha	%
I	0-5	963173.4907	63.19	1633200.4374	50.23
II	5-15	526742.9292	34.59	1370030.2082	42.13
III	>15	34266.9463	2.25	248319.9625	7.64

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/reservoirs; 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.

The last step in the HRU analysis was the HRU definition. The HRU distribution in this study was determined by assigning multiple HRU to each sub-watershed. In multiple HRU definition, a threshold level was used to eliminate minor land uses, soils or slope classes in each sub-basin. Subdividing the sub watershed into areas having unique land use, soil and slope combinations makes it possible to study the differences in evapo transpiration and other hydrologic conditions for different land covers, soils and slopes.

The land use, soil and slope datasets were imported overlaid and linked with the SWAT 2012 databases. To define the distributions of HRUs multiple HRU definition options were tested. For multiple HRU definition 10 percent land use, a 15 percent soil and 15 percent slope threshold were used. Finally, 98 HRU for Abelti and 193 for Gibe III water shade was created.

C. 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.

Digital Elevation Model :Topography is defined by a DEM that describe the elevation of any point in a given area at a specific spatial resolution. A 30 m by 30 m resolution DEM was taken from the Ministry of Water, Irrigation and Energy (MoWIE) for Omo basin and gibe III DEM was the extracted.

The DEM was used to delineate the watershed and to analyze the drainage patterns of the land surface terrain. Sub basin parameters such as slope gradient, slope length of the, and the stream network characteristics such as channel slope, length, and width were derived from the DEM.

Soil Data :SWAT model requires different soil textural and physio-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 1986–2015 in which three years was left to war map period.. These data were obtained from Ethiopian National Meteorological Agency (NMA) for stations located within and around the basin to fill the gaps due to missing data.

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 gibe III after fixing sensitive parameters and their values at Abelti station.

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

4.6 Model Sensitivity analysis, Calibration and Validation

A. Sensitivity Analysis

The sensitivity analysis tool in Arc SWAT has the capability of performing two types of analyses. The first type of analysis uses only modeled data to identify the impact of adjusting a parameter value on some measure of simulated output, such as average stream flow. The second type of analysis uses measured data to provide overall “goodness of fit” estimation between the modeled and the measured time series. The first analysis helps to identify parameters that improve a particular process or characteristic of the model, while the second analysis identifies the parameters that are affected by the characteristics of the study watershed and those to which the given project is most sensitive (Veith and Ghebre michael, 2009).

After a thorough preprocessing of the required input for SWAT model, flow simulation was performed for 30 years of recording periods. The first three year flow record was used as a warm up period and the simulation then used for sensitivity analysis of hydrologic parameters and for calibration of the model. The results from simulation cannot be directly used for further analysis but instead used for further analysis to sufficiently predict the constituent stream flow should be evaluated through sensitivity analysis, model calibration and validation (White and Chaubey, 2005). When a SWAT simulation is taken place there is a 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 ordered to analysis. It can increase the accuracy of calibration by reducing uncertainty.

The aim of sensitivity analysis is to estimate the rate of change in the output of a model with respect to changes in watersheds that result in a clear difference in hydrologic sensitivity. Sensitivity analysis was conducted for the Abelti watershed hydrology to determine the parameters needed to improve simulation results and better understand behavior of hydrologic system and to evaluate the applicability of the model. Parameters for sensitivity analysis were selected by reviewing previously used calibration parameters and documentation from SWAT manuals. The sensitivity analysis was made by using a built-in SWAT sensitivity analysis tool SWAT CUP. The sensitivity analysis tool is helpful to model users in identifying parameters that are most influential in governing stream flow response.

B. Model Calibration

Model calibration is a means of adjusting or fine tuning model parameters to match with the observed data as much as possible, with limited range of deviation accepted. It is also the modification of parameter values and comparison of predicted output of interest to measured data until a defined objective function is achieved. Parameters for modification are selected from those identified by sensitivity analysis. Additional parameters other than those identified during sensitivity analysis are used primarily for calibration due to the hydrological processes naturally occurring in the watershed. Sometimes it is necessary to change parameters in the calibration process other than those identified during sensitivity analysis because of the type of miss match of the observed variables and predicted variables (White and Chaubey, 2005).

The graphical and statistical approaches were also be used to evaluate the SWAT model performance a number of times until the acceptable values were obtained for surface runoff independently. The calibration was done following two approach:

- I. Taking 2/3 of the year observed flow for calibration(1989-2000) for all land use land cover (1987,2003 and 2013),i.e. 12 year for calibration.
- II. Different year range for each land use land cover i.e. for 1987 land use land cover from 1989-1995 for 2003 land use land cover from 1999-2005.

C. Validation

Validation is the comparison of the model outputs with in independent data set without making any adjustment. The purpose of model validation is to check whether the model can predict flow for another range of period. In order to utilize the calibrated model for estimating the effectiveness of future potential management practices, the model was tested against an independent set of measured data. 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 land use scenarios. The statistical model performance measure would be used in calibration as percent difference between simulated and observed data. The period from 2001 - 2007 was taken as a validation period for the three land use land cover in first approach and 1996-1998 for 1987 land use land cover as well as 2006-2007 for 2003 land use land cover for the second approach.

4.7 Model Performance Evaluation

The evaluation of hydrologic model behavior and performance is commonly made and reported through comparisons of simulated and observed variables. The selection and use of specific efficiency criteria and the interpretation of the results can be a challenge for even the most experienced hydrologist since each criterion may place different emphasis on different types of simulated and observed behaviors. The following performance evaluation criteria's were used in this study:

A. Nash-Sutcliffe Efficiency The Nash-Sutcliffe efficiency (NSE) is a normalized statistic that determines the relative magnitude of the residual variance (“noise”) compared to the measured data variance (“information”). NSE indicates how well the plot of observed versus simulated data fits the 1:1 line.

$$NSE = 1 - \frac{\sum_{i=1}^n (O_i - S_i)^2}{\sum_{i=1}^n (O_i - O_{mean})^2} \quad (9)$$

Where S = model simulated output; O = observed hydrologic variable; O_{mean} = mean of the observations that the NSE uses as a benchmark against which performance of the hydrologic model is compared; and N = total number of observations. NSE values range from negative

infinity to 1, where 1 shows a perfect model. NSE is zero, implies the observed mean is as good a predictor as the model.

B. Coefficient of Determination

Coefficient of determination (R^2) is an indicator of the extent to which the model explains the total variance in the observe data. A major limitation of R^2 is that it describes the linear relationship between the two data sets, and one may obtain large R^2 value with a poor model that consistently overestimates or underestimates the observations. (Muleta, M. K., and Nicklow, J. W., 2005)

$$R^2 = \frac{\sum_{i=1}^n (O_i - O_{mean}) * (S_i - S_{mean})}{(\sum_{i=1}^n (O_i - O_{mean})^2)^{0.5} * (\sum_{i=1}^n (S_i - S_{mean})^2)^{0.5}} \quad (10)$$

Where S_{mean} = mean of the model simulations

According to Moriasi, *et al.* (2007) simulation judged as satisfactory if $NSE \geq 0.5$ and $R^2 \geq 0.6$ for stream flow flow.

4.8 Evaluation of Stream Flow due to LULCC

Simulation of the impacts of land use and land cover change on stream flow was one of the most significant parts of this study and there was high expansion of agricultural lands in the expenses of other lands during the study periods considered.

The study was carried out for three different years i.e. 1987, 2003 and 2013. The three generated land use and land cover maps, soil, climatic and stream flow data values were used to evaluate the impacts of land use and land cover change on stream flow.

To evaluate the variability of stream flow due to land use and land cover changes from 1986 to 2015 three independent simulation runs were conducted on a monthly basis using land use and land cover maps of 1987, 2003 and 2013 keeping other input parameters unchanged. Seasonal stream flow variability of the three land use and land cover change was assessed and comparison were made on surface runoff to stream flow based on the three simulation outputs.

4.9 Flow transferring to the dam site

Since the gibe III dam basin at the dam site is not gauged flow transferring at gauged station was needed. Above the dam site Abelti, Gojeb and Wabi are the gauged stations in the basin and Abelti station was selected due to large area coverage as compared to the others. transferring hydrological characteristics of the water shade from available flow data (Abelti) to driven stream flow at gibe III performed. This was taking places using semi-disturbed, physically based hydrological model (SWAT) to represent a catchment characteristics including topography, land use, soil and slope.

The land use land cover for Abelti and Gibe III dam was nearly the same in which cultivated land is the major dominant land use next to forest land and range-grass land. There seven types of soil found in gibe III was also present at Abelti and as indicated in table 6 the coverage each soil to the a catchment was nearly same. The topography (slope) of Abelti and Gibe III also nearly the same as indicated in the table 8.

Transferring was by taking sensitive parameter value obtained from Abelti and edit SWAT parameters and rewrite SWAT in put table mainly the management and ground water data, then finally running SWAT model at Gibe III was taking place to get stream flow.

5. Result and discussion

5.1 Land Use Land Cover Map

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 three land use land cover maps (1987, 2003 and 2013) using the method maximum likelihood classification of land sat satellite image. after referring previous documents ,using different band combinations and contacting with persons who knows the study area the catchment dominant land use land cover are summarized to five major class namely cultivated land ,forest (deciduous and ever green),range-grass-wood land and water body. the percentage of each land cover class with referenced year (1987,2003 and 2013) results are expressed as follows:

5.1.1 Land use land Cover Map of 1987

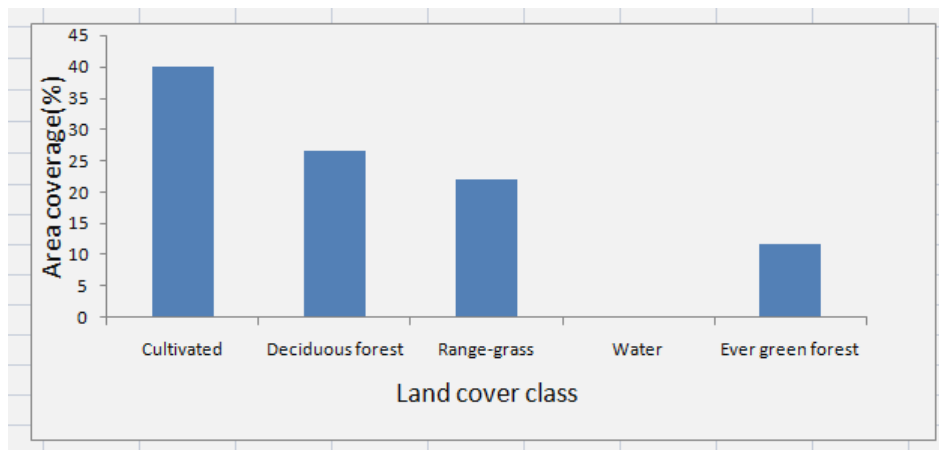


Figure:17 Land use Land cover percentage of Gibe III in 1987

The percentage of the land use Land cover class in figure 17 shows that Gibe III catchment was covered 39.87 % by cultivated land, 26.44 % by deciduous Forest , 22.01 % by range grass land , 11.6 % by ever green forest, and 0.08 % by water body. From this we can see that the large area of Gibe III catchment is covered with cultivated land and forest land.

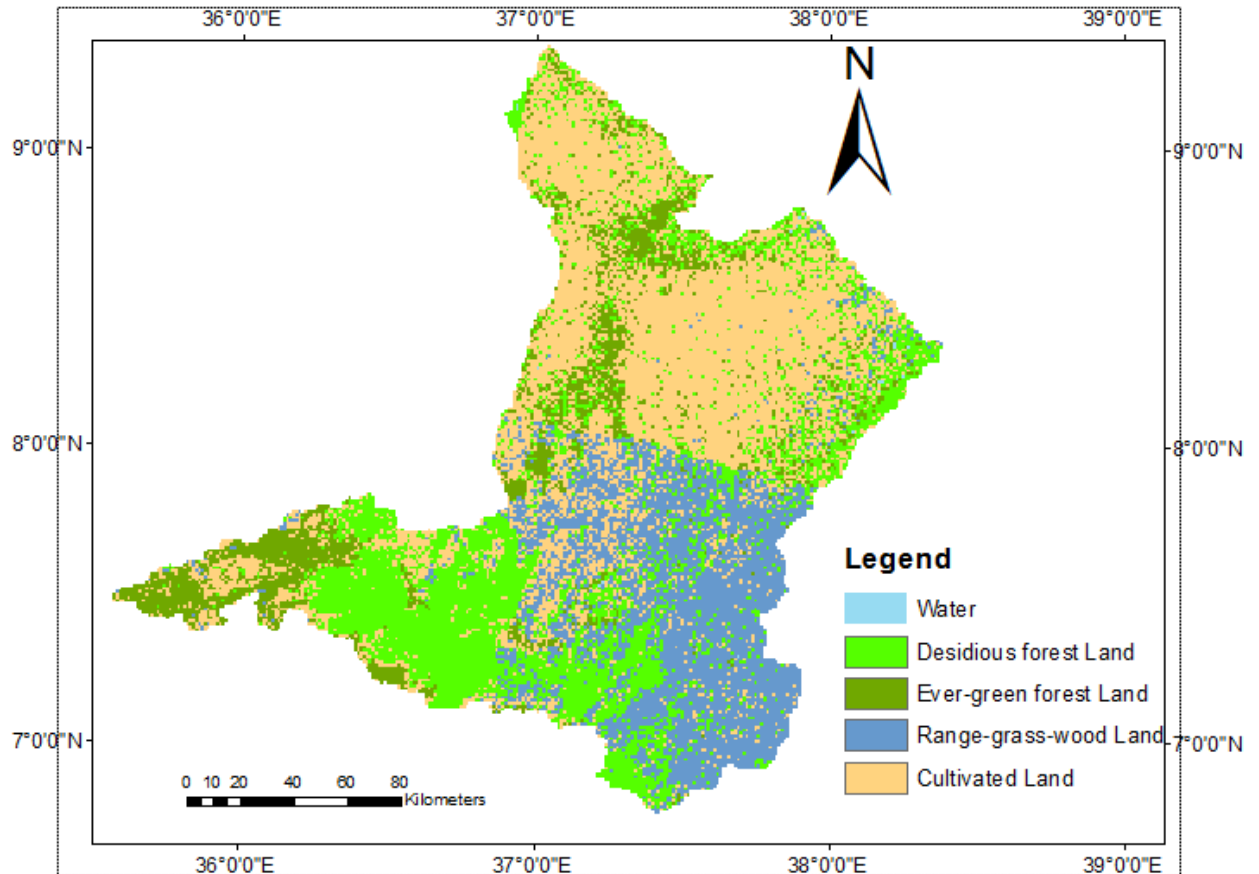


Figure 18. Land use map of Gilgel Gibe III in the year 1987

The distribution of land cover class as it is shown in the figure 18 cultivated land cover was found in most parts of the catchment; especially in the north eastern part of the catchment is more dominantly covered by cultivated and mixed (range-grass-wood), the forest land are also dominant in south eastern part of the catchment.

5.1.2 Land use land Cover Map of 2003

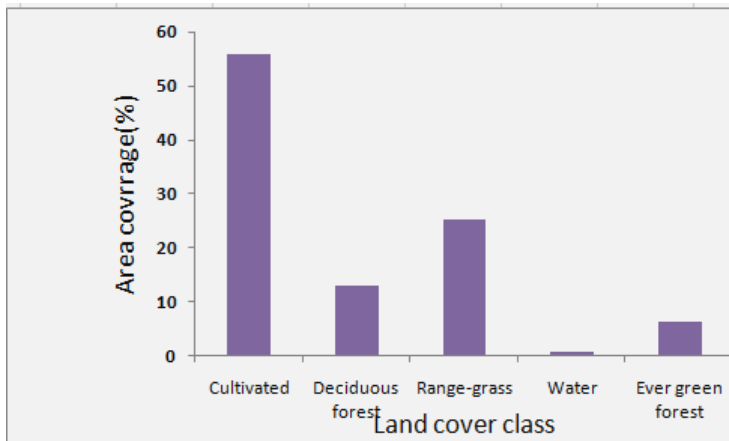


Figure 19. land use land cover percentage in the year 2003

The percentage coverage of each land cover class in figure 19 show that the catchment of 54.94 % covered by cultivated land, 12.9 % by deciduous Forest , 25.26 % by range grass land , 6.27 % by ever green forest, and 0.63 % by water body. During this period, mainly the forest land in the south eastern was decreased and cultivated land. On contrast the cultivated land was expanded in most parts of the catchment.

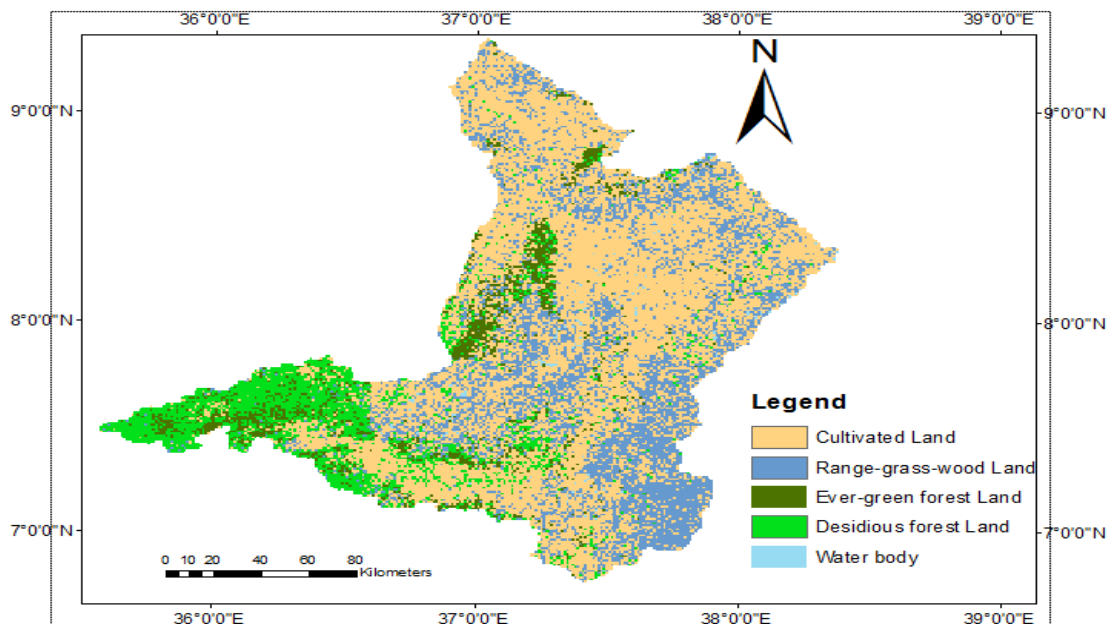


Figure :20. Land use map of Gilgel Gibe III in the year 2003

The distribution of land cover class as it is shown in the Figure 20 cultivated land cover was found in most parts of the catchment; especially in the north eastern part of the catchment as 1987 land use land cover. The forest land are also dominant in south western part of the catchment.

5.1.3 Land use land Cover Map of 2013

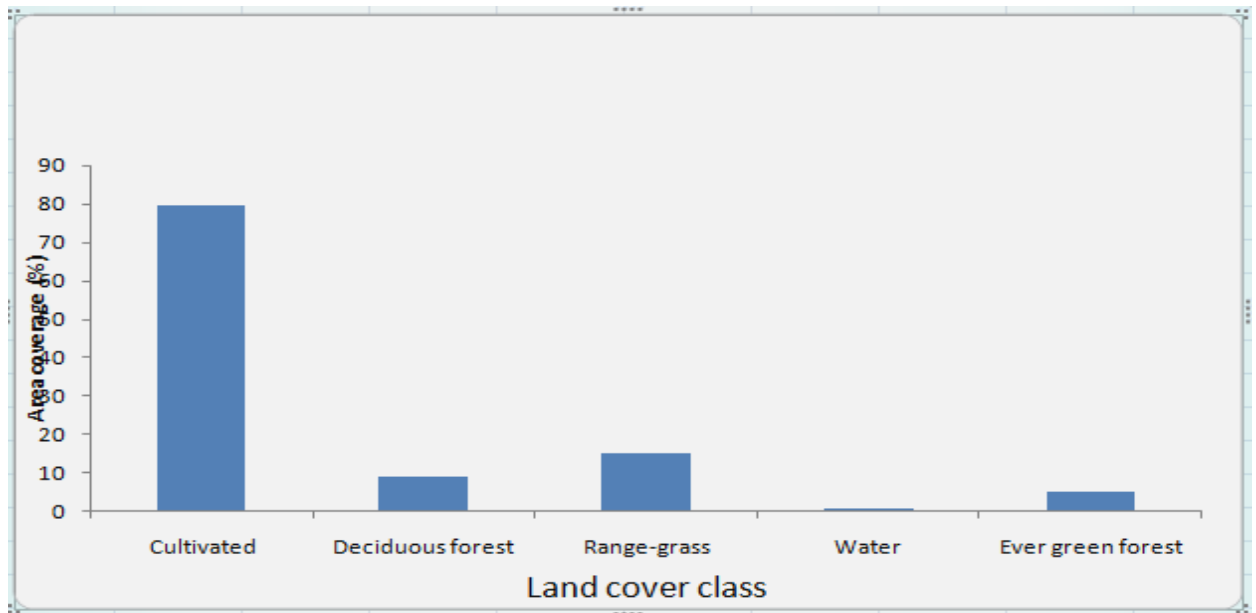


Figure 21. land use land cover percentage in the year 2013

The percentage coverage of each land cover class in figure 21 show that Gibe III catchment was covered 70.016 % by cultivated land, 8.99 % by deciduous Forest , 15.164 % by range grass land , 5.03% by ever green forest, and 0.8 % by water body. During this period, mainly the forest land in the Southern western and range-grass-wood land catchment was reduced. On contrast the cultivated land was expanded in most parts of the catchment.

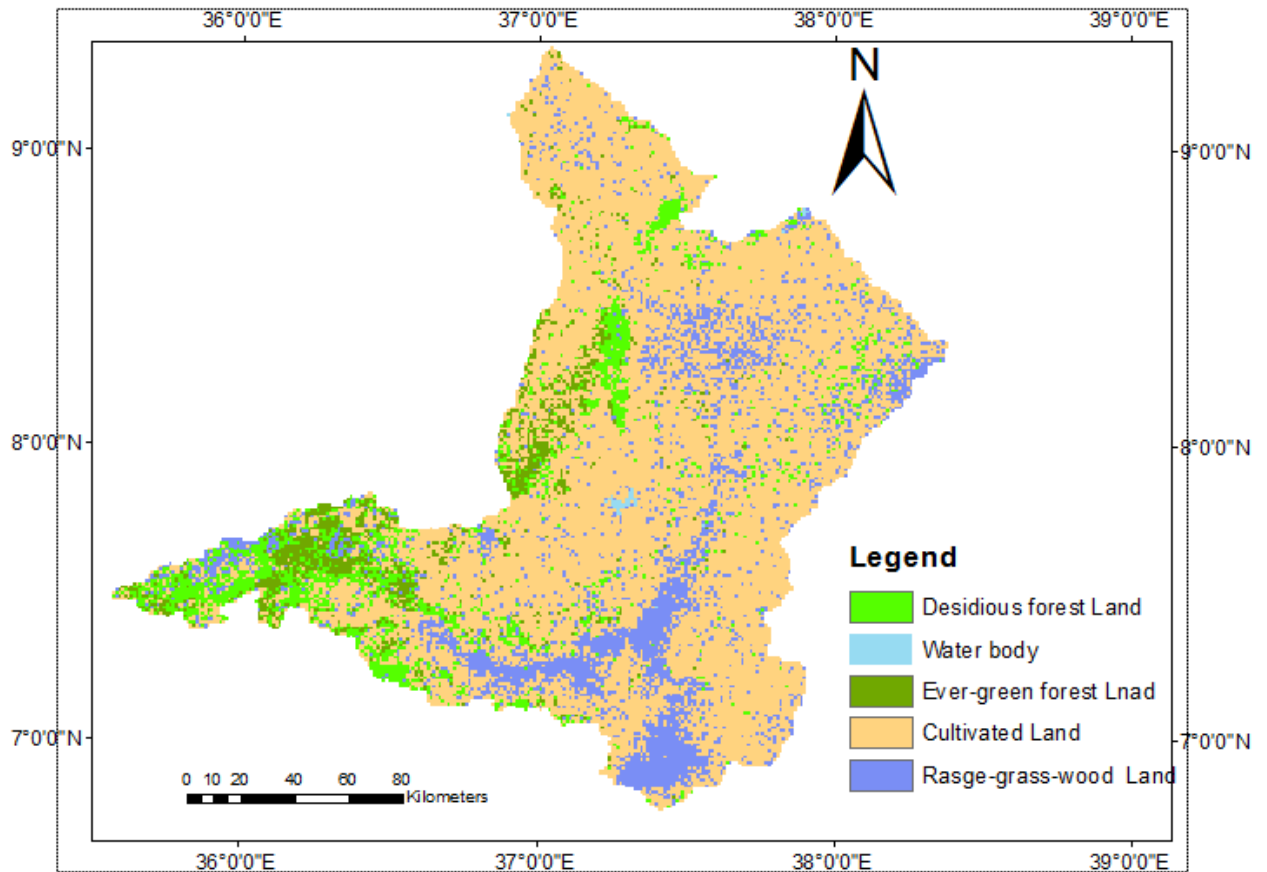


Figure 22. Land use map of Gilgel Gibe III in the year 2013

The distribution of land cover class as it is shown in the Figure 22 cultivated land cover was found in most parts of the catchment; especially in the north eastern and in south western part of the catchment. The forest land are also dominant in south western part of the catchment.

Land cover classification maps of the study area were generated for three reference years 1987, 2003 and 2013 and reflect land cover for the given periods. The overall land use /cover changes at watershed level are summarized in table 9 below:

Table 9. Summary of land use land cover

Land use Land cover class	years						Land use change detection		
	1987		2003		2013		1987- 2003	2003- 2013	1987- 2013
	ha	%	ha	%	ha	%			
Cultivated	1296393.227	39.87	1786401.9	54.94	2276605.67	70.016	15.07	15.076	30.146
Deciduous forest	859709.9808	26.44	419450.028	12.9	292314.4	8.99	-	-3.91	-17.45
Range- grass	715666.2889	22.01	821341.684	25.26	493065.134	15.164	3.25	10.096	-6.846
Water	2601.24	0.08	20484.7688	0.63	26012.4049	0.8	0.55	0.17	0.72
Ever green forest	377179.8706	11.6	203872.223	6.27	163552.996	5.03	-5.33	-1.24	-6.57

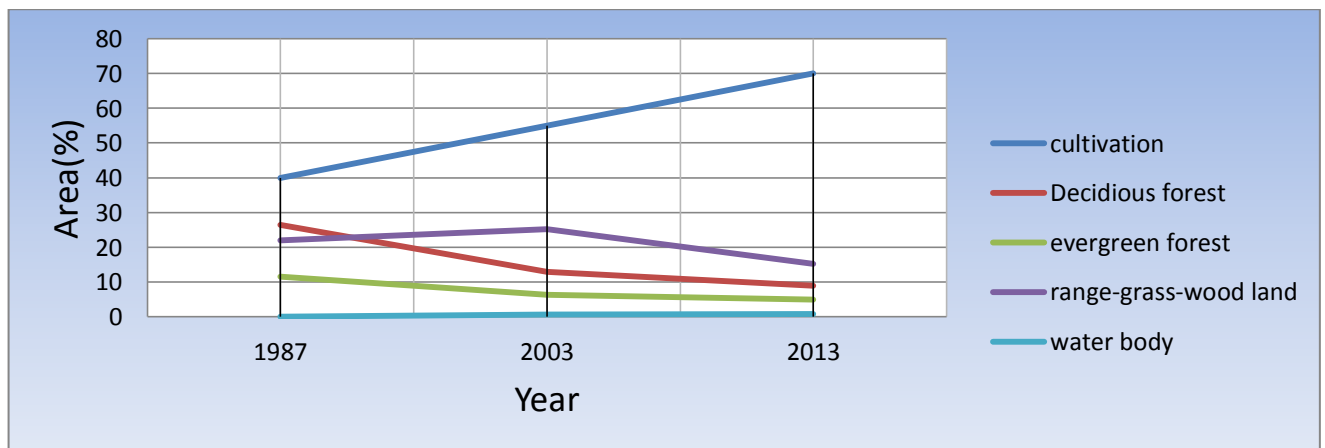


Figure 23. Land use Land cover change pattern

As the above table 9 shows that intensification of cultivated land in the basin was the same in the year 1987-2003 and 2003-2013 which indicated that there was no measure takes to control the deforestation activity in the basin and the forest area also decrease more 1987-2003 than 2003-2013. generally cultivation land was increased by 15.07 % from 1987 to 2003,15.076 % from

2003 to 2013 and 30.146 % from 1987 to 2013 and the water body witch cover small part of the water shade also shows an increase trends from 1987 to 2013 by 0.72 %.

On contrast the Deciduous forest land was reduced by 13.54 % from 1987 to 2003,by 3.91 % from 2003 to 2013 and by 17.45 % from 1987 to 2013. the ever green forest also decrease by 5.33 % from 1987 to 2003,by 1.24 % from 2003 to 2013 and by 6.57 % from 1987 to 2013. however the mixed land use land cover (range-grass-wood land) was increase by 3.25 % from 1987 to 2003 decrease by 10.096 % from 2003 to 2013 and decrease by 6.846 % from 1987 to 2013 land use land cover.

5.2 Sensitivity analysis

SWAT 2013 model output depends on many input parameters related to the soil, land use management, weather, channels and aquifer. The sensitivities to the model performance give insight in to parameter using the available information data like daily stream flow data, metrological data, soil and land use data.

Sensitivity analysis helps to identify parameters that affect stream flow on the water shade and even how those parameters are changed due to change in land use land cover. Those parameters includes management parameters, soil parameters and ground water parameters etc.

For the Gibe III catchment sensitivity analysis was carried out at Abelti. The simulation of model was from Jan, 1986 to Dec 2015. The simulation result from Jan 1986 to 1988 is used as model warm up period and from 1989-2000 as calibration period. Finally the period from Jan 2002 - Dec 2007 was used as model validation time for the first approach and 1989-1995 for calbratio,1996-1998 for validation (1987 land use land cover) ,1999-2005 for calibration and 2006-2007 for validation (2003 land use land cover). The result of sensitivity analysis indicated that eleven parameters are sensitive to the study area for stream flow, the relative values and rank are present in the table 10 and 11 respectively.

Table 10. calibrated parameters at Abelti sub basin.

Parameter	Absolute value	Fitted value 2013 LULC	Description
CN2	35-98	66.23	SCS runoff curve number
GW_DELAY	0-500	7.1700	Groundwater delay
GW_REVAP	0.02-0.2	0.1660	Groundwater "revap" coefficient
ESCO	0-1	0.9123	Soil evaporation compensation factor
CH_N2	-0.01-0.3	0.1438	Manning's "n" value for the main channel
SOL_AWC	0-1	0.2700	Available water capacity of the soil layer
LAT_TTIME	0-180	60.8269	Lateral flow travel time
HRU_SLP	0-1	0.7060	Average slope steepness
SLSUBBSN	10-150	41.9645	Average slope length
SOL_Z	0-3500	405.521	Depth from soil surface to bottom of layer
SOL_BD	0.9-2.5	2.4040	Moist bulk density

Table 11. Sensitivity of the objective function to the model parameters.

Parameters	1987		2003		2013		sensitivity rank		
	T-stat	P-value	T-stat	P-value	T-stat	P-value	1987	2003	2013
GW_REVAP	-115.342	2.05E-176	-128.384	4.73E-18	33.354	5.57E-14	1	1	1
GW_DELAY	-29.7898	4.05E-73	-34.3268	6.68E-83	11.06011	5.52E-08	2	2	2
CN2	-10.2209	8.78E-20	-14.6892	4.93E-33	-7.85328	2.74E-06	5	4	3
LAT_TTIME	-8.23954	2.88E-14	-11.113	2.23E-22	6.285057	2.81E-05	3	3	4
SOL_Z	-7.56349	1.69E-12	-8.45255	7.74E-15	5.890646	5.32E-05	4	5	5
SOL_BD	-3.7063	0.000277	-4.71233	4.75E-06	0.470828	0.645566	7	9	6
SOL_AWC	0.541739	0.588639	0.569982	0.56937	0.40956	0.688797	10	10	7
HRU_SLP	0.535309	0.593069	-0.3725	0.709942	-0.3981	0.697015	6	6	8
ESCO	-0.42949	0.668057	-0.36685	0.714146	-0.06011	0.952982	9	11	9
SLSUBBSN	0.280144	0.779675	-0.07738	0.938407	0.026152	0.979533	11	8	10
CH_N2	-0.20916	0.834553	-0.01115	0.991118	0.023848	0.981336	8	7	11

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.

5.3 Model calibration and validation at Abelti

The calibration was carried out for period of twelve years from January 1989 to December 2000 and flow validation was also done for six year from 2002-2007 for monthly stream flow using the sensitivity parameters listed from table 11. Abelti station was selected for calibration and validation because of one of sub basin for Gilgel gibe III and large area coverage as compared to the other stations. not only large area coverage but also the station has better data availability.

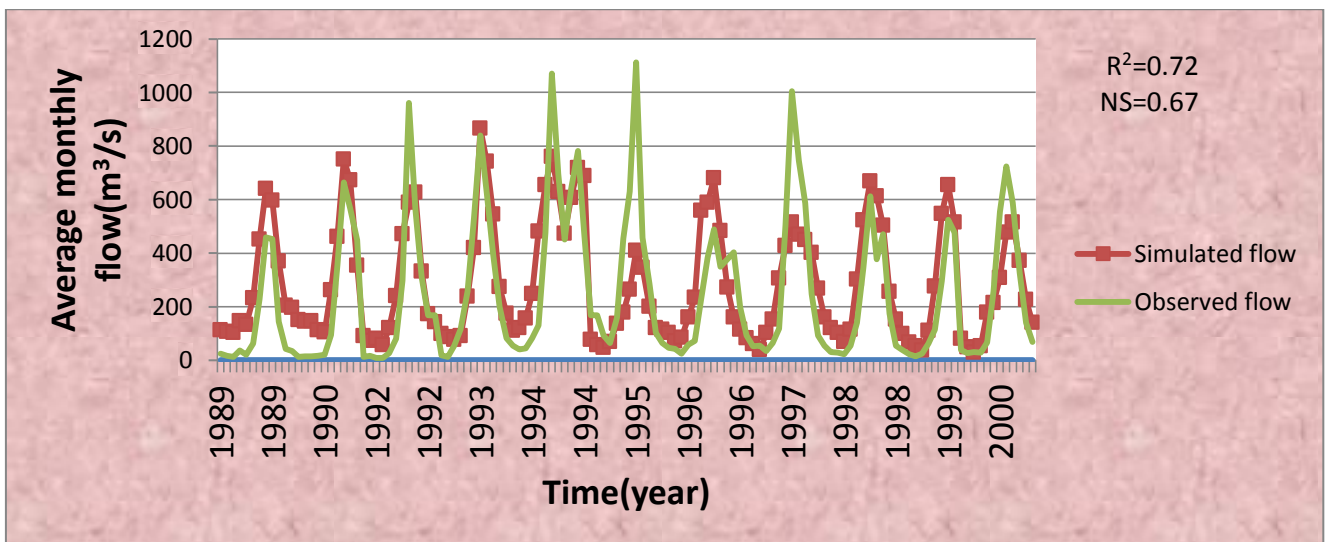


Figure 24. measured & simulated flow hydro graph at Abelti (calibration) (1989-2000)

As shows from figure 24 model was calibrated using monthly stream flow of observed data from the Abelti hydrological Station. The calibration results show that the coefficient of determination and Nash-Sutcliffe Efficient (NSE) i.e. 0.72 and 0.67 respectively. This indicated that the model performance assessment indicated a good correlation and agreement between the monthly measured data and simulated flow (D.N Moriasi,et al.207).

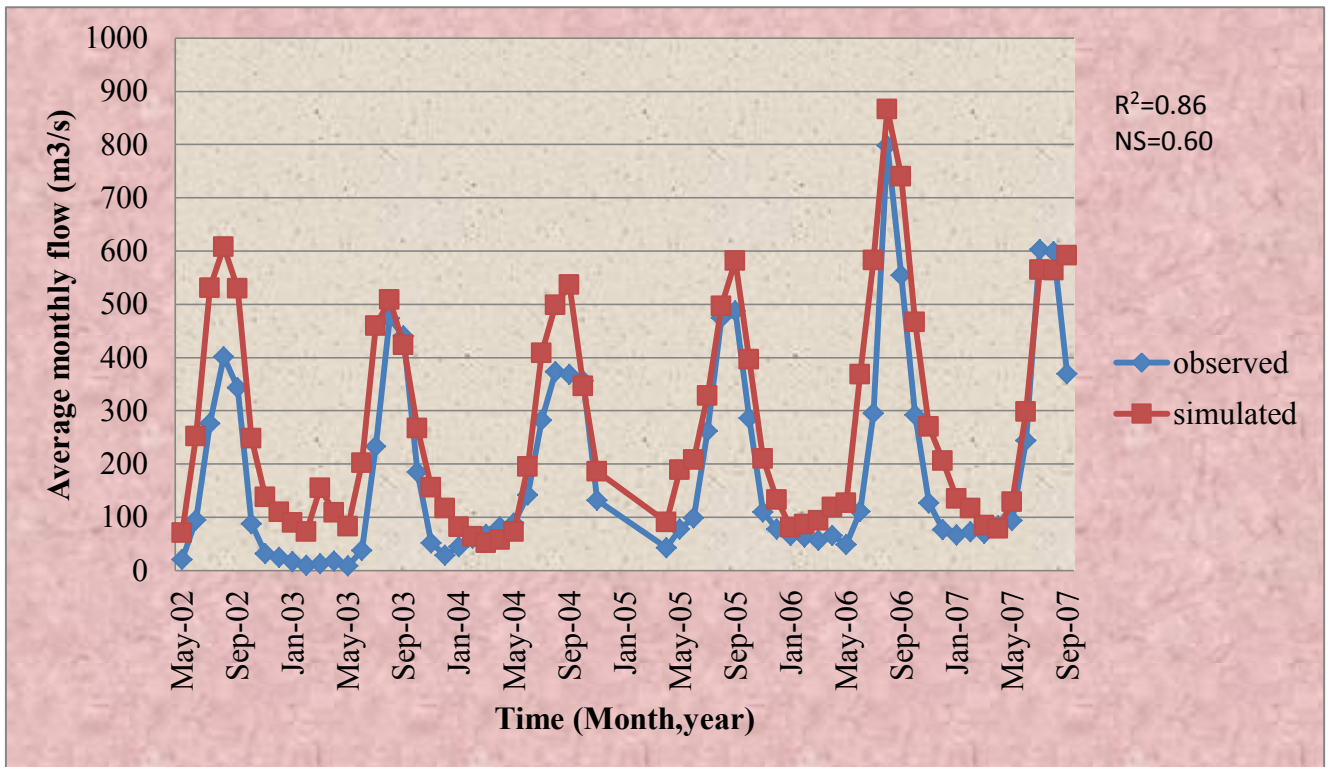


Figure 25. measured & simulated flow hydro graph at Abelti (validation) (2002-2007)

The validation period has shown a good agreement between monthly measured and simulated flow. The Validation result showed that the coefficient of determination (R^2) and the Nash-Sutcliffe efficient (NSE) are 0.86 and 0.60 respectively. The figure 25 and table 12 below show that the model performance assessment indicated a good correlation and agreement between the monthly observed and simulated flow.

Table 12. Comparison of Measured and simulated monthly Stream flow for calibration and validation period at Abelti station.

period	Average Monthly Flow (m3/s)		Model Efficiency	
	observed	simulated	R^2	NS
Calibration (1989-2000)	238.80	286.17	0.72	0.67
Validation (2002-2007)	188.23	276.16	0.86	0.60

As indicated from Table 12, the model performance values for calibration and validation of the flow simulations are satisfactory. This indicates that the physically processes involved in the

generation of stream flows in the watershed were adequately captured by the model. Hence, the model simulations can be used for various water resource management and development aspects.

5.4 Evaluation of Stream Flow due to Land Use and land Cover Change

One of the most important things of the study was to evaluate the impact of land use and land cover changes on Gilgel Gibe III watershed on surface runoff. The evaluation was done in terms of the impact of land use and land cover changes on mean annual base as shows from table 13 and seasonal base as shows from table 15.

5.4.1 Change in the annual Stream Flows

This was done by taking over all mean annual stream flow from 1989-2015 for each land use land cover (1987,2003 and 2013).

Table: 13 Comparisons of Simulated Mean annual Stream flow in m³/s at Gibe III (1989-2015)

	1987	2003	2013	Change (m ³ /s)		
	LULC	LULC	LULC	1987-2003	2003-2013	1987-2013
Stream flow	787.1894	824.32	885.2462	37.1306	60.9262	98.0568

As shows from table 13 mean annual stream flow show an increase trend from 1987 to 2003, 2003 to 2013 and 1987 to 2013 by 37.1306 m³/s, 60.9262 m³/s and finally by 98.0568 m³/s respectively. This shows how stream flow are changed due to change in land use land cover of the water shade. But to see the impact of land use land cover on stream flow in detail showing wet and dry season variation is more important as section 5.4.2 discussed below.

Table: 14 Generated stream flow for each land use land cover types for 1987,2003 and 2013 land use land cover.

Land use Land cover	Area (km ²)			Stream flow (m ³ /s)			Change in Stream flow (m3/s)		
	1987	2003	2013	1987	2003	2013	1987- 2003	2003- 2013	1987- 2013
Cultivated Land	12963.93	17864.02	22766.06	114.58	124.11	142.84	9.53	18.73	28.26
Desmoids forest	8597.1	4194.5	2923.14	28.5	35.23	42.53	6.73	7.3	14.03
Ever-Green forest	3771.79	2038.72	1635.53	13.05	19.36	25.23	6.31	5.87	12.18
Range grass land	7156.66	8213.41	4930.65	68.25	84.93	57.76	16.68	-27.17	-10.49

As the table 14 shows Stream flow has changed due to change in land use land cover and also shows the mean monthly stream flow generated for each land use land cover class for selected land use land cover reference year (1987,2003 and 2013).As shows from table due to increase in cultivated land, stream flow generated for cultivated land was increase by 9.53 m³/s, 18.73m³/s and 28.26 m³/s form 1987-2003,2003-2013 and 1987-2013 land use land cover respectively. On the other hand due to decrease in forest land the stream also shows an increasing trend from 1987 to 2013,i.e form 28.5 m³/s to 42.53 m³/s and 13.05 to 25.23 m³/s.

5.4.2 Change in the Seasonal Stream Flows

The calibration and validation to see the change in stream flow due to change in land use land cover was carried out using the following two approach:

- I. The same year for all three land use land cover twelve year (2/3 of the study period) January 1989 to December 2000 for calibration and six year (1/3 of the study period) from 2002-2007 flow for validation was carried out for monthly stream flow using the sensitive parameters listed above. This calibration and validation was performed at Abelti gauge station and transferring to Gibe III was done.

SWAT was run using the Three land cover maps (1987, 2003 and 2013 maps) for the period of 1986 to 20015 and the three year was considered as war map period for the model. while putting the other input variables the same for all simulations to quantify the variability of stream flow due to the changes of land use and land cover.

This process gave simulated discharge outputs for the three year land use and land cover (1987, 2003 and 2013). Then, these outputs were compared and the discharge change during the wettest months of stream flow taken as July, August and September and driest stream flow are considered in the months of January, February and March were calculated and used as indicators to estimate the effect of land use and land cover change on the stream flow. Table 15 and table 16 for Abelti and Gibe III respectively presents the mean monthly wet and dry month's stream flow for 1987,2003 and 2013 land use and land cover maps and its variability.

Table 15. Mean monthly wet and dry month's stream flow and their variability (1989-2008) at Abelti (after calibration and validation).

year		1987	2003	2013	change 1987-2003	change 2003-2013	change 1987-2013
Wet (m3/s)	(Jul-Sep)	477.843	501.508	552.035	23.665	50.527	74.192
Dry (m3/s)	(Jan-Mar)	98.31	93.417	88.476	-4.893	-4.941	-9.834

Table 16. Mean monthly wet and dry month's stream flow and their variability (1989-2015) at Gilgel Gibe III (by parameter transferring from Abelti)

year		1987	2003	2013	change 1987-2003	change 2003-2013	change 1987-2013
Wet (m3/s)	(Jul-Sep)	1448.090	1498.069	1714.33 7	49.979	216.268	266.247
Dry (m3/s)	(Jan-Mar)	342.681	300.568	149.848	-42.114	-150.719	-192.833

As can be indicated from figure 24 the observed flow for calibration (1989-2000) and figure 25 the observed flow for validation (2002-2007) period was used for the three land use land cover.

As shows from the table 15 stream flow for wet season was increase on going from year 1987 to 2013 and for dry season was decrease. Mean monthly stream flow during wet season at Abelti station was increase by 23.065 m³/s, 50.527 m³/s and 74.192 m³/s from 1987 to 2003,2003 to 2013 and 1987 to 2013 land use land cover respectively for period 1989 to 2008 and during dry period the stream flow was decrease by 4.893 m³/s,4.941 m³/s and 9.834 m³/s from 1987 to 2003,2003 to 2013 and 1987 to 2013 land use land cover for a period of 1989 to 2015.

On the same way as table 16 shows surface runoff for Gibe III was increase by 49.979 m³/s,216.268 m³/s and 266.247 m³/s from 1987 to 2003, 2003 to 2013 and 1987 to 2013 land use land cover respectively for period 1989 to 2015. On the other hand stream flow during dry period was decrease by 42.114 m³/s,150.719 m³/s and 192.833 m³/s from 1987 to 2003,2003 to 2013 and 1987 to 2013 land use land cover for a period of 1989 to 2015.

- II. The second approach was carried out by dividing flow for each land use land cover i.e for 1987 land use land cover the flow 1989 - 1995 for calibration and 1996 - 1998 for validation. on the other hand for 2003 land use land cover 1999-2005 for calibration and 2006-2007 for validation at Abelti station and transferring to Gibe III

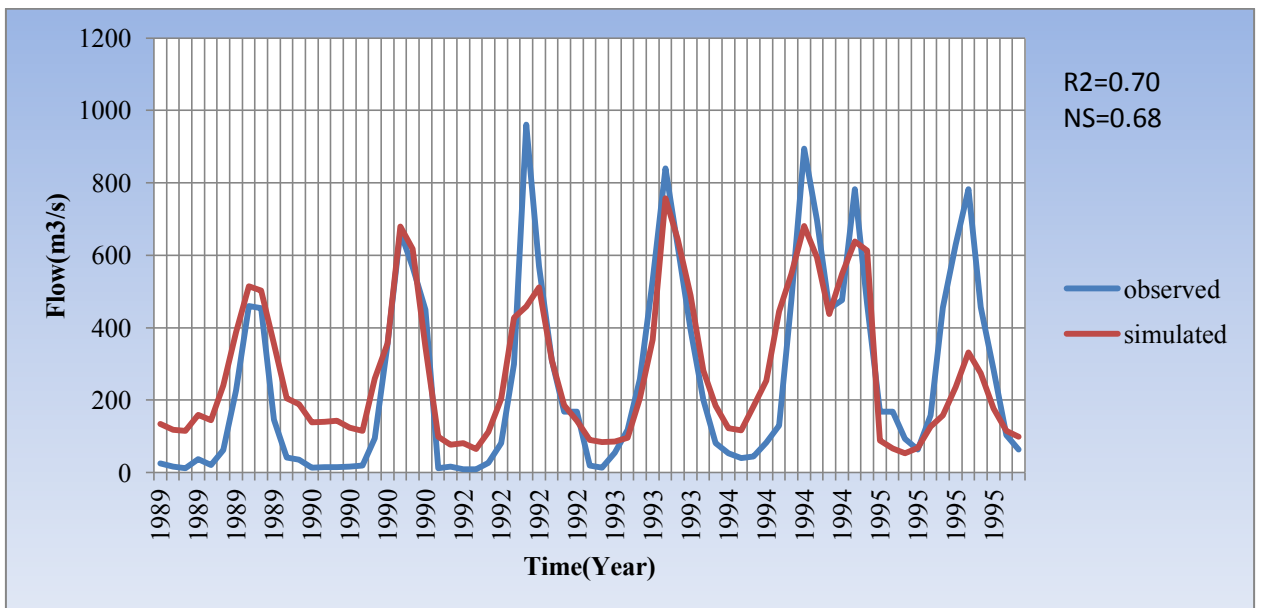


Figure 26. Measured and simulated hydrograph for 1987 land use land cover at Abelti (calibration) (1989-1995)

As shows from figure 26 model was calibrated using monthly stream flow of observed data from the Abelti hydrological Station for the period 1989-1995 for 1987 Land use Land cover and The calibration results show that the coefficient of determination and Nash-Sutcliff Efficient (NSE) 0.70 and 0.68 respectively. This indicated that the model performance assessment indicated a good correlation and agreement between the monthly measured data and simulated flow (D.N Moriasi,et al.207).

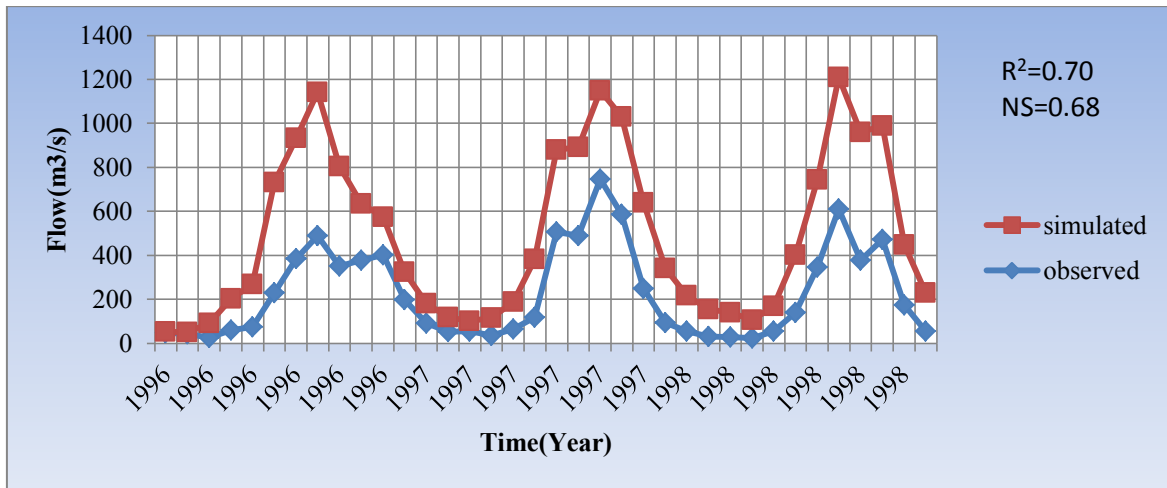


Figure 27. Measured and simulated hydrograph for 1987 land use land cover at Abelti (Validation) (1996-1998)

The validation period for 1987 Land use Land cover was taken from 1996-1998 and shown a good agreement between monthly measured and simulated flow. The Validation result showed that the coefficient of determination (R2) and the Nash-Sutcliff efficient (NSE) are 0.70 and 0.68 respectively. The figure 27 show that the model performance assessment indicated a good correlation and agreement between the monthly observed and simulated flow.

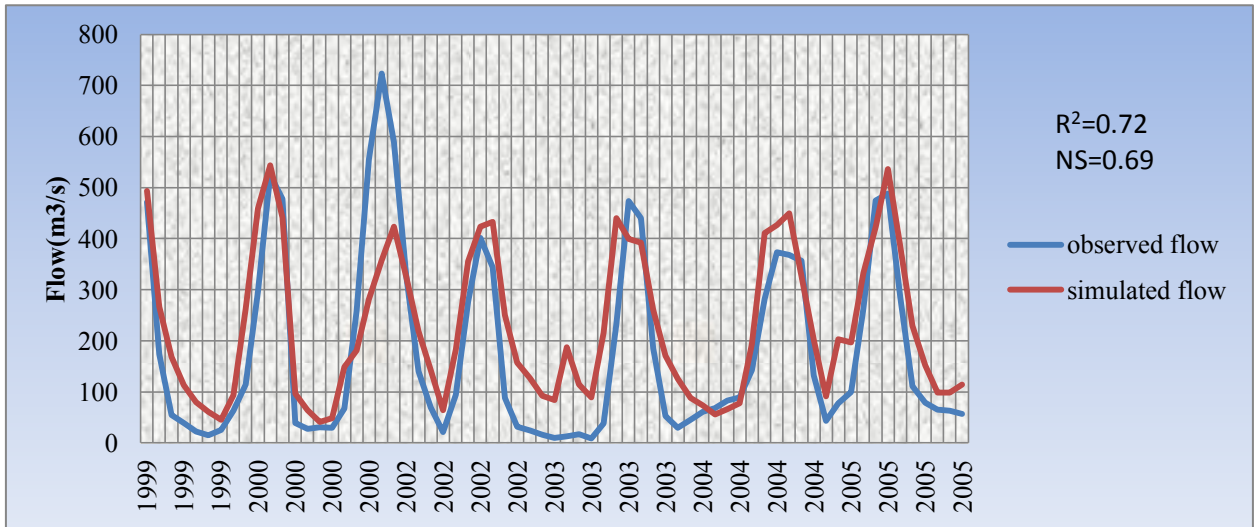


Figure 28. Measured and simulated hydrograph for 2003 land use land cover at Abelti (calibration) (1999-2005)

As shows from figure 28 model was calibrated using monthly stream flow of observed data from the Abelti hydrological Station for the period of 1999-2005 using 2003 Land use Land cover. The calibration results show that the coefficient of determination and Nash-Sutcliffe Efficient (NSE) of 0.72 and 0.69 respectively. This indicated that the model performance assessment indicated a good correlation and agreement between the monthly measured data and simulated flow (D.N Moriasi, et al.207) .

Table 17. Measured and simulated flow at Abelti for 1987 land use land cover.

Period	Average monthly flow (m ³ /s)		R ²	NS
	Observed	Simulated		
Calibration (1989-1995)	253.99	274.01	0.7	0.68
Validation (1996-1998)	225.8	263.07	0.65	0.61

Table 18. Measured and simulated flow at Abelti for 2003 land use land cover

Period	Average monthly flow(m ³ /s)		R ²	NS
	Observed	Simulated		
Calibration (1999-2005)	275.68	296.091	0.72	0.69
Validation (2006-2007)	254.29	342.58	0.66	0.62

Table: 19 Change in stream flow for 1987 and 2003 land use land cover at Abelti

Period	Average monthly flow (m ³ /s)		Change in Mean monthly stream flow
	For 1987 Land use	For 2003 Land use	
Calibration	274.01	296.091	22.081
Validation	263.07	342.58	79.51

As table 17 shows simulated stream flow for 1987 Land use Land cover was 274.01 m³/s and 263.07 m³/s for calibration and validation period respectively. On the other hand from table 18 simulated stream flow for 2003 Land use Land cover was 296.091 m³/s and 342.58 m³/s. This shows that significant change in stream flow due to change in land use land cover, i.e. has an increase by 22.081 m³/s and 79.51 m³/s for calibration and validation period respectively from year 1987 to 2003.

Table 20. Mean monthly wet and dry months stream flow for 1987 lulc and 2003 lulc for the period 1989 -1998 and 1999 - 2007 respectively at Gilgel Gibe III.

Year	1987	2003	Change 1987- 2003
	Wet (Jul-Sep) (m³/s)	1218.07	1305.54
Dry (Jan-Mar) (m³/s)	431.906	406.246	-25.66

In the second approach also the same result observed like the first approach. The stream flow for wet season was increase by 87.47 m³/s and during dry season the stream flow was decrease by 25.66 m³/s from 1987 land use land cover to 2003 land use land cover as shown from table 20.

Generality whatever I used the two approach the surface runoff increase from 1987-2003,2003-2013 and 1987-2013 land use land cover. This is because of change in land use land cover from one class to the other types mainly the expansion of agricultural land over forest that results in the increase of surface runoff following rainfall events. We can explain this in terms of the crop soil moisture demands. Crops need less soil moisture than forests; therefore the rainfall satisfies the soil moisture deficit in agricultural lands more quickly than in forests there by generating more surface runoff where the area under agricultural land is extensive (Brook et al, 2011). And this causes variation in soil moisture and groundwater storage. This expansion also results in the reduction of water infiltrating in to the ground. Therefore, discharge during dry months (which mostly comes from base flow) decreases, whereas the discharge during the wet months increases. These results demonstrate that the land use and land cover change have a significant effects on infiltration rates, on the runoff production, and on the water retention capacity of the soil.

Different studies have been conducted in different parts of the country to evaluate the effects of land use and land cover changes on stream flow. A modeling study of Anger watershed, in Ethiopia, (Brook et al, 2011) introduced that the surface runoff increased and the base flow decreased due to the expansion of agricultural land and declined of forest land. Study on a Hare watershed, in Southern Ethiopia, (Tadele, 2007) reported that due to the replacement of natural forest in to farmland and settlements, the mean monthly discharge for wet months had increased while in the dry season decreased. In the study of Chemoga watershed, in Blue Nile basin, (Abebe, 2005) reported that large volume of surface runoff occurs during the storm events since the area under forest cover decreased.

6. Conclusion and recommendation

6.1 Conclusions

An integrated approach of GIS and remote sensing with a hydrological model are excellent tools to map different land cover classes and to detect and analyses spatiotemporal land cover changes. These techniques were applied to enable and asses of the land cover change effects on the hydrology of the watershed for this study. The impacts of the land cover change on stream flow was analyzed statistically using the hydrological model, SWAT.

The study shows that land use and land cover changes in Gilgel Gibe III watershed for 1987,2003 and 2013 were identified from TM,ETM+ and L_s8 satellite images, respectively and The land use and land cover maps of those year were produced. From the land use and land cover change analysis, it can be concluded that the land use and land cover of the Gilgel Gibe III watershed for the period of 1987 to 2013 showed significantly changed. Cultivated land was increase by 30.15 % from 1987 to 2013 in the expenses of the other classes and water body also increase by 0.72 %. on the other hand the expansion of agricultural land has an impact on the decrement of forest land. Thus, ever green forest and deciduous forest was decrease by 6.57 % and 17.45 % respectively from 1987 to 2013.

Due to the expense of forest land and other land cover types, the cultivated land includes areas for crop cultivation and the scatter rural settlement that are closely associated with the cultivated fields dynamically increased in the period of the last 27 years (1987-2013). This might be due to the population pressure has caused a high demand for additional land as a result shortage of cultivated land is the major problem for farmers in the study area and deforestation of forest lands for constriction of projects like dams.

The sensitivity analysis using SWAT model has pointed out eleven most important parameters that control the stream flow of the studied watershed. On the other hand, model calibration and validation have showed that the SWAT model simulated the flow quit satisfactorily. Performance of the model for both the calibration and validation watershed were found to be reasonably good with Nash-Sutcliffe coefficients (ENS) values of 0.67 and 0.60 and coefficient of determination (R^2) values of 0.72 and 0.86 for the calibration and validation respectively.

Following calibration and validation of the model, impacts of the land use and land cover change on stream flow was carried out. Land use and land cover changes recognized to have major impacts on surface flow. The result of model for the three land use and land cover (1987,2003 and 2013) indicated that the mean monthly flow for 2013 land cover was increased by 266.247 m³/s and 216.268 m³/s during wet season and mean monthly flow was decreased by 192.833 m³/s and 150.719 m³/s during the dry season relative to that of 1987 and 2003 land cover maps respectively when the same period for calibration and validation was taken.

Mean annual stream flow also shows significant change from 1987 Land use Land cover to 2013 Land use Land cover. It shows that an increase of stream flow from 1987-2003 by 37.13 m³/s, from 2003-2013 by 60.92 m³/s and from 1987-2013 by 98.05 m³/s mean annual stream flow.

On the other hand when different period (rainfall variability is considered) relative to land use land cover of 1987 and 2003 the surface runoff was increase by 87.475 m³/s in the wet season and decrease by 25.66 m³/s in the dry season from 1987 land use land cover to 2003 land use land cover.

6.2 Recommendations

Generally from this specific study the following recommendations could improve similar research for future work:

- Integrating land use change models with hydrologic models could be applied to predict the potential impacts of land use change on the stream flow, a vital ecosystem services in the watershed and the country in general. This helps for stakeholders and decision makers to make better choices for land and water resource planning and management. It can be applied to a variety of watersheds, where time-sequenced digital land cover is available, to predict hydrological consequences to LULCC.
- Changes of the land use and land cover in the study area and the country in general are mainly caused by increasing population. Nowadays, household family size and its annual crop production are not proportional. Moreover, the farmers are unable to improve the amount of the production by the existing farming practices. For this reason, improve of household knowledge with the impact of population growth on their living status has paramount importance. Therefore, family planning should be given widely and continuously through formal and informal education in school and some other social gathering area.
- SWAT model calibrated using observed flow data at gauge stations. in order to improve the model performance metrological and hydrological stations should be improved both in quantity and quality.
- The model simulation only considered land use land cover change effect on stream flow by assuming all other parameters like change in climate, soil management and other land use variable will contribute great effect on rainfall runoff process of the catchment are constant.
- Further researches like Land use land cover impact on sedimentation effects on Gibe III dam shall have to be done.

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Appendices

Appendices 1: annual mean maximum temperature for selected stations

Year	assendabo	chida	chira	dedo	gedo	hosana	jima	sekoru	weliso	limu-Genet
1986	27.65	25.93	24.33	23.29	21.64	22.62	27.26	26.93	24.70	28.93
1987	26.88	25.79	23.71	22.27	21.97	22.84	27.45	23.89	25.36	27.81
1988	26.63	26.08	23.26	22.66	23.05	22.12	26.89	24.88	25.00	26.37
1989	26.22	25.79	22.64	22.15	21.52	21.45	26.38	24.40	24.36	25.61
1990	26.60	26.73	22.64	23.45	21.64	21.85	26.52	25.09	24.63	26.17
1991	26.70	27.33	23.09	25.60	22.98	22.17	26.49	26.05	23.30	26.46
1992	26.12	26.83	23.15	25.36	21.49	20.66	27.05	25.40	24.28	27.50
1993	26.12	26.33	23.26	22.62	21.59	21.07	27.17	24.89	22.56	28.79
1994	26.92	27.73	24.33	23.38	23.17	22.73	27.48	26.15	24.52	29.13
1995	26.96	27.58	24.37	23.02	22.58	22.96	28.03	26.44	25.29	29.14
1996	26.38	26.84	23.22	23.08	21.65	22.17	26.98	23.43	24.74	28.36
1997	26.86	26.95	23.93	22.59	21.85	22.80	27.56	25.85	25.30	29.12
1998	26.85	26.42	23.23	23.43	20.40	21.40	27.96	25.18	24.97	24.67
1999	26.97	26.57	23.44	24.05	21.51	22.65	28.40	26.05	20.95	26.94
2000	27.04	26.91	23.85	24.07	21.84	22.75	28.60	26.19	25.03	27.18
2001	26.93	26.93	23.72	23.59	22.05	22.26	28.33	26.06	24.98	27.16
2002	25.66	27.00	23.92	23.57	19.64	21.77	28.08	26.52	25.55	27.44
2003	27.58	27.44	24.08	22.74	23.24	22.44	28.03	26.28	24.51	27.60
2004	26.55	27.03	23.87	22.66	23.33	22.42	27.72	25.84	23.01	27.33
2005	27.79	27.06	23.85	23.09	23.10	22.71	27.82	26.20	22.87	27.20
2006	27.26	26.88	23.80	22.37	22.51	21.02	27.76	26.15	25.01	26.79
2007	27.39	27.36	23.94	22.76	22.79	22.94	27.95	25.82	25.23	26.91
2008	27.60	27.03	23.77	23.76	20.68	22.93	28.18	26.12	25.20	28.65
2009	27.96	27.62	24.13	23.92	23.09	23.30	27.59	26.73	25.84	27.28
2010	27.44	27.54	23.58	21.43	24.44	21.35	27.13	25.69	25.26	27.82
2011	28.01	27.60	24.22	23.80	23.02	22.60	28.02	26.34	25.42	28.83
2012	28.32	28.59	24.80	25.12	22.95	23.58	27.99	26.97	25.68	29.23
2013	27.74	27.26	22.64	25.27	22.38	23.05	27.76	25.40	24.21	27.24
2014	27.40	27.11	23.46	25.44	21.41	22.77	27.46	26.30	25.52	27.28
2015	28.05	27.98	24.26	25.31	22.01	23.77	28.12	26.96	25.72	28.02

Appendices 2: annual mean minimum temperature for selected stations.

year	assendabo	chida	chira	dedo	gedo	hosana	jima	sekoru	weliso	limu-Genet
1986	11.52	14.97	11.24	12.02	8.99	10.20	10.66	12.51	11.63	12.06
1987	12.42	15.35	11.81	13.06	8.91	16.53	11.16	12.46	13.22	12.70
1988	12.42	15.50	12.14	13.17	9.13	10.82	11.42	14.12	13.14	13.10
1989	11.75	15.01	11.81	10.89	8.23	10.20	11.46	13.53	12.29	12.15
1990	11.95	14.67	11.34	11.53	7.95	10.50	11.50	13.53	12.15	12.65
1991	11.62	14.91	11.90	12.04	9.66	10.75	11.08	13.97	11.64	12.38
1992	11.62	14.27	11.67	11.96	8.67	10.20	11.58	14.10	11.65	12.62
1993	12.34	14.91	9.93	11.90	9.03	9.38	11.34	13.20	10.97	12.15
1994	12.49	14.70	10.51	11.50	9.46	10.78	11.24	13.50	12.00	12.53
1995	13.26	15.46	12.01	12.15	9.37	10.51	11.83	14.03	12.79	13.30
1996	13.08	15.09	11.99	11.52	8.64	10.66	12.14	12.29	12.72	12.35
1997	13.80	15.05	11.75	11.48	8.45	11.15	12.66	11.96	13.41	12.95
1998	13.81	15.20	11.74	11.72	8.40	11.29	12.59	12.52	11.45	12.42
1999	12.40	14.76	11.79	10.90	8.49	10.41	10.56	12.26	10.49	12.89
2000	12.80	15.11	11.74	11.42	8.66	9.98	10.99	12.55	12.38	13.18
2001	13.25	14.94	11.84	11.30	6.32	10.80	11.86	12.72	13.02	13.35
2002	13.27	15.18	11.85	11.69	9.15	10.66	12.09	13.04	12.85	13.69
2003	12.36	15.13	12.09	12.22	11.59	11.04	11.70	12.93	13.10	13.64
2004	13.39	15.16	12.27	9.64	11.44	9.78	12.23	13.09	13.45	13.87
2005	12.72	15.39	12.58	9.00	10.19	11.05	11.32	13.38	13.50	13.65
2006	13.08	15.61	12.60	11.26	9.68	11.26	12.77	13.56	14.47	13.99
2007	11.53	14.95	12.40	12.13	8.71	11.11	11.74	13.02	13.48	13.51
2008	11.13	15.06	11.80	12.24	9.85	10.42	11.73	13.13	13.26	13.61
2009	11.09	15.08	12.58	12.15	10.69	10.72	12.18	13.79	13.38	13.84
2010	11.07	14.97	12.49	11.95	11.17	10.95	12.60	13.79	13.82	14.14
2011	10.18	15.07	11.87	12.67	10.51	10.93	11.67	13.64	13.50	13.74
2012	9.09	14.87	12.20	12.34	10.94	10.61	11.24	13.82	13.35	13.63
2013	9.64	14.76	10.65	12.77	11.14	10.32	12.67	13.46	12.37	12.87
2014	10.84	14.94	11.92	12.65	11.12	10.67	11.92	13.59	13.34	13.61
2015	11.67	15.10	12.42	12.31	11.13	11.52	11.88	14.14	13.77	13.94

Appendices 3: Symbols and description of Weather Generator parameters (WGEN) used by the SWAT model

S.No	Symbol	Description
1	TMPMX	Average or mean daily maximum air temperature for month (oC).
2	TMPMN	Average or mean daily minimum air temperature for month (oC).
3	TMPSTDMX	Standard deviation for daily maximum air temperature for month (oC).
4	TMPSTDMN	Standard deviation for daily minimum air temperature for month (oC).
5	PCPMM	Average or mean total monthly precipitation (mm H ₂ O).
6	PCPSTD	Standard deviation for daily precipitation for month (mm H ₂ O/day).
7	PCPSKW	Skew coefficient for daily precipitation in month.
8	PR_W1	Probability of a wet day following a dry day in the month.
9	PR_W2	Probability of a wet day following a wet day in the month.
10	PCPD	Average number of days of precipitation in month.
11	SOLARAV	Average daily solar radiation for month (MJ/m ² /day).
12	DEWPT	Average daily dew point temperature in month (oC).
13	WNDV	Average daily wind speed in month (m/s).

Appendices 4: Cumulative annual rainfall of each stations.

	Assendab o	Welis o	Chida	Chira	Dedo	Gedo	Hosan a	Jima	Lmu genet	Sekor u
198 6	1157	1196. 6	1386. 6	1602. 1	1466. 6	878	1417.9	1330. 8	1899. 9	1601
198 7	1132.4	1271	1515	1901. 1	1698. 8	1116. 2	1280.5	1439. 6	1599. 1	1385. 5
198 8	1271.8	1448. 4	1402. 5	2256. 9	1726. 6	1109. 8	1216.2	1549. 1	1964. 6	1462. 5
198 9	1255.4	1231. 1	1732	1659. 9	2332. 9	1203. 9	1199.7	1618. 3	1616. 5	1591. 3
199 0	1183	1259. 6	1647	1832. 6	2009. 5	839.6	1058.9	1711. 7	1881. 9	1332. 3
199 1	1144.8	964	1426. 4	1823. 3	1610. 4	968.4	1028.3	1443. 6	1773. 6	1295. 3
199 2	1155.4	1387. 1	1399. 5	1780. 3	3294	1127. 5	1387.6	1761. 6	2037. 3	1569. 5
199 3	1360.2	1553. 1	1721. 2	1913. 8	2405. 9	863.6	1413.5	1777. 4	2095. 1	1508. 7
199 4	1345.9	1082. 5	1475. 5	1499. 9	2217. 4	847.8	920.4	1397. 3	1576. 5	1186. 7
199 5	948	1070. 6	1683	1777. 1	1815. 3	724.7	1160.7	1313. 7	1259. 4	1162. 7
199 6	1380.3	1446. 7	1219. 2	2038	2572. 2	571.5	1168.2	1502. 1	1898. 6	1617. 5
199 7	1518.8	1050. 5	377.6	2120. 7	2844	577.4	1442.5	1966. 7	2183. 4	1482. 1
199 8	1307.7	1380. 6	1587	1577. 2	1956. 7	699.2	1556.4	1724. 4	1838. 8	1597. 9
199 9	1165.2	1404. 8	1133. 6	1414. 1	1825. 4	577.5	1011.3	1143. 8	1598. 8	1307. 8
200 0	972.2	1136. 1	1194. 4	1685	1997. 2	602.6	991.9	1621. 9	1665. 8	1137. 3
200 1	1481.7	1021. 2	1695. 5	2063. 9	2092. 6	1542. 9	1145.5	1771. 4	2140. 2	1370. 9
200 2	1059.3	1114. 4	1408. 9	1596. 4	1229. 7	831.7	1346.4	1409. 7	1535. 8	1090. 5
200 3	1102	1175. 4	1305. 6	1569. 4	1721	848	1152.9	1285. 3	1667. 1	1197. 5
200 4	1283.5	1229. 8	1211. 8	1842. 1	2150	650.9	1185.1	1468. 1	1634. 9	1191

200 5	1117.5	1209. 9	1106. 4	1653. 6	2059. 1	811.7	1179	1559. 6	1981. 2	1275. 2
200 6	1473.6	1400	1550. 3	2198. 2	2120. 5	1326	1201.7	1860. 1	2169. 3	1415. 4
200 7	1120.8	1170. 2	1348	1693. 1	1596. 4	1062. 5	1098.8	1390. 2	1777. 4	1612. 6
200 8	1355.3	1242. 2	1527. 4	1977. 5	1650. 4	1274. 5	1202.8	1550. 9	3036. 5	1465. 4
200 9	1209.8	978.5	996	1905. 8	2102. 8	928.3	1175.8	1581. 3	1831. 9	1188. 5
201 0	1277	1378. 3	1780. 5	1935. 3	1432. 3	992.6	1121.5	1587. 1	2595. 8	1579. 6
201 1	1153.7	1135. 8	1144. 6	1954. 5	1655. 2	705	1228.5	1518. 9	2586. 1	1235. 9
201 2	938.3	955	1231. 1	1605. 4	1576	864.9	981.6	1442. 9	1879. 7	1001. 3
201 3	1399.5	1399. 2	1632	1688. 3	1014. 2	925.1	1101.1	1644. 2	2190. 2	1422. 8
201 4	1061.5	1123. 9	1499. 8	1489. 2	1412. 8	870.3	1450	1574. 2	2395. 6	1517. 1
201 5	939.9	1033. 1	1004. 4	1449. 6	1161. 8	837	976	1462. 7	2118. 5	1289. 1