JIMMA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
JIMMA INSTITUTE OF TECHNOLOG
DEPARTMENT OF HYDRAULIC AND WATER RESOURCES ENGINEERING
MASTERS OF SCIENCE PROGRAM IN HYDRAULIC ENGINEERING

ASSESSING THE IMPACTS OF LAND USE AND LAND COVER CHANGE ON HYDROLOGY OF BARO AKOBO RIVER BASIN, ETHIOPIA (CASE STUDY: UPPER GILO WATERSHED)

BY
G/GIORGIS ASHEBIR

A RESEARCH THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF JIMMA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN HYDRAULIC ENGINEERING

NOVEMBER, 2017

JIMMA, ETHIOPIA

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ADVISOR: Ing. TAMENE ADUGNA (PHD)

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NOVEMBER, 2017

JIMMA, ETHIOPIA

Declaration and copyright

I, G/Giorgis Ashebir, declare that this is my own original work and that it has not been presented and will not be presented to any other university for similar or degree award.

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Signature

Assessing the Impact of Land Use and Land Cover change on Hydrology of Baro Akobo River Basin, Ethiopia (Case study: Upper Gilo Watershed)

Thesis submitted to Jimma University, Institute of Technology, school of Graduate studies in partial fulfillment of the requirements for the degree of Master of Science in Hydraulic Engineering stream.

Submitted By G/Giorgis Ashebir ______________ ________

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ABSTRACT

Land use land cover change is the global phenomenon that affects the watershed hydrological process and subject to changes causing the area to form impervious surface that affects the hydrological processes. This study was conducted to investigate the impact of land use land cover changes on hydrology of Upper Gilo Watershed located in the Baro Akobo River basin, southwest of Ethiopia. In this study SWAT model was selected as it applies distributed at required scale. Land use/Land Cover data, Hydrological data (stream flow) and meteorological data were obtained from Ethiopian Map Agency, Ministry of water Resources, Irrigation, and Electricity, National meteorological Service Agency respectively.. The result of sensitivity analysis has shown that the curve number (CN2), GWQMN, CH_K2, ALPHA_BF and SOL_Z are the top most sensitive parameters. The model was calibrated using stream flow data from 1993 to 2006 and validated from 2007 to 2014. The R^2 and NSE values were used to examine model performance and the result indicates 0.91 and 0.82 to R^2 and 0.77 and 0.61 to NSE during calibration and validation respectively. The classified Land use map of 1995, 2004 and 2013 which were obtained from Ethiopian Mapping Agency indicate that the cultivated land and settlement have expanded during the study period of 1995-2013 by 14% and 7% respectively and unlike that, forest and grass land were decreased by 11% and 4.7% respectively during the period. The effects of the land use land cover changes (1995-2013) have impacted on the stream flow of the watershed that changes the magnitude of surface runoff and sediment loading increased by 22% and 84% respectively but lateral flow, ground water flow, Aquifer recharge, and percolation capacity of the soil was decreased by 3.4%, 12.9% 8.4% and 14.6% respectively. During the study period, maximum annual surface runoff was contributed by sub-basin 31, 5 and 28 and the highest ground water was contributed by sub-basin 29, 25 and 25 for the period of 1995, 2004 and 2013 respectively. And maximum sediment load is contributed by sub-basin 22, 19 and 27.

Key Words: Hydrological process, Land Use land cove change, Model performance, SWAT Model

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ABBREVIATION

BASINS	Better Assessment Science Integrating point and Non point Sources
DEM	Digital Elevation Model
ERDAS	Earth Resources Data Analysis System
ETM+	Enhanced Thematic Mapper plus
FAO	Food and Agriculture Organization
GIS	Geographic Information System
GPNRS	Gambella People National Region State
GPS	Geographic Position System
HRUs	Hydrological Response Units
LULC	Land Use and Land cover Change
NSE	Nash Sutcliff Efficiency
MoWR	Ministry of Water Resource
PET	Potential Evapotranspiration
R^2	Coefficient of Determination
SWAT	Soil and Water Assessment Tool
USDA-ARS	United State Department of Agriculture Research Service
UTM	Universal Thematic Mapper
WGS1984	World Geodetic System1984

1. INTRODUCTION

1.1 Background

Water is the most essential natural resources for living species. Since the available amount of water is limited, scarce, and not spatially distributed in relation to the population needs, proper management of water resources is essential to satisfy the current demands as well as to maintain sustainability. Land use planning and management are closely related to the sustainability of water resources as changes of land use are linked with amount of water through relevant hydrological processes (Guo H., 2008). Land use and land cover dynamics are widespread, accelerating, and significant processes derived by human action but also producing changes that impact humans(Agarwal C., 2002), The dynamics alter the availability of different biophysical resources including soil, vegetation, Water, animal feed and others. Consequently, land use land cover changes could lead to a decreased availability of different products and services for human, livestock, agricultural production and damage to the environment as well. Depending on the fact that the alteration of land surface will disturb the bio physical system, this in turn alters the global atmospheric circulation resulting in stream pattern shift. Thus, land use land cover change is the global phenomenon that affects the watershed hydrological process as it characterizes the catchments response to the event of rainfall-runoff relationship (Dibaba *et al*., 2016).

Research on land use/land cover change is needed to explore how land use land cover change influences watershed hydrology. Besides, detecting and simulating the effects of land use land cover change on catchment hydrological process requires a new, strategic and improved procedure to conserve the catchment based on the hydrological sensitivity as a result of land use change at sub-watershed (Dibaba *et a*l., 2016).

Land use land cover plays a vital role in water transport in the hydrologic cycle and primarily aids in reducing overland flows. Due to its effect on evaporation, transportation and solar radiation interception, land use land cover is a driving factor in the energy balance within the hydrologic cycle (Prasad *et at*, 2009). The hydrology of local watersheds can vary drastically and water quality as well as water flow patterns is often dependent on a combination of soil, LULC and elevation characteristics unique to the area. For example, as forested area is lost and developed land expands it has shown to reduce base flow and/or an increase in soil erosion generally occurs (Walsh *et al*., 2005) used changes in watershed can also impact water supply by altering hydrological processes such as infiltration, ground water recharge, base flow and runof. Therefore, this study was investigated the effect of the land use and land cover changes on hydrological process of Upper Gilo Sub-catchment. Particularly, the trends of hydrological process under a varying land use land cover and the most vulnerable sub-basin of the catchment to the yield of the hydrological process was investigated using SWAT hydrological model.

1.2 Statement of the Problem

Land use 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 Gilo sub-Basin. Due to rapid development in the sub-catchment, land use/cover is subject to changes causing the area to form impervious surfaces. Deforestation, urbanization, and other land-use activities can significantly alter the maximum and minimum flows of the river (Tumin *et al*, 2006).Although land use changes in the area are a current phenomenon, the severity of their effects on both forest cover and hydrology of Gilo sub-basin might pose serious concern on the future functioning of this fragile resource if urgent action is not taken into consideration. Understanding of these activities influence on stream flow will enable planners to formulate policies towards minimizing the undesirable effects of future land-use and land cover changes on the hydrology of the river. For nature conservation the range of the discharges and the fluctuation is important (Yanda *et al*, 2006). Regarding the basin water balance, annual average discharges are fundamental. How the discharge regime of Gilo River reacts to the changing land use/cover is a central question of interest to be integrated in watershed management at the watershed level. Therefore, a strong need was identified for the hydrological techniques and tools that can assess the effects of land cover changes on the hydrologic response of a watershed. Such techniques and tools were provided information that used for water resources management at a watershed.

This research applies the Soil and Water Assessment Tools (SWAT) to understand the hydrological process of Upper Gilo watershed so as to investigate the land use dynamics in the watershed.

1.3 Objective of the study

1.3.1 General objective

The main objective of this study is to investigate the impact of land use and land cover change on hydrology of Gilo watershed on Upper Gilo sub-catchment.

1.3.2 Specific objectives

1) To evaluate the performance of the SWAT model in simulation stream flow of Upper Gilo watershed
2) To analysis the impact of land use land cover changes on hydrological responses
3) To investigate the contribution of sub-basins in the hydrological responses

1.4 Research questions

To address the above objectives, the following research questions were designed.

i. How is the performance of SWAT model to simulate stream flow in the watershed?
ii. Does land use and land cover change affect the hydrological processes of the watershed?
iii. What are the most contributing sub-basins towards hydrological responses?

1.5 Significant of the study

The land use and land cover change has significant impacts on natural resources, socio-economic and environmental systems. However, to assess the effects of land use and land cover change on stream flow, it is important to have an understanding of the land use and land cover patterns and the hydrological processes of the watershed. Understanding the types and impacts of land use and cover change 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 assess land use and land cover change and their impacts on hydrological regime. This was achieved through the hydrological model (SWAT) to simulate the hydrological processes and to analysis the land use and land cover change.

1.6 Scope of the study

This study was concentrated on the effect of land use and land cover change on the hydrology of Upper Gilo sub-catchment in Gilo River Basin. The study was focus on the effects and ways of managing them for sustainable resource use and planning by using rainfall data, Landsat images, and river flow. It is not possible to cover all aspects of the study area like climate change and LULC interaction etc. due to the scarcity of time. Therefore, the study was limited to focus on the impact of land use and land cover change on hydrology using SWAT model for impact simulation in the Upper Gilo Sub-catchment.

2. LITERATURE REVIEW

2.1 Definitions and Concepts

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

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

Increase of 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 increases in stream flow. In addition, deforestation also has its own impact on hydrological processes, leading to declines in rainfall, and more rapid runoff after precipitation(Legesse*et al*., 2003). Therefore, such changes of land use and land cover may have impacts on the stream flow during the wet and dry months, and on the components of stream flow (surface runoff and ground water flow) and assessing such impacts is the core of this study.

Generally, knowing of the impact of land use and land cover change on the natural resources like water resources depends on an understanding of the past land use practices, current land use and land cover patterns, and projection of future land use and land cover, as affected by population size and distribution, economic development, technology, and other factors. The land use land cover change assessment is an important step in planning sustainable land management that can help to minimize agro-biodiversity losses and land degradation, especially in developing countries like Ethiopia(Hadgu K., 2008).

2.2 Trends of land use and land cover change

Land use /land cover is a product of mutual interactions between human economic activities and the natural environment. When the LULC changes, it largely impacts on general environmental, especially water resources. General statements about land and water interactions need to be continuously questioned to determine whether they represent the best available information and phenomena have strongly accelerated in many regions. Land use changes are frequently indicated to be whose interests they support in decision-making processes (Bewket W, 2005).

Land use changes are complex processes that arise from modifications in land cover to land conversion process. Despite this complexity, little is known about how human and environmental factors operate and how they interact to affect land use patterns and hydrological processes (LUCID, 2004). According to (Bronstert *et al*., 2002) throughout the entire history of mankind, intense human utilization of land resources has resulted in significant changes on the land use and land cover. Since the area of industrialization and rapid population growth, land use change one of the main human-indicated factors influencing the hydrological system(Dams J., 2007).

2.3 Deriving Forces for Land use and Land cover Change

Land use and land cover change vary often due to the growing population and economy. In human history land, a fundamental factor of production has been coupled to economic growth (Subhash *et al*., 2016). The rapidly increasing population pressure in many rural areas of developing countries has often led to changes in land use in terms of deforestation, reclamation of wetlands, etc. mainly aiming at agricultural production. Neither population nor poverty alone constitutes the sole and major underlying causes of land cover change world-wide (Gassman *et al*., 2007).

2.3.1 Land use change impacts on water resources

Changes in land use have potentially large impacts on water resources; yet quantifying these impacts remains among the more challenging problems in hydrology, water, flood, energy and climate is linked through complex webs of direct effects and feedbacks. Land use effects on water resources are not restricted to water quality but also the hydrologic regime as well. Most urban and rural land use practices increase the peak rate and volume of surface runoff, but decrease ground water recharge. These can induce increased flooding and lowered ground water levels(Stonestrom *et al*., 2009).

2.3.2 Impacts on groundwater resources

Groundwater is the primary source of public water supply for almost half of the nation's population including 97% of the rural population. Groundwater is highly connected to the land use land cover of the ground system to perform at the portion of aquifer where it comes out to the surface and discharge at every spring and water course. Human activities affect the availability of groundwater though different mechanisms of abstraction and affecting the recharge process. Mainly recharge is affected by the different factor such as climate, soil of aquifer of hydraulic properties, types and amount of vegetation, types of land use topography, antecedent of soil moisture condition etc. impacts on surface water resources (AGBRS 2007).
Surface water resource is one of the key driving variables in river ecosystems. The natural characteristics of a river ecosystem are influenced by the underlying geology and tectonics created and maintained by geomorphic and hydrologic processes that results from energy and material interactions between flowing water and sediment supply; this in some cases are influenced by riparian vegetation. Impacts of land use practices on surface on surface water can be divided in to (i) impacts on the overall water availability or the mean annual runoff, and (ii) impacts on the seasonal distribution of water availability (Roosmalen, 2009).

2.4 Hydrological model

Hydrological model are simplified, conceptual representation of a part of the hydrologic cycle. They are primarily used for hydrological prediction and for understanding hydrological process. The overall intent of the hydrologic system analysis is to study the system function and predict its output(Chow *et al*., 1988). Hydrological modeling and water resources management studies are intrinsically related to the spatial processes of the hydrologic cycle. Land use land cover influence watershed hydrological responses by partitioning rainfall between return flow to the atmosphere as evaporation and transpiration and flow to aquifers and rivers. However, techniques for the analysis of the impact of land use /cover on modeled hydrological responses are still very much at early stage. The prediction of the effect of future change (and validation of prediction) has hardly started C55(Gassman *et al*., 2007).

2.4.1 Introduction to SWAT model

The SWAT (Soil and Water Assessment Tool) model is one of the most recent models developed at the United States Department of Agriculture Research Service (USDA-ARS) during the early 1970's. SWAT model is semi-distributed physically based on simulation model to predict the impacts of land use change and management practices on hydrological regimes over long periods and primarily as a strategic planning tool(Neitsch *et al*., 2005). It can also be used to simulate water and soil loss in agriculturally dominated small watersheds(Tripathi *et al*., 2003).

SWAT has been updated to the most recent version, ArcSWAT 2012 which is an ArcGIS 10.x extension. This interface streamlines data entry, the creation of required input files and parameter editing, all while allowing spatial parameters to be easily observed in the ArcGIS environment. In ArcSWAT, The watershed is delineated into a number of sub-basins which are further divided in to Hydrological Response Units (HRUs) that consist of homogeneous land use, management, and soil characteristics. The HRUs represent percentages of the sub-watershed area and are not identified spatially within a simulation(Fadil *et al*., 2011). Subdividing the watershed into HRUs enables the model to reflect differences in evapotranspiration and other hydrologic conditions for different land covers and soils. Runoff is predict separately for each HRU and routed to obtain the total runoff for the watershed which increases the accuracy of load predictions (Neitsch *et al*., 2009). By delineating the watershed, the user is able to reference different areas of the watershed to one another spatially. For each sub-basin input, information is grouped into the following categories: climate, groundwater, HRUs, ponds/wetlands, and the main channel draining the sub-basin(Gassman *et al*., 2007) .

SWAT was chosen for the compatibility of available data and software and for its complex representation of fine spatial scales. Moreover, SWAT has become popular among environmental managers since it has been adopted as a component of the US Environmental Protection Agency's Better Assessment Science Integrating Point and Non Point Sources (BASINS) software packages (Tripathi *et al.*, 2003). SWAT has shown to be successful for land use change assessments and has generated an expanding body of research projects.

The SWAT model application can have grouped in to five main steps: (1) data preparation, (2) sub-basin discretization, (3) HRU definition, (4) parameter sensitivity analysis, (5) calibration and validation. The SWAT model simulates major components: hydrology, weather, sedimentation, soil temperature, crop growth, nutrients, pesticides, and agricultural management.

2.4.2 SWAT Model Application Worldwide

The SWAT model has good reputation for best use in agricultural watersheds and its uses have been successfully calibrated and validated in many areas of the USA and other continents (Tripathi *et al*., 2003).The studies indicated that the SWAT Model is capable in simulating hydrological process and erosion/sediment yield from complex and data poor watersheds with reasonable model performance statistical values. (Ndomba P., 2002) applied the SWAT model in modeling of Pangari River (Tanzania) to evaluate the applicability of the model in complex and data poor watersheds. (Winchell *et al*, 2009) applied for Nagwan watershed in Indian with the objective of identifying and prioritizing of critical sub-watersheds to develop an effective management plan and the model was verified for both surface runoff and sediment yield. Accordingly, the study concluded that the SWAT model can be used in ungauged watersheds to simulate the hydrological sediment processes.

SWAT has gained international acceptance as a robust interdisciplinary watershed modeling tool as evidenced by international SWAT conferences, hundreds of SWAT related papers presented at numerous other scientific meetings, and large number of articles published in peer-reviewed journals (Gassman *et al.*, 2007). However, (Cibin *et al.*, 2010) indicated parameters show varying sensitivity in different years of simulation suggesting the requirement for dynamic updating of parameters during the simulation. The same study also indicated that sensitivity of parameters during various watersheds. In SWAT model, the impacts of spatial heterogeneity in topography, land use, soil and other watershed characteristics on hydrology are described in subdivisions.

The SWAT model simulates eight major components: hydrology, weather, sedimentation, soil temperature, crop growth, nutrients, pesticides, and agricultural management (Neitsch *et al.*, 2005). Major hydrologic processes that can be simulated by the this model include evapotranspiration, surface runoff, infiltration, percolation, shallow aquifer and deep aquifer flow, and channel routing (Arnold *et al.*, 1998). Stream flow is determined by its components (surface runoff and ground water flow from shallow aquifer).

SWAT model demonstrated versatility in modeling the effects of LULC changes on watershed hydrology with satisfactory accuracy and conclude that Urbanization and agriculture expansion were dominant land use types and subsequently the highest contributors to the hydrodynamics of the Olifants river basin(Gyamfi C., 2016, Charles G., 2016).

2.4.3 SWAT Model Application in Ethiopia

The SWAT model application was calibrated and validated in some parts of Ethiopia, frequently in Blue Nile basin. Through modeling of gumera watershed (in Lake Tana basin), (Awulachew *et al.*, 2008) indicated that stream flow and sediment yield simulated with SWAT were reasonably accurate. The same study reported that similar long term data can be generated from ungauged watershed using the SWAT model. A study conducted on modeling of the Lake Tana basin with SWAT model was successfully calibrated and validated (Setegn *et al*., 2008). This study reported that the model can produce reliable estimates of stream flow and sediment yield from complex watershed. Gessese (2008) used SWAT model performed well in predicting sediment yield to the Legedadi reservoir. The study farther put that the model proved to be worthwhile in capturing the process of stream flow and sediment transport of the watersheds of the Legedadi reservoir. Tadele (2007) stated that; Hare watershed has experienced a significant change in land use/cover over the past four decades. It can be presumed that deforestation and increase in farmland that was manifested by the rapid increase in human population has altered the whole watershed in general and some sub-watershed in particular.

The study found that the observed values showed a good agreement at Nash-Sutcliff Efficiency (NSE) of 80%. In light of this, the study suggested that the SWAT model can be used for further analysis of different management scenarios that could help different stakeholders to plan and implement appropriate soil and water conservation strategies.

The SWAT model showed a good match between measured and stimulated flow and sediment yield in Gumara watershed both in calibration and validation periods (Asres and Awulachew, 2010) through modeling of Bilate watershed also indicated that SWAT model was able to simulate stream flow at reasonable accuracy.

The literature reviewed and presented above showed that SWAT is capable of simulating hydrological and soil erosion process with reasonable accuracy and can be applied to large and complex watersheds.

2.5 Aerial photographs and Satellite Image

As a result of technological advancement, changes of the earth's surface have become visible by satellite imagery. As a result, remote sensing has become the most effective tool for assessing and monitoring all these transitions. Remote Sensing is defined as the science of obtaining information about an object, area, or phenomenon through the analysis of data acquiring by a device that is not contact with the object, area, 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 including digital elevation model (DEM) and land cover maps.

Some of the application of remote sensing technology in mapping and studying of the land use and land cover changes are; mapping and classifying the land use and land cover, assessing the spatial arrangement of the land use and land cover, allowing analysis of time-series images used to analyze landscape history, report and analyzing results of inventories including inputs to Geographic information system (GIS), provide a basis for model building.

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. For this purpose, remotely sensed imagery play a great role to obtain information not only temporal trends and spatial distribution of watershed areas and changes over the time dimension for projecting land cover changes but also to support change impact assessment (Atasoy*et al*, 2006).

2.6 ERDAS IMAGINE Model

ERDAS IMAGINE is a remote sensing application with raster graphics editor abilities designed by ERDAS for geospatial applications. 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. Other usage examples include linear feature extraction, generation of processing work flows ("spatial models" in ERDAS IMAGINE), import/export of data for a wide variety of formats, ortho-rectification, mosaicking of imagery, stereo and automatic feature extraction of map data from imagery(Wikipedia,2010).

3. METHODOLOGY

3.1 Description of the study Area

Baro Akobo basin is located in the south west part of Ethiopia. It covers approximately 75,912km^2 the area includes all or part of the four administrative regions: SNNPRS (Southern Nations & Nationalities People Regional State) in the south, Oromiya in the north east, Gambella in the central western part and Benishangul Gumuz in the northwestern extremity. This basin is the fourth largest basin in the country, between latitudes 5^{o}31'' and 10^{0}54'' N and longitude 33^o and 36^{0}17'' E. the western, north western and south western side of the basin borders with the Sudan, while in the northern and north east it is bordered by the Abay river basin and in the east and north east it is bordered by the Omo-Gibe river basin.

The Baro-Akobo basin is the second most important basin, next to Genale Dawa, as far as irrigation potential is concerned. The population is settled sparsely in the lowlands of the basin which offers a conductive environment for water resources development. Because of regular flooding, the and areas area mainly used as pastures for grazing and no major water resources development has taken place to-date (Awulachew *et.at.*, 2008)

The study area Upper Gilo sub-catchment, sub-basin of Baro Akobo basin, is located in Bench Maji Zone, Sheka zone and Majang zones between the geographical coordinates of 6^{0}48'00''N to 7^{0}34'48''N latitude and 34^{0}58'48''E to 35^{0}36'00''E longitude and it lays on parts of the four administrative Woredas of the region namely Sheko, Yeki, Godere and Semen Bench. These woredas are the upper part of the basin covered with high forest that contributes for Gilo sub basin; the main tributaries are Gatcheb, Beko, and Begwuha rivers.

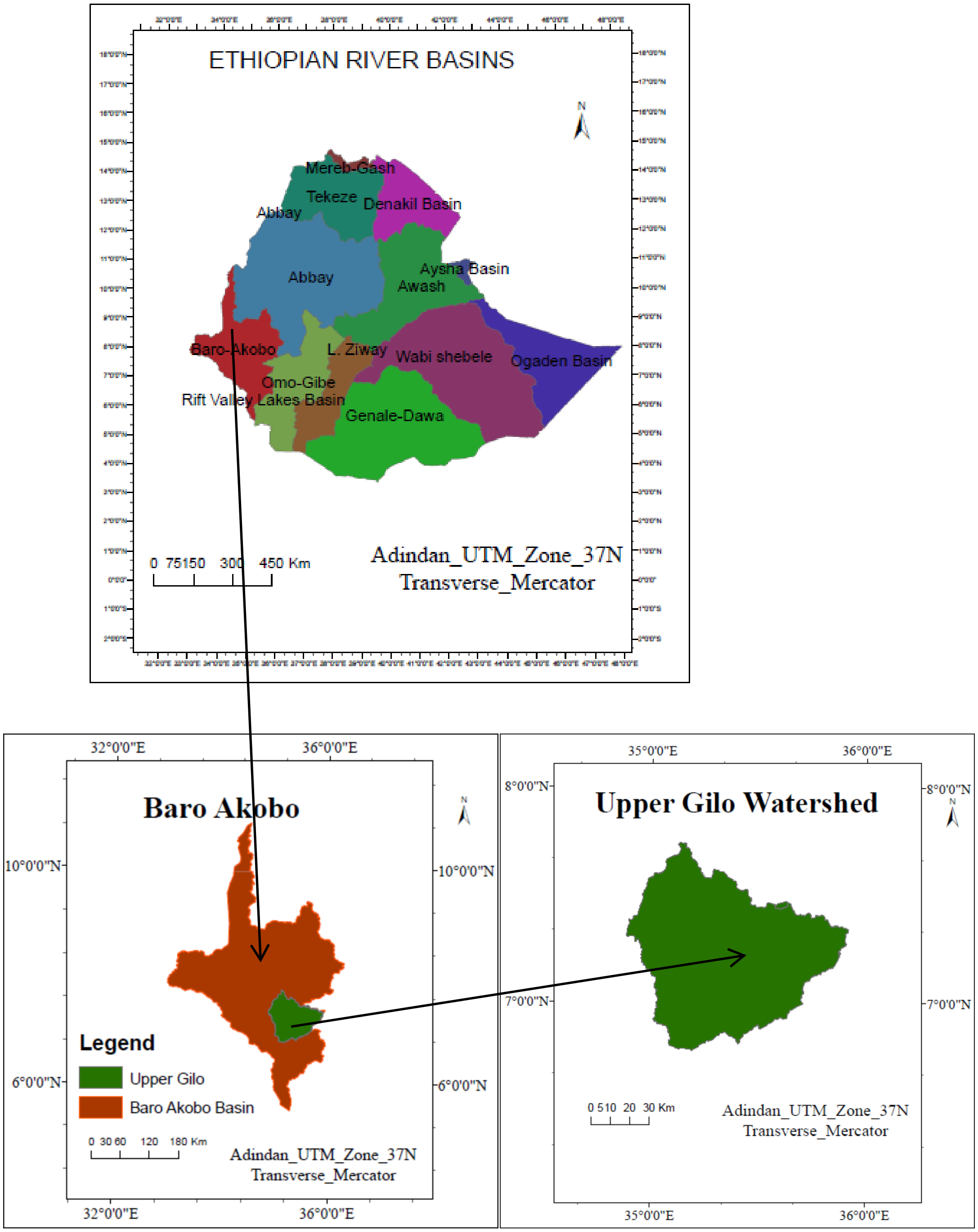

Figure 3. 1 Location of the study area

3.1.1 Vegetation and Land use cover

Vegetation and land cover with variation of altitude different forest types con be recognized in the study area. Accordingly, broadleaved Afro-montane forest without coffee, pure stands of highland bamboo (Arumdinaria alpine) forest, and bushes are the most vegetation found in the area. The north western and south western are dominant with forest and bushes and north eastern part is mostly cultivated land.

3.1.2 Farming systems

The agricultural activities in the area include both crop production and animal husbandry. The main livehood pattern is mixed farming. The production of cereal crops (maize, teff and occasionally wheat), enset, livestock (cattle, goats, sheep and horses) and honey is the main economic activity of the households in the study area.

3.1.3 Topography and soil types

The study area is mountainous with green vegetation which has attractive scene. The topography of the area comprises different land futures are flat area, rugged topography, plateau and steep sloppy areas are commonly observed in the study area. The soils of the study area differ in color and types depending on the topography and types of the parent materials. The commonly observed soils in the area vary in color from black to red. Regarding the types Nitosols, Vertisols, Cambisols are the dominant soil types of the study area(MoARD, 2009).

3.1.4 Climate

The mean annual evaporation over the basin is 1057mm. Mean annual air temperatures also vary with altitude from a high 28^{o}c in the lowland to a low of 17^{o}c in the mountains. December is usually the coldest month and March, April and May are the hottest months, but the variability over the year is not large.

3.2 Data Availability

3.2.1 Meteorological Data

The metrological data such as daily precipitation, daily maximum and minimum temperature, sunshine hour, relative humidity and daily wind speed were collected from the Ethiopian National Meteorology Service Agency. These data were used as the input to the SWAT hydrological model to simulate the hydrological process of the study area Upper Gilo Watershed.

Table3. 1 Meteorological stations and Variables

Sr.no	Station name	Rainfall	Tmax	Tmin	R.H	W.speed	S.shune
1	Tepi	98(%)	96(%)	96(%)	91(%)	82(%)	85(%)
2	Aman	89(%)	92(%)	92(%)	30(%)	10(%)	20(%)
3	Tnishu Meti	83(%(	84(%)	85(%)	No data	No data	No data

Precipitation

Rainfall data of twenty five years (i.e, 1990 to 2014) was obtained from NMSE. The mean annual rainfall at Tepi station is about 1595mm. Precipitation data were collected from the watershed, Tepi, Aman, and Tinshu Meti.

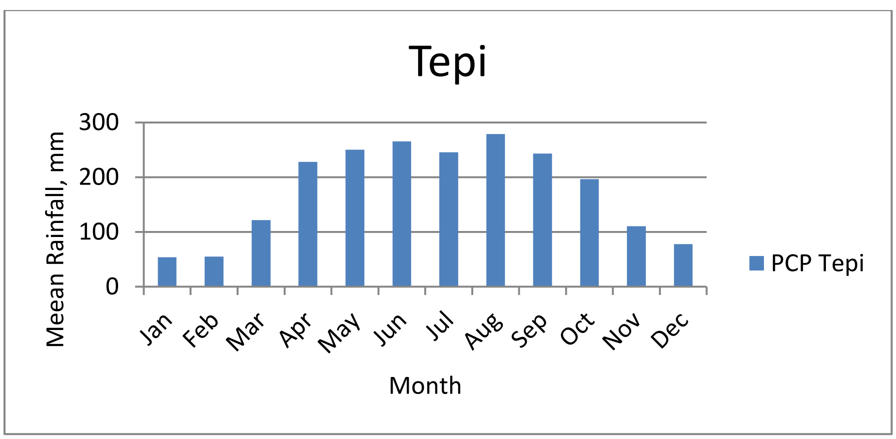

Figure 3. 2 Mean monthly Rainfall of Tepi station

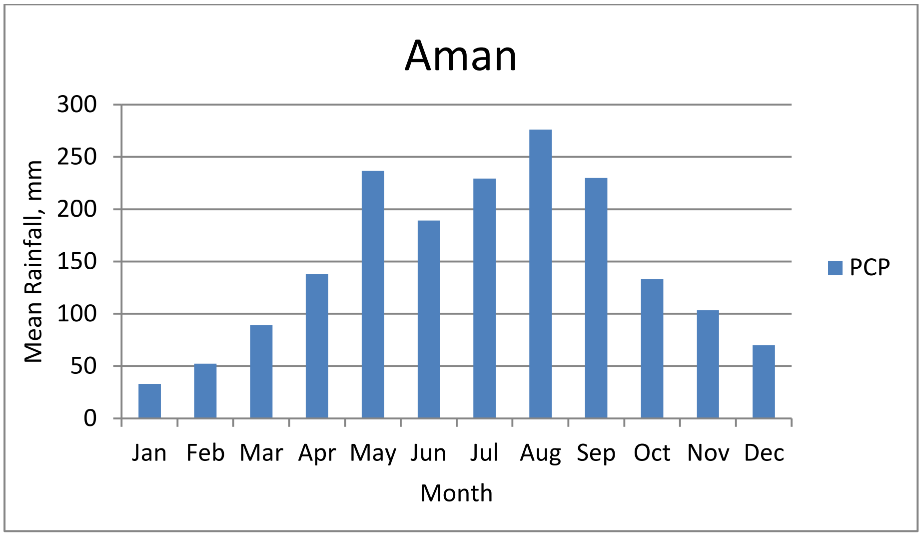

Figure 3. 3 Mean monthly Rainfall of Aman station

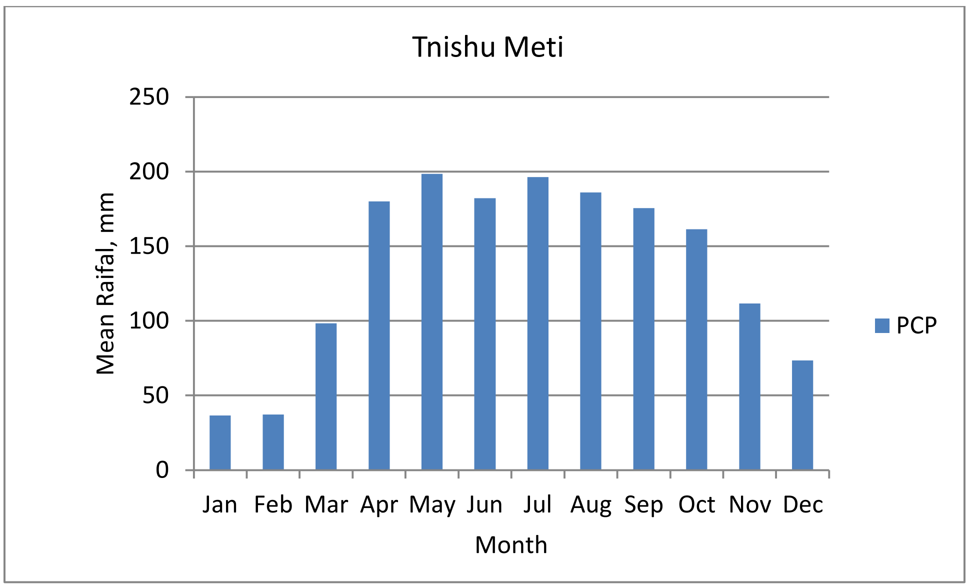

Figure 3. 4 Mean monthly Rainfall of Tnishu Meti

Temperature: Air temperature records for the study area obtained from Ethiopian Meteorological Agency of Tepi station were taken for analysis. From the data obtained, the daily minimum and maximum temperature are 13.35^{0}C and 32.26^{0}C respectively. The hottest and coldest months are February and January, respectively. The mean monthly temperature of Tepi station of 1990 to 2014 is shown as Fig. 3.3 below.

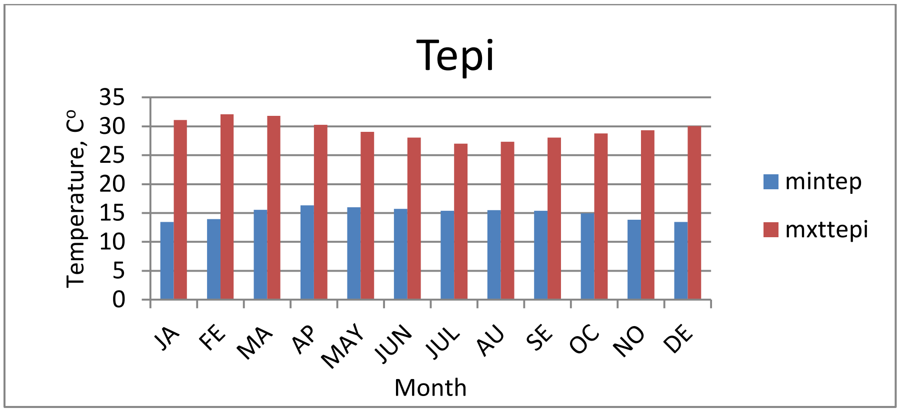

Figure 3. 5 Mean monthly temperature of Tepi station

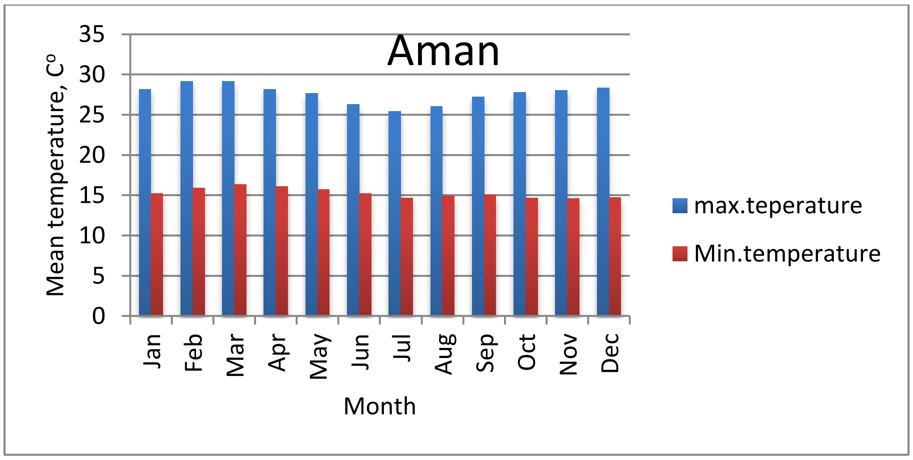

Figure 3. 6 Mean monthly temperature of Aman station

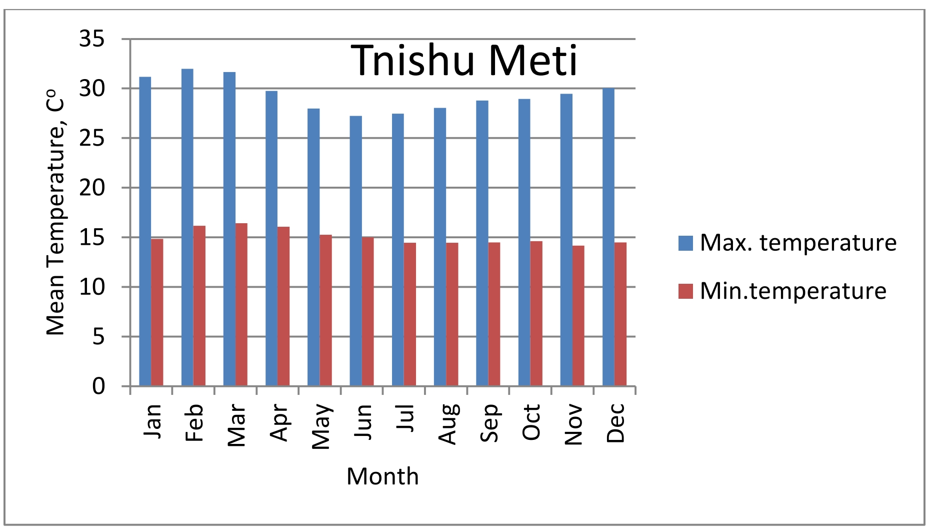

Figure 3. 7 Mean monthly temperature of Tnishu Meti

Relative Humidity (%): Relative humidity data of Tepi station (from 1990-2014) was obtained from NMSA. The mean monthly relative humidity ranges from 0.78 % in February to 0.87 in July.

Wind speed (m/s): Wind speed data which obtained from NMSA was used for this study and the data from 1990 to 2014 is used for analysis. From this long term series, the mean annual wind speed varies from 0.30 in 2008 to 0.49 in 2014 and this could be result of deforestation. Wind speed remains relatively constant (doesn't fluctuate) to it.

Sunshine Hours: The Sunshine hour for the study area is obtained from NMSA. The sunshine hour's variation for this period is 3.74 in August and 6.83 in January.

Solar Radiation: Different empirical models based on Angstrom-Prescott model were selected to estimate the monthly average daily global solar radiation, H, on a horizontal surface for Upper Gilo watershed using only the sunshine duration.

$$H/H_o = a + b\,(n/N) \qquad (3.1)$$

Where: H is the monthly average daily global radiation, H_o is the monthly average daily extraterrestrial radiation, n is the day length, N is the maximum possible sunshine duration and a and b are empirical coefficients.

3.2.2 Hydrological Data

The goal of the hydrological data is the estimation of water availability and its reliability. Twenty five years of daily and monthly flow data of three stations i.e. Begwuha, Beko, and Gatcheb around the catchment was obtained from MoWIE. The stream flow measured at Beko River is used for calibrating and validating the model. The other gauged rivers inside the catchments have been used to fill the missed flow using linear regression techniques. The incomplete gaps in the record are filled by developing correlations between the station with missing data and any of the adjacent stations with the same hydrological features and common data periods.

In present study the incomplete gaps in the record are filled by developing linear correlations equation between stations at Begwuha River and Beko River at outlet ($y = 0.0926x + 0.696$, which $R2 = 0.83$).

Table3. 2 List of Hydrological gauging stations and Recorded Period.

No	River/Lake Name	Latitude(degree)	Longitude(degree)	Recorded period
1	Beko River	7.21	35.26	1987-2013
2	Begwuha River	7.12	35.27	1990-2014
3	Bitun	7.2	35.26	1990-2014
4	Gatcheb	7.1	35.33	1990-2013

3.2.3 Spatial data

Digital elevation model (DEM) of 30mx30m SRTM was obtained from the USGS (earth explorer.usgs.gov) website in raster form. Geographical coordinates, catchment area and other related spatial data were processed and delineated from the 30mx30m DEM using arc GIS 10.3 Version. Classified map of Land use/land cover data was obtained from EMA. The soil data of the study area was also collected from (MWIE), GIS department. Based on MWIE soil data, in order to integrate with SWAT soil code FAO soil with map window was used for the study area.

3.3 .Data Analysis and Evaluation

3.3.1 Missing data completion

Missing data is a common problem in hydrology. To perform hydrological analysis and simulation using data of long time series, filling in missing data is very important. The missing data can be completed using meteorological and /or hydrological stations located in the nearby stations, if the stations are located in hydrological homogeneous region. Summary of all stations with their available meteorological data are shown below.

Table3. 3 Statistical distribution of hydro-meteorological stations

Station Name	Latitude (N)	Longitude(E)	Altitude	Record		% of missing data
				period	Length	
Tepi	7.2	35.433	1205	1983-2014	32	4%
Aman	6.95	35.56	1192	1990-2014	25	8%
Tinshu meti	7.25	35.31	1277	1990-2010	21	15 %

i. Filling in missing Rainfall data

A number of methods have been proposed for estimate missing rainfall data. The station average method is the simplest method. The normal–ratio and quadrant methods provide a weighted mean, with the former basing the weights on the mean annual rainfall at each gauge and the latter weights that depend on the gauges where recorded data are available and the point where a value is required. The station average method for filling missing data is conceptually the same as the station average method for estimating a mean precipitation.

This method may not accurate when the total annual rainfall at any of the n region gauges differs from the annual rainfall at the point of interest by more than 10%.

The normal-ratio method is conceptually simple; it differs from the station-average method of that the average annual rainfall is used in deriving weights. If the total annual rainfall at any of the n region gauges differs from the annual rainfall at the point of interest by more than 10%, the normal-ratio method is preferable. In a research with shortage of the total annual rainfall and normal rainfall, which is necessary conditions for the normal ratio and station average methods, the regression method was good methods of estimation to fill the gaps.

a) Method based on regression analysis

Assume that two precipitation gauges Y and X have long records of annual precipitation, i.e. Y_1, Y_2,…..Y_N and X_1, X_2, ….X_N. The precipitation Y_t is missing. We will fill in the missing data based on a simple linear regression model the model can be written as

$$\mathrm{Yt} = \mathrm{a} + \mathrm{bXt} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.2)}$$

In which the parameter a and b can be estimated by:

$$\hat{\mathrm{a}} = \overline{\mathrm{Y}} - \hat{\mathrm{b}}\overline{\mathrm{X}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.3)}$$

$$\hat{b} \; = \; xy\, \mathrm{S}^*_{\mathrm{y}/\mathrm{S}^*_{\mathrm{x}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.4)}$$

Where Y and X are sample mean, S*Y and S*X are the sample unbiased standard deviations of Y and X, respectively, and Υ_{XY} is the cross correlation coefficient between X and Y. The letter term can be estimated as:

$$\boldsymbol{\gamma_{xy}} = \frac{\frac{1}{N}\sum_{i=1}^{N}[(Xt-\bar{X}\,)(Yt-\bar{Y}\,)]}{SxSy} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.5)}$$

Where SY and SX are the sample biased standard deviations. The higher the square value of R_{xy} indicates the best fit of the regression equation. Thus based on this for this estimation different R values are calculated and the best fit selected for each station. Based on this method all stations were filled and the regression equations with basic parameters are shown in the table below.

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Table3. 4 Regression equations for meteorological stations missed data filling

Station	R2	Coefficient a	Coefficient b	Regression equation
Tepi	0.67	1.428	3.139	Y=1.428(Aman)+3.139
Aman	0.72	1.417	0.622	Y=1.417(Tepi)+0.622
Tnishu Meti	0.81	1.336	0.739	Y=1.336(Tepi)+0.739

b) Local Climate Estimator Model

A new model used to estimate and fill missing data is Local climate estimator model (New Local Clim_1.10). This model is a very simple and reduced time to estimate and fill missing data by considering the nearest area which has a known gauge station within the station with missed data by producing a linear correlation between the stations (Boke, 2017). Among the techniques the model used to fill the missed data, the following methods are very essential for developing country like Ethiopia which has no enough meteorological stations. These techniques are: Nearest Neighbor (NN), Inverse Distance Weighing Average (IDWA), Modified Inverse Distance Weighing Average (MIDWA) and Kriging Method (KM) methods. From these different techniques modified Inverse Distance Weighing Average method was used to fill the missed data for this study.

Modified Inverse Distance Weighing Average (MIDWA)

This method is used to fill missed data using the climate estimator model (New Local Clim_1.10). During this method stations 200km round the study area station (Tepi station) are considered by introducing the effect of elevations difference. One factor that affects the estimated value is elevation difference between the stations if the station difference is large(Boke, 2017). The missing value of meteorological variables (Precipitation, maximum and minimum temperature, wind speed and sunshine hour) at the points of in by an interest is done by a linear combination of the ratio of distance to elevation difference of measured variables at surrounding stations as inverse function of the distance of point of interest from surrounding meteorological stations.

$$\mu i = \frac{(\frac{di}{\Delta Hi})^p}{\sum_{i=1}^{n}(\frac{di}{\Delta Hi})^p} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.6)$$

Where:

Di = distance between surrounding station and station where the variable is missing

n = is the number of surrounding stations where the corresponding variable has measured value

P = is the power (influential parameter on IDWA factor and commonly 2)

ΔHi = the elevation difference between the base station and the surrounding stations.

μi = weighting factor assigned to each of the stations based on the ratio (di/ΔHi).

From the technique described above the result of R^2 obtained by Modified Inverse Distance Weighing Average (MIDWA) shows a good relation with the station. Therefore for this study missed data was filled by using the technique of MIDWA and the final adjusted daily data by this method was used for daily SWAT model run.

Table3. 5 Meteorological stations missed data filling using MIDWA method

Station	R2	Coefficient a	Coefficient b	Regression equation
Tepi	0.89	0.795	0.457	Y=0.795(Aman) + 0.457
Aman	0.87	0.635	1.378	Y=0.635(Tepi) +1.378
Tnishu Meti	0.91	0.477	1.283	Y=0.477(Tepi) +1.283

3.3.2 Checking consistency and Homogeneity

Homogeneity analysis is used to identify a change in the statistical property of the time series data which is caused by either natural or man-made. These include alteration to include and relocation of the observe station. The homogeneity test of the may be classified in to the two group as absolute method and relative method. The first test applied to each situation separately and second method the neighboring (reference station are used in testing).The recommended method to apply homogeneity has been tested with respect to neighboring station.

$$Pi = \frac{\overline{Pi}}{\overline{P}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.7)$$

Where P_i= non dimensional value of precipitation for i month. $\overline{Pi}$= over the year monthly precipitation for I month. $\overline{P}$= the year average year precipitation of the station.

A time series observational data is relatively consistent and homogenous if the periodic data proportionally behaves in a similar pattern. This proportionality is tested by double-mass curve analysis. The principle of double mass curve analysis is to plot accumulated values of the station under investigation against accumulated values of another station, or accumulated values of the average of other stations, over the same period. Through the double mass curve, in homogeneities in the time series (in particular jumps) can be investigated. These indicate in double mass plot showing an inflection point in the straight line. The data series, which is in consistent, adjusted to consistent values by proportionality.

The double mass curve: the accumulated totals of the gauge were compared with corresponding totals for a presenting group nearly gauge, it should be corrected as

$$P'_x = P_x X \frac{M'}{M} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.8)$$

Where P'_x = corrected precipitation at station X, P_x = original record precipitation at station X, M'= corrected slope of double mass curve and M =original slope of double mass curve.

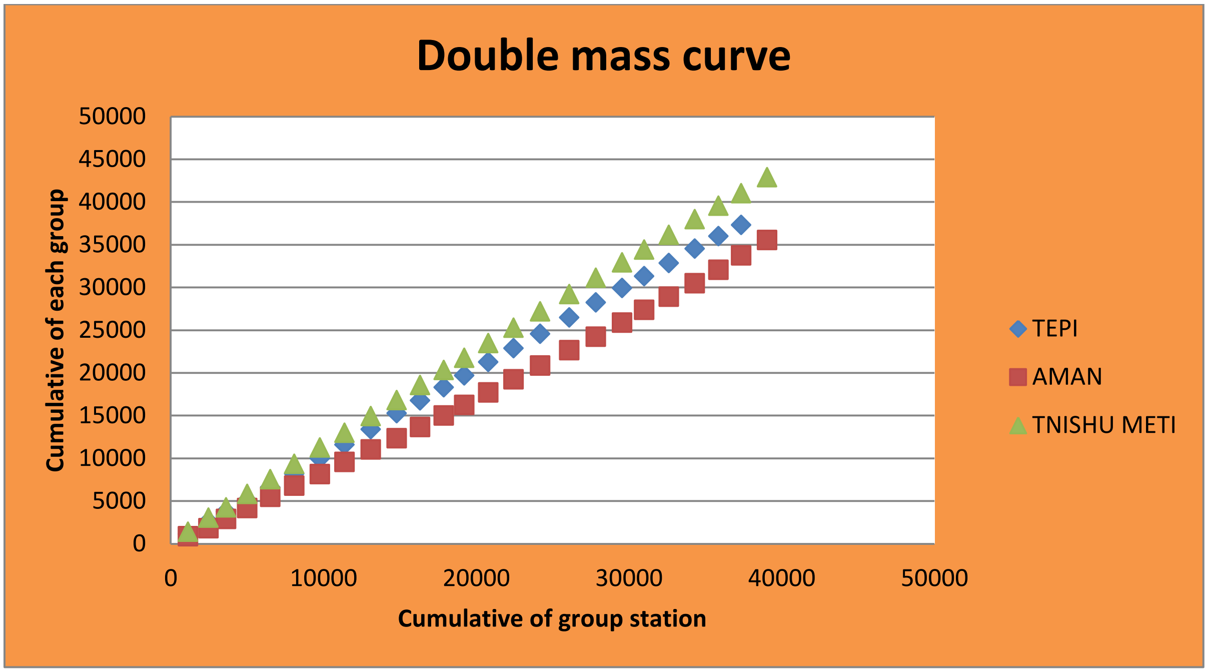


Figure 3. 8 Double mass curve of the stations

Double mass method helped in determining the best realistic correlation of stations located near watershed. The double mass curves shown in Figure 3.8 indicates that all these stations were found to be consistent for the period of 1990 to 2013 and the correlation coefficient of annual commutative rainfall in each station with average annual commutative rainfall value is respected in Table. 3.4

Materials

The main materials used for model input data preparation, analysis were:

ArcGIS version10.3 Soft ware

Arc SWAT (2012) Model

Microsoft Excel (2010)

SWAT-CUP (2012) Version 5.16 Model

New_LocClim1.10 (Local Climate Estimator version 1.10)

3.4 Methods

3.4.1 Description of SWAT model

Soil and water Assessment Tool (SWAT) will apply in the Upper Gilo watershed to assess the impacts of land use and land cover changes on hydrological components. The SWAT watershed model is one of the most recent models developed by the USDA-ARS to predict the impacts of land management practices on water, sediment and agricultural chemicals yield in watersheds with varying soils, land use and management practices over long periods of time(Neitsch *et al*., 2005).

One of the main advantages of SWAT is that it can be used to model watersheds with less monitoring data. For simulation, SWAT needs digital elevation model; land use and land cover map, soil data and climate data of the study area. These data are used as an input for the analysis of hydrological simulation of surface runoff and groundwater recharge.

Water balance is the driving force behind everything that happens in the watershed. As simulated by the model, the hydrologic cycle must conform to what is happening in the watershed to accurately predict movement of sediment.

The hydrologic cycle is simulated by SWAT based on the following water balance equation(Arnold *et al*., 1998).

$$SW\mathrm{t} = SWo + \sum_{i=1}^{t}(Rday - Qsurf - Ea - Wsweep - Qgw) \quad \ldots\ldots\ldots\ldots\ldots (3.9)$$

Where:

- t is the time in days
- SW_t is the soil water content at time t (mm)
- SW_o is the initial soil water content i (mm)
- R_{day} is amount of surface runoff 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)
- E_{sweep} is the amount of water entering the Mejang zone from the soil profile on day i (mm)
- Q_{gw} is the amount of return flow on day i (mm)

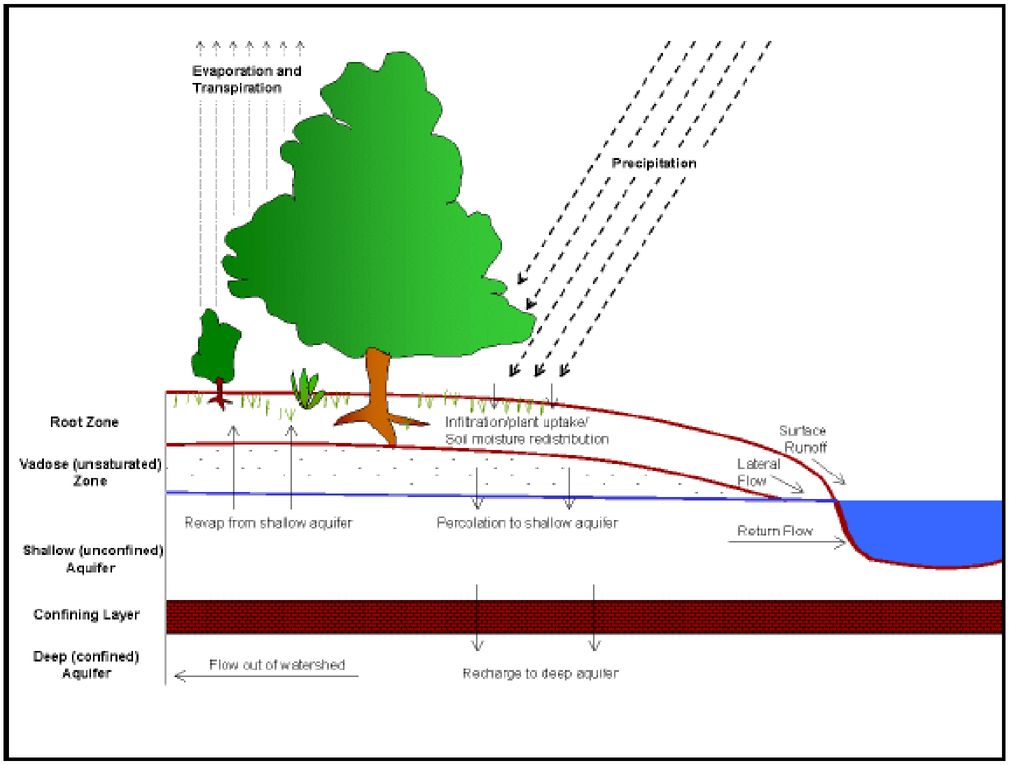


Figure 3. 9 Hydrological cycle considered by SWAT model

The SWAT model requires daily meteorological data that either could be read from a measured data set or generated by a weather generator model which include daily precipitation, maximum and minimum air temperature, solar radiation, wind speed and relative humidity. Those data were collected from National Meteorological Service Agency (NMSA).

These were used and for the stations which have no data like solar radiation, wind speed and relative humidity, different monthly parameters were estimated using PCPSTAT and Dew point estimation program and sunshine hours was converted in to solar radiation energy (MJ/m^2-day) using sunshine hour to radiation conversion tool which created by Eric White, (2008) using the Angstrom-Prescott Equation.

Hydrological data were the principal data set in the research work. Other sets of data were all collected depending on the availability and suitability of the data from the hydrological stations. Four continuous water level recording stations were obtained from the Ministry of Water, Irrigation, and Electricity (MWIE). The daily recorded of hydrological data was requested for twenty-five year for the research work. Conceptual framework of each step during the study can be summarized as follow.

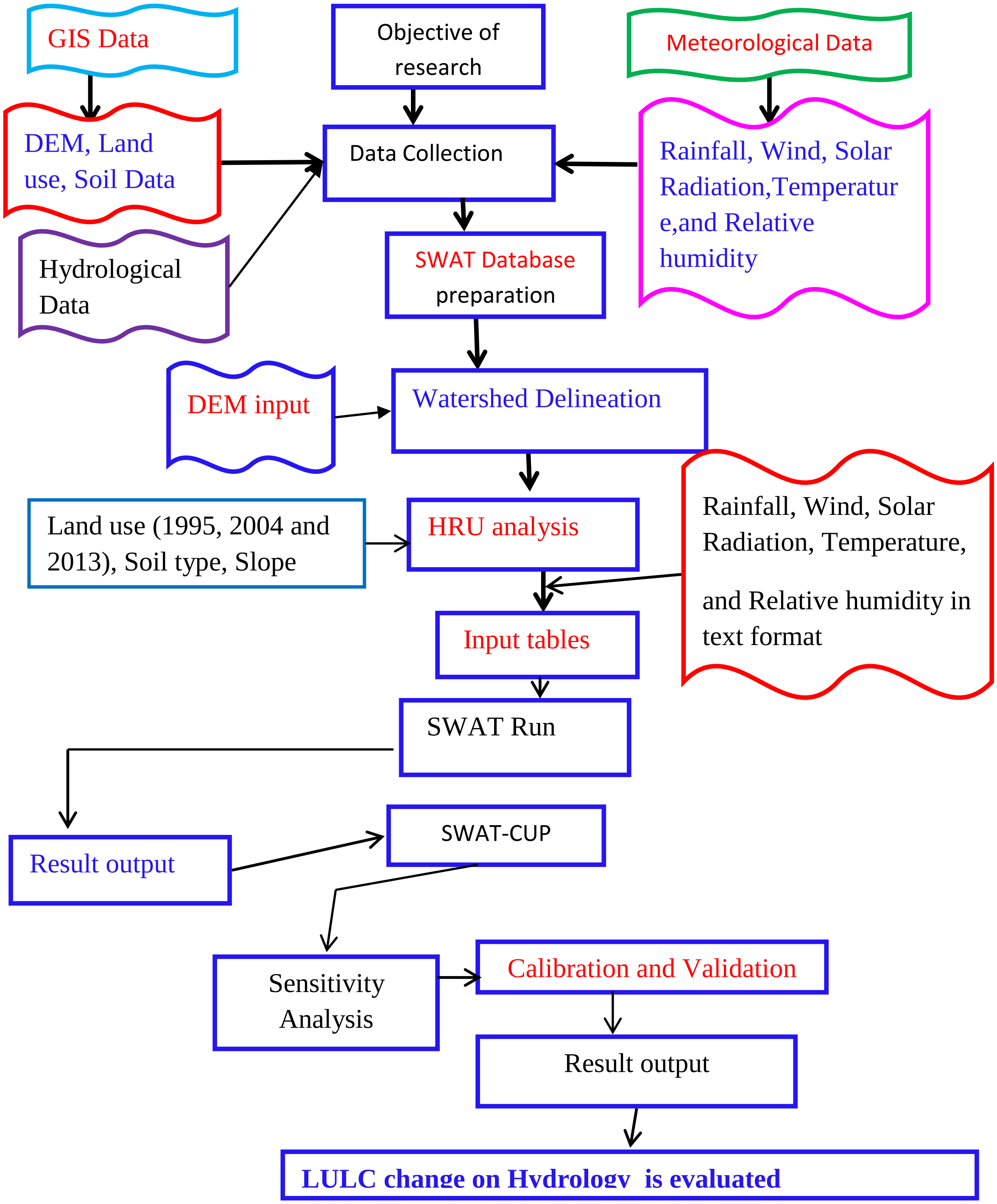


Figure 3. 10 Flow chart of ArcGIS processing step

3.4.2 Watershed Delineation

The first step in creating SWAT model input is delineation of the watershed from a DEM. Inputs entered in to the SWAT model where organized to have spatial characteristics. Before going in hand with spatial input data (i.e. the soil, LULC map and DEM) were projected in to the same projection called UTM Zone 37N, which projection parameters for Ethiopia. A watershed was partitioned in to a number of sub-basins, for modeling purposes. 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 was used to define the minimum size of the sub-basins.

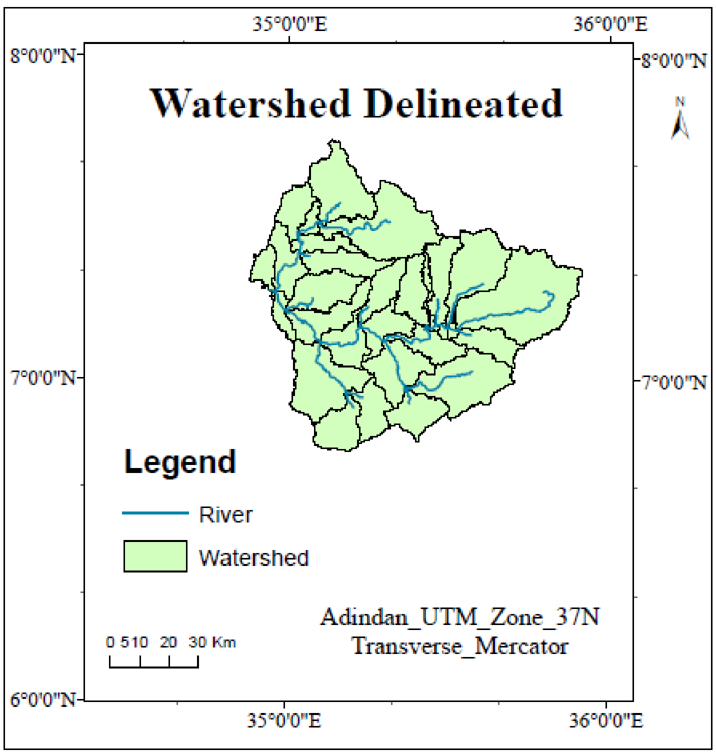


Figure 3. 11 Delineated Upper Gilo Watershed

3.4.3 Digital Elevation Model (DEM)

Digital Elevation Model (DEM) data is required to calculate the flow accumulation, stream networks, and watershed delineation using ArcSWAT watershed delineator tools. The DEM 30*30 obtained from Ministry of Water, Irrigation and Electricity was used to delineate and processed according to the location of the study area. This data was projected to Transverse Mercator (UTM) on adenine of WGS1984 and it was in raster format to fit in to the model requirement (Fig. 12). The DEM was used to delineate the watershed and to analyze the drainage patterns of the land surface. Therefore, watershed characteristics of BEKO River were basically delineated and standardized on the direction of pour point. That is topographic characterization of the watershed and determines the hydrological parameters such as, flow accumulation, direction, and stream network.

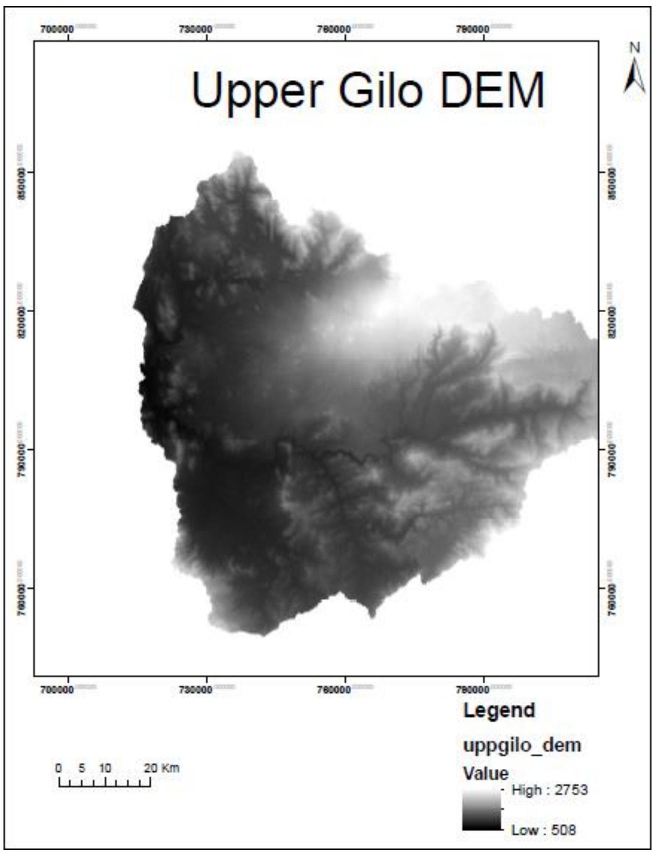


Figure 3. 12 Digital Elevation of Upper Gilo Watershed

3.4.4 Land use/Land cover and Soils

The soil and land use data is one of the major input data for the SWAT model with inclusive and chemical properties obtained from Ministry of Water, Irrigation, and Electricity was used to clip soil and land use grid of the study area. According to FAO/UNESCO-ISRIC classification major soil groups were identified in the Upper Gilo Catchment. 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 (up to 4 layers) of each soil type. These data were obtained from MoWIE.

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.

Land use is one of highly influencing hydrological properties of the watershed. It is one of the main input data for SWAT model to describe the Hydrological Response Units (HRUs) of the watershed. All weather data, soil data and land use/land cover data are the most important ones for the setup of the SWAT model and for the simulation of the hydrological components. Observed flow data at the main watershed and sub-basin outlets are used for the calibration and validation of the model.

The SWAT model has predefined four letter codes for each land use category (Table 3.6). 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.

Table3. 6 Land use/land cover classification as per SWAT model

Land use / Land cover	Land use according to SWAT database	SWAT code
Crop land	Agricultural land close to grown	AGRC
Forest	Forest ever Green	FRSG
Shrub land	Forest Mixed	FRST
Grass land	Range Grass	RNGE
Settlement	Residential-low density	URSD
Bare land	Barren	BARR
Swampy area	Water	WATR

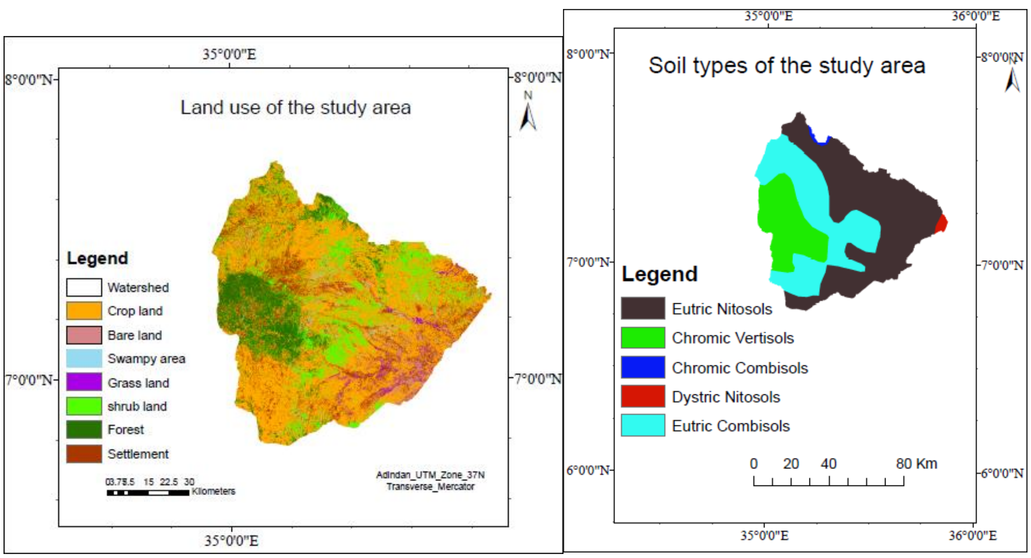


Figure 3. 13 Soil types and Land cover of the study area

3.4.5 Sub-basin discretization

In the standard SWAT sub-basin, discretization was made based on the slope, soil and land use percentage thresholds. Sub-basins are divided in to hydrologic response units (HRUs). An HRU is the smallest unit in SWAT defined based on a unique combination of slope, soil type and land use (Easton, 2008).

Using the SWAT Model, Upper Gilo watershed was divided in to 31 sub-basin and 136 HRU determined by unique inter selection of the LULC, slope and soil within the watershed.

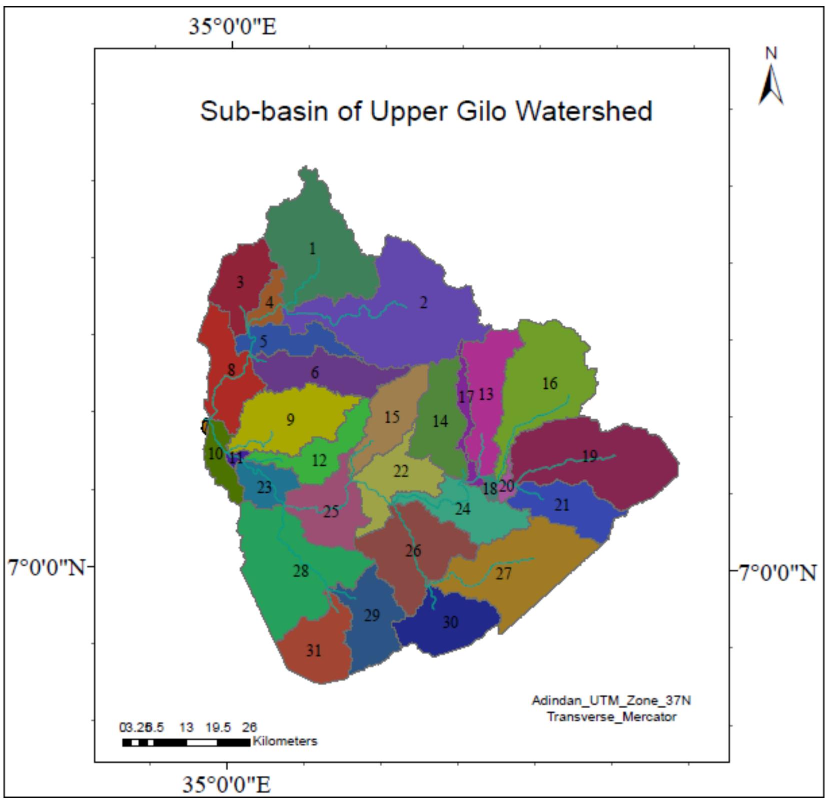


Figure 3. 14 Delineation of Upper Gilo watershed

3.4.6 Determination of Hydrologic Response Units (HRUs)

The sub-basin delineation was followed by the determination of HRUs, which are unique soil, land use combinations within a sub-basin modeled regardless of their spatial positioning. This describes better the hydrologic water balance and increases the accuracy of load predictions.

ArcSWAT predicts the land phases of the hydrologic cycle separately for each HRU and routes to obtain the total loading of the sub watershed.

ArcSWAT requires land cover and soil data accompanied by look-up table with attribute information for each specific land cover and soil type, and provides these tables for each layer. The last layer needed for the HRU Analysis setup is slope which is determined from the DEM supplied during watershed delineation. This method was adopted as it better describes the heterogeneity within the watershed and as it accurately simulates the hydrologic process.

3.4.6 Weather Generator

The SWAT model has an automatic weather data generator. However, it needs some input data to run the model. The model can be run if the following data are available. Daily precipitation, maximum and minimum daily temperature, sunshine hour, daily relative humidity and wind run data. If no data are available at the sometime for all stations, the model can generate all the remaining data from daily precipitation and temperature data. For this purpose the model needs some main stations with full data and from that it can generate for the remaining stations. In this research, one station (Tepi station) with full data was used to generate the missed data for the other stations and used to run the model. The model needs maximum and minimum temperature, Dew point data, precipitation data, average solar radiation data, average wind run data and standard deviation for temperature as input data for the remain stations. The available data of sunshine hour was converted to solar radiation by using Angstrom empirical equation as mentioned in methodology section. Then loading this WGEN parameter and location table was the last step for weather generator data.

3.4.7 Land Use Land Cover Classification

Rapid population growth, the need to increased food production and basic energy demand has initiated spontaneous land use change phenomena in upper Gilo watershed. Conversion of natural landscapes for agricultural and urban uses often impact soil integrity, nutrient fluxes and native species assemblages. Such changes can affect watershed hydrological behavior by altering the rates of interception, infiltration, evapotranspiration, and ground water recharge that result in changes to the timing and amounts of surface and river runoff. The present study deals with the status and trends of land use and land cover dynamics of Upper Gilo watershed. For the land cover information and trend of land cover change classified image of 1995, 2004 and 2013 was taken from Ethiopian Map Agency. The images which obtained from EMA were geo-referenced and geometrically rectified, image clipping was performed. This pre-process was performed using spatial analyst tool on a sub-scene from the full image on the basis of a frame covering of the watershed. These preprocessing tasks allowed exporting the satellite images to the ERDAS Imagine for classification and extracting land cover information In this study, totally seven different types of land use and land cover have been identified for the Upper Gilo watershed description as presented below.

Vegetation: land covered with dense trees which includes ever green forest land, mixed forest and plantation forest.

Crop land: areas used for crop cultivation, both annuals and perennials, and the scattered rural settlements that are closely associated with the cultivated fields in the upstream of the watershed.

Shrub lands: Areas with shrubs, bushes and small trees, with little wood, mixed with some grasses.

Bare lands: land of limited ability to support life in which less than one-third of the area has vegetation or other cover. It is an area of thin soil, sand or rocks and the areal coverage of available vegetation is much less than that of range land.

Settlement: Refers to people living in rural areas and calculated as the difference between total population and urban population.

Swampy Area: Areas which are water logged and swampy throughout the year, the rivers and its main tributaries.

Grass land: Areas covered with grasses used for grazing, as well as bare lands that have little grass or no grass cover. It also includes other small seized plant species.

Accuracy assessment

Accuracy assessment is an important step in the image classification process. The objective of this process is to quantitatively determine how effectively pixels were grouped in to the correct feature classes in the area under investigation. It is a process used to estimate the accuracy of image classification by comparing the classified map with a reference map. The most widely used classification accuracy is in the form of error matrix which can be used to derive a series of descriptive and analytical statistic (Manandhar, 2009). The columns of the matrix depict the number of pixels per class for the reference data, and the rows show the number of pixels per class for the classified image. In this study, the accuracy assessment which was done by EMA has a total of 131, 139 and 136 testing sample points for the year 1995, 2004 and 2013 respectively as showed in appendix E

Overall accuracy

The overall accuracy gives the overall results of the confusion matrix. It is calculated by dividing the total number of correct pixels (diagonals) by the total number of pixels in the confusion matrix. The results of the overall accuracy done by EMA for the maps of 1995, 2004 and 2013 were 85%, 87% and 86% respectively. According to (Anderson, 1976) the minimum accuracy value for reliable land cover classification is 85 %. The other authors (Bedru, 2006) explains that the expected accuracy is determined by the users themselves depending on the type of application the map product will be used later. Accuracy levels are accepted by users may not acceptable by other users for certain task (Bedru, 2006). Therefore, based on appendix E, the classification carried out in this study produces an overall accuracy that fulfills the minimum accuracy level defined by Anderson for three land cover maps of Upper Gilo watershed. Since the overall accuracy done by EMA fulfills the minimum requirement; the classified land used was used for this study.

3.4.8 Sensitivity Analysis

Sensitivity analysis is the process of identifying the model parameters that exert the highest influence on model calibration or on model predictions. Sensitivity analysis describes how the change in model output varies over a range change in parameter input variable. The aim of sensitivity analysis is to estimate the rate of change in the out of a model with respect to changes in model input. Therefore sensitivity analysis as an instrument for the assessment of the input parameters with respect to their impact on model output is useful not only for model development, but also for model validation and reduction of uncertainty(Kassa, 2009). The sensitivity analysis was performed on 27 SWAT parameters for the measured daily river flow at Beko River from the year 1990 to 2014 and the first three year are warm-up period. The most sensitive parameters were identified using Global sensitivity analysis method in SWAT-CUP SUFI2. SWAT-CUP is a public domain computer program for calibration of SWAT models. A t-stat provides a measure of sensitivity (larger in absolute value are more sensitive), whereas p-values the significance of the sensitivity, a value close to zero is more significant (Abbaspour, *et.al.*, 2015).

A *t*-test and p-values

The t-stat is the coefficient of a parameter divided by its standard error. It is a measure of the precision with which the regression coefficient is measured. If a coefficient is "large" compared to its standard error, then it is probably different from 0 and the parameter is sensitive.

The p-value for each term tests the null hypothesis that the coefficient is equal to zero (no effect). A low p-value(< 0.05) indicates that you can reject the null hypothesis. In other words, a predictor that has a low p-value is likely to be a meaningful addition to your model because changes in the predictor's value are related to changes in the response variable. Conversely, a larger p-value suggests that changes in the predictor are not associated with changes in the response. So that parameter is not very sensitive. A p-valueof < 0.05 is the generally accepted point at which to reject the null hypothesis (i.e., the coefficient of that parameter is different from 0).Finally, twelve most sensitive parameters were selected for calibration and validation processes.

3.4.9 Model Calibration and Validation

SWAT-CUP (calibration and Uncertainty Programs) was used for calibration and uncertainty analysis on stream flow parameters. SUFI-2 algorithm was used in this analysis for the calibration of the of stream flow for monthly SWAT run. The total available monthly discharges at the gauge station was from 1990 – 2014 year simulation period, however, the data were split into a calibration period of 1993-2006 and a validation period of 2007-2014.The first three years are considered for initializing (warm up) the model, using the daily stream flow observation data from gauging stations with in the study area. In this analysis the physically meaningful parameter identifiers were chosen and the initial ranges were assigned to each flow parameter from the SWAT outputs (Tadesse, 2015).

Using the calibrated SWAT run for 1993-2006, the model was validated for flow by running again for 2007-2014 as validation period. The observed stream flow data for 2007-2014 time periods were compared with that of the simulated stream flow values from the validation run. The validation was carried out using the R^2 and NSE coefficient.

3.4.10 Model Performance Indicators

The accuracy, consistence and adaptability performance of the model must be evaluated (Goswami M.O'Connor, 2005). Subjective and /or objective estimate of the closeness of simulated behavior of the model to observation is required to assess the performance of the model. The goodness of fit measures used to evaluate the models predictions included both the Nash-Sutcliffe (NSE) value and the coefficient of determination (R^2) value. The R^2 value is an indicator of the strength of the relationship between the observed and simulated values and ranges from 0 to 1. Nash-Sutcliffe coefficient measures the efficiency of the model by relating the goodness of fit of the model to the variance of the measured data. If R^2 and NSE values are close to zero, the model is considered "un acceptable or poor". However, if the values are 1.0 then the model is considered "perfect" (Wubishet T. *et al.*, 2015). Answer values of 0.5 or higher was considered an acceptable level of accuracy for this simulation based on a synthesis of existing peer-reviewed SWAT literature.

Determination coefficient for n time step is calculated as:

$$R2 = \frac{[\sum_{i=1}^{n}(\mathrm{Qsi}-\mathrm{Qs})(\mathrm{Qoi}-\mathrm{Qo})]2}{\sum_{i=1}^{n}(Qsi-Qs)2\sum_{i=1}^{n}(Qoi-Qo)2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eq. 3.10)}$$

$$NSE = \frac{\sum_{i=1}^{n}(Qoi-Qsi)2}{\sum_{i=1}^{n}(Qoi-Qo)2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eq. 3.11)}$$

Where:

Q_{si} – is the simulated value, Q_{oi}- is the value, Q_s - is the average simulated value and Q_o– is the average measured value.

4. RESULTS AND DISCUSSIONS

4.1 Calibration, Validation and Evaluation of SWAT performance

4.1.1 Parameter Sensitivity Analysis

Twenty seven parameters were used for the sensitivity analysis of the study area. Sensitivity analysis was performed on flow parameters of SWAT on monthly time steps with observed data of Beko River gauge station. The most sensitive parameters were identified using Global sensitivity analysis method in SWAT-CUP SUFI2.After set-up the SWAT-CUP model and connect with SWAT-2012 model and incorporating all input parameters simulations were carried out and sensitivity analysis was run for the period 1990- 2014 (the first three years are considered for initializing (warm up) the model) and the most sensitive parameters were selected as shown in table 4.1 below.

Table4. 1 The most sensitive Parameters in the study area

Rank	Flow Parameters	Upper and Lower Bond	Fitted value	Description
1	CN2	±25	0.17	SCS runoff curve number (%)
2	GWQMN	0 - 2	1.394	Threshold depth of water in shallow Aquifer
3	ESCO	08 - 1	0.955	Soil evaporation compensation factor
4	CH_K2	5 - 130	107	Effective hydraulic conductivity in main channel alluvium
5	ALPHA_BF	0 - 1	0.947	Base flow alpha factor(days)
6	SOL_Z	0 - 300	0.93	Total soil depth (mm)
7	GW_DELAY	30 - 450	31.26	Shallow aquifer required for return flow to occur (H2O mm)
8	GW_REVAP	0 – 0.2	0.109	Ground water revap coefficient
9	SOL_AWC	-0.2-0.4	0.714	Soil available water capacity (water/mm soil)
10	CH_N2	0-0.3	0.191	Manning's "n" value for the main channel
11	SOL_K	-0.8 – 0.8	0.36	Saturated hydraulic conductivity
12	SURLAG	0 - 12	0.08	Surface Lag

Table4. 2 Sensitivity parameter values using LULC of 2013

Parameter Name	t-Stat	P-Value
13:R__BLAI.mgt	0.00	0.95
18:R_SLSUBBSN.hru	0.00	0.94
4:R__EPCO.bsn	0.00	0.92
9:V__RCHRG_D.gw	0.00	0.91
1:R__LAT_TTIME.hru	0.00	0.74
16:R__HRU_SLP.hru	0.00	0.72
6:R__CANMX.hru	0.02	0.55
25:R__SOL_BD(..).sol	-0.03	0.53
8:R__REVAPMN.gw	0.04	0.51
5:R__AUTO_EFF{..}.mgt	-0.05	0.50
26:V__GW_SPYLD..bsn	-0.07	0.42
14:R__ BIOMIX.bsn	-0.09	0.41
15:R_OV_N.hru	-0.11	0.40
15:R__SLOPE.bsn	-0.13	0.39
22:V__ALPHA_BNK.rte	0.16	0.31
11:R__SURLAG.bsn	0.18	0.30
24:R__SOL_K(..).sol	0.37	0.26
17:V_CH_N2.rte	0.63	0.25
23:R__SOL_AWC(..).sol	0.81	0.23
10:V__GW_REVAP.gw	-1.05	0.20
7:V__GW_DELAY.gw	1.49	0.18
12:R__SOL_Z(..).sol	-1.73	0.06
3:V__ALPHA_BF.gw	-1.50	0.05
21:V__CH_K2.rte	-1.98	0.04
19:V__ESCO.hru	2.25	0.03
27:V__GWQMN.gw	-3.48	0.01
2:R__CN2.mgt	3.72	0.00

Based on A t-test that was used to identify the relative significance of each parameter that was a value larger in absolute value was most significant and p-value the significance of the sensitivity, a value close to zero (<0.05) is more significant. From the model output, the first five most sensitive parameters are SCS runoff curve number f actor (CN2), Threshold depth of water in shallow Aquifer (GWQMN), Soil evaporation compensation factor (ESCO), Effective hydraulic conductivity in main channel alluvium (CH_K2) and Base flow alpha factor(days) (ALPA_BF) rank 1 to 5. The other parameters Total soil depth (mm) (SOL_Z), Shallow aquifer required for return flow to occur (H2O mm) (GW_DELAY),Ground water Revap coefficient (GW_REVAP), Soil available water capacity (SOL_AWC), Manning's roughness coefficient (CH_N2), Saturated hydraulic conductivity (SOL_K2) and surface lag (SURLG) are identified as slightly important parameters that were rank 6 to 12 respectively.

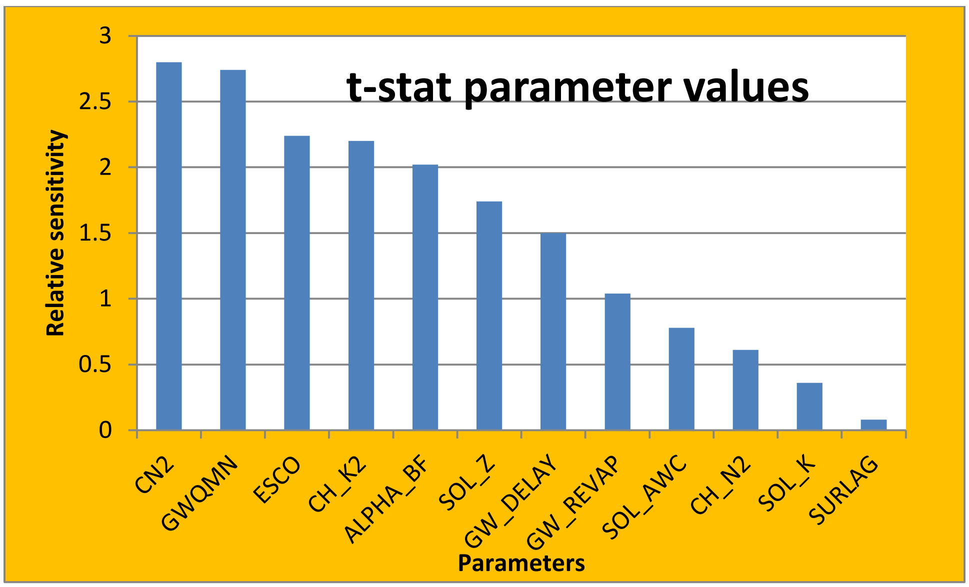


Figure 4. 1 Rank of sensitivity parameters in Upper Gilo WatershedFigure

4.1.2 Calibration and Validation Analysis

4.1.2.1 Calibration analysis:

The observed stream flow data of Beko River from 1990 to 2014 were used for calibration and validation of SWAT model. The SWAT model was calibrated for 1993-2006 and three years are considered for initializing (warm up) the model, using the daily stream flow observation data from gauging stations with in the study area. Twelve (12) parameters were selected for the calibrations which are associated with runoff (CN2), ground water (ALPHA_BF and GW_DELAY), soil (SOL_AWC), channel (CH_N2 and CH_K2), and evaporation (ESCO) processes.

The result of calibration performed (1993-2006), for monthly flow showed that there is a good agreement between the measured and simulated average monthly flows with Nash-Sutliffe simulation efficiency (ENS) of 0.77 and coefficient of determination (R2) of 0.88 as showed in Figure4.2 and table 4.3

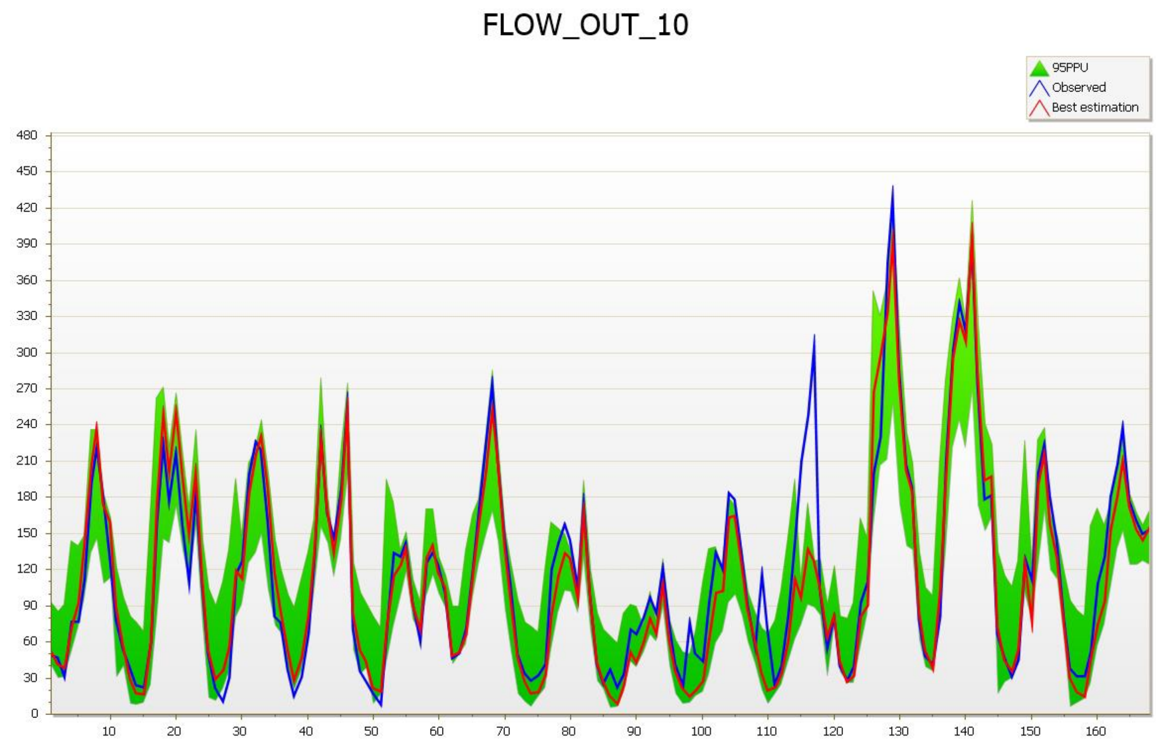


Figure 4. 2 Average Monthly observed and simulated stream flow during Calibration (1993-2006)

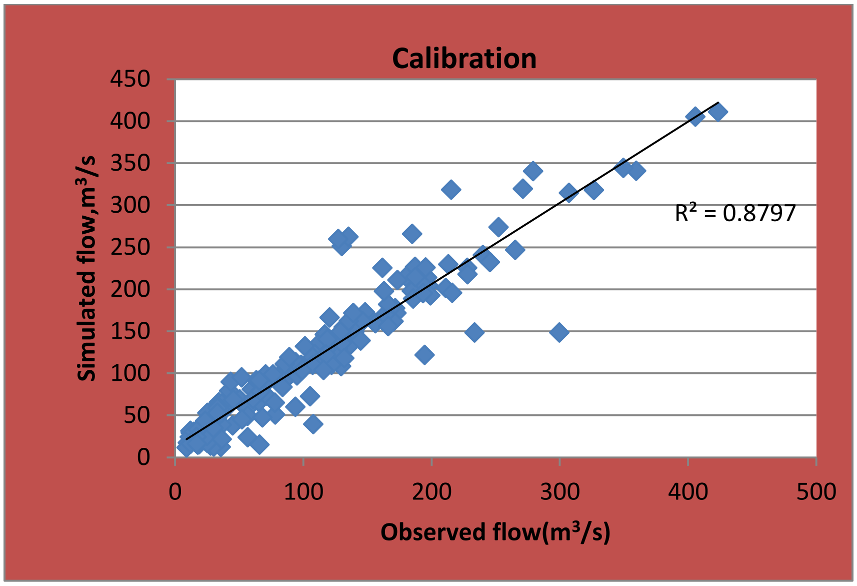


Figure 4. 3 Scatter plot of observed and simulated flow during Calibration

Table4. 3 Summarized result of calibration and validation

Results	Mean Observed		Mean Simulated	NSE	R^2
Calibration result of (1993-2006) land use land cover	1995	121.78	115.72	0.88	0.90
	2004	101.15	129.42	0.72	0.88
	2013	120.09	101.15	0.77	0.88
Validation result of (2007-2014) land use land cover	1995	88.1	107.53	0.79	0.87
	2004	88.10	118.31	0.63	0.87
	2013	109.29	86.92	0.61	0.82

4.1.2.2 Validation Analysis

Validation is evaluation of the model outputs with an independent data set without making further adjustments. The process is to confirm that the simulation is good enough that the validation was carried out using the calibrated parameters. The model validation also performed for 8 years from 2007 to 2014 and the simulation also showed good agreement between the simulated and measured monthly flow with the NSE value 0.61 and coefficient of determinant (R^2) value 0.82. The Figure 4.4 and table 4.3 show that the model performance assessment indicated a good correlation and agreement between the monthly observed and simulated flow.

The scatter plot value of the measured and simulated flow has also shown a fair linear correlation between the data set.

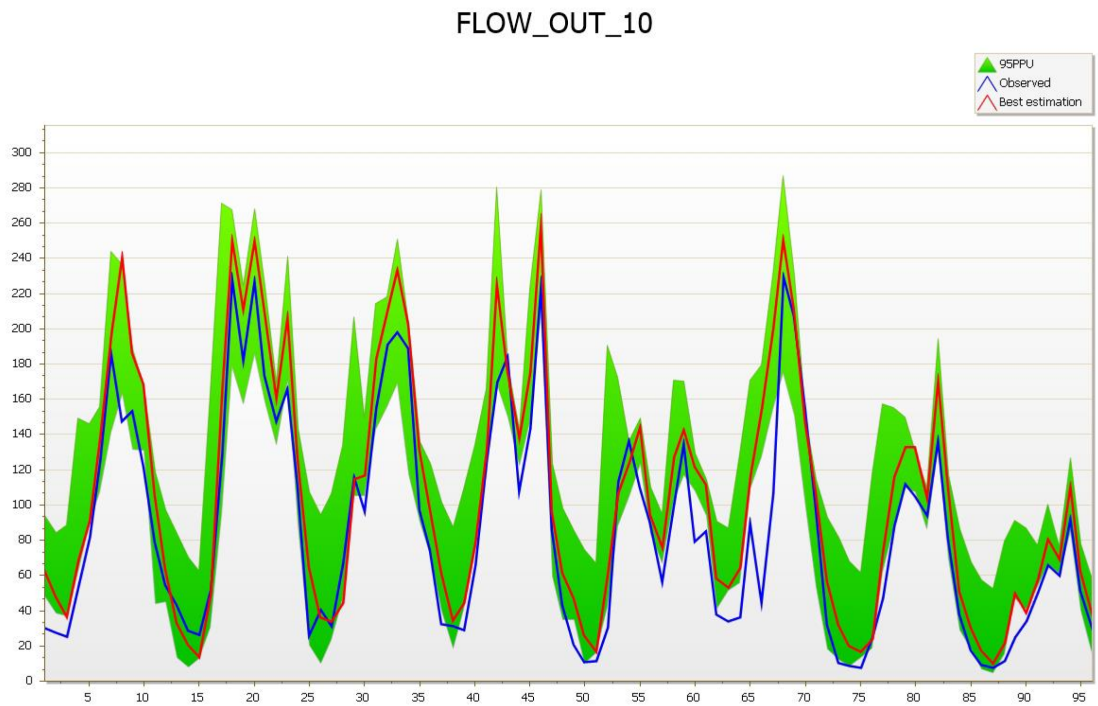


Figure 4. 4 Average monthly observed and simulated flow during Validation

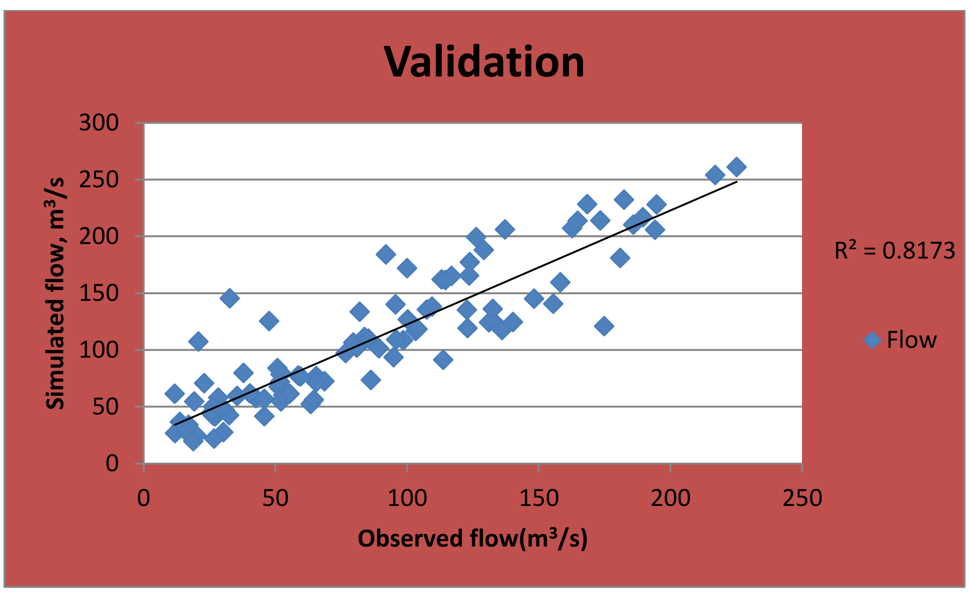


Figure 4. 5 Scatter plot of observed and simulated flow during Validation

4.2 Impacts of LULC Change on the hydrological process

4.2.1 Land use and land cover Detection

Land use/Land cover supervised classification maps of the study area for three reference years such as 1995, 2004 and 2013 were obtained from Ethiopian Map Agency and that reflect land cover for the given period. The overall land use/cover changes at watershed level are summarized in the table 4.4 below. Most significant changes were observed in the following land used classes, Agriculture, Forest, Settlement, Shrub land and Grass lands. Agricultural and settlement areas continually increased for all the years under review. Agricultural/crop land covered 43.36% in 1995, increased to 51.74% in 2004 and extent to 63.7 in 2013. This could be attributed to increase in population that has increased the demand for agriculture and built up land in the sub-catchment. The Settlement areas increased from 5.17% in 1995 to 10.22% in 2004 and 13.28% in 2013. Unlike Agriculture and Settlement areas, the Forest land continually decreased from 22.92% in 1995 to 17.24% in 2004 and to 11.87% in 2013. Similarly the shrub land decreased from 20% in 1995 to 14.66% in 2004 and decreased to 6.45% in 2013. This declination making the land use type to have received the most significant reduction for the period under study. On the other hand the Grass land decreased from 6.2% in 1995 to 3.13% in 2004 and decreased to 1.47% in 2013. This fluctuation is due to the conversion of shrub land to grass land and then to agricultural lands.

Table4. 4 Statistical summary of land use classification maps of 1995, 2004 and

SNO	**Land cover Name**	**Area (1995)**		**Area (2004)**		**Area (2013)**	
		Km^2	**%**	**Km^2**	**%**	**Km^2**	**%**
1	Forest	1539	22.92	1158.63	17.24	796.77	11.87
2	Crop land	2911.2	43.36	3473.82	51.74	4276.82	63.7
3	Shrub land	1343.5	20.01	984.27	14.66	433.05	6.45
4	Grass land	417	6.21	210.15	3.13	98.59	1.47
5	Settlement	347	5.17	684.82	10.22	891.62	13.28
6	Bare land	82.58	1.23	134.95	2.01	170.59	2.55
7	Swampy (water)	73.85	1.1	65.79	0.98	44.98	0.67

Table4. 5Percentage of Annual rate of change land cover

Class -Name	Annual rate of change (2004-1995) (%) 1st 9 years	Annual rate of change (2013-2004) (%) 2nd 9 years	Annual rate of change (2013-1995) (%) 18 years
Crop land	0.754	1.076	3.661
Forest	-0.511	-0.483	-1.989
Settlement	0.454	0.275	1.46
Grass land	-0.277	-0.149	-0.853
Shrub land	-0.481	-0.739	-2.441
Bare land	0.07	0.048	0.237
Swampy area	-0.011	-0.028	-0.077

Annual rate of change = %of change*9/100

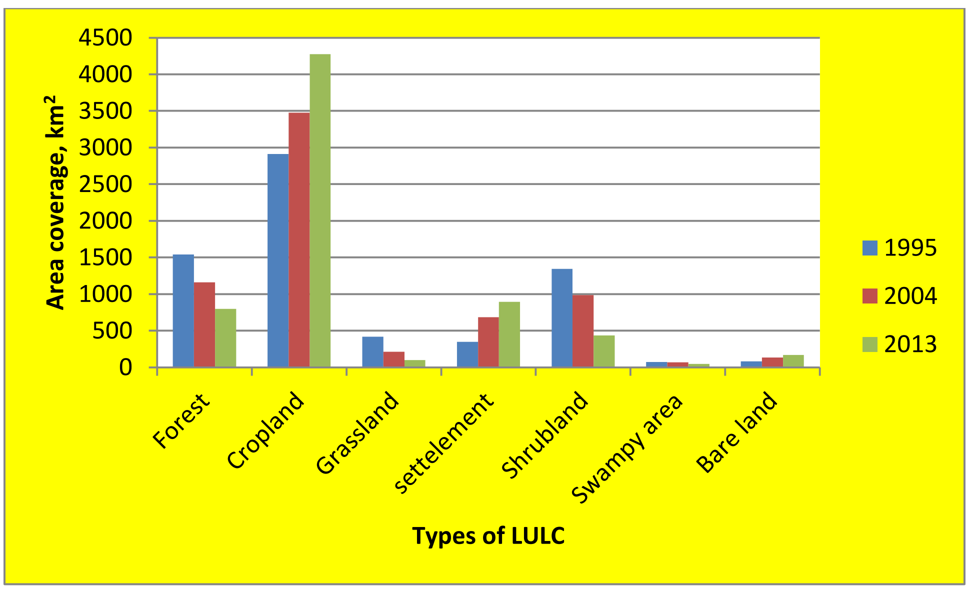


Figure 4. 6 Land use/Land covers Dynamics in Upper Gilo watershed

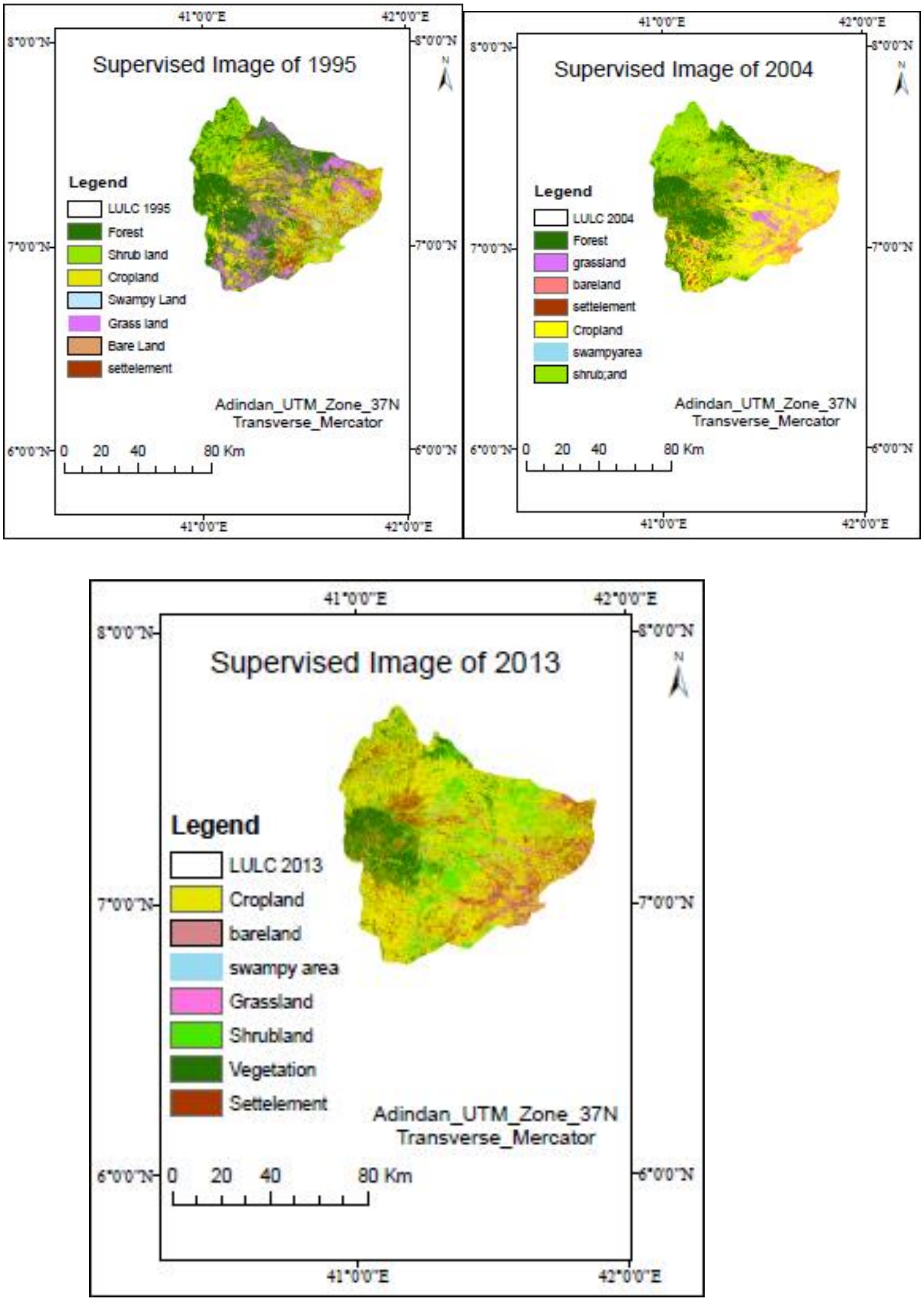


Figure 4. 7 Land use/Land cover map of 1995, 2004 and 2013

4.1.3 Hydrological Responses to land cover change

The hydrological impacts of land use have received a considerable amount of interest in hydrology. LULC is an important characteristic in the runoff process that affects infiltration, erosion, and evapotranspiration. Understanding of the effects of historical land use changes on river flow is required to understand the future effects of land use and land cover on stream flow of watershed level. Among with these changes, considerable consequences are expected in the hydrological cycles and subsequent effects on water resources (Githu, 2009)

The calibrated SWAT model was used to simulate the impact of LULC change on the hydrological responses of the Upper Gilo sub-basin considering three different land use scenarios. The analysis of the LULC contribution were made on surface runoff, lateral flow, total aquifer recharge, percolation out of soil, total water yield, sediment load, evapotranspiration and potential evapotranspiration as characteristics of the hydrological process of the catchment. Average annual comparisons of land use land cover effects on the hydrological process are presented in Table 4.6.

Table4. 6 Annual simulation hydrological processes of 1995, 2004 and 2013

Item	LULC_1995	LULC_2004	LULC_2013
Surface Runoff, mm	290.75	321.24	354.6
Lateral flow, mm	128.01	126.28	123.66
Ground water flow, mm	438.64	405.6	381.82
Total AQ Recharge, mm	484.22	446.19	443.29
Total Water Yield, mm	881.42	879.2	873.62
Percolation out of soil, mm	484.71	446.64	413.91
Total Sediment Yield	38.82	57.89	71.3
ET, mm	710.9	694.4	690.6
PET, mm	1057	1054	1052.8

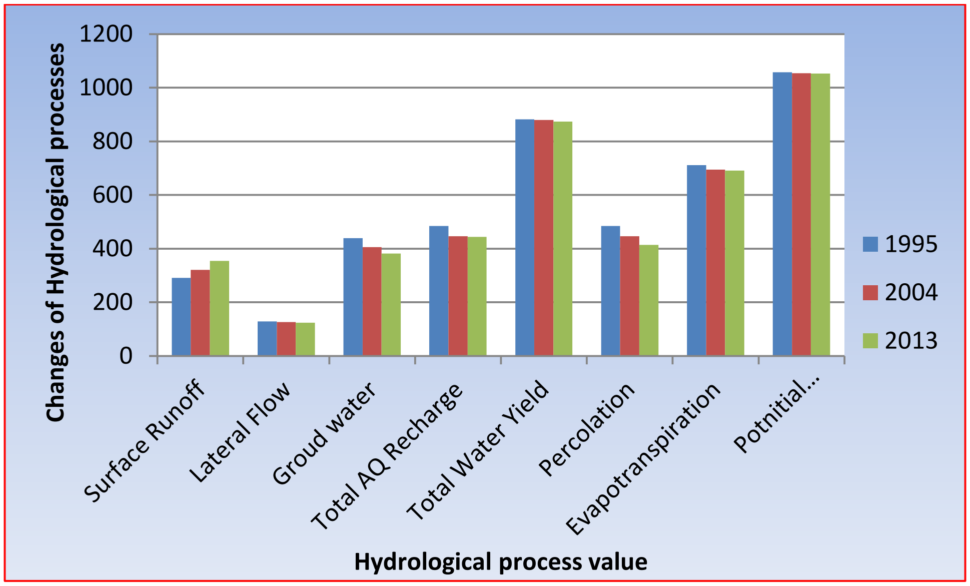


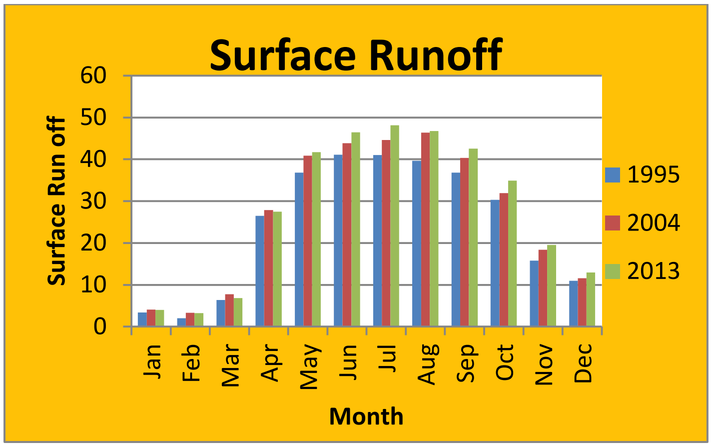
Figure 4. 8 Average annual basin values of Hydrological responses

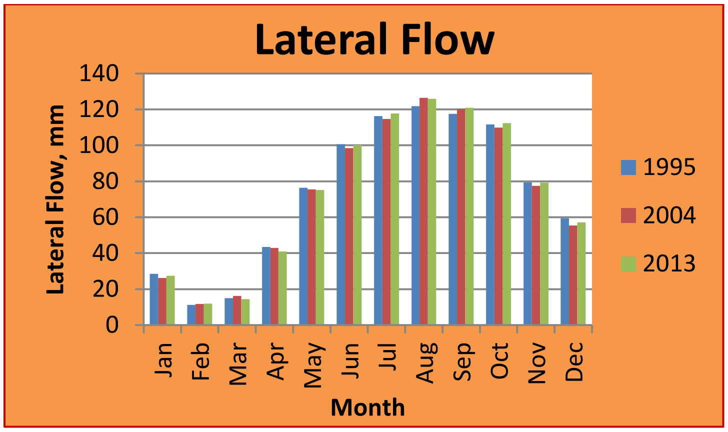
Compared to the LULC in the average annual surface runoff over the basin is 30.49mm higher in 2004 and 63.85mm higher in 2013: an increase of 10.5% and 22% respectively. This was related the surface cover of the catchment. From the result of land cover map, areas of forest and shrub land have decreased from 1995 to 2013 which has contributed to the increased surface runoff contribution.

Lateral flow in 1995 was 128.01mm, decreased to 126.28mm (decreasing of 1.35%) in 2004 and with LULC of 2013 decreased to 123.66mm (decreased by 3.3%) in 2013. The annual ground water recharge decreased by 33.04mm (7.5%) from 1995 to 2004 and further decline by 56.82mm (12.9%) was observed in 2013.

The contribution of Ground water, total aquifer recharge and percolation out of soil, with in the period from 1995 to 2004 were decreased by 33.04mm (7.5%), 38.03mm (7.8%), 38.07mm (7.8%) and also from 2004 to 2013 decreased by 23.78mm (5.2%), 2.9mm (0.6%) and 32.74mm (7.3%) respectively. The declining trend seen in the average ground water recharge can be attributed to increase in surface runoff and less soil infiltration. It is the case that ground water within the basin is sourced for several activities, related with increasing agricultural land, settlement and bare land. The increased in settlement and bare land has the highest potential for runoff because the land is impervious cover in a watershed and reduces infiltrations. A resulting effect of these uses of ground water may account for the continuous decline in ground water recharge due to over exploitation of the source over the years. Within the period of study from 1995 to 2013, total aquifer recharge was decreased due to the reduction of percolation rate. This declination rate was related with the expansion of crop land, settlement and bare land. The result of evapotranspiration and potential evapotranspiration change in small amount from 1995 to 2013 and this shows that the spatial distribution of the significant increases in ET somewhat matches fairly with the areas detected to covered by forest and agriculture lands. Trees and plants in forest and agriculture land take up much water for transpiration and photosynthetic purposes. Unlike forest and agriculture, the increased of settlement and bare land decreases the amount of ET.

The total water yield slightly decreased within the period 1995 to 2004 by 0.25% and from 2004 to 2013 decreased by 5.37mm (0.6%). This shows that resulting in decreasing water yield was not due to the change in evapotranspiration and potential evapotranspiration but due to the change of LULC. Sediment yield was increased from 1995 to 2004 by 19.1/ha (49%) and from 2004 to 2013 by 13/ha (23%). As the increment of crop land, bare land and settlement, sediment yield in the area was increased to contribute maximum sediment rate, because change in LULC will increase overland flow and peak flows. The results of monthly hydrological process under the land use land cover changes are summarized in figure 4.9 below.





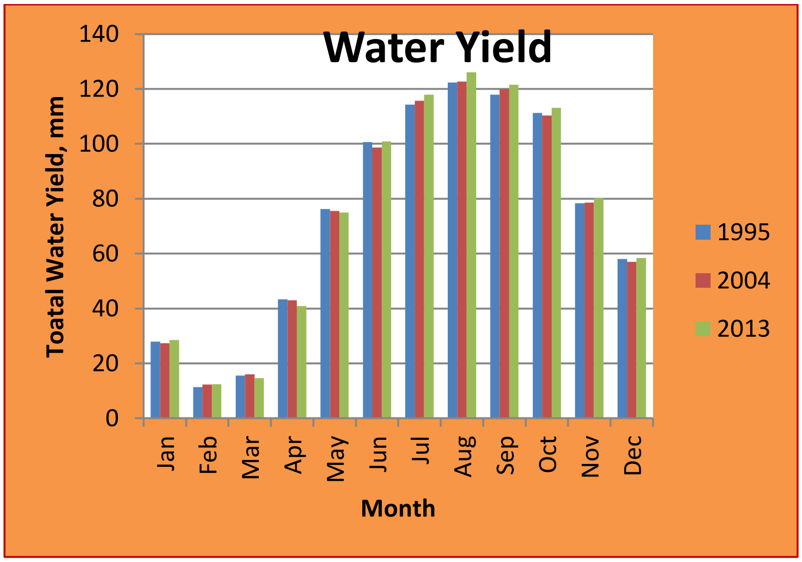
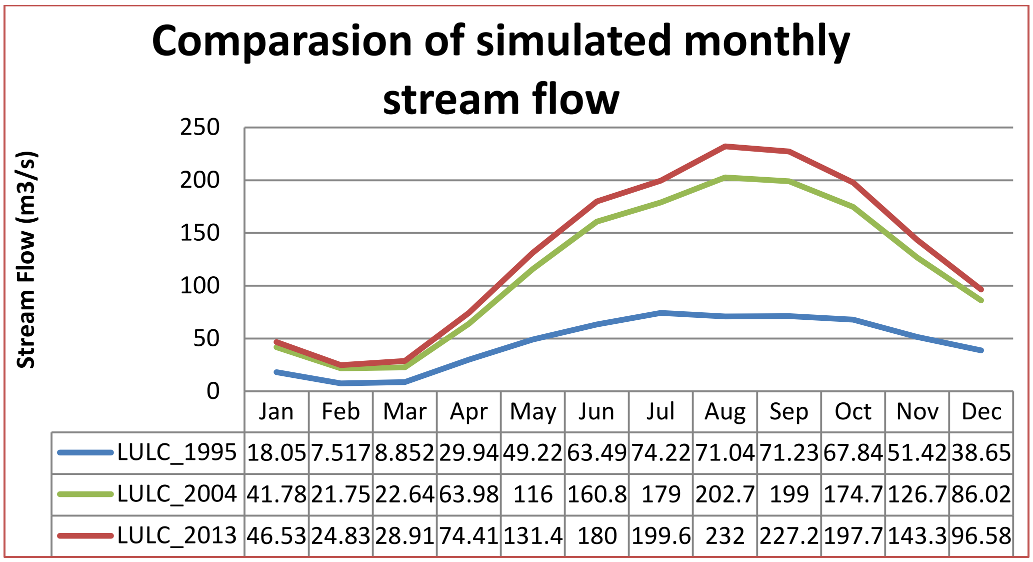


Figure 4. 9 Simulated mean monthly Yield of Surface runoff, Lateral flow and Water Yield

The average dry monthly stream flow (Fig.4.10) shows differences between simulations. For the 1995 land cover average monthly stream flow was 7.52m^3/s, for 2004 land cover change 21.75m^3/s, and for 2013 land cover was 24.83m^3/s. For that wet months, the hydrographs generated for 1995 land cover produced the highest peak flow of 74.22m^3/s, for 2004 land cover produced 202.7m^3/s and the 2013 land cover produced the monthly flow of 232m^3/s. the majority of peak flow occur during the month of July and August which is the rainy season in the study area.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
LULC_1995	18.05	7.517	8.852	29.94	49.22	63.49	74.22	71.04	71.23	67.84	51.42	38.65
LULC_2004	41.78	21.75	22.64	63.98	116	160.8	179	202.7	199	174.7	126.7	86.02
LULC_2013	46.53	24.83	28.91	74.41	131.4	180	199.6	232	227.2	197.7	143.3	96.58

Figure 4. 10 Simulated monthly stream flow for LULC of 1995, 2004 and 2013

4.2 Sub-basin contribution on the Hydrological Process

The study area upper Gilo watershed has 31 sub-basins, which have different contributions to change hydrological processes. Even though there are 31 sub-basins the contribution of them to increase the annual surface runoff differ each other. Sub-basins having the highest contribution annual surface runoff for LULC maps of 1995, 2004 and 2013 are 31, 5 and 28 with discharge of 32.89m3/s, 37.72m3/s and 36.12m3/s respectively. And sub-basins having the lowest contribution of annual surface runoff are 11, 29 and 13 with amount of discharge 20.09m3/s, 22.63m3/s and 22.07m3/s for LULC of 1995, 2004 and 2013 respectively. The most significant increasing in hydrologic components of surface runoff occurred mainly in the south-east part of the basin, corresponding to large extent with spatial distribution of settlement and agricultural expansions. This is explicit in the positive correlation surface runoff has with settlement and agricultural areas.

On the other hand the contribution of ground water discharge was maximum for sub-basins 29, 25 and 25 with flow 45.01m^3/s, 43.47m^3/s and 42.87m^3/s respectively for the year 1995, 2004 and 2013. Without considering any standard evaluations, when compared the amount of sediment contribution, Sub-basin 27 has maximum load 32.02 T/ha and sub-basin 9 has the minimum load 0.32T/ha contribution in terms of sediment yield for the study periods.

Table4. 7 The most contributed sub-basin to the hydrological process

Hydrology	Amount	1995		2004		2013	
		Value	Sub-basin	Value	Sub-basin	value	Sub-basin
Surface runoff	Max.	32.89	31	37.72	5	36.12	28
	Min.	20.10	11	22.64	29	22.08	13
Ground water	Max.	45.01	29	43.84	25	42.87	25
	Min.	22.29	25	22.17	24	22.58	27
Sediment	Max.	10.77	22	13.51	19	32.02	27
	Min	0.32	9	0.37	7	0.33	9

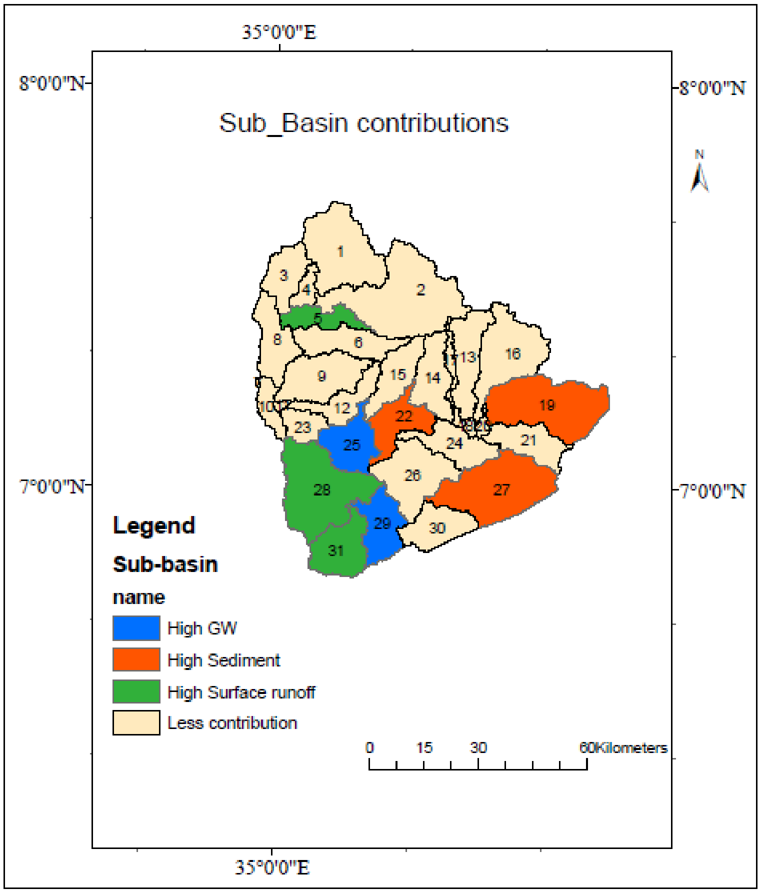


Figure 4. 11 Sub-basin contribution of Upper Gilo watershed

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

The aim of this study was to evaluate the impact of Land Use Land Cover changes on the hydrology over the period (1995-2013) years by considering the land use conditions of 1995, 2004 and 2013's in Upper Gilo watershed using a calibrated and validated version of the SWAT_CUPSUFI2 model.

The sensitivity analysis using SWAT model has pointed out 12 most important parameters that control the stream flow of the studied watershed. Model calibration and validation have showed that the SWAT model simulated the flow quit satisfactory. Performance of the model for both the calibration and validation watershed were found to be reasonably good with Nash-Sutcliff coefficients (ENS) values 0.77 and 0.61 and coefficient of determination (R2) values of 0.88 and 0.82 for calibration and validation respectively.

Following calibration and validation of the model, impacts of the land use and land cover change on the stream flow was carried out.

From the LULC change analysis, it can be concluded that the land use and land cover of Upper Gilo watershed for the period of 1995 to 2013 showed significant changed. Forest land and grass land decreased from the period 1995 Thus, by the expense of forest land and other land cover types, the cultivated area includes areas for crop cultivation and the scatter rural settlement that are closely associated fields dynamically increased in the period of the study (1995-2013). 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. LULC changes recognized to have major impacts on hydrological processes, such as surface runoff, ground water flow, lateral flow, water yield, Aquifer loading and retention capacity of the soil.

5.2 Recommendations

Land use changes are the most significant factors that result in increased surface runoff and decrease in infiltration rate. The simplest method to assess these effects on catchment hydrology is by comparing stream flow and runoff generated from catchment areas with contracting land use types. The finding of this study on land use change detection indicate mainly the expansion of cultivated land on watershed was the increments of surface runoff, evaporation, decrease of infiltrations and ground water etc. An increase in runoff and river discharge in the watershed is linked to the partial removal of vegetation causing a reduction of the soil water holding capacity. Generally it is recommended that:

Integrating land use change with hydrologic models could be applied to predict the potential impacts of land use change on the stream flow of the watershed. This helps for stakeholders and decision makers to make better choices for land and water resource planning and management and encourage better national resource management to predict hydrological consequences to LULC changes.

SWAT model were calibrated using observed data at gauging station in order to improve the model performance that can be produce meaningful catchment predictions to aid management decisions and hence it is recommended to establish good meteorological and hydrological stations.

Changes of the land use and land cover in the study area are mainly caused by increasing population, that family size and its annual crop production are not proportional. Therefore, family planning should be given widely and continuously through formal and informal education.

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APPENDIXS

Appendix-A Tepi Station Meteorological data

Mean monthly precipitation (mm) of Tepi station

Year/month	1	2	3	4	5	6	7	8	9	10	11	12
1990	1.89	0.90	5.55	3.99	9.77	5.74	5.90	12.97	5.44	6.28	2.47	1.34
1991	1.65	1.81	3.45	6.27	4.38	4.71	7.03	4.81	8.68	2.30	2.33	1.44
1992	2.01	0.60	2.03	4.53	4.33	6.17	5.58	6.25	7.13	6.65	3.60	2.01
1993	3.07	2.33	2.65	4.49	5.15	4.50	8.08	7.07	3.99	5.20	1.11	2.11
1994	0.10	0.79	1.20	6.73	8.98	5.85	5.45	6.21	6.44	3.20	4.79	3.25
1995	0.11	0.76	4.89	5.48	6.24	5.05	4.66	6.68	8.42	3.25	3.29	2.84
1996	2.15	2.11	4.14	5.89	6.43	8.78	5.85	5.55	7.48	5.73	2.72	1.86
1997	3.19	0.18	3.57	8.31	8.07	4.97	3.17	4.95	3.38	7.72	4.75	4.81
1998	4.30	2.72	4.60	6.15	4.19	7.23	7.31	10.82	6.93	5.08	2.36	0.63
1999	0.53	0.28	2.81	6.16	7.68	5.22	5.59	5.12	4.89	5.78	2.07	1.16
2000	0.72	0.27	1.25	4.56	3.55	5.89	5.46	6.22	5.32	2.32	1.25	1.20
2001	0.35	2.53	4.48	5.66	4.63	6.30	5.09	7.99	7.22	2.87	1.58	1.59
2002	1.25	0.28	3.85	4.85	4.32	7.43	2.77	4.86	3.60	5.74	1.11	2.04
2003	0.37	0.65	2.55	4.35	2.66	6.05	3.94	7.04	8.00	2.71	3.67	2.50
2004	0.98	0.42	1.10	6.97	6.28	5.17	4.92	8.09	5.68	1.32	4.59	3.67
2005	0.18	1.34	1.79	3.91	5.30	4.69	7.88	3.93	4.90	3.79	1.81	2.14
2006	1.16	0.61	5.43	3.87	6.45	6.89	5.72	7.21	4.82	6.04	5.00	2.84
2007	1.44	2.51	3.21	3.81	7.47	3.40	4.78	9.78	8.87	2.13	2.97	0.21
2008	2.30	2.55	2.07	9.04	5.69	28.28	5.71	4.70	7.75	7.94	2.21	0.44
2009	0.71	0.84	5.05	8.00	4.92	5.49	3.77	2.43	4.60	4.13	2.13	2.62
2010	1.45	3.22	1.55	3.95	9.56	3.64	5.74	7.28	7.58	4.29	2.79	3.21
2011	0.58	0.58	1.49	6.38	6.94	3.53	7.99	8.23	7.16	4.49	2.49	1.44
2012	0.35	1.09	1.35	2.34	2.66	6.05	3.94	7.04	6.08	2.13	3.67	2.50
2013	1.03	1.77	3.18	4.71	7.38	6.92	3.93	7.04	8.00	2.71	4.59	3.67
2014	1.03	1.77	3.18	4.04	5.30	4.69	7.88	4.18	7.09	4.41	1.81	1.44

Mean monthly max Temperature (^0C) Tepi station												
	month											
year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	27.62	26.83	27.30	28.83	26.76	26.03	25.12	25.08	25.51	27.20	27.86	28.59
1991	28.56	29.75	29.49	27.57	27.18	23.91	24.88	27.47	28.09	27.15	26.74	28.13
1992	28.89	29.01	30.47	28.48	27.75	26.10	24.88	24.88	25.89	26.56	27.42	26.52
1993	26.95	26.71	28.92	28.49	27.04	22.81	23.01	24.85	27.30	27.59	28.14	28.55
1994	28.77	29.04	29.16	28.50	26.57	25.05	24.87	25.03	27.97	27.74	25.93	26.79
1995	28.23	26.69	29.14	27.82	26.13	25.76	23.80	25.98	30.02	30.89	31.27	30.23
1996	27.24	28.52	27.95	26.73	25.83	28.75	25.68	25.89	29.53	31.53	31.73	30.98
1997	27.04	29.30	28.48	22.11	26.21	26.16	26.93	29.22	30.37	26.44	27.09	28.76
1998	29.12	29.19	28.49	30.14	31.25	29.25	25.83	27.36	31.49	29.63	32.56	28.94
1999	28.28	28.83	29.09	27.92	30.64	30.95	27.63	29.12	32.07	31.14	33.96	32.18
2000	28.56	28.57	29.19	27.97	32.29	26.88	28.71	29.62	28.93	27.99	28.05	29.24
2001	27.60	28.16	28.18	27.44	26.41	25.02	24.00	24.07	24.73	25.46	26.10	26.82
2002	26.26	30.64	28.63	29.24	28.00	25.98	26.23	25.57	27.21	26.82	27.23	27.15
2003	28.63	31.21	30.08	29.25	28.79	25.91	24.80	25.23	26.01	28.31	27.76	28.06
2004	29.13	29.86	30.99	28.41	28.16	26.05	25.69	26.24	25.72	27.80	27.28	27.42
2005	29.54	33.12	30.97	29.78	27.45	26.50	25.60	25.88	25.97	26.90	27.85	31.04
2006	26.89	28.27	30.42	28.38	27.61	26.17	25.35	24.98	25.43	27.82	28.61	29.42
2007	28.12	28.83	30.31	27.87	27.46	26.61	24.74	25.36	25.98	26.59	28.04	29.66
2008	26.91	30.39	29.82	29.16	28.26	27.90	26.41	26.26	25.80	27.87	28.26	27.06
2009	29.66	30.48	29.89	30.72	28.46	27.21	26.46	27.72	29.42	30.65	28.15	27.02
2010	27.24	29.24	27.76	27.47	26.69	26.50	26.90	26.69	26.66	28.10	26.29	28.40
2011	27.87	28.34	28.35	27.64	26.78	25.51	24.60	24.62	25.18	25.85	26.39	27.14
2012	27.62	28.18	28.17	27.40	26.37	24.97	23.99	24.09	24.76	25.48	26.12	26.85
2013	27.62	28.18	28.17	27.40	26.37	24.97	23.99	24.09	24.76	25.48	26.12	26.85
2014	27.87	28.34	28.35	27.64	26.78	25.51	24.60	24.62	25.18	25.85	26.39	27.14

Mean Monthly min. Temperature (^{0}C) of Tepi station

Month / Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	13.72	15.43	15.72	16.15	16.19	16.14	15.73	15.77	15.51	14.65	14.52	13.58
1991	14.46	14.79	15.92	16.37	16.25	16.23	16.58	16.65	15.61	14.14	14.09	14.12
1992	13.49	14.71	16.05	16.92	16.70	15.73	15.38	15.90	15.21	15.49	13.39	14.23
1993	14.06	14.68	14.65	16.79	16.23	16.19	14.15	15.83	15.57	14.20	13.47	12.99
1994	12.56	13.68	15.95	16.76	16.35	16.15	15.98	15.92	15.66	14.83	15.02	14.84
1995	13.39	13.42	14.64	17.30	16.50	20.49	15.36	16.20	15.98	15.26	14.57	14.08
1996	14.01	15.07	16.58	16.32	15.39	16.51	16.18	15.69	15.85	14.66	13.50	13.06
1997	13.91	11.93	15.52	15.96	15.61	15.30	15.64	16.02	15.85	16.08	16.36	15.83
1998	16.43	14.70	17.09	17.59	17.24	16.95	16.79	16.59	16.56	16.67	13.20	12.14
1999	13.16	13.41	15.21	16.99	16.67	15.87	15.19	15.47	15.25	15.45	12.31	13.48
2000	13.14	12.90	15.81	16.61	16.55	15.83	15.46	16.11	15.97	16.13	13.65	13.54
2001	12.20	13.93	15.92	17.08	16.78	16.18	15.68	16.40	15.74	16.13	15.28	14.30
2002	14.61	13.93	16.65	16.78	16.85	16.22	16.22	15.93	15.37	15.14	15.13	14.75
2003	13.41	14.61	16.75	17.00	16.66	15.58	15.19	15.30	15.08	14.16	13.39	12.61
2004	13.91	12.84	15.26	15.81	15.50	15.21	14.41	14.46	14.59	13.30	13.51	13.36
2005	11.74	13.67	15.04	15.71	15.28	15.39	15.01	14.77	14.98	13.94	12.28	9.38
2006	12.25	13.68	14.83	15.29	14.83	14.35	14.89	14.39	14.38	14.39	14.37	14.35
2007	13.46	12.88	14.59	16.45	16.17	15.59	15.59	15.30	15.07	13.48	13.07	11.28
2008	12.63	13.00	13.64	15.05	14.52	13.97	13.74	13.87	13.72	14.11	12.73	11.27
2009	12.13	13.79	15.82	16.10	15.19	14.57	15.71	16.00	16.30	16.15	13.83	15.56
2010	13.65	16.18	16.03	17.82	17.90	16.95	16.02	16.47	16.40	15.85	14.47	15.05
2011	14.11	14.15	13.99	13.62	13.50	13.50	15.19	16.02	15.85	14.66	13.17	13.71
2012	13.74	13.53	16.15	17.00	17.03	16.72	14.15	14.15	16.13	15.16	12.78	14.53
2013	14.11	14.15	13.99	13.62	13.50	13.50	15.90	14.15	13.98	13.48	12.78	12.35
2014	12.57	13.52	16.47	16.78	17.00	14.23	14.15	13.82	13.73	16.57	15.64	12.35

Mean monthly wind speed (m^3/s) of Tepi Station

month

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	0.46	0.54	0.59	0.57	0.53	0.46	0.44	0.47	0.50	0.50	0.43	0.39
1991	0.49	0.56	0.57	0.52	0.52	0.49	0.42	0.45	0.56	0.46	0.45	0.41
1992	0.46	0.47	0.65	0.56	0.54	0.35	0.29	0.29	0.40	0.39	0.38	0.37
1993	0.37	0.41	0.45	0.49	0.44	0.37	0.44	0.34	0.40	0.46	0.36	0.36
1994	0.42	0.48	0.53	0.52	0.43	0.35	0.36	0.35	0.41	0.43	0.42	0.39
1995	0.35	0.42	0.56	0.49	0.42	0.39	0.33	0.36	0.37	0.35	0.30	0.34
1996	0.35	0.39	0.42	0.42	0.46	0.36	0.33	0.38	0.41	0.50	0.39	0.32
1997	0.34	0.42	0.46	0.43	0.38	0.33	0.31	0.35	0.36	0.35	0.29	0.31
1998	0.28	0.28	0.34	0.39	0.37	0.34	0.27	0.32	0.31	0.30	0.41	0.35
1999	0.39	0.55	0.46	0.45	0.38	0.35	0.29	0.31	0.36	0.28	0.34	0.37
2000	0.38	0.43	0.58	0.48	0.45	0.36	0.32	0.34	0.39	0.36	0.35	0.32
2001	0.33	0.46	0.49	0.49	0.41	0.37	0.32	0.35	0.39	0.35	0.34	0.38
2002	0.40	0.46	0.53	0.53	0.39	0.38	0.31	0.31	0.36	0.36	0.36	0.30
2003	0.34	0.44	0.56	0.49	0.43	0.33	0.28	0.30	0.32	0.35	0.33	0.29
2004	0.33	0.54	0.41	0.37	0.32	0.23	0.26	0.27	0.25	0.32	0.31	0.26
2005	0.27	0.36	0.45	0.43	0.33	0.28	0.26	0.28	0.29	0.26	0.33	0.33
2006	0.46	0.54	0.59	0.57	0.53	0.46	0.44	0.47	0.50	0.50	0.43	0.41
2007	0.46	0.54	0.59	0.57	0.53	0.46	0.44	0.47	0.50	0.50	0.43	0.39
2008	0.29	0.34	0.37	0.34	0.33	0.25	0.19	0.23	0.26	0.50	0.25	0.32
2009	0.31	0.54	0.41	0.34	0.53	0.46	0.44	0.47	0.50	0.49	0.43	0.41
2010	0.46	0.54	0.59	0.57	0.53	0.46	0.44	0.47	0.50	0.50	0.43	0.39
2011	0.39	0.54	0.59	0.57	0.53	0.46	0.44	0.47	0.50	0.50	0.43	0.41
2012	0.46	0.54	0.59	0.57	0.53	0.46	0.44	0.47	0.50	0.50	0.43	0.41
2013	0.46	0.54	0.59	0.57	0.53	0.46	0.44	0.47	0.50	0.50	0.43	0.41
2014	0.46	0.54	0.59	0.57	0.53	0.46	0.44	0.47	0.50	0.50	0.43	0.41

Mean Monthly Relative Humidity (%) of Tepi station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	**0.80**	**0.78**	**0.79**	**0.83**	**0.84**	**0.87**	**0.87**	**0.88**	**0.86**	**0.85**	**0.81**	**0.79**
1991	0.78	0.79	0.77	0.81	0.84	0.87	0.88	0.88	0.86	0.87	0.83	0.82
1992	0.79	0.80	0.78	0.83	0.87	0.88	0.87	0.86	0.85	0.85	0.82	0.78
1993	0.77	0.77	0.78	0.81	0.88	0.89	0.88	0.87	0.85	0.83	0.84	0.81
1994	0.77	0.78	0.78	0.82	0.88	0.86	0.88	0.86	0.87	0.87	0.84	0.84
1995	0.81	0.78	0.81	0.84	0.87	0.90	0.89	0.89	0.89	0.87	0.84	0.80
1996	0.79	0.77	0.79	0.88	0.88	0.87	0.88	0.87	0.84	0.87	0.88	0.85
1997	0.81	0.78	0.81	0.81	0.86	0.88	0.89	0.88	0.86	0.88	0.81	0.78
1998	0.78	0.76	0.78	0.83	0.87	0.86	0.87	0.86	0.85	0.87	0.79	0.80
1999	0.77	0.76	0.77	0.82	0.85	0.84	0.85	0.85	0.84	0.88	0.82	0.78
2000	0.76	0.78	0.80	0.82	0.85	0.87	0.87	0.87	0.87	0.88	0.84	0.82
2001	0.81	0.76	0.80	0.80	0.84	0.85	0.83	0.85	0.83	0.86	0.83	0.82
2002	0.78	0.77	0.80	0.81	0.82	0.86	0.86	0.87	0.84	0.82	0.84	0.82
2003	0.79	0.77	0.77	0.84	0.84	0.85	0.85	0.87	0.86	0.84	0.85	0.83
2004	0.78	0.76	0.79	0.82	0.88	0.88	0.86	0.86	0.87	0.87	0.83	0.77
2005	0.77	0.77	0.79	0.82	0.88	0.87	0.88	0.89	0.87	0.88	0.87	0.86
2006	0.84	0.81	0.80	0.83	0.87	0.89	0.88	0.88	0.88	0.85	0.83	0.80
2007	0.80	0.78	0.79	0.85	0.87	0.87	0.88	0.88	0.88	0.88	0.84	0.81
2008	0.82	0.82	0.82	0.86	0.86	0.87	0.85	0.86	0.87	0.89	0.84	0.87
2009	0.82	0.82	0.81	0.85	0.90	0.89	0.89	0.88	0.89	0.89	0.86	0.83
2010	0.80	0.77	0.79	0.81	0.87	0.88	0.87	0.88	0.88	0.87	0.88	0.85
2011	0.81	0.77	0.78	0.83	0.88	0.88	0.89	0.89	0.89	0.87	0.88	0.86
2012	0.82	0.80	0.81	0.82	0.88	0.88	0.88	0.88	0.88	0.88	0.87	0.82
2013	0.77	0.78	0.78	0.82	0.88	0.86	0.88	0.86	0.87	0.87	0.84	0.84
2014	0.81	0.78	0.81	0.84	0.87	0.90	0.89	0.89	0.89	0.87	0.84	0.80

Monthly Solar Radiation (KJ/M^2) Tepi station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	22.04	21.22	20.51	20.97	19.49	9.03	17.04	19.51	21.34	20.40	21.56	21.15
1991	20.65	21.90	23.42	20.28	21.82	18.87	14.56	18.30	18.86	20.62	22.66	21.53
1992	20.63	23.04	21.63	19.83	22.38	18.91	15.25	20.87	19.79	20.86	21.63	19.04
1993	21.65	19.33	21.93	19.83	20.27	20.13	16.87	16.43	20.89	22.57	21.51	21.28
1994	20.69	21.47	22.04	22.66	21.66	18.86	13.81	17.13	21.23	21.58	21.19	19.93
1995	14.82	14.43	23.55	21.88	21.50	18.87	17.53	15.43	19.90	19.07	22.11	20.61
1996	19.43	20.47	25.06	19.45	19.68	18.35	15.45	18.72	20.11	20.92	22.42	22.08
1997	22.75	21.75	21.98	21.79	20.97	17.25	15.11	17.18	21.18	22.11	20.80	22.30
1998	22.72	22.14	20.64	20.83	22.94	20.89	16.14	16.55	20.07	20.55	20.97	21.33
1999	20.85	23.23	22.46	21.74	21.34	15.08	15.47	18.52	19.98	22.15	21.25	22.08
2000	21.44	24.77	23.09	18.48	21.89	19.47	16.68	20.30	22.65	20.21	18.54	19.03
2001	18.37	19.60	21.98	22.46	20.49	18.23	13.86	13.76	18.84	15.81	20.93	17.76
2002	8.32	8.85	9.31	9.42	9.21	9.03	9.08	9.27	9.29	8.93	8.40	8.12
2003	8.32	8.85	9.31	9.42	9.21	9.03	9.08	9.27	9.29	8.93	8.40	8.12
2004	20.13	22.13	20.40	14.35	9.21	9.02	9.09	9.28	20.31	13.80	8.39	8.11
2005	8.32	8.85	20.12	22.03	20.46	17.96	18.10	9.82	20.45	20.99	22.01	18.54
2006	21.97	23.93	23.27	20.74	21.45	19.12	15.14	15.83	21.61	21.88	21.50	21.36
2007	20.27	22.14	21.87	18.91	21.24	18.24	16.48	18.70	19.50	20.70	20.66	20.60
2008	21.74	23.32	22.20	22.06	19.18	18.54	15.65	18.81	18.63	19.90	21.57	22.58
2009	22.22	22.42	22.21	20.05	22.27	18.78	15.62	16.38	19.43	20.08	19.59	20.07
2010	20.90	22.56	23.32	21.31	20.19	15.66	16.46	16.34	17.55	21.60	21.53	22.49
2011	21.84	22.93	23.74	22.29	21.00	17.29	15.81	17.30	19.01	18.06	21.21	22.19
2012	21.06	23.90	24.14	20.58	20.84	20.81	18.50	18.61	19.86	19.98	21.82	17.07
2013	20.47	17.77	20.18	21.22	19.40	18.73	13.84	16.51	19.06	20.19	22.31	18.26
2014	22.88	24.43	22.74	23.00	19.59	16.74	16.39	16.28	19.16	20.79	8.40	8.12

Appendix-B: Hydrological data of Tepi station

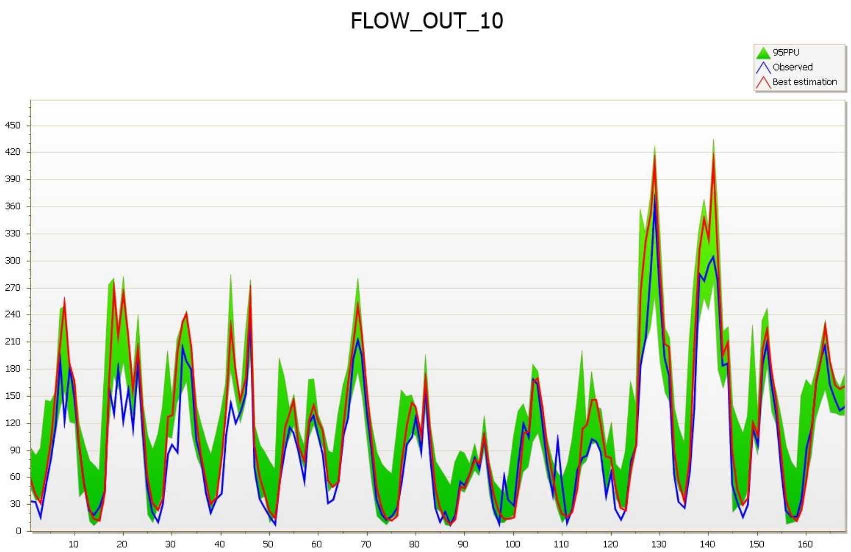
Beko River Flow (m3/s)												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	36.79	44.77	45.57	44.26	142.02	173.04	141.07	182.68	169.98	114.77	76.16	45.25
1991	26.13	20.12	30.08	101.34	82.76	113.62	177.31	121.82	139.69	77.96	88.11	68.69
1992	22.07	21.29	18.55	36.89	104.11	125.21	152.16	129.01	182.54	171.65	93.60	44.66
1993	34.57	33.88	25.29	45.86	88.33	189.00	168.68	118.67	104.65	106.86	42.53	24.13
1994	19.56	32.31	59.61	90.27	113.58	176.11	215.01	234.67	162.02	96.11	95.77	50.98
1995	25.75	19.87	37.96	69.73	111.84	114.29	166.50	223.54	224.25	195.03	87.06	68.66
1996	58.13	44.31	106.91	94.29	144.64	291.79	235.43	157.30	195.20	173.36	86.32	67.00
1997	44.03	23.24	54.84	140.14	150.63	144.06	269.65	189.97	125.94	224.17	270.41	170.75
1998	226.80	54.74	77.83	112.11	330.53	273.52	499.82	462.69	258.58	295.39	90.85	41.50
1999	26.28	22.57	18.37	34.93	97.67	87.04	130.18	158.59	115.54	154.71	65.31	38.99
2000	26.57	20.12	38.24	55.61	71.08	66.83	104.77	109.18	110.20	155.04	67.58	32.16
2001	26.93	23.85	28.09	37.34	60.52	153.45	124.48	172.28	142.94	121.28	70.50	58.35
2002	81.26	66.09	70.93	79.00	101.77	149.82	135.88	166.35	142.66	135.31	100.51	95.91
2003	71.35	61.32	64.16	80.34	72.81	148.85	176.96	251.94	210.98	166.93	98.43	124.16
2004	95.96	76.09	68.14	87.71	188.67	206.08	187.41	263.12	226.01	143.44	112.57	98.12
2005	72.82	61.28	65.99	72.82	118.14	150.41	200.81	171.34	221.55	174.11	117.93	70.11
2006	51.38	56.07	27.67	39.86	111.58	135.98	188.72	229.24	247.78	270.84	102.99	74.75
2007	43.95	37.98	29.39	53.90	106.48	116.38	######	159.44	154.20	82.58	53.48	28.59
2008	24.33	20.50	28.45	55.74	89.46	120.97	112.78	177.06	172.46	129.14	95.52	41.40
2009	36.31	30.61	68.15	133.46	120.79	148.11	128.32	125.31	120.95	146.66	77.47	75.81
2010	46.77	83.16	78.68	72.34	155.36	171.33	190.06	221.82	203.26	188.75	135.97	122.83
2011	97.38	99.32	69.50	77.75	161.85	197.98	158.34	168.97	170.66	142.39	151.04	118.97
2012	112.46	87.10	91.46	85.91	121.06	175.57	193.57	180.23	170.48	120.01	119.90	130.37
2013	102.43	113.91	108.73	141.56	157.73	151.23	222.74	223.65	228.09	190.32	181.31	106.75
2014	58.10	43.94	47.58	118.21	176.48	165.17	212.27	204.15	232.34	185.03	136.17	90.88

APPENDIX C: List of Common Parameter used for Sensitivity Analysis

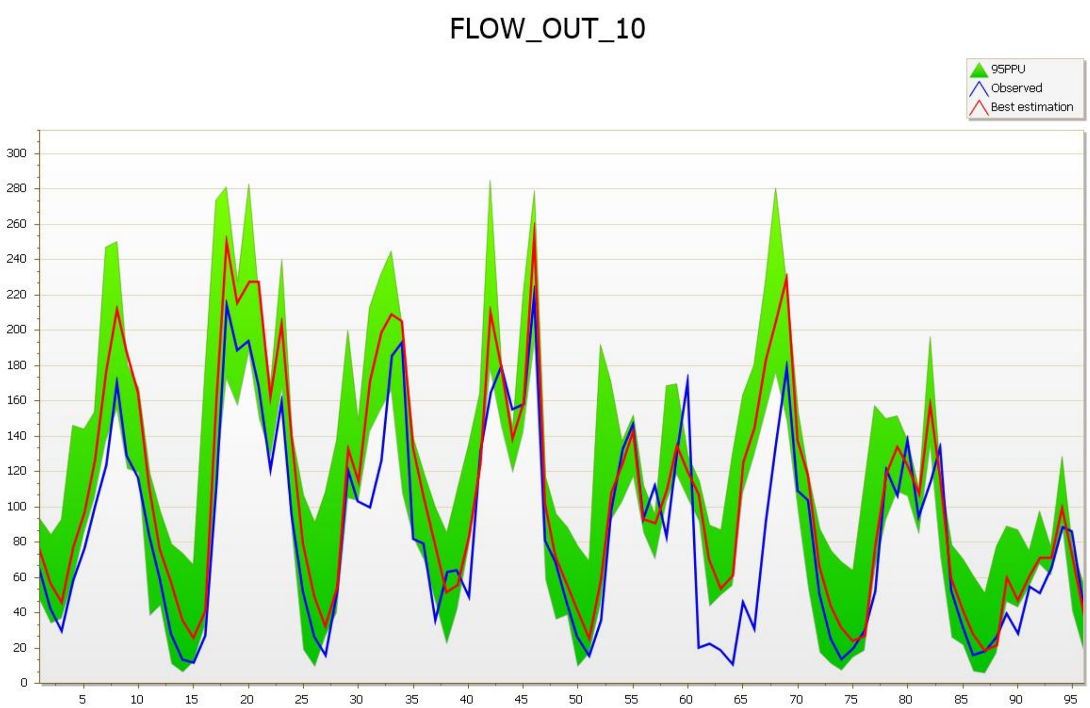
Parameter Code	Parameter Description	File
CN2	Initial SCS CN II value	*.mgt
RCHRG_DP	Deep Aquifer percolation coefficient	*.gw
GWQMN	Threshold depth of water in the shallow aquifer required for return flow	*.gw
GW_REVAP	Groundwater revap coefficient	*.gw
CANMX	Maximum canopy storage	*.hru
SOL_AWC	Available water capacity	*.sol
ESCO	Soil evaporation compensation factor	*.hru
SLOPE	Average slope steepness	*.hru
SOL_Z	Soil depth	*.sol
SOL_K	Saturated hydraulic conductivity	*.sol
REVAPMN	Threshold water in the shallow aquifer for revap to occur	*.gw
ALPHA_BF	Base flow alpha factor	*.gw
GW_DELAY	Groundwater delay	*.gw
BIOMIX	Biological mixing efficiency	*.mgt
CH_K2	Channel effective hydraulic conductivity	*.rte
SURLAG	Surface runoff lag time	*.bsn
SOL_ALB	Moist soil albedo	*.sol
SLSUBBSN	Average slope length	*.hru
BLAI	Sub Maximum potential leaf area index	*.crp
EPCO	Plant uptake compensation factor	*.hru
CH_N	Manning’s n value for main channel	*.rte.
ALPHA_BNK	Base flow alpha factor for bank storage	*.rte
GW_SPYLD	Specific yield of the shallow aquifer (m3/m3)	*bsn
AUTO__EFF	Application efficiency	*.mgt
LAT_TTIME	Lateral flow travel time	*.hru
SOL_BD	Moist bulk density.	*.sol
HRU_SLP	Average slope steepness	*.hru
OV_N	Manning's "n" value for overland flow.	*.hru

APPENDIX D: Calibration and Validation Result

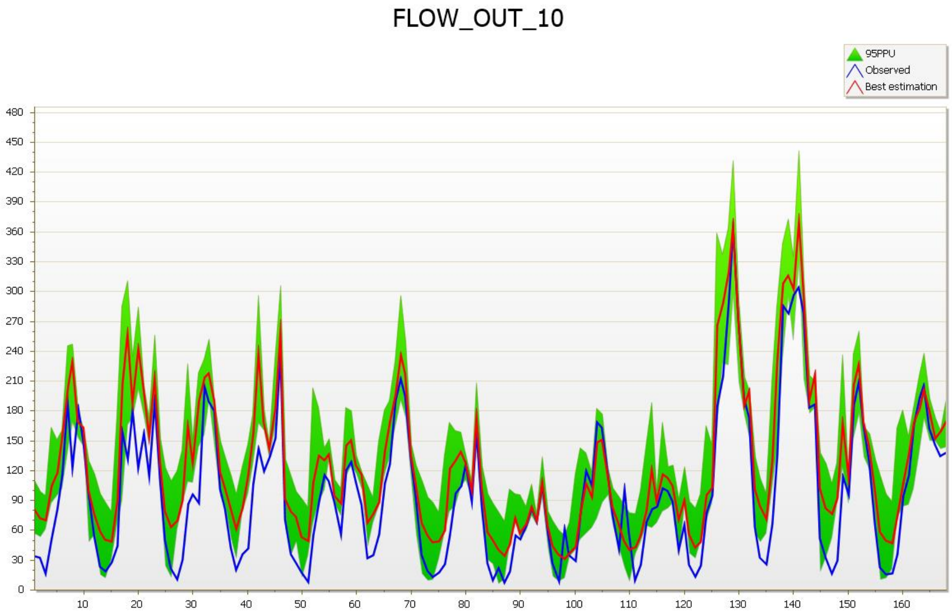
Calibrated Graph for LULC of 1995



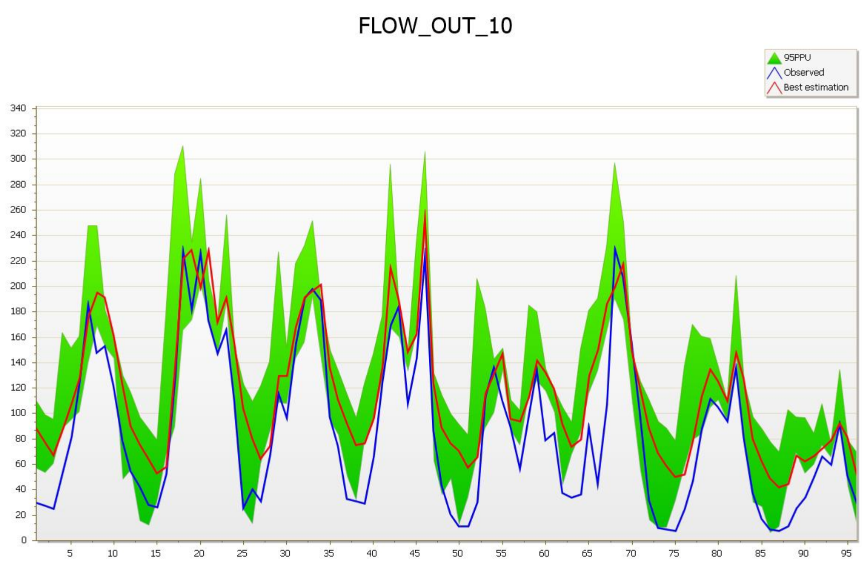
Validation graph for LULC of 1995



Calibration for LULC of 2004



Validation for LULC of 2004



APPENDIX E: Accuracy Assessment of LULC 1995, 2004 and 2013 from EMA

RD / CD	Accuracy of 1995								
	CRL	FS	GS	SH	SWP	ST	BRL	Total	UA
CRL	32	2	1					35	91%
FS	5	13	1					19	68%
GS		1	14	2				17	82%
SH			2	15	2			19	79%
SWP				1	15	1		17	88%
ST					2	18	1	21	86%
BRL							14	15	100%
Total	37	16	18	18	19	19	15	143	
PA	86%	81%	77%	83%	80%	95%	0.93%		OA=85%

RD / CD	Accuracy of 2004								
	CRL	FS	GS	SH	SWP	ST	BRL	Total	UA
CRL	25	3						28	89%
FS	3	18	1					22	82%
GS		2	15	1				18	83%
SH			1	20	1			22	91%
SWP				1	12	1		14	86%
ST					1	18	1	20	90%
BRL						2	13	15	87%
Total	28	23	17	22	14	21	14	139	
PA	89%	78%	88%	91%	86%	86%	92%		OA=87%

RD / CD	Accuracy of 2013								
	AL	FS	GS	SH	SWP	ST	BRL	Total	UA
CRL	22	1						23	95%
FS	3	16	2					21	76%
GS		2	18	1				21	95%
SH			1	15	2			18	83%
SWP				1	16	1		18	89%
ST					1	13	2	16	81%
BRL						1	14	15	88%
Total	25	19	21	17	19	15	16	132	
PA	88%	84%	86%	88%	84%	87%	88%		OA=86%

Where CD = Classified Data, RD=Reference Data, CRL=Crop Land, FS=Forest, GS=Grass land, SH=Shrub Land, SWP=Swampy Area, ST=Settlement, BRL=Bare Land,

PA = Producer's Accuracy, UA = User's AccuracyOver All Accuracy for LULC of 1995, 2004 and 2013 are 85%, 87& 86

APPENDIX F; Hydrological Responses

Month	RAIN	SURF	LAT FLOW	YIELD	ET	SEDIM	PET
(MM)	(MM)	(MM)	(MM)	(MM)	(T/HA)	(MM)	
1	34.76	3.98	2.75	27.47	35.03	2.65	94.67
2	35.07	3.21	1.78	11.89	34.99	2.92	94.58
3	91.47	6.82	4.13	14.47	83.19	1.99	103.73
4	163.71	37.5	8.62	40.99	80	4.61	91.44
5	190.83	41.73	14.69	75.15	67.84	6.93	87.74
6	186.57	46.46	15.95	100.26	56.71	6.59	78.61
7	194.26	55.13	16.42	117.76	57.56	8.15	76.38
8	198.21	48.79	17.47	125.91	60.66	8.96	80.2
9	180.46	42.56	15.67	120.92	60.17	8.18	84.04
10	153.1	35.88	11.77	112.3	60.53	7.92	88.89
11	99.09	19.55	8.55	79.29	51.33	6.79	89.25
12	66.88	12.98	5.84	57.18	42.25	5.2	89.77
Total	**1594.41**	**354.59**	**123.64**	**883.59**	**690.26**	**70.89**	**1059.3**
		2004					
	RAIN	**SURF**	**LAT FLOW**	**YIELD**	**ET**	**SEDIM**	**PET**
(MM)	(MM)	(MM)	(MM)	(MM)	(T/HA)	(MM)	
1	36.3	4.09	2.78	26.2	35.13	3.11	94.45
2	38.09	3.34	1.92	11.79	35.17	3.05	92.49
3	93.9	7.76	4.52	16.15	83.26	1.79	102.86
4	166.27	27.89	9.1	42.87	80.2	4.09	91.4
5	190.83	40.91	12.92	75.57	69.24	4.83	88
6	185.08	43.88	15.37	98.51	57.72	4.71	78.26
7	189.41	44.66	16.72	114.73	57.84	4.79	75.56
8	202	46.4	18.25	126.4	60.8	5.54	78.96
9	178.11	40.37	16.15	120.16	60.9	6.76	84.55
10	147.87	31.95	13.97	109.88	60.73	7.84	89.12
11	98.27	18.38	8.6	77.51	50.84	6.36	88.89
12	65.02	11.61	5.97	55.33	42.23	4.99	89.3
Total	**1591.15**	**321.24**	**126.27**	**875.1**	**694.06**	**57.86**	**1053.84**
		1995					
MONTH	**RAIN**	**SURF**	**LAT FLOW**	**YIELD**	**ET**	**SEDIM**	**PET**
(MM)	(MM)	(MM)	(MM)	(MM)	(T/HA)	(MM)	
1	37.58	3.42	3.02	28.55	36.96	2.84	94.95
2	36.71	2.03	1.88	11.23	35.5	1.8	93.06
3	96.83	6.38	4.62	14.99	83.99	1.09	103.41

4	175.27	26.5	9.74	43.37	81.38	1.92	91.68
5	194.46	36.85	15.32	76.43	71.58	2.23	87.87
6	185.55	41.09	15.65	100.68	59.68	2.3	78.31
7	189.97	41.03	16.28	116.24	59.17	2.53	77.81
8	192.59	39.62	16.53	121.76	60.3	3.2	80.16
9	177.31	36.79	15.08	117.51	61.07	4.93	84.66
10	155.36	30.28	14.44	111.66	62.19	6.45	89.28
11	102.77	15.78	9	79.45	53.69	5.07	88.96
12	69.71	10.97	6.42	59.46	45.07	4.46	89.51
Total	**1614.11**	**290.74**	**127.98**	**881.33**	**710.58**	**38.82**	**1059.66**

Annual surface water, ground water and sediment in each sub-basins

Sub basin	**Surface runoff (m^3/)**			**Ground Water(m^3/s)**			**Sediment(T/ha**		
	1995	**2004**	**2013**	**1995**	**2004**	**2013**	**1995**	**2004**	**2013**
1	23.12	32.03	29.05	29.25	24.96	26.34	3.11	8.34	6.35
2	23.68	31.26	29.17	29.69	30.82	34.39	4.09	5.31	3.88
3	23.13	36.22	30.24	28.48	30.55	33.05	3.22	4.53	3.95
4	23.26	35.05	30.85	34.42	28.64	32.52	2.74	7.94	3.77
5	22.24	37.72	33.15	37.67	31.96	34.34	1.34	4.50	3.26
6	22.70	35.63	32.50	36.95	35.49	36.43	1.59	5.11	2.68
7	25.09	25.56	24.56	38.91	35.43	37.00	1.65	0.37	2.29
8	27.22	32.91	31.27	40.34	36.79	37.59	2.30	8.12	5.17
9	25.59	30.48	29.36	35.71	42.96	42.06	0.32	3.01	0.33
10	25.57	29.17	31.23	42.01	42.83	40.39	2.58	4.01	3.97
11	20.10	29.31	28.24	29.30	38.97	39.83	4.08	5.54	4.91
12	22.20	29.36	29.26	35.40	43.31	42.61	2.98	3.07	2.60
13	28.72	22.72	22.08	43.31	36.68	37.58	2.20	2.42	2.27
14	29.86	24.79	23.05	41.42	35.34	37.06	3.59	2.49	2.17
15	27.15	30.43	31.53	39.85	37.00	36.72	4.38	3.23	2.92
16	27.64	24.37	22.26	43.47	30.08	27.43	2.22	1.65	1.99
17	22.61	25.79	22.80	37.50	33.71	36.74	3.14	2.36	1.83
18	26.16	24.39	24.72	35.84	22.18	22.84	3.47	2.44	3.46
19	27.13	27.92	24.13	39.92	31.34	33.93	3.11	13.51	1.87
20	24.77	25.43	27.62	38.05	31.19	29.79	3.14	3.44	12.50
21	25.28	27.50	27.44	35.44	27.02	23.13	3.24	4.10	28.60
22	24.35	28.68	30.42	23.04	37.45	37.44	10.77	3.55	4.20
23	26.96	33.38	31.32	32.98	39.02	39.61	6.25	5.78	4.63

24	26.26	24.24	22.51	26.61	22.17	23.83	8.78	4.63	2.01
25	26.70	29.83	31.08	22.29	43.48	42.87	8.84	2.26	2.83
26	27.55	23.16	23.39	39.31	33.80	33.65	4.80	3.09	2.86
27	29.75	27.39	28.93	40.77	27.24	22.58	3.93	4.22	32.02
28	22.66	33.99	36.12	24.61	35.73	34.43	4.07	5.14	4.38
29	29.08	22.64	22.70	45.01	41.42	35.86	2.47	2.20	2.68
30	23.02	25.12	24.22	34.17	38.53	33.46	4.51	2.09	3.37
31	32.89	25.39	24.11	37.62	38.76	34.74	4.11	3.41	1.47
Max	**32.89**	**37.72**	**36.12**	**45.01**	**43.48**	**42.87**	**10.77**	**13.51**	**32.02**
Min	**20.10**	**22.64**	**22.08**	**22.29**	**22.17**	**22.58**	**0.32**	**0.37**	**0.33**

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