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The Dynamics of Land use Land cover change on the Stream Flow in Fincha Amerti Neshe Sub-basin: Abay basin, Ethiopia.

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Certification

I, the undersigned, certify that I read and hear by recommend for acceptance by Addis Ababa Institute of Technology a thesis entitled **“The Dynamics of Land Use Land cover change on the stream flow in Fincha Amerti Neshe Sub-Basin, Abay Basin, Ethiopia’’** in partial fulfillment of the requirements for the Degree of Master of Science in Hydraulic Engineering.

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Abstract

Fincha Amerti Neshe sub-basin is densely populated causing various effects on resource bases because of deforestation, expansion of residential area, and agricultural land. The sub basin is also facing high erosion by the effects of intense rainfall of the watershed which aggravates the land cover change of the watershed. The objective of this study was to evaluate the dynamics of land use land cover change and its effects on stream flow using SWAT model in Fincha Amerti Neshe watershed. The land use land cover change analyses were performed using ERDAS Imagine 2014 which was used for an input in analysis of SWAT. Land use land cover changes for three different years of 1990, 2000 and 2015 land use scenarios were used for estimation of stream flow. During the study period most parts of the grassland and shrub land were changed to cultivated land. An increase of cultivated land by 18.57% over 25 years period (1990 – 2015) resulted in an increase of stream flow by 13.39m^3/s. In Amerti, there was also an increase of cultivated land and wet lands by 15.57%, 15.27% for the periods 1990 – 2000 to 2000-2015 years respectively. On the other hand grasslands were decreased by 10.44% within 10 years period and 11.78 for the 15 year's period. Moreover, shrub lands and forest showed a significant decrease through the period. i.e Shrub lands showed a higher decrease during the second period from 2000_2015 by -11.13% than the first period from 1990_2000 by -0.84%. The water body becames increased through the decades to promote Fincha reservoir through the tunnel for adding the efficiency of Fincha hydropower. The Nash Sutcliff efficiency, coefficient of determination (R^2) and RSR were used for evaluating the model performance. The model results showed a good agreement and correlation with the observed data with NSE > 0.65, R^2> 0.84, and RSR < 0.6 values.

Key words: Fincha Amerti Neshe watershed, land use change, stream flow, Rainbow, SWAT, ERDAS Imagine.

Dedication

I dedicate this thesis to my Father HABTE ASEFA, and to my mother DINKINESH DESA, for nursing me with affection, love and for their dedicated partnership in the success of my life.

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List of Acronyms

ODSWE	Oromia Design Supervision Works Enterprise
a.m.s.l	above mean sea level
IWM	Integrated Water Management
CSA	Central Statistics Agency
DEM	Digital Elevation Model
ERDAS	Earth Resources Data Analysis System
HRUs	Hydrologic Response Units
HYMO	Hydro-Morphological
ITCZ	Inter-Tropical Convergence Zone
LULC	Land use and land cover change
MoA	Ministry of Agriculture
MoWIE	Ministry of Water, Irrigation and Energy
NABU	Nature and Biodiversity Conservation Union
NSE	Nash Sutcliff Efficiency
R^2	Coefficient of Determination
RSR	Ratio of root mean square error to the measured deviation of measured data
SRTM	Shuttle Radar Topography Mission
SWAT	Soil and Water Assessment Tool
FSBOO	Fincha Sub-Basin Organization Office
WHAT	Web Based Hydrograph Analysis Tool

1. Introduction

1.1 Background

Land use change is an undeniable and significant global ecological trend. As it notes, "Three of the well-documented global changes are increasing concentrations of carbon dioxide in the atmosphere; alterations in the biochemistry of the global nitrogen cycle; and on-going land use/land cover change." (Agarwal, 2000)

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. The relationship between land use and hydrology is complex, with linkages existing at a wide variety of spatial and temporal scales. Land cover and use directly impact the amount of evaporation, groundwater infiltration and overland runoff that occurs during and after precipitation events. The effect of the land cover changes and best management practices has impact on the stream flow of the watershed by changing the magnitude of surface runoff and ground water flow. The change in land use controls the water yields of surface streams and ground water aquifers and thus the amount of water available for both ecosystem function and human use.

Understanding the implications of changes in land cover and land use is a fundamental part of sustainable land planning and development. On one hand, transformation of land cover and land use by human action can affect the integrity of a natural resource system and the output of goods and services of the ecosystem. On the other hand, by careful planning, the development of new patterns of land cover and land use can enhance the well-being of people. Modeling tools have changed the scientific framework for analysis of land use systems, from one that is descriptive to one that is more quantitative which addresses both spatial and temporal dynamics. (Hari Krishna B., *et al*, 2014)

The knowledge how land use/cover change influence watershed hydrology will enable local governments and policy makers to formulate and implement effective and appropriate response strategies to minimize the undesirable effects of future land use/cover change or modifications. Given that impacts of land use/cover change on water resources are the result of complex interactions between diverse site-specific factors and offsite conditions, standardized types of responses will rarely be adequate. General statements about land water interactions need to be continuously questioned to determine whether they represent the best available information and whose interests they support in decision-making processes. (FAO, 2002)

According to Central Statistical Authority (2005), the total land holding area under different land uses in Ethiopia was estimated to be about 11,047,249 hectares. This area is composed of 98.5% of the rural private holdings and 1.5% of the urban private holdings in the country. Of this land, area under temporary crops accounted for 8,193,391 hectares (74.2%); land under permanent crops estimated to be 667,768 hectares (6%); grazing land amount to be 957,856 hectares (8.7%); fallow land is reported to be 839,949 hectares (7.6%); woodland amounted to be 87,057 hectares (0.8%) and land for other uses is estimated to be 301,232 hectares (2.7%).

Land and water resources degradation are the major problems in the Ethiopian highlands that experiences persistent land, water and environmental degradation due to localized and global climatic anomalies. These leave the country to recurrent crop failures and severe food shortages. Low soil fertility coupled with temporal imbalance in the distribution of rainfall and the substantial non-availability of the required water at the required period are the principal contributing factors to the low and declining agricultural productivity. Hence, proper utilization of the available land and water resources is essential to Ethiopia's agricultural development and achievement of food security.

In the 1960s, Blue Nile Basin investigations showed that Fincha river, a tributary of the Blue Nile in western Ethiopia, had great potential for a multi-purpose dam that would provide power generation and water storage for fisheries, irrigation, and recreation. Following these studies, Fincha hydropower dam was constructed in 1973 as a strategy for fostering economic growth in the country through generation of hydroelectricity, irrigation, fishery and tourism (harza, 1965; 1975). Currently out of the installed hydropower capacities generated in the country, this power plant generates 128 MW (Assefa, 2003). The original installed capacity of this scheme was 100 MW but increased to the current level following the diversion of Amerti River into this scheme in 1987. Moreover, the hydropower reservoir supplies water to a sugar factory downstream, created new economic activities such as fishery and has become an important wetland that attracts various bird species.

In spite of these benefits, studies done by the Oromia Agricultural Development Bureau (OADB, 1996) showed that the reservoir has inundated large areas of different land use types and evicted several people from their original places. The lake created after completion of the dam initially submerged an area of approximately 100 km^2, but a few years later the area had increased to approximately 149 km^2. Bezuayehu and De Graaff (2006) estimated that some 3100 families have been relocated against their will after the construction of the dam in 1973. These displaced people mostly moved to available areas within the watershed, and often have started agricultural activities on steep and marginal areas within Fincha watershed. This process of migration and new agricultural activities, in combination with the normal population increase in Ethiopia, have caused land use changes and aggravated the degradation rate of the environment in the upstream parts of the watershed (Assefa, 1994). But there has been no study conducted at this watershed that shows the magnitude of land use changes caused by the creation of the hydropower dam and the implication of such changes at the recent. This study aims to evaluate land use/land cover dynamics and its consequent impacts on stream flow at the current.

1.2 Statement of the Problem

The dynamic nature of land use emanating from increasing population, technology and climatic change is of paramount stage in Ethiopia that needs primary concern. Expansion and intensification of agriculture, growth of urban areas, and extraction of timber and other natural resources will likely accelerate over the coming decades to satisfy demands of increasing population (McColl, 2007).The absence of Land use planning in Fincha amerti-Neshe watershed may have occurred, resulting in erosion problems due to population density changing forests into agricultural land. There is certainly a general lack of conservation measures in the watershed. The land that is now submerged by the lake was previously used for arable crops and grazing, sustaining the lives of many farmers and their families. The number of people forced off their land by flooding is probably increasing, even though the exact figure is not documented. It is likely that some of those whose land has been submerged have either settled in other parts of the watershed or have left the area to make a living elsewhere.

In addition to those evicted by back water who have settled elsewhere, the annual population growth rate have added more people to the population, increasing the demand for land. There is no doubt that this process has put pressure on natural resources through deforestation and over grazing. The increased population migrated up the hills of the watershed area and cleared land to open up new farmland on slopes steeper than 45% (Assefa, 1994). Although Bezuayehu T. (2006) has considered the People and Dam: Environmental and Sochio-economic changes induced by a reservoir in Fincha watershed, Western Ethiopia. he has considered the three periods of land use changes beore the Fincha dam is constructed. In his study he has not considered the recent land use land cover change effect evaluation of the catchment. Therefore, this study aims to estimate the current dynamics of

Land Use and Cover Changes (LUCC) with SWAT model that are related to hydrology mainly stream flow of the sub basin. In addition, this study takes place to asses the main factors for the causes of land use change in the sub basin.

1.3 Research Questions

Fincha Amerti-Neshe sub basin has been affected with different factors due to deforestation, over population, agricultural land expansion and others described above in the statement of the problem. Therefore this study will try to address the following questions:

- ✓ What type of land use change occurred in the sub basin?
- ✓ What are the effect of land use/ land cover change on the stream flow of the catchment?
- ✓ What are the factors/actors for the land use change in the sub basin?
- ✓ What are the different possible measures that able to mitigate the adverse effects of the land use changes?

1.4 Objective of the Study

The main objective of this study is to analyze the recent dynamics Land use Land cover change of the Fincha Amerti-Neshe sub basin and pattern of stream flow under different land use/cover changes of the catchment by using advanced distributed parameter hydrologic model SWAT (Soil and Water Assessment Tool) and available data. Moreover, this research will address the following specific objectives:

- ▪ To analyze the change of land use/land covers for the last Three decades (1990, 2000 and 2015) by using Arc SWAT.
- ▪ To evaluate the land use change on the stream flow of the sub basin.
- ▪ To identify the main factors for the land use change.
- ▪ To identified possible measures to mitigate the adverse effect of land use change.

1.5 Significance of the Study

Hydrologic response is an integrated indicator of watershed condition, and changes in land use/cover may affect the overall health and function of a watershed. Such changes vary spatially and occur at different rates through time. Direct and powerful linkages exist among Spatially distributed watershed properties and watershed processes (Tadele, K., 2007).To envisage the future effects of land use change on river flow, it is important to have an understanding of the effects of historic land use/cover changes have had on watershed hydrological system. Moreover, detecting and simulating the effects of land use/cover change and management on hydrological processes requires a new and improved procedure to instrument watersheds based on the hydrological sensitivity due to land use/cover changes at sub-watershed levels.

This research finding measures for the knowledge of how the land use land cover dynamic change effects on stream flow of the catchment. The knowledge how land use land cover changes influences watershed properties and the compressive analysis of the catchment will enable: local governments, farmers and policy makers about proper land use and different management options. The findings of this research disseminated to different concerned organizations, decision makers and farmers through Medias, libraries and brochures.

In addition, this study is expected to help concerned sectors in planning, developing and managing water resource projects in the study area and be an input for those who are interested to further research in related field and area of study.

1.6 Thesis outline

In this study the land use cover dynamics were detected using spatially semi- distributed SWAT model for three different years land use data. The first chapter states about the introduction or background of study, problem statement and objectives of the study. Chapter 2 deals about review of literatures related to the objectives of the study, hydrological models description Chapter 3 describes about description of the area regarding location, topography, soil and geology of the study area and focuses on the methodology which includes data collection, hydrological model selection, methods of data analysis and model performance evaluation criteria’s. Chapter 4 describes about the results and discussion of the study. Chapter 5 deals about the conclusion of research outcomes and recommendations of for further activities and studies.

2. Review of Literature

2.1 Land Use and Land Cover Changes

2.1.1 Land Use and Land Cover Changes

Land cover refers to the physical and biophysical characteristics or state of Earth's surface and immediate, captured in the distribution of vegetation, water, desert, ice and other physical features of the land, including those created solely by human activities e.g., settlements. ***Land use*** refers to the intended use or management of the land cover type by human beings. Thus, land use involves both the manner in which the biophysical attributes of land are manipulated and intent underlining that manipulation (the purpose for which the land is used e.g., agriculture, grazing, etc), which are more subtle changes that affect the character of the land cover without changing its overall classification. Definition of land use in this way establishes a direct link between land cover and the actions of people in their environment (FAO, 1998a).

Land Use and Land Cover Changes (LUCC) is the shift in intent and/or management constitutes land use and land cover. LUCC can be classified into land use and land cover conversions, and land use and land cover modification. Conversion refers to change from one cover or use type to another, as is the case in agricultural expansion, deforestation, or change in urban extent. Land use and land cover modification, on the other hand, involves the maintenance of broad cover or use type in the face of change in its attributes. Both conversion and modifications of land use and land cover have important environmental consequences through their impacts on soil and water, biodiversity, and microclimate, hence, contribute to watershed degradation (Stolbovoi, 2002).

LUCC is always caused by multiple interacting factors originating from different levels of organization of the coupled human environment systems. It is the result of complex interactions between several biophysical and socio-economic conditions which may occur at various temporal and spatial scales. The mix of driving forces of LUCC varies in time and space, according to specific human-environment conditions. Understanding the underlying LUCC drivers is an important input for planning and decision making (Xiuwan, 2002).

Quite often the study of LUCC is necessitated by the need to know, in quantitative terms, the nature, the extent and the rate at which these changes advance and the problems or impacts they cause. Furthermore, some studies tried to comprehend the effect of changes in upstream land use and land cover, resulting alterations in the movement of water and water availability at the downstream. Increased consciousness of these impacts enhanced their estimating, forecasting and modeling at the regional scales. However, quantifying impacts of LUCC and managements practices at a watershed scale is still complex because of the inherent variability and complex interactions among the different factors. Thus, in order to provide foundations for effective management of natural resources, an understanding must be built on the variability in time and space of the resources and role of human cultures and institutions in bringing those variations (Thomas, 2001).

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

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

2.1.2 Land-Use and Land-Cover dynamics and links

Land cover has gone under continuous change for millennia. This change has occurred through the use of fire for game hunting and clearance of patches of land for agriculture and livestock production, since the advent of plant and animal domestication. This is because human's production demands cannot be fulfilled without modification and/or conversion of land covers. In the past two centuries, the impact of human activities on land has grown enormously because of population increase, technological development and the requirements thereafter, altering entire landscapes, and ultimately impacting the biodiversity, nutrient and hydrological cycles as well as climate (de Sherbinin, 2002), especially in the developing world. These diverse roles have been recognized in a large number of research publications and international conferences, symposia, and workshops devoted to the subject over the past few years.

According to de Sherbinin (2002), land use is the term that is used to describe human uses of land, or immediate actions modifying or converting land cover. On the other hand, land cover refers to the natural vegetative cover types that characterize a particular area. Land-use change is the proximate cause of land-cover change. The driving forces to this activity could be economic, technological, demographic, are the factors. Hence, Land Use and Land Cover dynamics is a result of complex interactions between several biophysical and socio-economic conditions which may occur at various temporal and spatial scales (de Sherbinin, 2002).

2.1.3 Rationale of Land Use and Land Cover Change

Land use and land cover changes result from various natural and human factors within social, economic and political contexts. Hence, the local human activities expressing the drivers can be determined by measuring the rates and types of changes and analyzing other relevant sources of data like demographic profiles, household characteristics and policies related to land resources administration. (Oumer, 2009)

SWAT models have been used to predict the impact of land use change on environmental cycles. Although their solutions vary in terms of the effect magnitude, most of them show that land use change can be an important variable in SWAT models as well as they state that SWAT would be a useful tool for further investigation of land use dynamic implementation. A common weak point of these models is the fact that the land use application was always non-dynamic (steady state land use) and without regard to the spatial variability of the changes. (Friedrich J. *etal*, 2012)

Stream and river control works may have a serious local influence on channel erosion. Channel straightening which increases slope and flow velocity, may initiate channel and bank erosion. If the bed of a main stream is lowered, the beds of tributary streams are also lowered. In many instances, such bed degradation is beneficial because it restores the flood-carrying capacity of channels.(Julien, 2010)

2.1.4 Land Use and Land Cover changes and the hydrological cycle

It is obvious that land cover can affect both the degree of infiltration and runoff following rainfall events, while the degree of land cover can affect rates of evaporation. Land cover has various properties that help to regulate water flows both above and below ground. For example, tree canopy and leaf litter can help reduce the impact of raindrops on the ground, hence reduce soil erosion, while roots hold the soil in place and also absorb water. In the absence of vegetative cover, soil erosion will result and the effects of this phenomenon have been detailed previously.

Ethiopia is the water tower of northeastern Africa. However, land cover change can affect the amount of runoff to the downstream countries of the Nile basin, where every main rainy season big floods are reported. The effects of land cover are not only contained within the country, but also on the low-lying countries of northeastern Africa as well. That is why agreements are being signed between Ethiopia and these countries so that Ethiopia takes care of its soil erosion. Land cover change does not only affect the neighboring countries but also the Nile basin, within the country, where flooding is a common phenomenon. As a result of this, millions worth of resources are lost nearly every main rainy season. Low level vegetative cover could also affect infiltration and could lead to reduced groundwater levels and therefore the base flow of streams (Dagnachew *et al,* 2003).

2.1.5 Effects of Land Use on Hydrology

The relationship between land use and hydrology is of greater interest worldwide as it can provide advice for management actions in order to avoid or minimize the negative effects of specific land use activities on the hydrology of a certain region. However, there are still uncertainties on the impact of specific land use practices to different processes of the hydrological cycle due to the complexity and specificity of characteristics of each catchment. Much of the present understanding

Of land use effects on hydrology is derived from controlled experiments and manipulations of the land surface coupled with observations of hydrological processes, commonly precipitation inputs and stream discharge outputs (De Friesand Eshleman,2004).

According to Calder (1999), the largest changes in terms of land area, and arguably also in terms of hydrological impacts, of tenarise from afforestation and deforestation activities. One of the direct effects of land use changes on hydrology and hence on water resources is through its link with the evapo transpiration regime. Any change inland use and vegetation cover can have impacts on potential and actual evapo transpiration as well as on the discharge regime, which reflects the integrated behavior of all the hydrological processes acting in the catchment (Zahabiyoun,1999). The higher evapotranspiration loss from afforest than from any other land surface is the main reason for this situation.(Lorupand Hansen,2002).

2.1.6 Effects of Afforestation and Deforestation on Hydrology

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

In the case of the In comati basin, few detailed studies have been conducted to assess the impact of land use changes on river flow regime. Nkomo (2003) modeled the water resources in the basin using the WAFLEX model and observed that commercial afforestation, which is one of the major economic activities in the basin, created significant reduction of the natural runoff.

2.1.7 Land Use and Land Cover Classes

The Land use and land cover change studies usually need the development and the definition of homogeneous land use and land cover units before the analysis is started. These have to be Differentiated using the available at a source such as remote sensing, any other relevant information and the previous local knowledge. Hence, based on the priori knowledge of the study area and additional information from previous research in the study area (Buzayehu, 2006) five different types of land use and land cover have been identified for the Fincha catchment. The descriptions of these land use and land covers are given as follows:

Cultivated land: are areas used for crop cultivation, both annual sand perennials, and the scattered rural settlement that are closely associated with the cultivated fields. Due to the difficulty encountered to identifying the dispersed rural settlements this kind of land cover was combined with the cultivated land during classification.

Forest land: Land covered with dense trees which includes evergreen forest land, mixed forest and plantation forests.

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

Grass land: Areas covered with grass used for grazing, as well as bare lands that have little grass orno grass cover. It also includes other small sized plant species.

Water and marshy land: Areas which are water logged and swampy throughout the year, the rivers and its main tributaries.

2.1.8 Land Use Classification Criteria

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

1. The minimum level of interpretation accuracy in the identification of land use and land cover categories from remote sensor data should be at least 85 percent.

2. The accuracy of interpretation for the several categories should be about equal.

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

2.2 Image Classification

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

Image processing takes a basic understanding of remote sensing and of digital images through the fundamental stages of image processing. It also provides a varied set of cases for application of image processing and introduces a wide range of processing techniques. These form the basis for continued development to advanced level. It is the process of assigning each pixel of an image to a particular group or class. In this case the classes are land cover or crop types, so that the aim is eventually to map the land cover types of the whole image. Usually it needs to acquire ground reference land cover information from a field test site within the image. This site or sites were representative of the range of land cover types that might be found in the area.

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

A. Supervised Classification

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

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

B. Unsupervised Classification

Unsupervised classification is a method which examines a large number of unknown pixels and divides into a number of classed based on natural groupings present in the image values. Unlike supervised classification, unsupervised classification does not require analyst-specified training data. The basic premise is that values within a given cover type should be close together in the measurement space (i.e. have similar gray levels), whereas data in different classes should be comparatively well separated (i.e. have very different gray levels) (Lillesand and Kiefer, 1994; Eastman, 1995).

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

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

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

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

C. Maximum likelihood Classification

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

2.2.1 Ground truth and classification accuracy assessment

Ground truth or field survey is done in order to observe and collect information about the actual condition on the ground at a test site and determine the relationship between remotely sensed data and the object to be observed. It is recommended to have a ground truth at the same time of data acquisition, or at least within the time that the environmental condition does not change.

Classification accuracy assessment is a general term for comparing the classification to geographical data that are assumed to be true to determine the accuracy of the classification process. Usually, the assumed true data are derived from ground truth. It is usually not practical to ground truth or otherwise test every pixel of a classified image. Therefore a set of reference pixels is usually used. Reference pixels are points on the classified image for which actual data are known. The reference pixel is randomly select.

2.2.2 Evaluating the accuracy of a classification

The basic idea is to compare the predicted classification (supervised or unsupervised) of each pixel with the actual classification as discovered by ground truth. Accuracy assessment is a general term for comparing the classification to geographical data that are assumed to be true, in order to determine the accuracy of the classification process. The accuracy of a classification is usually assessed by comparing the classification with some reference data that is believed to accurately reflect the true land-cover. Sources of reference data include among other things ground truth, higher resolution satellite images, and maps derived from aerial photo interpretation. Note that virtually all reference data (even ground truth data) are inaccurate to some degree as well.

Accuracy assessment is the measurement of the rate and level to which classified image agrees with the reference (ground) data it represents. In statistical terms, accuracy comprises bias and precision and the distinction between the two is sometimes important as one may be traded for the other (Campbell *et al*, 1989). In mapping of features from a remotely sensed data, the term accuracy is often used to portray the level of ‘validity’ and ‘correctness’ of a map or classification. ‘Valid’ or ‘Correct’ (thematic) maps are those that represent the reality to a significant level of acceptance. That is, a map (thematic) derived from remotely sensed data classification may be considered accurate if it provides an unbiased representation of the actual area of the region it depict. Therefore, classification accuracy describes the degree to which the derived image classification agrees with reality or conforms to the ‘truth’ (Campbell *et al*, 1989). A classification error is, thus, some discrepancy between the situation depicted on the thematic map and reality (Giles M. Foody, 2002).

Classification Accuracy Assessment Measures: Accuracy of any image classification may be tested in four different ways;

1. **Field checks at selected points –** this is usually a non-rigorous statistical technique and it is subjective, that is, it may not be applicable to all classification cases. Selected points of verification are chosen either randomly or along a grid
2. **Map overlays –** this is a qualitative comparative method which aims to estimate the agreement of theme or class that are identified between a class map and

reference maps. The class map and the reference maps are usually superimposed – one on the other

3. **Statistical analysis of numerical data** developed in sampling, measuring, and processing data, using such tests as root mean square, standard error, analysis of variance, correlation coefficients, linear or multiple regression analysis, and Chi-square testing, and
4. **Confusion matrix calculations**. The confusion matrix is a simple cross-tabulation of the mapped class label against the observed in the ground or reference data for a sample set.

   Several measures of classification accuracy may be derived from a confusion matrix. One of the most popular is the percentage of cases correctly classified. The following are some of the accuracy calculations and indices that can be generated from a confusion matrix;

   A. **Overall accuracy:** it is obtained by dividing the total number of correct pixels (diagonal) by the total number of pixels in the error matrix.

   B. **Mapping accuracy:** Mapping accuracy for each class is stated as the number of correctly identified pixels within the total in the displayed area divided by that number plus error pixels of commission and omission.

   C. **Producer accuracy**: Omission error is another term used to mean producer accuracy, it occurs whenever pixels that should have been identified as belonging to a particular class were simply not recognized as present. Producer accuracy is obtained by dividing the total pixels not correctly classified for each class in the reference data (column) by the total pixels for that class in the reference data/image (column total)

   D. **User accuracy:** User accuracy is also referred to as Commission Error. Commission error occurs when pixels associated with a class are incorrectly identified as other classes, or from improperly separating a single class into two or more classes. Commission error is calculated by dividing the number of pixels not correctly classified for each class in the classification (row) by the total number of pixels for that class in the classification (row total).

E. **Kappa co-efficient of agreement:** Cohen’s kappa coefficient is a chance-adjusted measure that was developed and has often been used and adopted as a standard measure of classification accuracy.

Table 2.1 Confusion Matrix and possible accuracy measures (source: Giles M. Foody, 2002)

		Actual Class				
		A	B	C	D	Ƹ
Predicted class	A	n_AA	n_AB	n_AC	n_AD	n_A+
	B	n_BA	n_BB	n_BC	n_BD	n_B+
	C	n_CA	n_CB	n_CC	n_CD	n_C+
	D	n_DA	n_DB	n_DC	n_DD	n_D+
	Ƹ	n_+A	n_+B	n_+C	n_+D	n

$$Overall\ accuracy = \frac{\sum_{k=1}^{q} n_{kk}}{n} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots..3.1$$

$$User's\ accuracy = \frac{n_{ii}}{n\_i+} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots 3.2$$

$$Producer's\ accuracy = \frac{n_{ii}}{n\_+\ i} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.3$$

$$Kappa\ Coefficient = \frac{n\sum_{k=1}^{q} n_{kk} - \sum_{k=1}^{q} n_{k+}n_{+k}}{n^2 - \sum_{k=1}^{q} n_{k+}n_{+k}} * 100 \ldots\ldots\ldots\ldots\ldots 3.4$$

2.3 Hydrological Models

Hydrological models are models describing the hydrological cycle or its major parts. Variations in climate, topography, land types and land-use as well as various man-made interferences with the system make it very difficult to construct general models that treat the whole hydrological cycle in any given catchment in the world. Most models only treat a part of the cycle, e.g., runoff. Models developed in a certain climatic or geologic region often have difficulties when used in a different setting.

Hydrological models are tools that integrate our knowledge of hydrologic systems to simulate the real world hydrologic processes. These models comprise a set of mathematical descriptions of portions of the hydrologic cycle and they are based on a set of interrelated equations that try to convert the physical laws, which govern extremely complex natural phenomena, to abstract mathematical forms. Any hydrological model emphasizes some aspects which are considered relevant instead of others considered of secondary importance, and should be sufficiently comprehensible and easy to be used and in the same way sufficiently complex to represent the physical studied problem. Moreover different varieties of models can be used, depending upon the conceived output, the existing database, input variables and required analysis. Watershed hydrologic models have been developed form any different reasons and therefore have many different forms. However, they are designed to meet one of the two primary objectives. One objective of watershed modeling is to gain a better understanding of the hydrologic processes in a watershed and of how changes in the watershed may affect these phenomena. Another objective of watershed modeling is the generation of synthetic sequences of hydrologic data for facility design or for use in forecasting. They are also providing valuable information for studying the potential impacts of changes in land use or climate. The variety of uses and the rapid increase both in scientific understanding and in technical support, from data collection systems and computer technology, have produced an enormous range in levels of sophistication. (Kassa T., 2009)

There are two major types of hydrologic models can be distinguished:

- Stochastic Models. These models are black box systems, based on data and using mathematical and statistical concepts to link a certain input (for instance rainfall) to the model output (for instance runoff). Commonly used techniques are regression, transfer functions, neural networks and system identification. These models are known as stochastic hydrology models.
- Process-Based Models. These models try to represent the physical processes observed in the real world. Typically, such models contain representations of surface runoff, subsurface flow, evapotranspiration, and channel flow, but they can be far more complicated. These models are known as deterministic hydrology models. Deterministic hydrology models can be subdivided into single-event models and continuous simulation models.

2.3.1 Model Selection

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

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

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

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

- ✓ The model is one that can be applied over a range of catchment sizes from large to global
- ✓ The model have been used for water-balance studies
- ✓ Adequate sophistication to simulate all relevant hydrologic processes
- ✓ Representation should also include the river flow network.
- ✓ The output is in daily values
- ✓ The minimum input data requirements for the model must be easily available.
- ✓ The model able to use data from various global databases.
- ✓ The model is readily and freely available with available documentation
- ✓ Ease of use and modification
- ✓ Software cost and transferability
- ✓ Usage and technical support

Based on the above selection criteria SWAT model was selected for detail analysis and investigation of land use cover change effects on stream flow of Fincha Amerti Neshe watershed.

2.3.2 SWAT Model Description

The Soil and Water Assessment Tool (SWAT) model was developed by US Department of Agriculture – Agriculture Research Service (USDA-ARS). It is a conceptual model that functions on a continuous time step. Model components include weather, hydrology, erosion/sedimentation, plant growth, nutrients, pesticides, agricultural management, channel routing, and pond/reservoir routing. SWAT model is a distributed parameter model that operates on a daily time step so as to predict the impact of management measures on flow, sediment and agricultural chemical yields of the watersheds (Neistsch*et al.*, 2002). SWAT works on a continuous time scale to simulate long-term effects of management changes. Among the many advantages of this model are; it has incorporated several environmental processes, it uses readily available inputs, it is user friendly, it is physically based and distributed, and it is computationally efficient to operate on large basins in a reasonable time. Despite the strengths mentioned above SWAT model have some known weaknesses:

- There is no routing of flow and pollutants with in a sub-watershed
- No routines for concentrated animal feeding operation
- Simplified stream channel degradation and sediment deposition routines
- The tile drainage routine of SWAT does not account for the drain spacing and depth of shallow water table

Agricultural components in the model include fertilizer, crops, tillage options, and grazing and have the capability to include point source loads (Neitsch*et al*., 2001a; Neitsch*et al*., 2001b). The SWAT model predicts the influence of land management practices on constituent yields from a watershed.

SWAT is a theoretical model that adequately simulates hydrologic processes in a basin; the basin is divided into sub-basins through which streams are routed. The subunits of the sub-basins are referred to as hydrologic response units (HRU’s) which are the unique combination of soil and land use characteristics and are considered to be hydro logically homogeneous. The model calculations are performed on HRU basis and flow and water quality variables are routed from HRU to sub-basin and subsequently to the watershed outlet. The SWAT model simulates hydrology as a two-component system, comprised of land hydrology and channel hydrology. The land portion of the hydrologic cycle is based on a water mass balance. (Arnold *et al*., 1998)

Water enters the SWAT model’s watershed system boundary predominantly in the form of precipitation. Precipitation inputs for hydrologic calculations can either be measured data or simulated with the weather generator available in the SWAT model. Precipitation is partitioned into different water pathways depending on system characteristics. The water balance of each HRU in the watershed contains four storage volumes: snow, the soil profile (0-2 m), the shallow aquifer (2-20 m) and the deep aquifer (>20 m). The soil profile can contain several layers. The soil water processes include infiltration, percolation, evaporation, plant uptake, and lateral flow. Surface runoff is estimated using the SCS curve number or the Green-Ampt infiltration equation. Percolation is modeled with a layered storage routing technique combined with a crack flow model. Potential evaporation can be calculated using Hargreaves, Priestly-Taylor or Penman-Monteith method (Arnold *et al.*, 1998).

Loadings of flow, nutrients, pesticides, and bacteria from the upland areas to the main channel are routed through the stream network of the watershed using a process similar to HYMO (Williams and Hann, 1973). The stream processes modeled by SWAT include channel sediment routing and nutrient and pesticide routing and transformation. The pond/reservoir routing allows for sediment settling and simplified nutrient and pesticide transformation routines. The command structure for routing runoff and chemicals through a watershed is similar to the structure for routing flows through streams and reservoirs.

While the SWAT model provides algorithms for calculating different watershed constituent dynamics, the ability of the SWAT model to depict processes in a particular watershed is partially dependent on the quality of input data.

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

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

SWAT-CUP (**SWAT Calibration and Uncertainty Procedures**) is a program designed to integrate various calibration/uncertainty analysis programs for SWAT using the same interface. The program can run SUFI2, GLUE, and Para Sol. The program guides the input files necessary for running a calibration program. Each SWAT-CUP project contains one calibration method and allows running the procedure many times until convergence is reached. It allows saving calibration iterations in the iteration history for later use.

2.4 Watershed Characterization

2.4.1 Approaches of watershed characterization

The choice of catchments from which information is transferred is usually based on some sort of similarity. A number of methods have been applied to modeling un gauged basins such as similarity of spatial proximity and similarity of catchment characteristics (Deckers D, 2006). While catchments for which flow time series are to be estimated may not have comparable gauged catchments thus prohibiting extrapolation using similarity of spatial proximity. Hence, the approach of characterization using similarity of catchment characteristics is applied to estimate the flow of un gauged catchments; earliest; the SWAT model was calibrated against the observed discharge to determine well performing parameters of gauged catchments. Next, a relationship was made between the model parameters and physical catchment characteristics to establish the regional model that serves to estimate model parameters for un gauged catchments. This was done by developing regression equations, which is the most commonly used method, which predicts the model parameter values using one or a combination of physical catchment characteristics. Commonly for each model parameter a separate equation is derived. Then the SWAT model was used to simulate the discharges for the gauged catchment at the outlet to Fincha.

A) Similarity of spatial proximity

Regarding the similarity of spatial proximity, this method is based on the rationale that catchments that are close to each other will likely have a similar runoff regime since climate and catchment conditions will often only vary marginally in space. So the assumption is made that catchments are highly homogeneous with respect to topographical and climatic properties of the watershed. Therefore a particular model approach and accompanying calibrated model parameter values from gauged catchments can be derived and applied at the un gauged catchments in order to predict the discharge regime because of this approach parameter uncertainty is reduced.

B) Similarity of catchment characteristics

With regard to the similarity of catchment characteristics, the classical approach of regionalization consists of three steps. The first step implies calibration of the chosen model structure for a large number of catchments for which sufficiently long and informative observations of discharge regimes are available. This can be done using several criteria which are to be established. Secondly, an attempt is made to derive regression equations, which is the most commonly used method, which predicts the model parameter values using one or a combination of physical catchment characteristics (PCCs). Commonly for each model parameter a separate equation is derived. Finally, parameter values for the un gauged catchment can be estimated using the regional model, which comprehends all the established relationships between PCCs and model parameters merged in the hydrological model, and a runoff prediction can be made.

A common approach for estimating time series of flows at un gauged sites is the extrapolation of flow records from gauged sites. Catchments for which flow time series are to be estimated may not have comparable gauged catchments hence prohibiting extrapolation. For such cases the use of a rainfall-runoff model with regionalized parameters may be a feasible option.

2.4.2 Physical catchment characteristics

Hypsometric integral: indicates the distribution of elevation across the catchment and simply calculated as:

$$HI = \frac{H_{mean} - H_{min}}{H_{max} - H_{min}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..3.5$$

Where: H_{mean}- average altitude of the basin above mean sea level (m)

H_{max}- maximum altitude of the basin above mean sea level (m)

H_{min}-minimum altitude of the basin above mean sea level (m)

Average slope: slope is one dominant factor that controls the water flow velocity where a high slope result in high velocities that reduce the travel time of water to reach the catchment outlet.

- Class a: level to undulation, dominant slope ranging from 0 to 8
- Class b: rolling to hilly, dominant slope ranging from 8 to 30
- Class c: steeply dissected to mountainous, dominant slope over 30 percent

Catchment shape: $Shape = \frac{H_{max}-H_{min}}{\sqrt{Area}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.6$

Circularity index: the ratio of perimeter (km) square to the catchment area in km^2.

$$CI = \frac{P^2}{A} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.7$$

Elongation ratio: represents how the shape of the basin deviates from a circle.

$$EL = \frac{Dc}{L} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.8$$

Where Dc: is the diameter of the circle with the same area as the catchment, L: is the maximum length of the catchment along a line basically parallel to the main stream.

Longest flow path: one of the outputs in catchment delineation process has an indirect indication of time for water to reach to gauging station or outlet.

Catchment area: the amount of water reaching the outlet of the catchment depends on its area.

Land use: which includes land cover types such as water, cultivated, grassland, shrub land and forest area percentage calculated from Land sat classified image.

Geology and soil: the major soil groups of the catchment classified as per FAO soil group which were collected from MoWIE.

Stream density: The stream density of a drainage basin is expressed as the number of streams per square kilometer. $Ds = \frac{N_s}{A} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. 3.9$

Where; Ns= number of streams, A= area of the basin

Drainage density: is expressed as the total length of all stream channels per unit area of the basin and serves as an index of the areal channel development of the basin

$$Dd = \frac{Ls}{A} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 3.10$$

Where Ls= total length of all stream channels in the basin.

Drainage density varies inversely as the length of overland flow and indicates the drainage efficiency of the basin. A high value indicates a well-developed network and torrential runoff causing intense floods while a low value indicates moderate runoff and high permeability of the terrain.

$$Average\ stream\ slope = \frac{total\ fall\ of\ the\ longest\ water\ course}{length\ of\ the\ longest\ water\ course} \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. 3.11$$

Form factor: $Ff = \frac{Wb}{Lb} = \frac{A}{Lb^2} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 3.12$

Where; Wb= axial width of basin

Lb= axial length of basin, i.e., the distance from the measuring point (MP) to the most remote point on the basin.

Compactness coefficient: $Cc = \frac{Pb}{2\sqrt{\pi A}} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . 3.13$

Where Pb= perimeter of the basin

2 πA= circumference of circular area, which equals the area of the basin.

The compactness coefficient is independent of the size of the catchment and is dependent only on the slope.

2.5 Watershed Hydrologic Response

2.5.1 Effects of Watershed Characteristics on stream flow

The flow of a stream is directly related to the amount of water moving off the watershed into the stream channel. It is affected by weather, increasing during rainstorms and decreasing during dry periods. It also changes during different seasons of the year, decreasing during the summer months when evaporation rates are high and shoreline vegetation is actively growing and removing water from the ground.

Stream velocity, which increases as the volume of the water in the stream increases, determines the kinds of organisms that can live in the stream (some need fast-flowing areas; others need quiet pools). It also affects the amount of silt and sediment carried by the stream. Sediment introduced to quiet, slow-flowing streams will settle quickly to the stream bottom. Fast moving streams will keep sediment suspended longer in the water column. Lastly, fast-moving streams generally have higher levels of dissolved oxygen than slow streams because they are better aerated.

Rivers are always moving, which is good for everything, as stagnant water doesn't stay fresh and inviting very long. There are many factors, both natural and human-induced, that cause rivers to continuously change:

- Natural mechanisms which causes change to rivers are runoff from rainfall and snowmelt, evaporation from soil and surface-water bodies, transpiration by vegetation, ground-water discharge from aquifers, ground-water recharge from surface-water bodies, and wetlands ;and formation or dissipation of glaciers, snowfields, and permafrost
- Human-induced mechanisms that also causes changes to stream flows are **s**urface-water withdrawals and trans basin diversions, river-flow regulation for hydropower and navigation, construction, removal, and sedimentation of reservoirs and storm water detention ponds, stream channelization and levee construction, drainage or restoration of wetlands, land-use changes such as urbanization that alter rates of erosion,

infiltration, overland flow, or evapo transpiration, wastewater outfalls and irrigation wastewater return flow.

Watershed characteristics affect river flows. Watersheds with large areas have the potential to generate large river flows because; they have an increased capacity to store water. The velocity of the flows depends on the geology of the watershed, and resulting slope of the channel, which varies among the reaches of the streams throughout the watershed. Assisted by the force of gravity, rivers that flow through steep reaches of a watershed have the potential to move at much higher velocities than rivers that flow through low gradient channels. Elevation of the watershed also can affect the timing of high flows through the river. High elevation watersheds receive abundant snow during the winter which will melt and increase river flows during the late spring/early summer.

2.5.2 Base flow separation

Base flow separation uses the time-series record of stream flow to derive the base flow signature. Graphical separation methods tend to focus on defining the points where base flow intersects the rising and falling limbs of the quick flow response. Filtering methods process the entire stream hydrograph to derive a base flow hydrograph. Recursive digital filters, which are routine tools in signal analysis, are commonly used to remove the high-frequency quick flow signal to derive a low-frequency base flow signal. Such filters are simple and robust but the results are very sensitive to the filter parameter, which needs calibration before the results can be considered to be numerically valid.

Base flow discharge to streams is an important concept in many current watershed models. Base flow recession coefficients can be used to route recharge to the stream (Arnold *et al.,* 1995, Leavesley*et al.,* 1983). SWAT model output results can be significantly improved by estimating the correct average annual ratio of surface runoff to base flow. Hence, application of some type of separation techniques is essential for calibration of the SWAT model.

As the hydrographic record represents a net water balance, base flow is also influenced by any water losses from the stream such as direct evaporation, transpiration from riparian vegetation, or seepage into aquifers along specific reaches. Water use or management activities such as stream regulation, direct water extraction, or nearby groundwater pumping can significantly alter the base flow component. Hence, careful consideration of the overall water budget and management regime for the stream is required.

The direct flow is primarily the direct response of a rainfall event and includes the overland flow (runoff) and lateral flow in the soil profile also known as interflow. The base flow is a component of stream flow which is discharged from natural storage aquifers. A stream flow can be affected by the interruption of the direct flow, such as by diversion of runoff and water harvesting mechanisms. Moreover, in order to have targeted policy in water resources development and use, it is essential to have a reasonable estimation of the direct and base flow components of stream flow.

In stream flow separation, the most frequently used method is filtering separation method which separates the base flow from the stream flow time series data by processing or filtering procedure. Although these methods do not have any physical or hydrological basis it aims at generating an objective, repeatable and easily automated index that can be related to the base flow response of the catchment (Arnold *et al.*,2000).

The digital filter method has been used in signal analysis and processing to separate high frequency signal from low frequency signal. This method has been used in base flow separation because high frequency waves can be associated with the direct runoff, and low frequency waves can be associated with the base flow (Eckhardt, 2005).

Thus, filtering direct runoff from base flow is similar to signal analysis and processing. Equation (1) shows the digital filter used for base flow separation (Arnold *et al.*, 2000).

$$q_t = \alpha * q_{t-1} + \frac{1+\alpha}{2} * \ Q_t - Q_{t-1} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.14$$

Where, q_t is the filtered direct runoff at the t time step(m^3/s); $q_{t-1}$is the filtered direct runoff at the t-1 time step (m^3/s); α is the filter parameter; Q_t is the total stream flow at the t time step (m3/s); and $Q_{t-1}$is the total stream flow at the t-1 time step (m^3/s).

The Base Flow Index (BFI) is used as a measure of the base flow characteristics of catchments. It provides a systematic way of assessing the proportion of base flow in the total runoff of a catchment. It indicates the influence of soil and geology on river flows, and is important for low flow studies. Eckhardt (2005) proposed the general form of a digital filter considering a digital filter parameter and BFI max (maximum value of long term ratio of base flow to total stream flow) (Equation 3.15).

$$b_t = \frac{1 - BFI_{max} \quad * \propto + b_{t-1} + \quad 1 - \propto \quad * BFI_{max} * Q_t}{1 - \propto * BFI_{max}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.15$$

Where b_t is the filtered base flow at the t time step; b_{t-1} is the filtered base flow at the t-1 time step; BFI_{max} is the maximum value of long term ratio of base flow to total stream flow; α is the filter parameter; and Q_t is the total stream flow at the t time step.

BFI_{max} is a new variable introduced in the digital filter method by Eckhardt (2005). To reduce the subjective influence of using BFI max on base flow separation, representative BFI max values were estimated for different hydrological and hydro geological situations by comparing the base flow from conventional separation methods with those of the Eckhardt digital filter method.

2.6 Integrated watershed management Principles

The watershed has been promoted as a useful unit for integrating conservation and development planning since the early 1980s. Sometimes water management efforts (e.g. construction of dams) have been unsuccessful because they have focused on water only, rather than on other environmental components such as sediment, air, or biological issue (Heathcoat, 1998; WCD, 2000). They have failed to incorporate the full range of values and perspectives present among water users or agencies. Consequently, besides their advantages, construction of dams has caused social, environmental and economic problems (Dixon et al., 1989; De Wet, 1999; WCD, 2000).

Although integration at watershed level is increasingly possible, integration at larger scales is conspicuously absent (McDonald and Kay, 1988; Johnson and Baltodano, 2004; Attwater et al., 2005). When small-scale watersheds are considered, the planning tools have commonly focused on participatory development and livelihood systems. However, when regional watersheds or river basins are considered a mismatch between the existing administrative hierarchies and the physical and societal boundaries could be contestable and could affect stakeholders’ participation (Voinov and Costanza, 1999; Attwater et al., 2005). Under such circumstances, appropriate institutions that would allow communication between many administrative entities such as towns, districts and regions are required.

Population density and a limited resource base make integrated watershed management (IWM) essential for sustainable natural resource management. As global concerns about the need for integrated management grows, it may now be social and economic forces, rather than technical considerations, that determine the success of an IWM planning effort (Heathcoat, 1998). IWM approaches have, therefore, shifted from an engineering focus, to a rational comprehensive, and more recently to a participatory approach (Attwater et al., 2005). Stakeholders’ participation is expected to make IWM more successful and sustainable (Johnson et al., 2001). This is one of the lessons coming out of decades of failures of centrally planned watershed development projects through which local people have been either coerced or paid to participate (Pretty, 1995; Pretty and Ward, 2001). IWM is a relatively new a practice in Ethiopia. This concept was introduced to Ethiopia by the soil and water conservation (SWC) programme of the country in the 1980s.

The aim of this IWM approach was to concentrate the human and financial resources in hydrological units in order to achieve better soil erosion control (Sterk, 2006b). Over the years this approach has promoted various SWC measures, restored degraded farmlands, improved soil water holding capacities, increased woodlots, and improved the productivity of pasture lands (Kebede, 1991; WFP, 2002; Betru, 2002; WFP, 2004).

On the other hand, construction of dam projects were planned and implemented without recognizing people as partners and caused community relocation against their will (Dessalegn, 1999). Most dams were planned as a single purpose project by the public power or water supply utility (Michael, 2004), and options assessment has been typically limited in scope and confined primarily to technical cost-benefit analysis (Yonas, 1997). Integration of dam construction with land use change and SWC are seldom practiced in Ethiopia. As a result, sedimentation and the consequent long-term loss of storage of dams is a serious concern (MoWR, 1997; Sileshi, 2001; Michael, 2004). In order to meet its food security, electrification and water supply objectives, the Ethiopian Government envisages construction of new dams, implementation of SWC, *in situ* water harvesting and reforestation. To achieve these objectives the government has formed various organizations, which have different duties and responsibilities and endorsed various policies and acts. To make the implementation of these policies and acts more effective, it is necessary to better understand the factors that influence the adoption of IWM.

2.6.1 Integrated watershed management

Although a strategy that is increasingly advocated in the literature, IWM is still a relatively new concept (Heathcote, 1998). Therefore it is important to clarify this concept. In this paper a watershed is defined as the drainage basin: an area of land within which all waters flow to a single river system. Today there is a clear global consensus that the watershed is an appropriate unit for water and natural resources management (Goodman and Edwards, 1992; Heathcote, 1998; Lixian, 2002). Watersheds have been promoted as useful integrating units for land use planning, SWC and linking upstream and downstream effects. It is also useful for considering the temporal and spatial social organizational structures which overlap the landscape patterns in an open and complex way (Attwater et al., 2005). Watershed management is, therefore, the protection, improvement and rational use of water, land and other renewable natural resources in a watershed, in order to reach the optimal goals of ecological, economic and social benefits (Lixian, 2002). The watershed based planning has the advantage that the watershed is the natural geomorphologic unit for water erosion, in which risks at any point can be understood in relation to its topographic position and the effects this has on local hydrology and sediment production (Morgan, 2005).

Therefore, both on-site and off-site effects of erosion can be appreciated within a watershed. IWM involves a comprehensive multi-resource management planning process, in which all stakeholders within the watershed jointly negotiate how they will define their interests, set priorities, evaluate alternatives, and implement and monitor outcomes (Heathcote, 1998; Johnson et al., 2001; Sims, 2001). The IWM planning process strives to understand the needs and impacts of stakeholders on the natural functions of a watershed and provides a blueprint for making decisions regarding resource management and sustainable development.

Community developed IWM plans are often most effective (Sharma, 1997; Heath cote, 1998). Participation in IWM becomes high when the direct and visible benefits of the programme are in congruence with the interest of the people or community. There are generally two schools of thought on inducing stakeholders' participation: incentive proponents and opponents. The incentive proponents such as the 'Green Water Credits' argue that the downstream users of water should pay the upstream ‘producers’ (Dent, 2005). The rationale for this idea is that the upstream producers are generally poor to invest in SWC and benefit accrues mostly on long-run. SWC techniques increase the supply of clean water and reduce sedimentation. Consequently, compared to the often limited and retarded onsite economic benefits, the offsite economic benefits will be huge and immediate for the downstream users (e.g. hydropower companies, water supply utilities and breweries).

3 Methodology

3.1 Description of the study area

3.1.1 Location

Fincha Amerti-Neshe watershed is situated in the western part of Ethiopia between 9°10’30” to 9°46’45”N latitude and 37°03’ to 37°28’30”E longitudes.

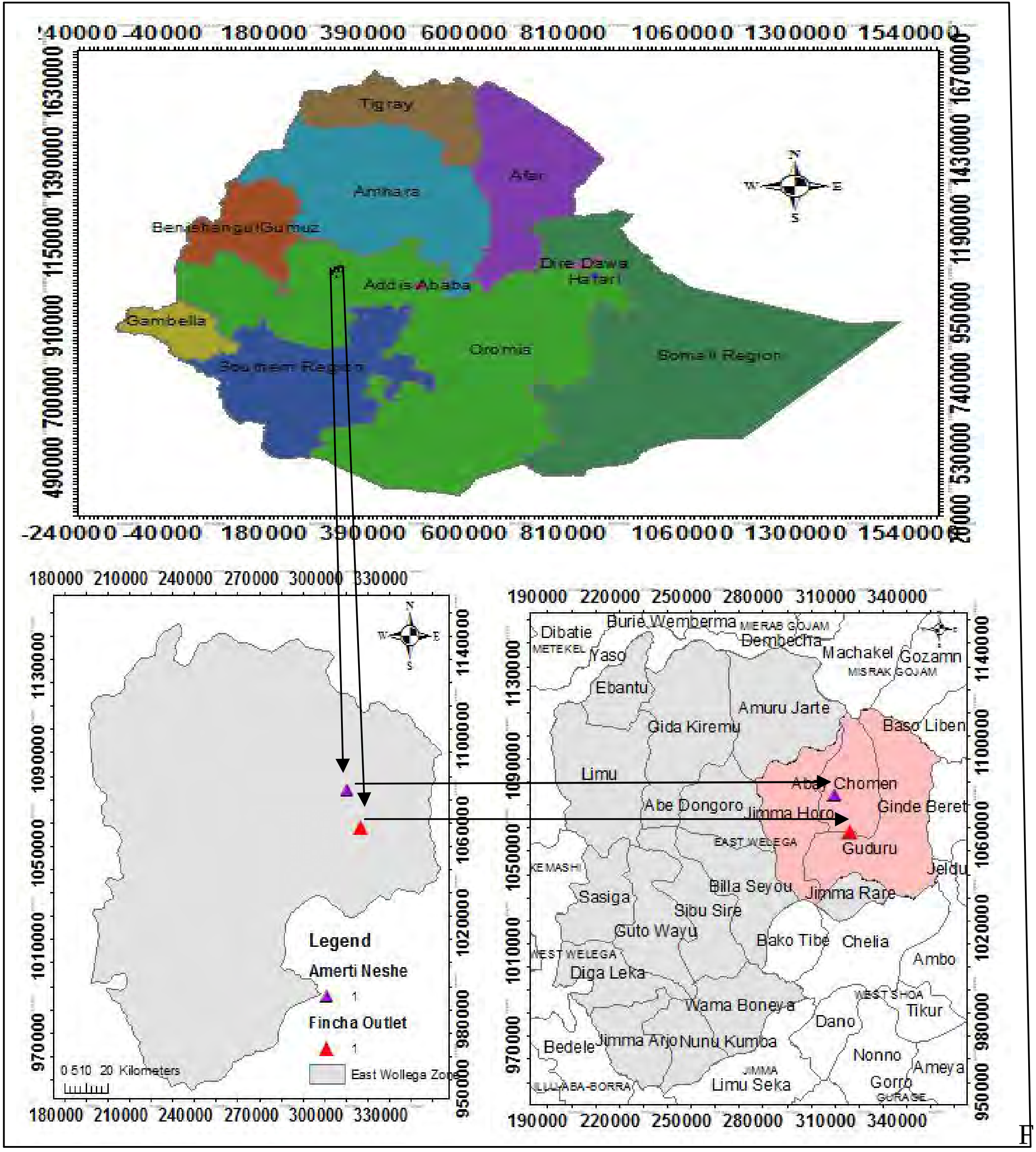

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Figure 3.1 Fincha Amerti_Neshe Location a) Region b) Zonal c) Woredas respectively.

This watershed includes 5 woredas' from Horo Guduru Wollega zones of Oromia National Regional State (ONRS) namely: Abbay Chomen, Horo, Guduru, Jimma Rare, and Jimma Genneti. The Fincha hydropower dam has 340 m crest length and is 20 m high above the lowest foundation level (HARZA, 1975).

3.1.2 Topography

Elevation in the watershed ranges between 2200 m to 3100 m. Most of the area (80%), which can be described as a wide rolling plateau is within the altitude range between 2200 m and 2400 m. About 51% of the watershed is flat (0 to 3% slope steepness), which is mainly under water reservoir and swamp. The gently sloping (3 to 8% slope steepness) to sloping (8 to 15% slope steepness) area covers about 34%, steep (15 to 30% slope steepness)to very steep (> 30% slope steepness) covers about 15% of the watershed area. The higher parts of the watershed near the boundary (where the drainage of all the streams begin) as well as the elevated parts in the middle of the watershed, which are isolated outcrops, are made of Quaternary volcanics. (Bezuayehu T. 2006)

3.1.3 Climate

The climate of Ethiopia is mainly controlled by seasonal migration of Inter-tropical convergence zone (ITCZ) and its associated atmospheric circulation but the topography has also an effect on the local climate. The traditional climate classification of the country is based on altitude and temperature shows the presence of five climatic zones namely: Wurch (cold climate at more than 3000 m altitude), Dega (temperate like climate-highland with 2500-3000 m altitude), Woina Dega (warm 1500-2500 m altitude), Kola (hot and arid type, less than 1500 m in altitude), and Bereha (hot and hyper-arid type) climate (NMSA, 2001). According to this classification, almost all part of the study area falls in Woina Dega climate.

Weather data were available from a station at Shambu (Zonal town), which is situated at the middle part of the watershed (37°06' latitude and 09°34' longitude and elevation 2430 m). The station has a dataset of daily values of rainfall, temperature, relative humidity, sunshine hours, and wind speed from 1970 till today. The yearly average rainfall over the period1970-2003 was 1823 mm. About 80% of the annual rain falls between May to September. The monthly mean temperature varies from 14.9°C to 17.5°C. (The average annual Reference Evapo-transpiration (based on Penman-Monteith) is 1320 mm, with low monthly variations.

3.1.4 Soil, Geology and Land Cover

Quaternary volcanic rocks overlay the older Tertiary volcanic over much of the Fincha Amerti-Neshe watershed boundary. The Quaternary volcanic sequence comprises blocky and fractured vesicular basalt, some basaltic breccias' and tuffs perhaps as much as 200-300 m thick(SMEC, 2007). The soil of Fincha Amerti-Neshe catchment is mostly covered by type of clays and haplic Luvisols with area coverage of around the watershed. Luvisol are generally fertile soils because of their mixed mineralogy, relatively high nutrient content and presence of weather able minerals. The cultivated areas are mostly located on this type of the soil throughout the catchment (Tessema, 2006).

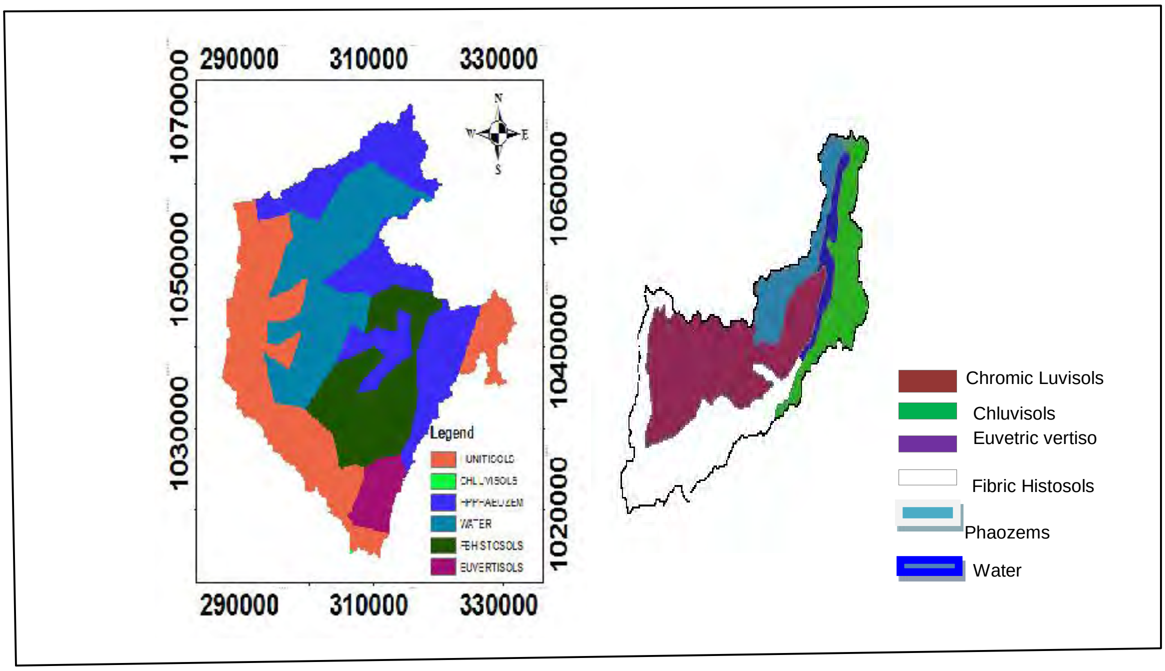


Figure 3.2 Major soils in Fincha watershed

The main land covers in the Fincha Amerti-Neshe watershed are grassland, Wetland, cultivated land, forest and grassland with frequent patches of shrubs, woods, trees and cultivated lands.

3.2. Data Collection

3.2.1 Land use land cover data

Land use is one of the most important factors that affect runoff, evapo transpiration and surface erosion in a watershed. Land use land cover data which is very essential for SWAT input for determining the watershed characteristics, and also used for comparison of impacts on stream flow of the catchment. The LULC map and all datasets for the years 1990, 2000 and 2015 were collected from USGS Earth Explore and USGS GLOVIS. The land use map of the area were reclassified based on the available topographic map (1:50,000) and satellite images. The reclassification of the land use map was done to represent the land use according to the specific land cover types such as type of crop, pasture and forest. A lookup table that identifies the SWAT land use code for the different categories of LULC was also prepared so as to relate the grid values to SWAT LULC classes.

3.2.1.1 Field Survey

The primary data were collected at the field which was used for further analysis, interpretation, and comparison and expressing of watershed characteristics. The data that were collected at field are GPS data of some selected rivers, reservoirs, and other sites, photographs of rivers, some topography, reservoirs, irrigation sites and other relevant data for this study. The collected Ground control points were used for as training points for supervised classification accuracy assessment and geometric correction of satellite images of the watershed.

Figure 3.3 Upper Fincha Dam location

May, 2016

Figure 3.4 Sample photos during field survey around the Fincha catchment (Part of the Watershed)

3.2.1.2 Image Pre-processing

Land sat satellite imageries were used in this study to identify changes in land use land cover distribution in Fincha watershed over 25 years from 1990 – 2015. For this time period three images were selected for land cover mapping of Fincha watershed. During this time period TM and ETM+ were selected to represent the land cover conditions in the years 1990, 2000 and 2015.

Layer Stacking images - In order to analyze remotely sensed images, the different images representing different bands must be stacked. This allows different combinations of RGB to be shown in the view. A layer stack is often used to combine separate image bands into a single multispectral image file. Layer stacking is also commonly used to combine image derivatives with spectral bands for further analysis (i.e., layer stack an NDVI image with spectral bands for input to an image classification).

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

As the images used in this research were obtained in different time scales, they have haze and dust in different proportions and these camouflages the real changes or may show the same kinds of land cover classes as different. To overcome these kinds of problems, atmospheric correction methods are used (Berberoglu and Akin, 2009). The radiometric enhancement of images is an important stage of pre-processing. The aim of image enhancement is to make the objects more prominent by raising the quality of images so as to differentiate between different objects or land cover classes. So the techniques of haze reduction and noise reduction were applied on the images for a better understanding of the LULC classes (Lillesand & Kiefer, 1994). ERDAS Imagine 2014 was used for atmospheric correction, haze and noise reduction and of the Land sat images

3.2.1.3 Geo-reference and Geometric Correction

In order to prepare the multi-temporal satellite images for accurate change analysis and detection, the Land sat images were pre-processed using standard procedures including georeferencing and geometric correction. The World Geodetic System Datum (D-WGS-1984) was used as the coordinate system. Subsets of Land sat satellite images were rectified using ortho photos with UTM projection Zone 37N using first order polynomial method and nearest neighbor image re-sampling algorithm. A total of 20 Ground Control Points (GCPs) were used to register the ETM image subset with the rectification error less than 1 pixel. Rectified digital ortho photos were used in the process and this allowed direct comparison of features between the images and ortho photos during the selection of training samples for use in image classification and accuracy assessment of classified maps. In performing this image pre-processing, ERDAS Imagine Version 2014 was used.

The path and rows used for downloading Fincha Amerti Neshe watershed's satellite image were 170 and 52 respectively. Band compositions of those satellite images that are used for this study were 4, 3 and 2 and also it has 6 numbers of bands for each of satellites.

Table 3.1 Description of Land sat images

Reference data	Sensor	Date of acquisition
1990	Landsat 4, TM	03/01/1990
2000	Landsat 5, TM	11/02/2000
2015	Landsat 5, TM	08/01/2015

3.2.2 Digital Elevation Model

Topography is defined by a DEM that describes the elevation of any point in a given area at a specific spatial resolution. ASTER 30m by 30m DEM of Abay Basin or 90m by 90mof Ethiopia was collected from Ministry of Water, Irrigation and Energy of Ethiopia. The DEM collected were in different layers which was mosaic ked into one raster data set and further Fincha Amerti Neshe watersheds DEM were extracted from this mosaic ked data using ERDAS Imagine 2014. The DEM were used to delineate the watershed, to extract information about the topography/elevation of the watershed and to analyze the drainage patterns of the land surface terrain. Sub-basin parameters such as slope gradient, slope length of the terrain, and the stream network characteristics were derived from the DEM.

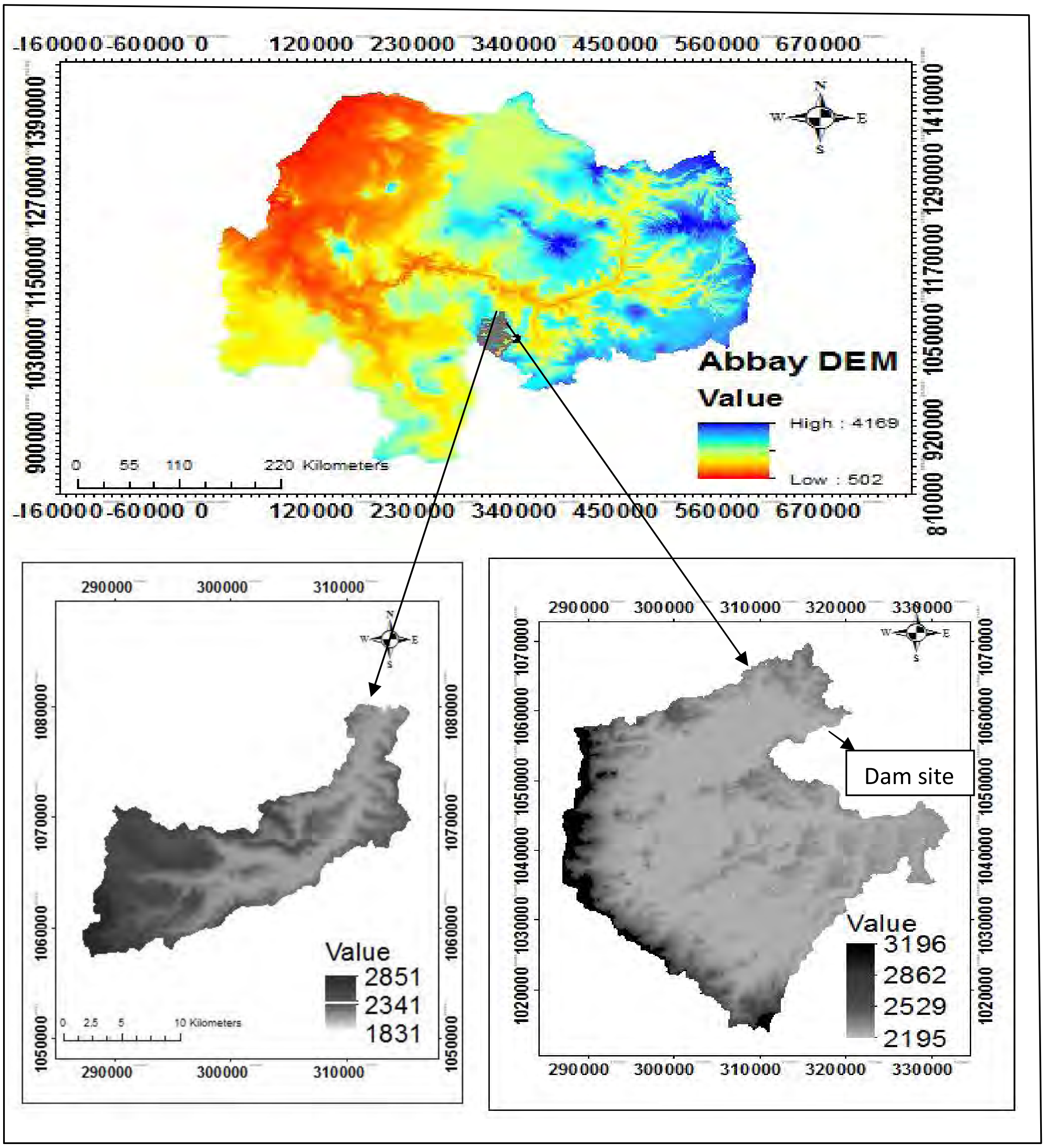


Figure 3.5 ASTER 30m X 30m DEM

3.2.3 Flow Data and Soil Data

Daily flow data is required for SWAT simulation result calibration and validation. This data were obtained from MoWIE. Depending on the extent of calibration and validation, flow data was collected and arranged as per the requirement of SWAT model. SWAT model requires different soil textural and physico-chemical properties such as soil texture, available water content, hydraulic conductivity, bulk density and organic carbon content for different layers of each soil type. These data were obtained mainly from the following sources: MoA, MoWIE or Abbay River basin Integrated Development Master Plan Project-Semi detailed Soil Survey (1999).

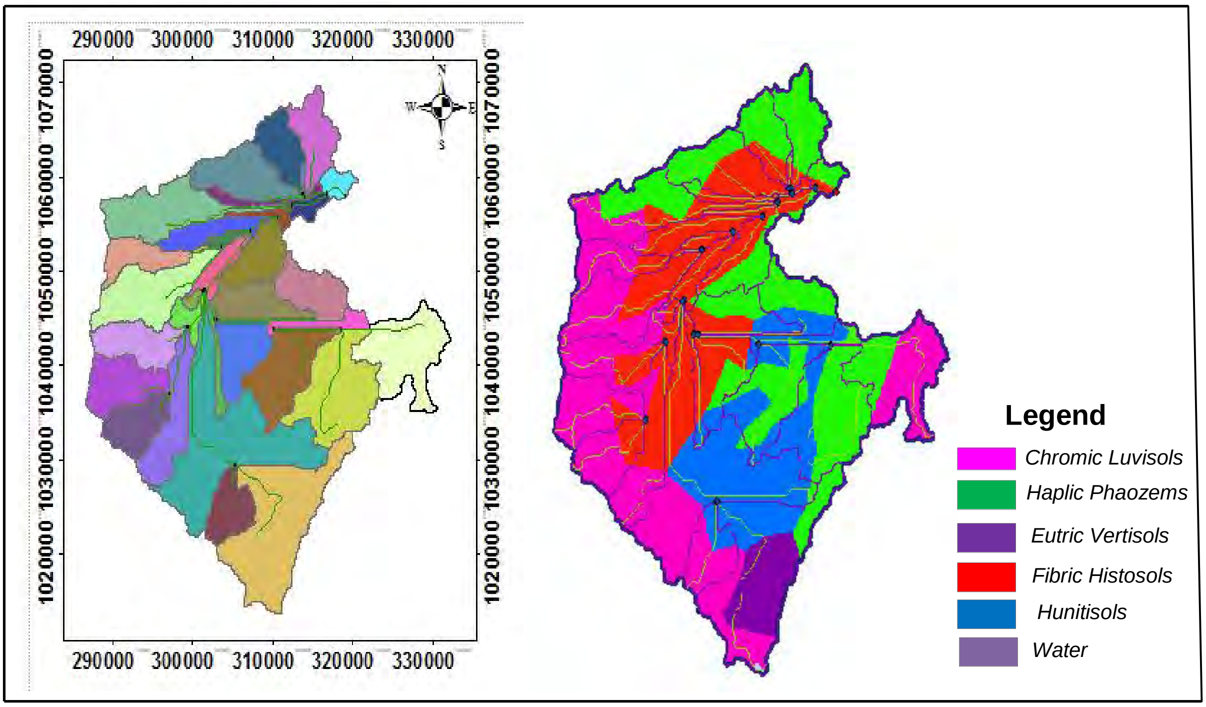
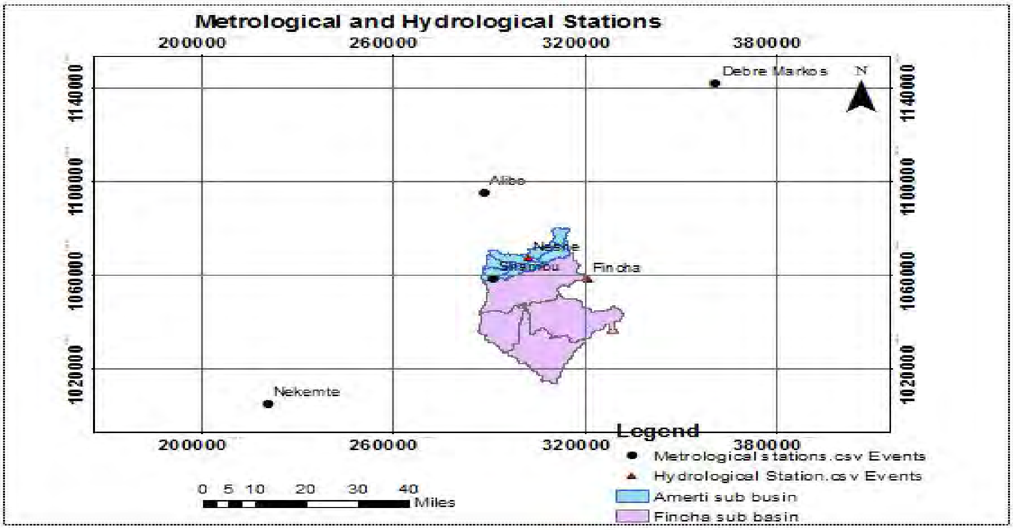


Figure 3.6 Sub basin watersheds and Soil Profile in Fincha respectively.

3.2.4 Climate Data

The climate data is among the most prerequisite parameter of SWAT model. This data were collected from Ethiopian National Metrological Agency. The maximum and minimum temperature, precipitation, relative humidity, wind and solar radiation daily data were collected and arranged downward parallel to corresponding date of record.

The SWAT weather generator model (WXGEN) was used to fill missing values in weather data. The Penman–Montheith method which utilizes the solar radiation, relative humidity and wind speed data records was employed for estimation of potential evapo transpiration (PET) for this specific study. Meteorological stations also geo-referenced using latitude, longitude, and elevation data. The precipitation statistical analysis model (PcpSTAT) was used for



$$difference \qquad \frac{N_X \quad N_i}{N_X}$$

$$P_x \qquad n \quad {}^{\;n}_{\overline{i=1}} P_i$$

In which Pi is the rainfall at gage i. Equation 4.6 is accurate when the total annual rainfall at any of the n regional gages when the mean of percent difference is less than 10%. This method gives equal weight to the rainfall at each of the regional gages. The value 1/n is the weight given to the rainfall at each gage used to estimate the missing rainfall.

If the mean difference is greater than 10% the normal ratio method should be used.

The N_x–N_i must be positive. If $N_i>N_x$ the numerator will become $N_i - N_x$. Then, the mean of the nearby stations' differences is determined.

$$P_X = \frac{1}{n} * [\ \frac{N_X}{N_1} * P_1 + \frac{N_X}{N_2} * P_2 + \cdots + \frac{N_X}{N_n} * P_n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4.7$$

Where P_X is the missing data at station x, N_X is the missing data stations normal annual rainfall, N_i is normal annual rainfall at station i, and n is number of nearby gauges.

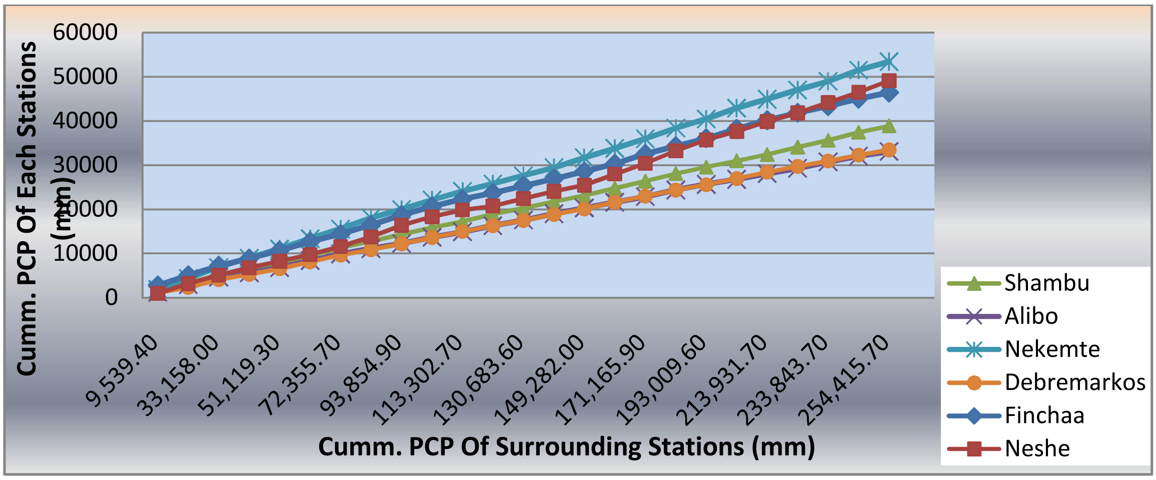
3.3.1 Consistency and homogeneity of Data

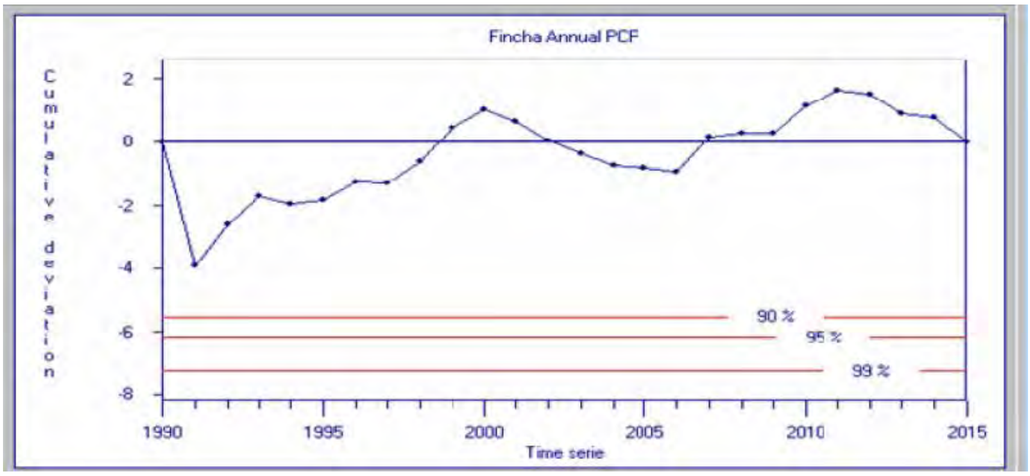
Numerous factors could affect the consistency of rainfall record at a given station. Double Mass Curve (DMC) was used to check the homogeneity and consistency of rain fall as well for adjustment of inconsistent data. This technique is based on the principle that when each recorded data comes from the same parent population, they are consistent. A group of *6* base stations in the neighborhood of the problem station *X* is selected. Annual (or monthly mean) rainfall data of station *X* and also the average rainfall of the group of base stations covering a long period is arranged in the reverse chronological order (i.e. the latest record as the first entry and the oldest record as the last entry in the list).

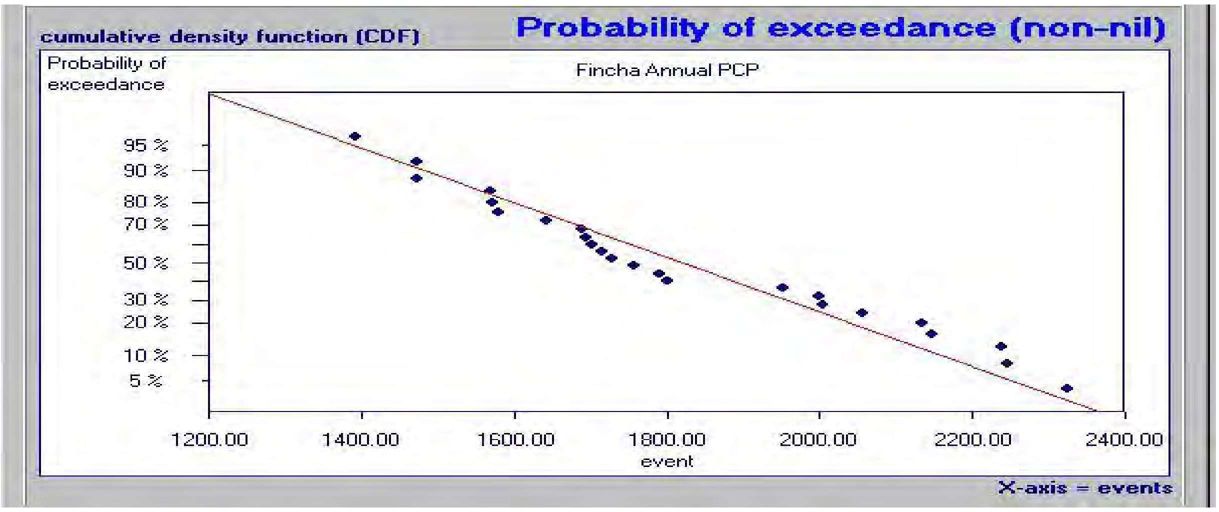
$$\frac{P_a}{P_d} = \frac{Y}{Y_d}\frac{X}{X_d} = \frac{Slope\ of\ Original\ line}{Slope\ of\ deviated\ line} = correction\ factor \ldots\ldots\ldots\ldots .4.8$$

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

$$= \frac{Slope\ oe\ deviated\ line - slope\ of\ original\ line}{slope\ of\ deviated\ line} * 100 \ldots\ldots 4.9$$ greaterthan 10%.


Cumm. PCP Of Each Stations (mm)
60000
50000
40000
30000
20000
10000
0
9,539.40
33,158.00
51,119.30
72,355.70
93,854.90
113,302.70
130,683.60
149,282.00
171,165.90
193,009.60
213,931.70
233,843.70
254,415.70
Cumm. PCP Of Surrounding Stations (mm)
Shambu
Alibo
Nekemte
Debremarkos
Finchaa
Neshe


Fincha Annual PCF
Cumulative deviation
2
0
-2
-4
-6
-8
90 %
95 %
99 %
1990
1995
2000
2005
2010
2015
Time serie


cumulative density function (CDF)
Probability of exceedance (non-nil)
Probability of exceedance
Fincha Annual PCP
95 %
90 %
80 %
70 %
50 %
30 %
20 %
10 %
5 %
1200.00
1400.00
1600.00
1800.00
2000.00
2200.00
2400.00
event
X-axis = events

just like any other imported layer and can be exported in any one of the supported raster formats.

Image classification and enhancement for this study were performed using ERDAS Imagine. ERDAS Imagine was also used for preparation of land use land cover data for SWAT input. This model uses for Data acquisition, image processing and classification of the land use and land cover image of the catchment which is used for further analysis and interpretation of the result.

The land sat data image of the catchment which shows the land use land cover for three different years of 1990, 2000 and 2015 were downloaded and used for ERDAS Imagine for further image enhancement, processing and re-classification.

Layer staking of the different bands of downloaded satellite images were done for all the data on ERDAS Imagine. Afterwards, sub setting or extraction of the watersheds satellite image were done for simplification and time saving of image classification on ERDAS Imagine using the watershed's shape files which was derived from delineated results of the watershed.

Land use / land cover classes were mapped by using supervised classification method and digital remote sensing (satellite images) data. The main objective of classifying satellite images is to categorize pixel values automatically and transform them directly in to the classes or forms of land use. The supervised and unsupervised classification tools of ERDAS Imagine software were used for the classification of satellite images. Maximum likelihood was selected as the parametric rule while using supervised classification. The best grouping of unknown pixels was provided by the use of parameters of the maximum likelihood statistical method. In this particular study Maximum Likelihood classifier has been used in the supervised classification method.

The Ground control points (GCP's) collected from the field, integrating with Google Earth were taken as a signature for supervised classification. A signature level taken was between 10 and 15 for each of the land cover classes over an image.

Ground truth/verification was used on those particular areas, for checking the accuracy of classification. For each class i.e. cultivated, forest, water bodies, shrub land and grassland a between 22 and 36 points were marked as a ground control point. After supervised classification initial LULC map were edited on the basis of ground verification of doubtful areas and some classes were recorded into their respective classes.

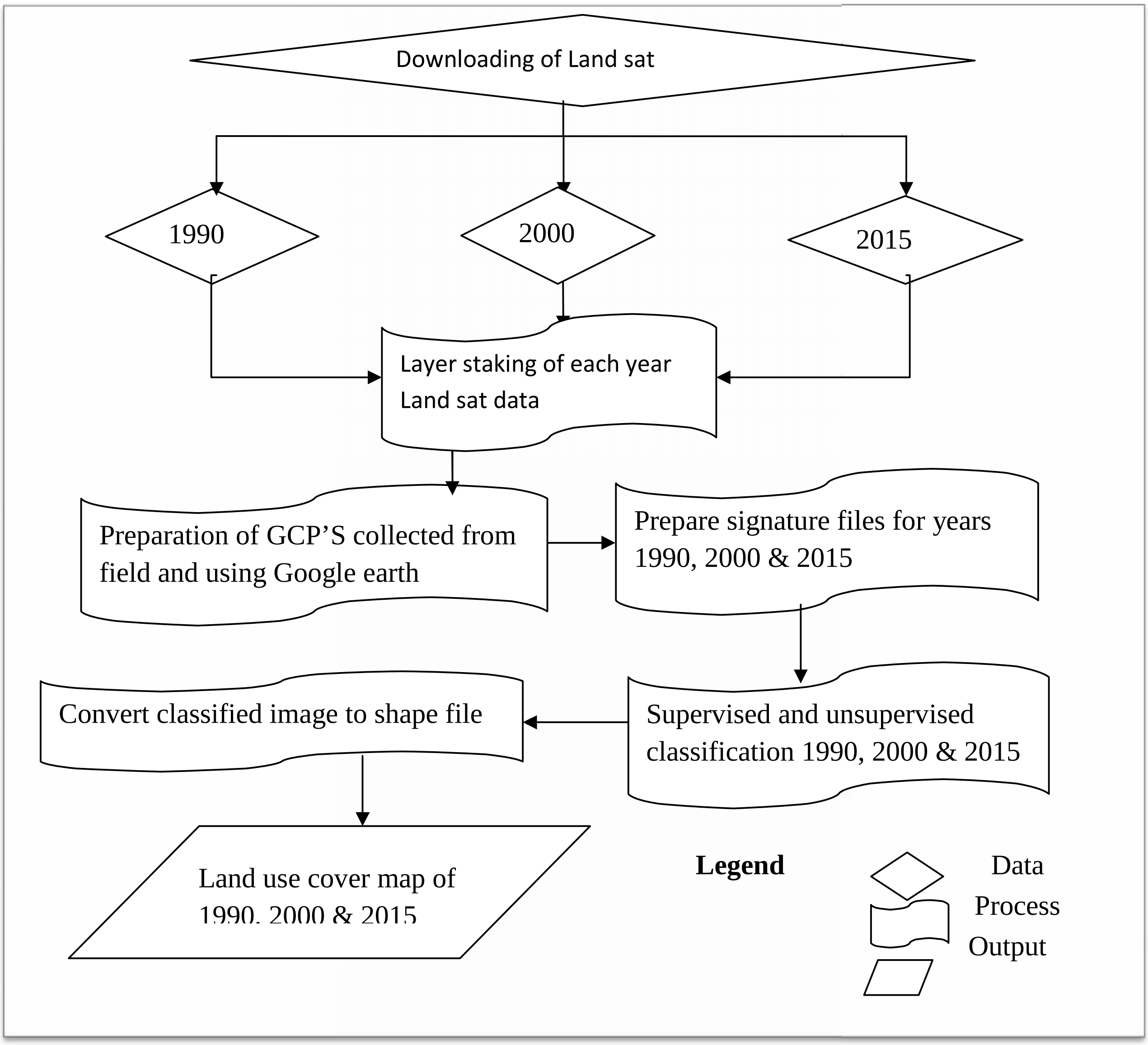


Figure 3.10 Methodology of Land use map preparation

3.5.2 SWAT Model Setup

A. Watershed Delineation

The first step in creating SWAT model input is delineation of the watershed from a DEM. Inputs entered into the SWAT model were organized to have spatial characteristics. Before going in hand with spatial input data i.e. the soil map, LULC map and the DEM were projected into the same projection called UTM Zone 37N, which is a projection parameters for Ethiopia. The watershed delineation process include five major steps, DEM setup, stream definition, outlet and inlet definition, watershed outlets selection and definition and calculation of sub-basin parameters. For the stream definition the threshold based stream definition option were used to define the minimum size of the sub-basins.

B. Hydrological Response Units (HRUs)

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

The HRU analysis tool in Arc SWAT helps to load land use, soil layers and slope map to the project. The delineated watershed by Arc SWAT and the prepared land use and soil layers were overlapped. HRU analysis in SWAT includes divisions of HRUs by slope classes in addition to land use and soils. The multiple slope option (an option which considers different slope classes for HRU definition) was selected. The LULC, soil and slope map was reclassified in order to correspond with the parameters in the SWAT database. After reclassifying the land use, soil and slope in SWAT database, all these physical properties made to be overlaid for HRU definition. Subdividing the sub watershed into areas having unique land use, soil and slope combinations makes it possible to study the differences in evapo transpiration and other hydrologic conditions for different land covers, soils and slopes.

The land use, soil and slope datasets were imported overlaid and linked with the SWAT2012 databases. To define the distributions of HRUs multiple HRU definition options were tested. For multiple HRU definition 10 percent land use, a 10 percent soil and 10 percent slope threshold were used as an adequate for most applications.

c) Outlet and Inlet Definition

In this section additional outlet points were added at the place where stream flow measured data are available or estimated and unwanted ones were removed. The two most important ones are at the dam sites of the catchments, where flow is monitored. These outlets enable finally to calibrate and validate the model output. In this study there was no inlet definition made in the catchment. Finally, after sub basin parameter calculation the each catchment is sub divided in to sub-basins.

3.5.3 Hydrological Component of SWAT

The Simulation of the hydrology of a watershed is done in two separate divisions. One is the land phase of the hydrological cycle that controls the amount of water, sediment, nutrient and pesticide loadings to the main channel in each sub-basin. Hydrological components simulated in land phase of the Hydrological cycle are canopy storage, infiltration, redistribution, evapo transpiration, lateral subsurface flow, surface runoff, ponds, tributary channels and return flow. The second division is routing phase of the hydrologic cycle that can be defined as the movement of water, sediments, nutrients and organic chemicals through the channel network of the watershed to the outlet. In the land phase of hydrological cycle, SWAT simulates the hydrological cycle based on the water balance equation (equation 4.10).

$$SW_t = SW_o + \sum_{i=1}^{t} (R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw} \ldots\ldots\ldots\ldots\ldots\ldots 4.10$$

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

More detailed descriptions of the different model components are listed in (Arnold, J.G *et al*, 1998*)* and (Neitsch S.L *et al*, 2005). Surface runoff occurs whenever the rate of precipitation exceeds the rate of infiltration. SWAT offers two methods for estimating surface runoff: the SCS curve number procedure (USDA-SCS 1972) and the Green &Ampt infiltration method (Green, W.H. and Ampt, G.A., 1911). Using daily or sub daily rainfall, SWAT simulates surface runoff volumes and peak runoff rates for each HRU. In this study, the SCS curve number method was used to estimate surface runoff because of the unavailability of sub daily data for Green &Ampt method.

The SCS curve number equation is:

$$Q_{surf} = \frac{(R_{day} - 0.2S)^2}{R_{day} + 0.8S} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .4.11$$

In which, Q_{surf} is the accumulated runoff or rainfall excess (mm), R_{day} is the rainfall depth for the day (mm), S is the retention parameter (mm). The retention parameter is defined by the equation

$$S = 25.4 * \frac{100}{CN} - 10 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4.12$$

3.5.4 Stream Flow Routing

The flow of a stream is directly related to the amount of water moving off the watershed into the stream channel. It is affected by land use, weather, increasing during rainstorms and decreasing during dry periods. It also changes during different seasons of the year, decreasing during the summer months when evaporation rates are high and shoreline vegetation is actively growing and removing water from the ground. The amount of stream flow that comes from the watershed were estimated or simulated by using Arc SWAT and then calibrated and validated with the observed flow.

SWAT uses the Muskingum routing method to route flow through the stream network of the watershed. The model incorporates losses in flow from factors such as evaporations and infiltration. The model also has the ability to factor in point sources of flow additions or reductions such as surface water pumping or point source water discharges. SWAT provides the modeler with tools to model flow impacts within the channel throughout the watershed. (Neitsch, *et al*, 2005)

The Muskingum method is used to develop the flow in grouting equation used by SWAT:

$$q_{out,2} = C1 * q_{in,2} + C2 * q_{in,1} + C3 * q_{out,1} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 4.13$$

- $q_{in,1}$= inflow rate at the beginning of the time step (m3/s)

•$q_{in,2}$= inflow rate at the end of the time step

•$q_{out,1}$= outflow rate at the beginning of the time step

•$q_{out,2}$= outflow rate at the end of the time step

Base flow separation was done by using Web Based Hydrograph Analysis Tool (WHAT) using the validated stream flow results. Even though, there are three WHAT base flow separation methods (local minimum method, one parameter digital filter and recursive digital filter), recursive digital filter was used in this study; since the other two methods underestimates the portion of base flow of total stream flow.(Neitsch*et al*., 2005).

3.6 Model Sensitivity analysis, Calibration and Validation

3.6.1 Sensitivity Analysis

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

After a thorough preprocessing of the required input for SWAT model, flow simulation was performed for 25 years of recording periods. The first year flow record was used as a warm up period and the simulation then used for sensitivity analysis of hydrologic parameters and for calibration of the model. The results from simulation cannot be directly used for further analysis but instead used for further analysis to sufficiently predict the constituent stream flow should be evaluated through sensitivity analysis, model calibration and validation (White and Chaubey, 2005). When a SWAT simulation is taken place there is a discrepancy between measured data and simulated results. So, to minimize this discrepancy, it is necessary to determine the parameters which are affecting the results and the extent of variation. Hence, to check this, sensitivity analysis is one of SWAT model tool to show the rank and the mean relative sensitivity of parameters identification and this step ordered to analysis. It can increase the accuracy of calibration by reducing uncertainty.

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

Uncertainty

It is necessary to consider uncertainties in predictions of hydrology. There are different uncertainties from different sources. Sources of uncertainty are;

- Input data uncertainties i.e. inadequate data, errors in hydrological and meteorological data,
- output uncertainty (errors in stream flow uncertainty),
- Simplifications in the conceptual model
- Model structural uncertainty and parametric uncertainty.

Hence during this study there was full record data at the outlet which is used for calibration and validation. Meteorological data were not full. The observed data collected were also having missing and outlier. Land use classifications were not fully accurate and it may have effects on

HRU class determination. The other uncertainty is simulation or prediction uncertainty by the model.

3.6.2 Model Calibration

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

Manual and automatic calibration methods were applied. First the parameters were automatically calibrated by using SWAT CUP for the first 15 years until the model simulation result becomes acceptable as per the model performance measures. Next, the final parameter values that were calibrated using SWAT CUP were used as the initial values for the manual calibration procedure. The graphical and statistical approaches were also be used to evaluate the SWAT model performance a number of times until the acceptable values were obtained for surface runoff independently.

3.6.3 Validation

Stream flow data of 6 years were used for validation. The three statistical model performance measures used in calibration procedure were also used in validating stream flow. Similarly, model validation is testing of calibrated model results with independent data set without any further adjustment at different spatial and temporal scales.

3.7 Model Performance Evaluation

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

A. Nash-Sutcliffe Efficiency

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

$$NSE = 1 - \frac{\sum_{i=1}^{n} S_i - O_i \ ^2}{\sum_{i=1}^{n} O_i - O_{mean} \ ^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..4.16$$

Where S = model simulated output; O = observed hydrologic variable; O_{mean} = mean of the observations that the NSE uses as a benchmark against which performance of the hydrologic model is compared; and N = total number of observations. NSE values range from negative infinity to 1, where 1 shows a perfect model. NSE is zero, implies the observed mean is as good a predictor as the model.

B. Ratio of root mean square error to the measured deviation of measured data

$$RSR = \frac{RMSE}{STDEV_{obs}} = \frac{\overline{\frac{1}{n} * \sum_{i=1}^{n}(S_i - O_i)^2}}{\sum_{i}^{n}(O_i - O_{mean})^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..4.17$$

C. Coefficient of Determination

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

$$R^2 = \left(\frac{\sum_{i=1}^{n} O_{i} {}_{-} O_{mean} \ * \ S_i - S_{mean}}{(\sum_{i=1}^{n} O_i - O_{mean} \ ^2)^{0.5} * (\sum_{i=1}^{n} S_i - S_{mean} \ ^2)^{0.5}}\right)^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4.18$$

Where S_{mean} = mean of the model simulations

According to Moriasi, *et al*. (2007) simulation judged as satisfactory if NSE ≥ 0.5, RSR ≤ 0.70 and $R^2 \geq 0.6$ for flow.

3.8 Evaluation of Causing Land Use Land Cover Change

3.8.1 Social case (Population Growth)

The Fincha hydropower reservoir in western Ethiopia has caused major land use changes by inundating 100 km_2 grazing land, 120 km_2 swamp, 18 km_2 cropland and 1.2 km_2 forestland (Bezuayehu and Sterk, 2006a) and has relocated approximately 3100 families against their will (Bezuayehu and de Graaff, 2006). Those people who have been using the inundated parts of the watershed were forced to migrate from their villages and self-resettled in steep and fragile parts of this watershed. As more and more people seek to make a living in this watershed, they expand their cropland into forests and steep hillsides, farm their land in erosive ways and fail to replenish the soil nutrients that have been removed. The construction of the dam was decided by the central government and implemented without the participation of the inhabitants in 1973. A limited amount of monetary compensation was paid to a few landlords but nothing was paid to the majority of the tenants in case the growth of population was increasing from time to time. Animals from the community have drowned in the reservoir and others are exposed to water borne diseases. The rural people in the watershed do not benefit from the electricity generated. In spite of these the dam generate about 128 MW electric power, supply irrigation water for a sugar factory downstream and introduced fishery to the area.

In general communities in Ethiopia have been blamed for not taking an active part in irrigation development projects. This is attributed to a lack of technical expertise to run such projects and lack of ownership feeling. Community participation for effective utilization and management of irrigation schemes were reduced by lack of incorporating the traditional irrigation systems into the design and construction of improved irrigation schemes (Dessalegn, 1999). Instead, some of the traditional irrigation schemes were taken over and upgraded by the government without the consent of the communities and given to the producer co-operatives during 1980s. Those farmers who were unwilling to join the producers' co-operatives were denied access to water and relocated to elsewhere.

Population pressure has been a driving factor of land use changes in many countries in the world (e.g. Mungai et al., 2004; Semwal et al., 2004), and it certainly has played an important role in Fincha watershed as well. But, according to the key informants that were interviewed as part of this study, the creation of the hydropower reservoir also had an important impact on the land use in the watershed. This finally makes land use land cover change around the watershed area.

3.8.2 Environmental Change

In this section environmental problems caused by the dams were explained based on case studies from different dam sites in Ethiopia. IWM to reduce soil erosion and reservoir sedimentation have been seldom practiced in Ethiopia. Failure to do this has increased soil erosion and reduced ground water recharge and base flows of rivers. Moreover, farming is practiced directly along water reservoirs increasing the connectivity of gullies and streams to the water reservoir. As a result, sedimentation and the consequent long-term loss of storage of dams is a serious concern in Ethiopia (MoWR, 1997; Sileshi, 2001; Michael, 2004).

Bezuayehu et al. (2006) have modelled the spatial erosion dynamics in the sub watershed of Fincha watershed. This is mainly because of the conversion of natural vegetation into cropland. Poor vegetation cover on cropland provides insufficient protection from rainfall and runoff detachment. The amount of sediment detached and that actually leave the sub-watershed have increased between 1957 and 2001. The sediment delivery ratio (SDR) has increased from 0.18 in 1957 to 0.20 in 1980 and 0.40 in 2001. Compared to the year 1957, SDR in 2001 has increased by 120% due to major land use changes that occurred across the sub-watershed mainly due to dam construction. Since there has been no buffer strip established between the reservoir and croplands the mobilized sediment load can easily find its way into the reservoir and could reduce the reservoir lifetime and increase the level of water pollution. Field observations showed deposition of high sediment loads at the point where the streams and water reservoir meet. Relatively coarser sediment loads have been deposited before reaching the reservoir where sudden slope changes occurred. Fine particles did probably directly enter into the water reservoir reducing the water storage capacity of the dam. A holistic long-term approach to minimizing the amount of sediments entering a reservoir is to reduce soil erosion in the watershed upstream through SWC (Saavedra, 2005). However, SWC is lacking in the entire Fincha watershed. Deforestation is also another Environmental cause for the changing of land use land cover in the Fincha Amerti Neshe catchment.

3.8.3 Economic Change

The Water Policy Act of Ethiopia recognizes water as an economic good for its substantive and significant contribution to the country’s economy. However, lack of finance, uneven spatial and temporal distribution of water resources, and the trans-boundary nature of the major rivers have been some of the major factors for the insufficient utilization of water resources (Dessalegn, 1999; Gedion, 2003). In order to reduce financial constraints for irrigation development the central government has recently introduced cost recovery or cost sharing mechanisms. An example is the 15-year water sector development programme of Ethiopia that was presented in 2002. The programme envisaged cost sharing mechanisms for small-scale irrigation scheme development. Beneficiary farmers have to pay 20% of the total cost. The remaining costs were planned to be covered by the central government, donors, NGOs and private investors.

3.8.4 Lack of an integrated planning approach

In Fincha, dams are planned top-down, relocate people against their will, cause haphazard land use changes and cause increased soil erosion and reservoir sedimentation. Communities have not been sufficiently recognized and compensated and environmental protection measures such as land use planning and SWC have not been adopted in watersheds where dams have been implemented. Revenues generated from hydropower and water supply dams often benefit urban dwellers or the national economy at the costs of rural inhabitants. The creation of different state organizations responsible for planning, development and monitoring water resources and formulation of environmental policies is a major step fore ward in Ethiopia. Effective implementation of these policies and strategies may improve the quality of future watershed based developments. However the question of how participation and integration are to be promoted in their implementation has not been adequately addressed. Since public goals by their nature are trans-disciplinary the use of multi-disciplinary teams should be employed whereby each member contributes its professional perspective to the problem at hand. In the process of forging partnership between the government, dam builders and community to plan new dams bringing stakeholders to a common platform is essential

3.9 Integrated watershed management in Fincha Amerti-Neshe

Fincha dam is a multi-purpose dam that was completed in 1973 for electric power generation, irrigation, and fishery. The dam has caused major land use changes in the watershed and led to some 3100 households being displaced from their villages against their will. The relocated rural population has resettled in steep and fragile parts of the watershed because no formal resettlement arrangements were made for them, nor were they paid appropriate compensation. Elderly farmers described these parts of the watershed as very productive in terms of grass and crop production. The major drivers of land use changes in Fincha watershed were the creation of the reservoir and the population pressure induced by forced migration due to the dam and normal growth. The 1975 land reform in Ethiopia should have contributed to some extent to land use changes in this watershed, because this reform opened up access to grazing lands and forests for the expansion of cropland and settlements. As more and more people seek to make a living in this watershed, they expand their cropland into forests and steep hillsides, farm their land in erosive ways, and fail to replenish the soil nutrients that have been removed**.** The factors of land use change in this watershed have therefore been interacting in a very complicated way.

The removal of vegetation cover on steep slopes probably reduced rainfall infiltration and groundwater recharge. Consequently, some farmers with fields on steep slopes reported that their crops often fail because of moisture stress. Rivers and streams often transport debris and stones to downstream areas, often bursting their banks and flooding crops and sometimes villages during heavy rains. Nowadays, most perennial springs dry up, exposing the community to the problem of water shortage. Despite these problems, the entire watershed has not been subjected to SWC measures. Neither are any meaningful policies in place to prevent unwise land use changes in the watershed.

The group discussions held with poor and rich farmers in two sub-watersheds identified five major agricultural problems in the community: 1) decreased cropland area, 2) increased costs of chemical fertilizers, 3) decreased crop yield due to erratic rainfall and soil erosion, 4) decreased grassland area and grassland productivity, and 5) increased livestock diseases. There was not much difference between the sub-watersheds in the type and ranking of the problems identified, but quite a big difference was noticed between the problems and priorities of the rich and poor farmers. The shortage of grazing land and increase in livestock disease has not concerned the poor farmers as much as it has concerned the rich farmers, because the poor farmers own fewer animals. The poor farmers were very concerned about meeting their immediate need for crop production, which is constrained by land shortage and declining soil fertility. The rich farmers apply the traditional soil fertility enhancement practice, known as *ciicata*, and chemical fertilizers to sustain crop production. The poor farmers stressed that though the rising costs of chemical fertilizers is a general community problem; the poor farmers are worst affected. For example, the high cost of chemical fertilizer was the foremost problem mentioned by the rich farmers, but the most important problem for the poor farmers has become the decline in cropland area. The farmers expressed interest in doing something that would enable them to extricate themselves from these multifaceted problems.

In the past, farmers and agricultural extension officers believed that the traditional trenches for collecting runoff would be sufficient to protect fields against erosion. Recently, however, agriculture has been practiced on steep slopes, where the runoff trenches are inadequate for controlling soil erosion. Scouring of the embankments and overtopping have undermined their performance, leading to rill formation and losses of seed, fertilizer, and moisture. The trenches can be combined with other SWC measures if their gradients are low. But if the gradients of trenches exceed the gradients of conventional SWC measures, there is a risk that the trenches will counteract the other measures of soil erosion control. The possibility of improving the performance of the trenches on steep slopes needs to be studied, as does the mechanism of combining them with conventional terraces. The high concern farmers showed about the escalating costs of fertilizer indicates an interesting option for the promotion of erosion-reducing measures that prevent nutrient losses. If farmers can be convinced about the stabilizing effects of these measures on crop yields, they may become more interested in adopting the measures. Though the implementation of the SWC measures requires large initial investments, in the long-term they may reduce expenditure on fertilizers, thus making the land more profitable.

The major factors affecting SWC adoption are the farmer’s wealth status, land tenure arrangements, and degree of access the farmers have to information. Wealthy farmers grow food and cash crops (nitrogen fixers), apply *ciicata*, practice fallowing, and plant trees. These farmers clearly have more options to invest in the farm and their land. Poor farmers are

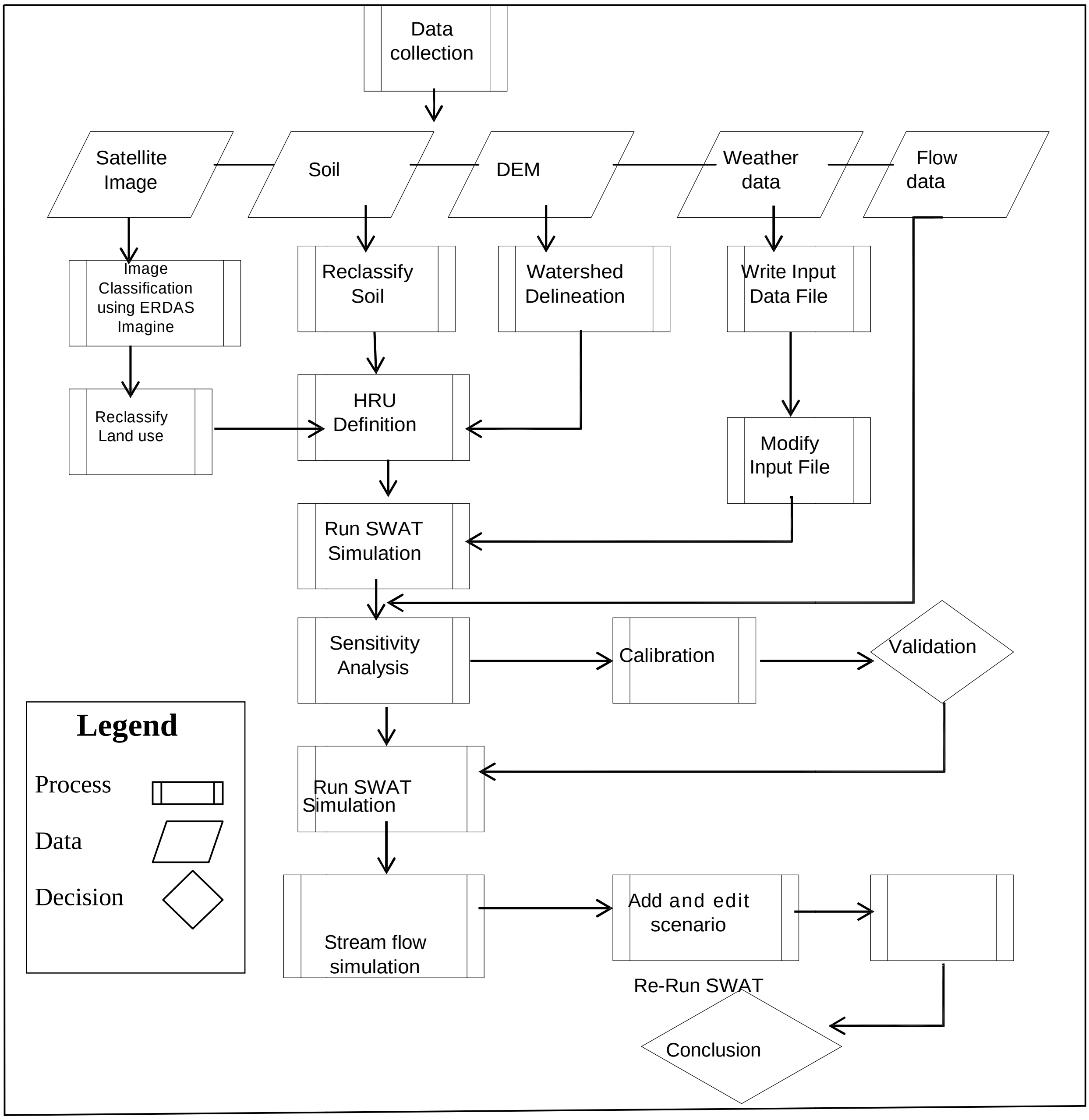
Constrained by land insecurity and low livestock numbers. They rarely apply management practices that sustain or enhance the crop production levels. Hence, the practices of the poor farmers may lead to soil mining and erosion, and threaten the family's future food security. However, the few farmers that had a clear interest in SWC measures were from the group of poor farmers. But they were not yet convinced that the recommended measures would improve their crop yields, so had not yet implemented SWC measures.

Individual farmers have rights to use the cropland that they have been allocated. On the other hand, a large area of grazing land and woodland is common property. This common land is mainly on steep slopes. It is being encroached on by members of the farming community, which is creating hotspots of runoff generation and soil erosion. In order to minimize land degradation problems on these land use types, the local government could perhaps give this land to users' groups on a long lease, giving the members of the group the right to own the benefits harvested from the lands. Moreover, the users' groups could be encouraged to practice joint forest management. Since such joint forest management can have significant offsite effects and the forest products may not give immediate economic benefit to the farmers, certain amounts of money could be allocated to encourage the management initiatives. The cost of seed could be split between the power company and the farmers.

It has become clear that the number of farmers who had contacted the SWC professionals and development agents was extremely low. There are two possible explanations for this: (1) farmers are not convinced about the foreseeable economic benefits of applying SWC, and (2) the extension methods followed in the past could have demotivated them. The lack of community participation in problem analysis, technology selection, design, and construction may have fostered aversion to SWC among farmers. Local government institutions believe that farmers are often mismanages of forests, soils, and water and must be advised and forced to adopt SWC technologies.

On the other hand, farmers believe that their soil management practices are appropriate and they rely on their traditional practices. These differences in outlook have hampered smooth communication between government extension workers and farmers in Fincha watershed and probably elsewhere. To bridge these gaps, improved extension services and institutional support are required. In many cases the farmers were very wise not to accept the unproven technologies that were on offer because their life is fraught with risks of crop failure that could be caused by poorly implemented SWC technologies. Farmers have to be cautious; they cannot afford to make mistakes. When a new technology does meet a real need, the rate of spontaneous adoption can be very rapid. This situation was clearly reflected when the number of farmers who adopted SWC was compared against those who applied chemical fertilizers and used improved seeds.

Figure 3.11 General Framework of Methodology Used are as shown below



4 Results and Discussion

4.1 Physical catchment characteristics

The physical catchment characteristics of the watershed are affected by the pattern of land use Land cover scenario. The physical catchments characteristics of the two watersheds are discussed below. Geography and physiographic characteristics estimated from the 30mX30m DEM (Table 4.1).

Table 4.1 Geographic and Physiographic Characteristics of Fincha and Amerti Watershed

No.	Geographic and physiographic characteristics	Units	Name of the watershed	
			Fincha	Amerti Neshe
1	Catchment Area	km^2	1283.92	260.45
2	Perimeter	km	256.78	65.11
3	Longest flow path	km	73.10	22.50
4	Circularity Index		51.36	16.27
5	Elongation ratio		0.93	0.75
6	Shape Length		655.12	133.2
7	Hypsometric integral		0.13	0.25
8	Compactness coefficient		3.92	2.12
9	Form factor, Ff		0.68	0.14
10	Drainage density		0.007	0.034

From table 4.1 we can conclude that two of the watersheds have different characteristics. The topography and slope of the two watersheds was also determined from 30mX30m DEM.

The correlation results of table 4.1 catchment characteristics showed that Fincha Amerti Neshe at outlet to Lake Chomen has different correlations with Fincha and Amerti watersheds. These correlation values indicate that those two watersheds have more or less differ in geographic and physiographic characteristics.

The topography and slope of the watershed was determined from Digital Elevation Model.

Table 4.2 Topography and elevation of the two watersheds

Item		Name of the watershed	
		Fincha	Amerti
Slope in (%)	0-5	42.22	33.56
	5-10	38.10	21.33
	> 10	19.68	45.11
Elevation (m)	Min	2177	1851
	Max	3197	2851
	Mean	2304	2103.5
	St.dev	131.62	127.23

Those of the two watershed at outlet to Fincha reservoir have more or less similar slope and topographic or elevations. The characteristic features of soil, for the Upper Fincha and Amerti at outlet to Fincha were derived from MoWIE (Table 4.3).

Table 4.3 Soil class comparison of the two watersheds

No.	Types of soil	Units	Name of the watershed	
			Fincha	Amerti
1	Eutric Vertisols	%	4.15	1.25
2	Humic Nitosols	%	16.77	9.25
3	Water bodies	%	0.02	3.50
4	Chromic Luvisols	%	29.01	32.25
5	Haplic Phaozems	%	26.45	24.50
6	Fibric Histosols	%	23.59	29.25

The soil correlation results of Fincha Amerti Neshe Watershed at outlet to Lake chomen were also 0.87, with Amerti watersheds. These values indicated that soils of the catchment showed good agreement.

Table 4.4 Land cover class comparison of the two watersheds.

No.	Types of land cover	Units	Name of the watershed	
			Fincha	Amerti
1	Cultivated	%	57.73	55.11
2	Water	%	17.53	9.93
3	Grassland	%	6.78	5.41
4	Shrub land	%	1.43	7.08
5	Forest	%	1.96	2.39
6	Wetland	%	14.57	20.08

The land use cover comparisons for those watersheds (Table 4.4) were taken from the classified Land sat satellite images of 2015.The Land cover classes correlation results of Fincha and Amerti watershed outlet to Lake Chomen were somehow similar. Hence, the land cover conditions throughout the watershed shows similar characteristics of land use type.

4.2 Land Use Land Cover Change Analysis

4.2.1 Land Cover Classification

The Fincha population depends mainly on the extensive cereal based farming system that mounts pressure on the remaining fragile lands. Besides, 20 to 35% of the farm households, who have recently formed their own families, have already become landless (OADB, 1996). Following the inundation of the vast grazing lands and cropland expansion, livestock production activity, which is equally important as crop production, has faced a serious challenge. The two major economic activities have entered a state of competition rather than supplementing each other. Crop intensification is still lacking and improved livestock feed sources were not developed in the area either. Hence, the free grazing practices have been one of the major causes of land degradation in

Fincha watershed as well as the country. But so far, there has been no meaningful policy implementation, which either regulates the livestock numbers or promotes the production of improved fodder sources. Due to the current shortage of grazing land, livestock numbers have decreased (Bezuayehu and De Graaff, 2006) and farmers were forced to graze the swamp that resulted in drowning of animals.

After through step by step processing and land cover detection the map showing only six (cultivated, water, grass land, shrub land, wetland and forest) classes of land use cover were created unifying these classes for the 1990, 2000 and 2015.Afterwards, spatial analysis of land cover has been performed to describe the overall land use cover patterns throughout the watershed. Generally major parts of cultivated land are found at the corner of water body and grass land for the Fincha and north western parts of the watershed at large in Amerti, and grasslands at south and middle parts, while shrub lands at south eastern and south western parts of the watershed respectively.

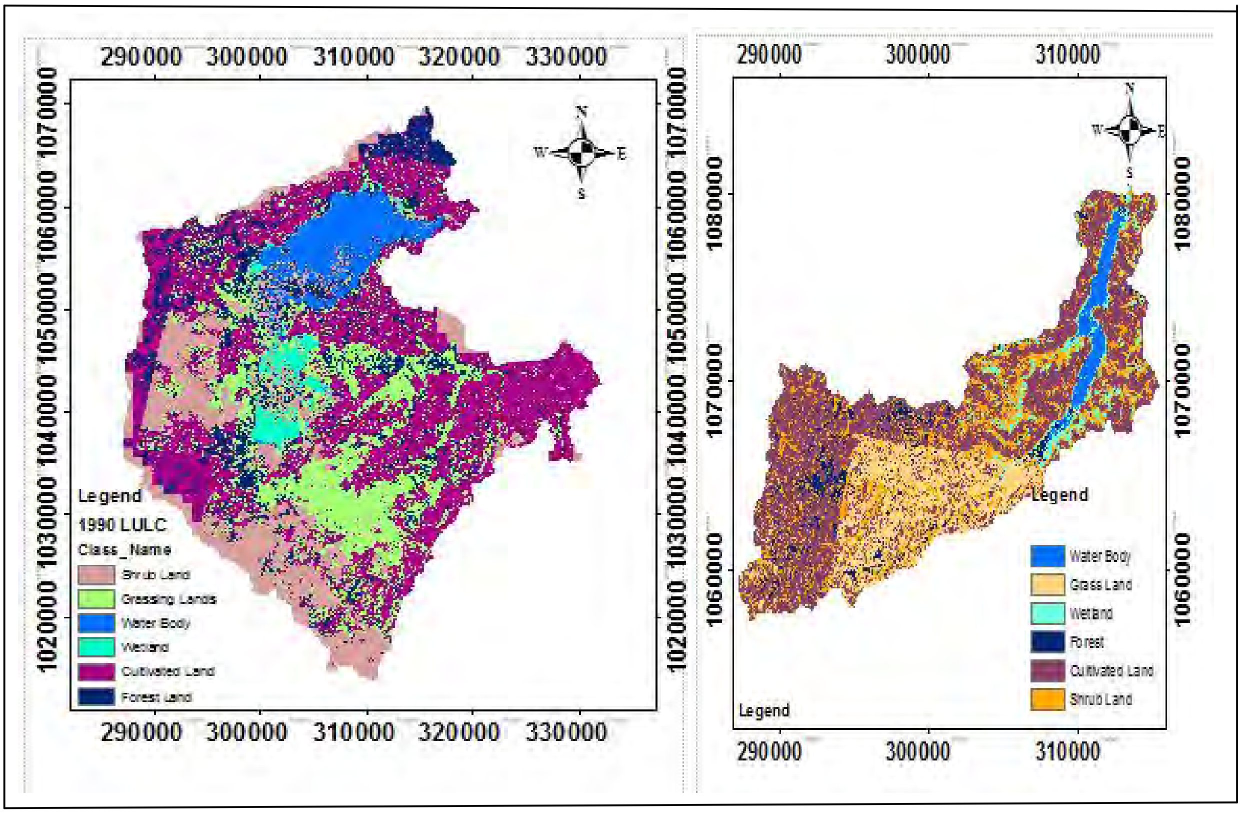


Figure 4.1 Land use land cover map of Fincha and Amerti for the year 1990 respectively.

According to maximum likelihood classification of 1990 land sat satellite image; the land cover classes (Figure 4.1 and Table 4.5) of Fincha showed dominantly covered with cultivated and grassland with 38.28%, 21.34% coverage, followed by shrub land and Forest with 18.13% and 13.54% coverage's respectively. Water and wetland covers small percentages, i.e. 6.43% and 2.27% respectively.

At the same time the areas of grazing land and Cultivated Lands are increased in Amerti having 27.63% and 39.54% respectively, which is a similar trend as in the Fincha watersheds. Compared to the Fincha study areas, the land cover of Amerti was attaining similar situation during the 1990 period. Shrub land and Forest was existed by having 19.05%, 5.27% and the wetland and water body was relatively a low proportion of the entire area at the first and increasing through the year. But, Due to growing populations, the crop based farming systems at Amerti, and Fincha demanded more land for cultivation and incase increased deforestation (Assefa, 2003).

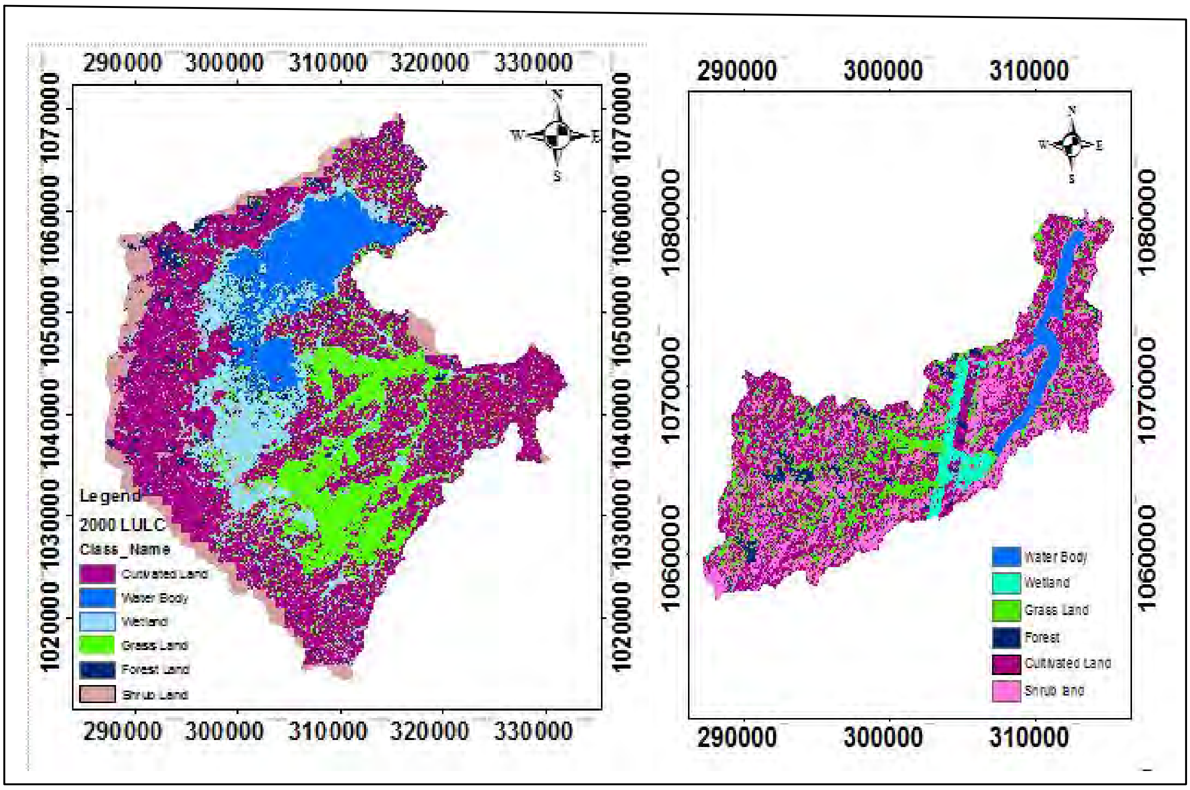


Figure 4.2 Land use land cover map of Fincha and Amerti for the year 2000 respectively.

The maximum likelihood classification of 2000 land sat satellite image showed that the land cover classes (Figure 4.2 and Table 4.5) were dominantly covered with cultivated land having 45.59% coverage of the whole watershed, followed by grassland, swamp, water with17.20%, 14.84%, 9.56%and shrub lands of 8.51% coverage respectively. Forest covers the remaining small percentage of the watershed, 4.29%. These results remarked, there was an agricultural expansion during the periods 1990 – 2000, and also a rapid increase of swamp land by 14.93%. This happens a decrease of shrub and grassland land by 9.62% and 5% on the other hand. These reveals that the changes in one land use cover resulted in a change in on the other land cover types.

The Land cover of Amerti was no more changed because of the Dam construction is not finished rather the land use change showing little change by increasing the cultivated land and wetland during the study period having 48.92, 5.56% respectively. Moreover Shrub land, Grass land, and Forest land were decreased with relatively low proportion having 18.21%, 17.19%, and 5.06% of the entire area. The water body catchment area has increased with 5.07% from 3.69% in the past.

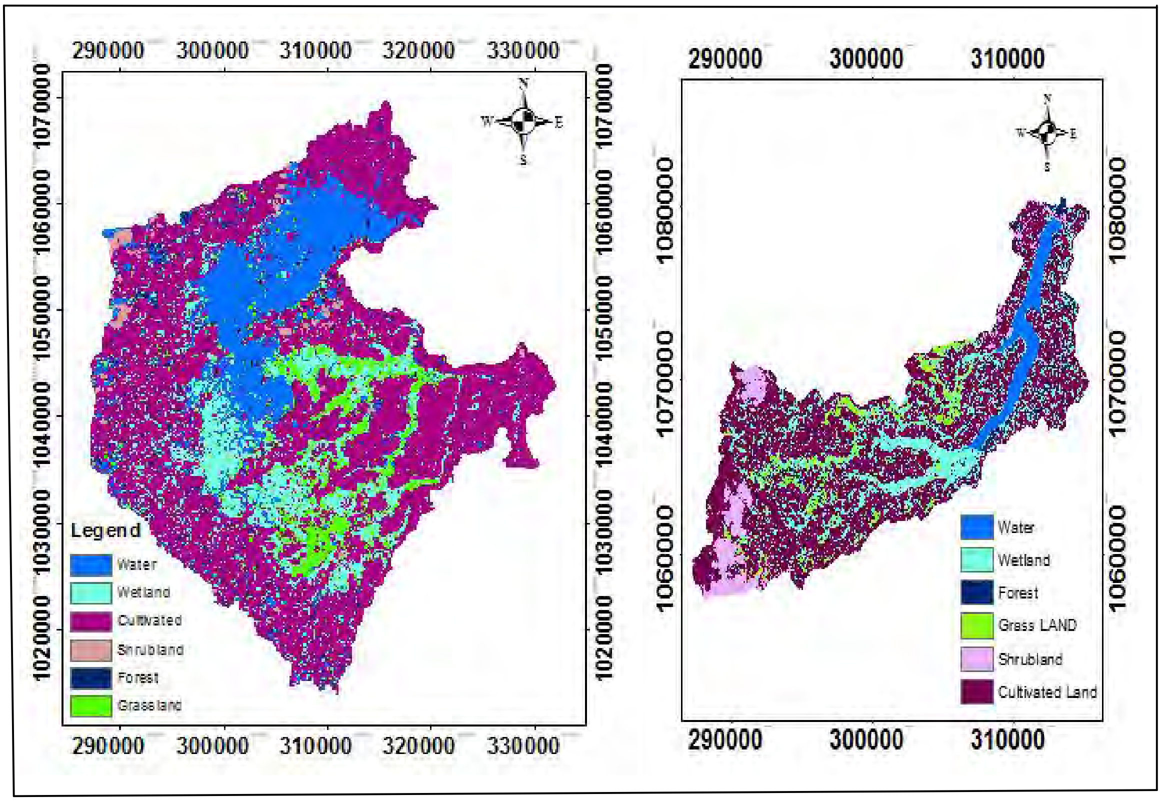
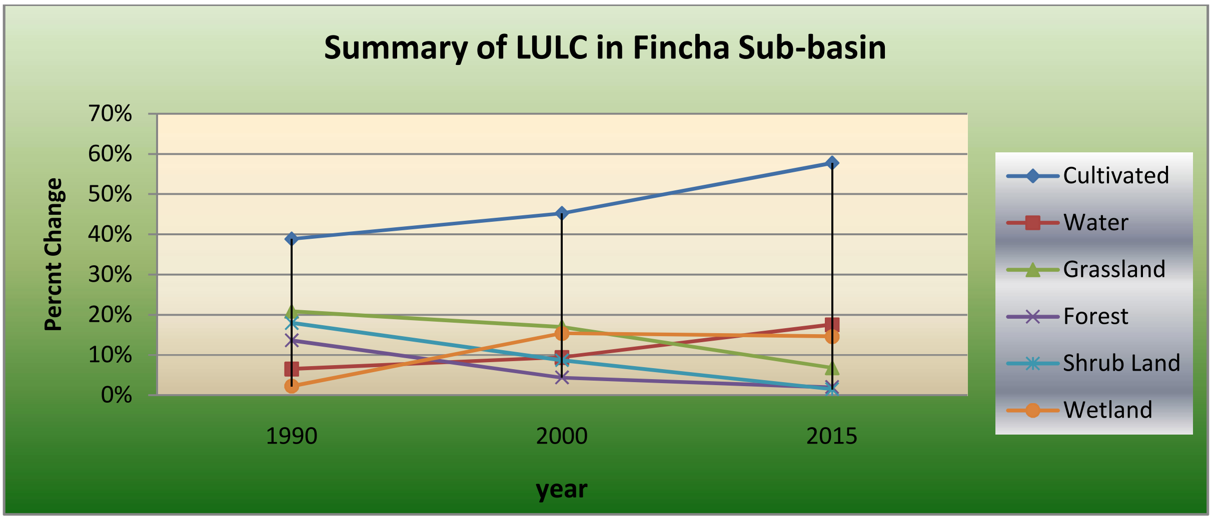


Figure 4.3 Land use land cover map of Fincha and Amerti for the year 2015 respectively

According to maximum likelihood classification results of 2015 land sat satellite image; the land cover classes (Figure 4.3) were also dominated by cultivated lands with 57.73% in Fincha. Other land cover classes also cover the remaining 42.27%, with water 17.53%, wet land 14.57%, Grass land 6.78%, forest 1.96% and shrub land 1.43%.

In 2015, Amerti had a better shrub and wetland cover as compared to Fincha watershed with 7.08%, 20.08%, but the forest area was much reduced in to 2.39%. In this, 55.11% of the area was cropland in 2015 showing a high possibility for further expansion in future. The proportion of increasing water and decreasing grass land were 9.93%, 5.41% respectively. Due to growing populations, the case of based farming systems at Amerti and Fincha demanded more land for cultivation and increased deforestation. Grazing land showed a decreasing trend in all the study areas due to cropland expansion. There was no system in place that protects the grazing lands and forests that were not distributed to individual farmers from encroachment in all the study areas. Hence, these land use types have been the potential cropland sources for mainly the newly emerging farm households.

Land cover classes	Years			Land use change detection		
	1990	2000	2015	1990-2000	2000-2015	1990-2015
Cultivated	38.83	45.22	57.73	+6.39	+12.18	+18.57
Water	6.51	9.41	17.53	+2.90	+8.12	+11.02
Grassland	20.85	16.98	6.78	-3.87	-10.20	-14.07
Forest	13.61	4.37	1.96	-9.24	-1.96	-11.20
Shrub Land	17.97	8.68	1.43	-9.17	-7.25	-16.42
Wetland	2.24	15.37	14.57	+13.13	-0.80	+12.33



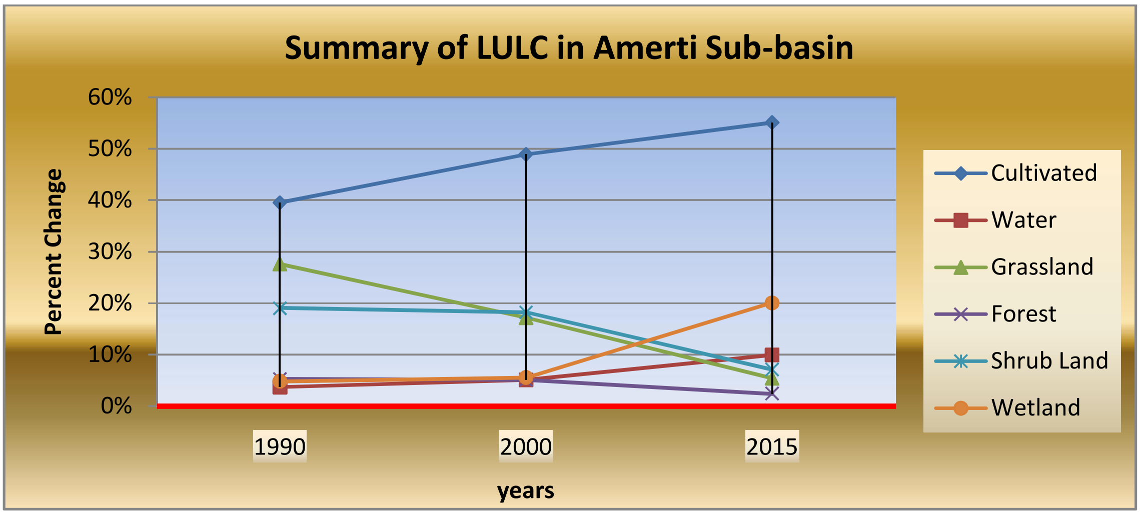
Due to the current shortage of grazing land, livestock numbers have decreased and farmers were forced to graze the swamp that resulted in drowning of animals.

The area of cultivated land has increased by 18.57 % between 1990 and 2015, and a net decrease of grassing land by 14.07% between 1990 and 2015. Overlay analysis of the 1990 and the 2000 land use maps show that western parts of Chomen have been inundated. This makes a total of 100.2 km_2 grazing land that was lost to the farmers due to the creation of the dam in 1973 and the Amarti river diversion of 1987. Grazing lands were situated at depression areas of the watershed where seasonal water logging occurred and along the water divide lines in the western and south-western parts of the watershed, on the hills and along embankments of streams and rivers.

Much of the flat areas of the upper part of the lake (Chomen) used to be seasonal swamp before the creation of the dam. This land cover type has shown a pattern of increase in the first period and a decrease in the second period, i.e., an increase of 13.13% between 1990 and 200 but a decrease of 0.8% between 2000 and 2015. Overlay analysis of the water body is somehow increase in the first 1990 _2000 and land use maps show that 8.12% of increases between 2000_2015 as swamp in the Chomen area have been inundated with Amerti. There was a general decrease of forest cover in the watershed area It has changed from 13.61% in 1990 to 4.37% in 2000 and 1.96% in 2015,

Table 4.6 Summary of land use cover change percentage of Amerti Watershed

Land cover classes	Years			Land use change detection		
	1990	2000	2015	1990-2000	2000-2015	1990-2015
Cultivated	39.54	48.92	55.11	+9.38	+6.19	+15.57
Water	3.69	5.07	9.93	+1.38	+4.86	+6.24
Grassland	27.63	17.19	5.41	-10.44	-11.78	-22.22
Forest	5.27	5.06	2.39	-0.21	-2.67	-2.88
Shrub Land	19.05	18.21	7.08	-0.84	+11.13	-11.97
Wetland	4.81	5.56	20.08	+0.75	+14.52	+15.27


Summary of LULC in Amerti Sub-basin
Percent Change
60%
50%
40%
30%
20%
10%
0%
1990
2000
2015
years
Cultivated
Water
Grassland
Forest
Shrub Land
Wetland

46% which agrees with the findings of study which was 45.22 during in 2000. Results of similar studies in other parts of the country also reflect the similar facts. TadeleK. (2009) reported that there was a decrease of grasslands and shrub lands by 18.9 and 14.5 percent respectively in Hare watershed, southern Ethiopia from the periods 1975 – 2004.Eleni*et al*. (2013) stated that crop field coverage in Koga watershed in 2010 were 15,683ha (76.83%) and water covers also 5.24%. This refers similar land use change of trend was happened as the country around the sub basin.

4.2.2 Accuracy Assessment of Land cover classification

Post-classification enhancements are used to reduce the classification faults stemming from base fields, cities and classes which have similar responses like some crop areas and wetlands. As the classes which were among the fallow fields and perceived as extraction were accepted as fallow ploughed at the time the image was taken, they were included in the category of farm lands. There are numerous grasslands in the study area and these have the same spectral responses as small grains in agricultural areas. Therefore they were accept as small grains most of time, but were sometimes accepted as grass lands/herbaceous, depending on the growing areas.

Having made the enhancements of post classification mistakes, it is necessary to test the accuracy of the classification. Because changes in land use are discovered through the estimation of total squares of land use classes in the land use cover maps created for each different years (1990, 2000 and 2015), errors in the classification can lead to the misinterpretation of change analysis. The main technique for accuracy assessment is using change maps for evaluating each class and calculating the expected accuracy (Yuan *et al*., 1998). Another method leading to more exact results is by checking points accurately classified or not, after the selection of the points where changes are available or not upon the map. An accuracy assessment test was applied by using an accuracy matrix with 150 randomly selected points. The accuracy assessment was performed by using land use maps, ground truth points and Google Earth. Great importance was given to the representation of different LU/LC classes by these randomly chosen points.

The accuracy of the classification was performed by using visual/ spatial comparison by linking the view with the collected training site and Google earth. Evaluation of classification results is an important process in satellite image classification procedure. It is the most commonly

		Ground Truth							
Classified		Water	Shrub land	Wetland	Forest	Cultivated	Grass Lan	Row Tota	User's accuracy
	Water	40	0	3	0	0	3	46	87%
	Shrub land	0	18	0	1	1	0	20	90%
	Wetland	2	0	14	0	0	2	18	78%
	Forest	0	4	0	39	2	1	46	85%
	Cultivated	0	1	0	0	116	3	120	97%
	Grass Lan	0	1	0	1	2	17	21	81%
	Column T	42	24	17	41	121	26	271	
	Producer's accuracy	95%	75%	82%	95%	96%	65%		90%

4.3 Stream flow modeling

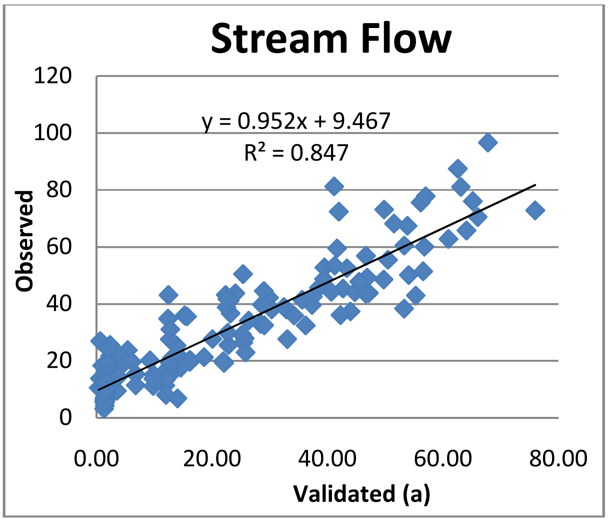
4.3.1 Sensitivity analysis of simulated stream flow

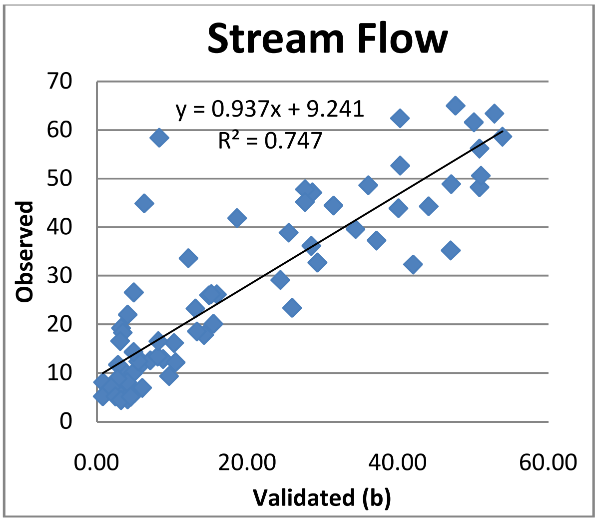
Sensitivity analysis of simulated stream flow for the watershed was performed using the daily observed flow for identifying the most sensitive parameter and for further calibration of the simulated stream flow. During this time 26 flow parameters were checked for sensitivity and twelve sensitive parameters were identified. From those twelve parameters the first four (RCHRG_DP, GW_REVAP, REVAPMN and SURLAG.bsn) were highly sensitive and given to high priority for calibration. The sensitive parameters identified were presented in the table below.

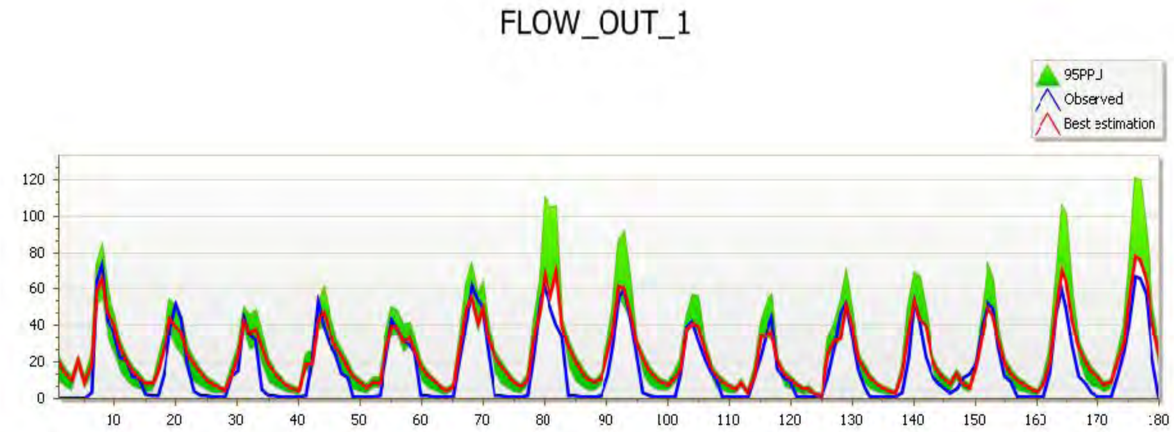
Table 4.8 Sensitive stream flow parameters

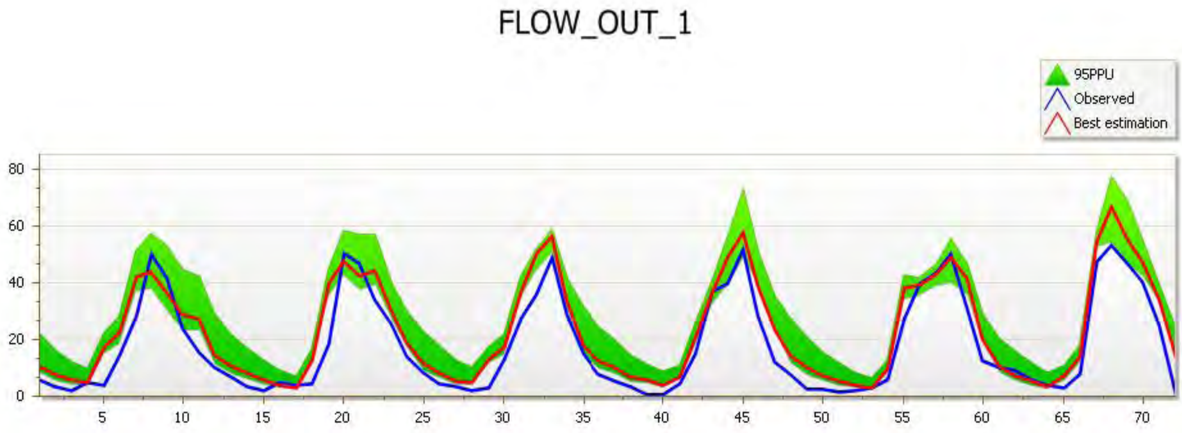
No.	Parameter name	Parameter value range	Calibrated value	Sensitivity	Significance
1	RCHRG_DP	0 – 1	0.389	1	Very high
2	GW_REVAP	0.02 – 0.2	0.197	2	Very high
3	REVAPMN.gw	0-500	96.843	3	Very high
4	SURLAG.bsn	1 – 24	15.410	4	Very high
5	GW_DELAY	0-500	0.005	5	High
6	ESCO	0.001 – 1	0.009	6	High
7	SOL_K	±25%	-0.233	7	High
8	ALPHA_BF	0 – 1	0.877	8	High
9	CN2	±25%	0.023	9	High
10	GWQMN	0 – 5000	4880.857	10	Low
11	SOL_AWC	±25%	0.029	11	Low
12	CH_N2	0 – 0.3	0.247	12	Low

Performance criteria	Calibration			Validation		
	1990	2000	2015	1990	2000	2015
NSE	0.86	0.64	0.64	0.82	0.61	0.62
R^2	0.86	0.84	0.85	0.92	0.85	0.85
RSR	0.49	0.6	0.60	0.42	0.62	0.61






FLOW_OUT_1
95PPU
Observed
Best estimation
0
20
40
60
80
100
120
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180


FLOW_OUT_1
95PPU
Observed
Best estimation
0
20
40
60
80
5
10
15
20
25
30
35
40
45
50
55
60
65
70

The calibrated and validated stream flow results showed a good agreement to the observed data (Figure 4.5 and 4.6). Therefore, these results of estimated stream flows indicate that SWAT model is good predictor of stream flow of Fincha Amerti Neshe watershed. In which the observed mean annual flow were used as a comparison for simulated stream flow results. Hence, as in table 4.6 the observed mean flows shows a good agreement with the simulated flows. The green colour indicate the pridected percentage of uncertainity (95PPU) which shows the closeness of agreement between the measured and the observed flow with 95% good fit.

4.3.3 Evaluation of stream flow due to land use land cover change

According to Land use land cover changes detection of the three different year's satellite image results showed an effect on stream flow of the watershed. The calibrated and validated results of simulated annual average stream flow for the 1990, 2000 and 2015 land use are presented in table 4.10.The results have shown that there is an increase of stream flow in both of the calibration and validation periods.

Table 4.10 Mean annual stream flow results for the calibration and validation period in m^3/s.

Years	1990	2000	2015	Change detection		
	Simulated	Simulated	Simulated	1990 -2000	2000-2015	1990-2015
Calibration	310.45	322.89	328.49	12.44	5.6	18.04
Validation	304.85	312.89	318.24	8.04	5.35	13.39

The stream flow results for the different years were compared based on the validated values (Table 4.10). Stream flows showed a higher increase in the first period ($8.04m^3/s$) than the second period ($5.35m^3/s$). Generally speaking stream flows has increased throughout the study period for over 25 years period with a magnitude of $13.39m^3/s$. These tremendous changes of stream flow were due to the land cover changes of the watershed (an increase of cultivated land trough study period).

Table 4.11 Dry and wet period season average stream flow results of 1990, 2000 and 2015

Years	1990	2000	2015	Change Detection		
				1990 – 2000	2000 – 2015	1990 - 2015
Dry period	17.54	19.67	16.89	2.13	-2.78	-0.65
Wet period	80.37	92.42	97.91	12.05	5.49	17.54

Months January, February and March were considered as a dry period, and months June, July and August were also taken as wet period for detecting the change of stream flow. The amount of stream flow were increased by 2.13m^3/s for the first period (1990 – 2000) and decreased by (-) 2.78m^3/s for the second period (2000 – 2015) during the dry season. There are also changes in stream flows in the wet period with an increase of stream flow by 12.05m^3/s and 5.49m^3/s for the first and second periods respectively.

In general, for over the twenty five years period (1990 – 2015) stream flows has showed an increase (+17.54m^3/s) during the wet season due to an increase of cultivated land by 18.57%, which implies that agricultural lands increased surface runoff (peak runoff). On the other hand, stream flows has showed a decreasing trend for the whole dry study period with a magnitude of (-) 0.65m^3/s, which has reflected that base flow has decreased with an intense agricultural expansion.

The result of Emiru W. (2009) indicated that peak flow is increased by 0.762 m^3/s while base flow decreased by 0.069 m^3/s. In general Emiru indicated that flow during the wet season has increased, while the flow during the dry season decreased. Shimel s*et al (*2008) also point out the mean flow of Gilgel Abay at the gauging station was increased by 47m^3/s which is comparable with the results of this study.

4.3.4 Evaluation of Water yield due to land use land cover change

In this study water yield or the amount of water leaving Fincha Amerti Neshe watershed and entering to Lake Chomen was also analyzed. Water yield (mm H2O) is the total amount of water leaving the HRU and entering main channel during the time step.

$$WYLD = SURQ + LATQ + GWQ - TLOSS - pond\ abstractions \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .4.1$$

Where; WYLD is water yield, LATQ: is Lateral flow contribution to stream flow (mm H2O). It is also Water flowing laterally within the soil profile that enters the main channel during time step. GWQ is Groundwater contribution to stream flow (mm H2O); water from the shallow aquifer that enters the main channel during the time step. It is also referred to as base flow. TLOSS: is Transmission losses (mm H2O); Water lost from tributary channels in the HRU via transmission through the bed. This water becomes recharge for the shallow aquifer during the time step. Net surface runoff contribution to the main channel stream flow is calculated by subtracting TLOSS from SURQ.

Table 4.12 Annual hydrology of Fincha Amerti Neshe watershed

Year	Surf Q (mm)	Lat Q (mm)	GW Q (mm)	WYLD (mm)	ET (mm)	PET (mm)	Contribution to stream flow DO	GWQ
1990	202.43	79.026	522.28	803.43	95.63	158.08	35.03%	65.06%
2000	240.61	83.71	507.49	831.93	113.1	183.61	38.98%	61.06%
2015	271.16	98.33	498.75	868.80	121.3	202.89	42.52%	57.40%

Where DO=direct runoff contribution, GWQ=groundwater contribution to stream flow

Effects of agriculture on water yield are of particular interest because the prior appropriation doctrine is used to allocate water rights. Therefore, understanding how agricultural activities influence the quantity of water lost from agricultural lands is crucial to account for the effects of more efficient use of water as well as to decide how much water is potentially available for appropriation by other users.

Surface runoff results (Table 4.12) signify an increase by 38.18mm and 30.55mm for the first and second periods, due to an increase of cultivated land. Surface runoff was increased with increased agricultural land because the potential for loss by runoff is increased from soil that is bare or partially bare during the cropping cycle. On the other hand, ground water flow decreased by 14.79m^3/s and 8.74m^3/s for the first (1990 – 2000) and second (2000 – 2015) periods respectively. This is exemplified due to an increase of cultivated land, which leads a decrease of infiltration, as a result decreased lateral and ground water flow. Hence, this reveals that the ground water flow has showed an inverse relation with cultivated area of the watershed.

Moreover, the direct runoff contribution to stream flow has increased throughout the study period; on the other hand ground water contribution has decreased.

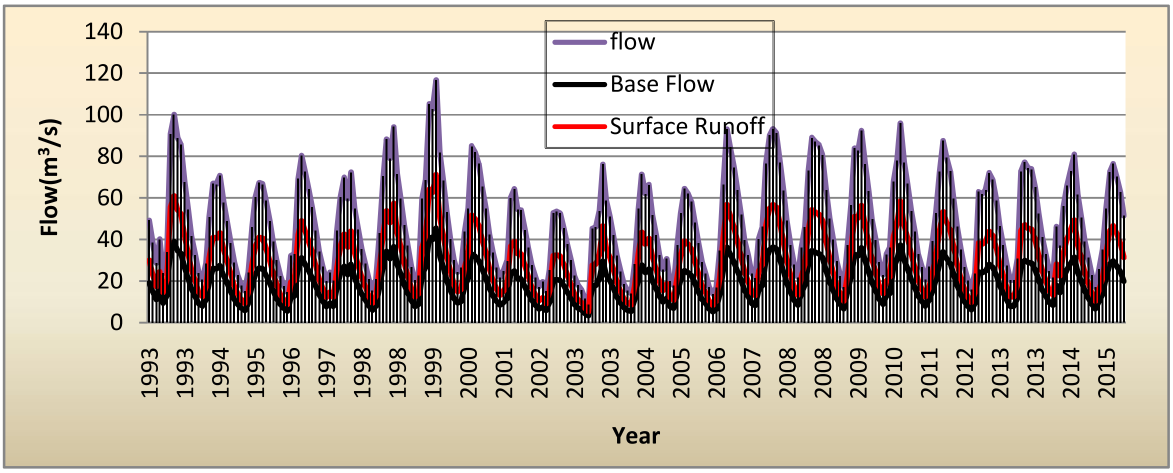
The water yield (Table 4.12) of Fincha Amerti Neshe watershed has reflected a significant increase during the second period (2000 – 2015), with a magnitude increase by +36.87 mm than the first period (+28.50mm).Moreover water yield has increased by 65.37mm from 1990 – 2015 due to most of the land uses were changed to cultivation.

Agricultural lands has showed an increasing trend from 1990 to 2000 to 2015, similarly evapo transpiration, ET and potential evapo transpiration, PET has also increased within this study period, since agriculture has a direct relationship with ET and PET of the watershed.

Other studies on the watershed, for the period 1986 –2001 Rientjes*et al*. (2010) also showed that the annual and the high flows of the catchment were increased by 13% and 46%, respectively while the low flows decreased by 35%.

4.3.5 Base flow separation

The total runoff simulated for Fincha Amerti Neshe watershed were comprised of mainly two hydrograph flow components; hence the direct runoff and base flow for Fincha Amerti Neshe watershed were decomposed using WHAT recursive digital filter method. The Base flow (also called drought flow, low flow, or groundwater recession flow) is the portion of stream flow that comes from the sum of deep subsurface flow and delayed shallow subsurface flow. Sequentially base flow separation was done since it is used to determine the portion of stream flow hydrograph that occurs from base flow and direct runoff or overland flow.


140
120
100
80
60
40
20
0
Flow(m³/s)
flow
Base Flow
Surface Runoff
1993
1993
1994
1995
1996
1997
1998
1998
1999
2000
2001
2002
2003
2003
2004
2005
2006
2007
2008
2008
2009
2010
2011
2012
2013
2013
2014
2015
Year

stakeholder platform that addresses these problems is vital for implementing IWM. The platforms should effectively interact on public policies, dam planning, implementation, monitoring, evaluation, and conflict resolution. The formation of different state organizations that are responsible for planning, developing, and monitoring water resources and formulating environmental policies is a major step forward in Ethiopia. Effective implementation of these policies and strategies may improve the quality of future watershed-based developments. Since public goals are, by nature, trans-disciplinary, multi-disciplinary teams should be deployed, with each member contributing their professional perspective to the problem at hand.

In general, for better promotion and adoption of improved agriculture, the focal point of any programme of agricultural development should be betterment of the people and sustenance of the resource base. For farmers, what is important is production; what is most important for subsistence farmers is the production of the current season, as this guarantees the survival of their families (Herweg and Ludi, 1999). Therefore strong institutions are required to achieve the coordinated action necessary for involving stakeholders in sustaining agricultural production and resource conservation. When a development project requires that people be relocated, it is necessary to ensure that the productive base and income-earning ability of those affected are improved, so that they share the benefits of the new development and they are compensated for the transitional hardships. The displaced people should at least regain their previous standard of living and, at their relocation site, they should be assisted to become socially and economically integrated into the host communities.

Fincha dam plays a significant role in supporting the national economy through electric power generation, supplying water for a sugar factory downstream, and introducing fishery in the area. However, reviewing the possible compensation for the loss of physical resources after 30 years is no longer a sensible strategy to pursue. Instead, the issues that need to be addressed are the implementation of SWC, agricultural intensification, promotion of family planning, improvement of health and education services, and infrastructure development. Reclamation of the 600 km_2 Choomen swamp could still be an option to reduce land shortage and evaporation losses from the reservoir. If, instead, the community problems are allowed to persist, the ubiquitous social and economic activities in the upstream part of the watershed will intensify, leading to more food insecurity and reservoir sedimentation. It would be justifiable in terms of property rights and equity to allocate a certain portion of the revenue obtained from the electric power generation to the abovementioned social and economic endeavours. Since the watershed is located in the Blue Nile river basin, the social and economic changes attributable to this dam may have local and regional impacts. This calls for cooperation at local level and beyond.

5 Conclusions and Recommendations

5.1 Conclusion

During this study the land use cover dynamics on Fincha Amerti Neshe watershed for over 25 years period were detected using Land sat satellite images from USGS earth explorer and GLOVIS. The classified land use covers performed on ERDAS Imagine 2014 were integrated with other GIS data as a result stream flow simulations were done using SWAT model.

From this study it can be concluded that Fincha Amerti Neshe watershed has experienced a significant change in land use land cover over the past 25 years. It can be recognized that deforestation and increase of agricultural lands was exhibited by rapid increase of human population which changes the whole Fincha watershed in general and some sub-watersheds in particular. Grasslands and shrub lands were significantly changed to cultivated lands showing an identical trend for the two consecutive periods (1990 – 2000 and 2000 – 2015).There were also a decrease of forests for the first period and while it resulted slight decrease during the second period due to reforestation policy implemented on Ethiopian millennium. The results revealed the magnitudes of the cultivated land were increased by 6.39% from 1990 – 2000 and by 12.18% from 2000 to 2015. The Shrub land and Grassland were decreased by 9.17%, 3.87% and 7.25%, 10.20% from 1990 to 2000 and 2000 to 2015 respectively.

The two watersheds in Fincha and Amerti watershed have different physical catchment characteristics with each other and similar with the whole watershed including topographic watershed. The correlation results of this physical catchment characteristics revealed a value greater than 0.8.

The changes in land use has resulted changes in stream flow, in which the expansion of agriculture results an increase of surface runoff, on the other hand, lateral and ground water flow decreases with an expansion of agriculture. The significant changes of stream flow were occurred in wet periods than dry periods. The water yield was also increased with an increase of cultivated land. The base flow contribution of Fincha Amerti Neshe watershed was 39% of total runoff of simulated flow.

The land use changes in these Watersheds were mainly caused by population increases, Environmental Change, Economic Change and Lack of an Integrated Water Management through the watersheds. This was because of, there there was lack of practice/adopt an effective family planning, absence of implementation of SWC and less effective participatory integrated watershed development.`

In order to alleviate the dramatic land use/ land cover change and adverse environmental impacts of Agricultural expansion and increasing built up surfaces, the current growth pattern needs to be managed through effective land use planning and management. This would be useful to protect the fertile agricultural land in the watershed and further reduce environmental degradation in the form of soil erosion and desiccation and water stress and pollution.

It should be noted that the IWM approach assumes the management of the entire watershed or river basin, so also land is considered apart from the water resources. IWM, therefore, should address the interests of both the upstream and downstream communities. Since public goals by their nature are trans-disciplinary, the use of multi-disciplinary teams should be employed whereby each member contributes its professional perspective to the problem at hand.

5.2 Recommendations

Based on the results/findings of this study the following recommendations are made;

- An increase of cultivated land (reduction of shrub lands and forests as well grasslands) were a results of population growth. Therefore, there should have practice/adopt an effective family planning.
- Due to growing populations, the case of based farming systems at Amerti and Fincha demanded more land for cultivation and increased deforestation. Incase there is significant land use change, it needs effective participatory integrated watershed development.
- Further researches like sedimentation effects on Fincha Amerti-Neshe with all reservoirs and development of best management practices with detail land use survey shall have to be done.
- Most of the stations in this catchment are located at upper parts of the watershed which is a challenge for calibration and validation of hydrologic characteristics (stream flow at the out let to Lake Chomen. Therefore, more number of meteorological and hydrological stations should have to be installed at downstream parts of the watershed.
- The results of these analyses also showed that Fincha Amerti Neshe dam has caused major land use changes, which in turn have increased soil erosion rates, and Stream flow across the watershed. During this study, it has been learned that IWM should give emphasis to environmental sustainability because agriculture leads to the removal of biomass and nutrients, which are not or only partially returned. Environmental sustainability is also one of the U.N. Millennium Development Goals.

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7 Appendices

Appendix A: List of Meteorological Stations

No	Station Name	Class	X	Y	Altitude (m)
1	Fincha	principal	321,103.09	1,058,197.90	2248.00
2	Neshe	principal	302,485.99	1,067,139.06	2500.00
3	Alibo	principal	288,374.34	1,094,869.92	2513.00
4	Debre Markos	3rd Class	360,943.01	1,142,071.83	2446.00
5	Nekemte	3rd Class	220,787.28	1,004,582.69	2080.00
6	Shambu	4th Class	291,460.26	1,058,349.76	2460.00

Appendix B: Weather Generator parameters (WGEN) used by the SWAT model, Symbols and Statistical Analysis of Daily Precipitation and Solar radiation Data (1991 - 2015) Input of Debre Markos where:

PCP_MM = average monthly precipitation[mm]

PCPSTD = standard deviation

PCPSKW = skew coefficient

PR_W1 = probability of a wet day following a dry day

PR_W2 = probability of a wet day following a wet day

PCPD = average number of days of precipitation in month

SOLARAV = average daily solar radiation in month

Statistical Analysis of Daily Precipitation Data (1991 - 2015)
Input Filename = dmst.txt

Number of Years = 25
Number of Leap Years = 6
Number of Records = 9131
Number of No Data values = 0

Month	PCP_MM	PCPSTD	PCPSKW	PR_W1	PR_W2	PCPD
Jan.	12.37	2.2676	9.3096	0.0598	0.4247	2.92
Feb.	9.90	1.7930	7.5534	0.0552	0.5778	3.60
Mar.	44.21	3.6316	3.7668	0.1642	0.6163	9.80
Apr.	66.52	5.3198	4.2705	0.2500	0.6290	12.40
May.	108.31	6.6144	3.2121	0.2737	0.7165	15.80
Jun.	167.04	6.7547	2.3571	0.6446	0.8474	25.16
Jul.	264.55	8.4913	2.1128	0.8611	0.9256	29.56
Aug.	303.45	10.1909	2.3913	0.8302	0.9058	28.88
Sep.	226.46	9.0358	1.8138	0.5361	0.8065	23.36
Oct.	91.00	6.7361	3.6144	0.1137	0.7109	10.24
Nov.	25.98	3.1704	5.7542	0.0984	0.5286	5.60
Dec.	17.75	2.8353	7.6933	0.0581	0.5865	4.16

Appendix C: Weather Generator parameters (WGEN) used by the SWAT model, Symbols and Statistical Analysis of Daily Precipitation and Solar radiation Data (1991 - 2015) Input of Nekemte

Number of Years = 25
Number of Leap Years = 6
Number of Records = 9131
Number of No Data values =0

Month	PCP_MM	PCPSTD	PCPSKW	PR_W1	PR_W2	PCPD	SOLAV
Jan.	10.36	1.9178	9.9143	0.0601	0.4211	3.04	7.98
Feb.	11.75	1.6926	5.5840	0.0649	0.5000	3.60	8.37
Mar.	51.24	4.9413	4.6792	0.1525	0.6071	8.96	7.34
Apr.	93.94	7.4743	3.6523	0.2168	0.6885	12.84	7.59
May.	263.38	12.5314	2.6830	0.4189	0.8047	22.12	6.10
Jun.	397.31	14.7450	2.6301	0.8852	0.8911	27.56	4.62
Jul.	403.60	15.7019	1.9309	0.8644	0.8994	28.64	5.33
Aug.	401.02	14.5157	2.0016	0.8163	0.9118	29.04	6.30
Sep.	288.60	11.0705	1.7833	0.7444	0.8621	26.40	7.16
Oct.	154.06	9.1557	2.6799	0.3353	0.7117	17.76	7.18
Nov.	46.85	4.8450	4.8264	0.1643	0.4684	7.60	5.73
Dec.	15.72	2.9442	8.6953	0.0566	0.3529	2.72	6.20

PCP_MM = average monthly precipitation[mm]

PCPSTD = standard deviation

PCPSKW = skew coefficient

PR_W1 = probability of a wet day following a dry day

PR_W2 = probability of a wet day following a wet day

PCPD = average number of days of precipitation in month

SOLARAV = average daily solar radiation in month

Appendix D: Average Daily Dew Point Temperature and Wind for Period (1991 - 2015) For Nekemte

Month	tmp_max	Tmp min	hmd	dewpt	WNDAV	TMPSTDMX	TMPSTDMN
Jan	25.98	12.24	65.04	12.73	0.649	10.631	4.440
Feb	27.63	13.24	47.13	8.93	0.725	10.628	4.437
Mar	27.81	14.10	65.37	14.29	0.878	10.626	4.434
Apr	26.92	14.35	53.34	10.52	0.969	10.625	4.432
May	24.71	13.83	80.06	15.40	0.894	10.623	4.431
Jun	22.33	12.89	76.34	12.80	0.904	10.621	4.429
Jul	20.86	12.72	89.87	14.28	0.752	10.620	4.428

Aug	20.84	13.14	82.77	13.27	0.702	10.618	4.427
Sep	22.34	12.75	89.59	15.24	0.688	10.617	4.427
Oct	23.83	12.83	73.37	13.39	0.719	10.616	4.427
Nov	24.55	12.73	75.87	14.24	0.664	10.615	4.427
Dec	25.04	12.14	59.41	10.85	0.552	10.614	4.428

tmp_max =average daily maximum temperature in month [°C]

tmp_min = average daily minimum temperature in month [°C]

hmd = average daily humidity in month [%]

dewpt = average daily dew point temperature in month [°C]

WNDAV = average daily wind speed in month [m/s]

TMPSTDMX = average daily standard devation of maximum temperature in month [^{0}C]

TMPSTDMN = average daily standard devation of minimum temperature in month [^{0}C

Appendix E: Average Daily Dew Point Temperature and Humidity for Period (1991 - 2015) For Debre Markos

```
This file has been generated by the program 'dew02.exe'
 Input Filename    = Dmdp.txt
 Number of Years   =          25
 Number of Records =        9131

 Average Daily Dew Point Temperature for Period (1991 - 2015)


  Month      tmp_max      tmp_min          hmd        dewpt


    Jan        25.98        12.24        65.04        12.72
    Feb        27.63        13.24        47.13         8.93
    Mar        27.81        14.10        65.37        14.29
    Apr        26.92        14.35        53.34        10.52
    May        24.71        13.83        80.06        15.40
    Jun        22.33        12.89        76.34        12.80
    Jul        20.86        12.72        89.87        14.28
    Aug        20.84        13.14        82.77        13.27
    Sep        22.34        12.75        89.59        15.24
    Oct        23.83        12.83        73.37        13.39
    Nov        24.55        12.73        75.87        14.24
    Dec        25.04        12.14        59.41        10.85


 tmp_max = average daily maximum temperature in month [°C]
 tmp_min = average daily minimum temperature in month [°C]
 hmd     = average daily humidity in month [%]
 dewpt   = average daily dew point temperature in month [°C]
```

Appendix F: Soils parameters and Symbols description used in SWAT model

NLAYERS	Number of layers in the soil (min 1 max 10)
HYDGRP	Soil hydrographic group (A, B, C, D)
SOL_ZMX	Maximum root depth of the soil profile
ANION_EXCL	Fraction of porosity from which an ions are exchanged

SOL_CRK	Crack volume potential of soil
TEXTURE	Texture of the layer
SOIL_Z	Minimum depth from soil surface to bottom of layer
SOL_BD	Moist bulk density
SOL_AWC	Available water capacity of soil surface to bottom of the layer
SOL_K	Saturated hydraulic conductivity
SOL_CBN	Organic carbon content
CLAY	Clay content
SILT	Silt content
SAND	Sand content
ROCK	Rock fragmented content
SOL_ALB	Moist soil albedo
USLE_K	Soil erodibility factor (K)

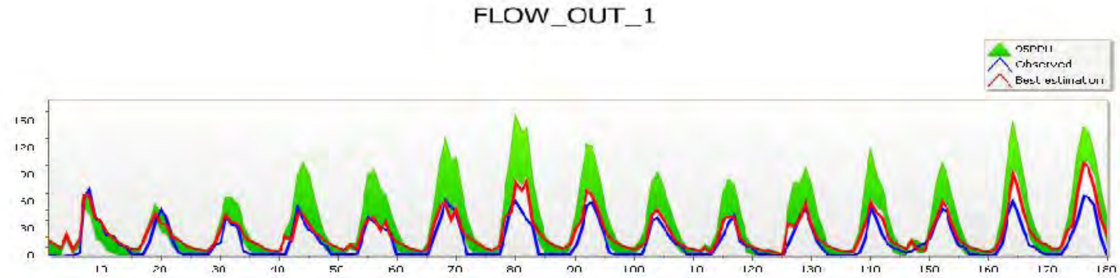
OBJECTID	MUID	SEQN	SNAM	S5ID	CMPPCT	NLAYERS	HYDGRP	SOL_ZMX	ANION_EXCL	SOL_CRK	TEXTURE
1	ETO44	1	HUNITISOLS			1	B	1000	0.5	0.5	loam
2	ETO38	2	CHLUVISOLS			1	B	1000	0.5	0.5	loam
3	ETO45	3	HPPHAEOZEM			1	B	1000	0.5	0.5	loam
4	ETO58	4	WATER			1	D	0	0	0	Water
5	ETO28	5	FBHISTOSOLS			1	D	1000	0.5	0.5	Clay
6	ETO56	6	EUVERTISOLS			1	D	1000	0.5	0.5	Clay

SOL_Z1	SOL_BD1	SOL_AWC1	SOL_K1	SOL_CBN1	CLAY1	SILT1	SAND1	ROCK1	SOL_ALB1	USLE_K1	SOL_EC1	SOL_Z2
100	1.39	150	18	2.25	24	31	45	9	0.226	0.127311	0.1	0
100	1.4	150	18	0.83	24	28	48	12	0.198	0.158201	0.1	0
100	1.38	150	18	1.95	23	39	38	2	0.226	0.133783	0.1	0
0	0	0	0	0	0	0	0	0	0	0	0	0
100	1.26	150	0.00036	33.63	40	40	20	1	0.226	0.130304	0.1	0
100	1.22	125	0.00036	1.05	56	25	19	4	0.231	0.132894	0.1	0

Years	Fincha	Neshe	Debre Markos	Shambu	Alibo	Nekemte
1991	2,741.20	951.20	1,125.80	1,568.00	1,205.10	1,948.10
1992	2,323.50	2,221.40	1,221.20	1,794.90	1,796.20	2,428.10
1993	2,146.50	1,913.30	1,742.20	1,871.20	1,647.90	2,512.20
1994	1,641.30	1,675.80	1,207.40	1,275.80	976.80	2,090.00
1995	1,801.30	1,457.30	1,248.90	1,376.20	1,150.50	2,060.00
1996	2,003.10	1,535.30	1,590.40	1,629.00	1,628.80	2,320.90
1997	1,726.40	1,785.20	1,517.70	1,809.30	1,500.30	2,190.00
1998	2,056.80	2,174.90	1,208.90	1,466.80	1,207.90	2,535.40
1999	2,237.60	2,643.00	1,344.10	1,568.70	1,143.20	1,911.90
2000	1,998.20	1,941.00	1,400.10	1,508.70	1,443.30	2,152.00
2001	1,580.80	1,538.60	1,374.20	1,350.80	1,217.90	1,942.20
2002	1,472.60	917.60	1,305.50	1,686.40	1,397.20	1,706.00
2003	1,570.10	1,656.80	1,210.80	1,349.30	1,271.10	1,837.50
2004	1,572.80	1,619.00	1,325.00	1,489.30	1,417.10	1,792.10
2005	1,715.80	1,445.40	1,252.90	1,403.50	1,316.80	2,248.70
2006	1,694.30	2,483.60	1,521.60	1,619.80	1,274.00	2,139.40
2007	2,246.60	2,419.90	1,400.50	1,656.60	1,254.60	2,173.00
2008	1,791.70	2,818.60	1,315.20	1,708.30	1,525.50	2,441.30
2009	1,757.30	2,476.00	1,259.90	1,444.30	1,282.80	2,022.80
2010	2,135.40	1,920.10	1,362.70	1,431.70	1,120.10	2,482.10
2011	1,952.20	2,277.80	1,483.80	1,421.90	1,323.90	2,010.40
2012	1,702.40	1,957.50	1,272.50	1,675.60	1,186.10	2,109.30
2013	1,474.10	2,357.80	1,227.30	1,543.40	1,440.50	1,965.50
2014	1,690.50	2,319.50	1,337.10	1,807.90	1,295.70	2,537.50
2015	1,391.60	2,604.80	1,182.70	1,464.90	1,056.10	1,883.70

Appendix H: List of stream flow parameters and their description

No.	Parameter name	Description	Rank	Parameter value range
1	RCHRG_DP	Soil evaporation compensation factor	1	0 – 1
2	GW_REVAP	Ground water “revap” coefficient	2	0.02 – 0.2
3	REVAPMN.gw	Threshold depth of water in the shallow aquifer for "revap" to occur	3	0-500
4	SURLAG.bsn	Surface runoff lag time	4	0.05 – 24
5	GW_DELAY	Groundwater delay	5	0-500
6	ESCO	Soil evaporation compensation factor	6	0.001 – 1
7	SOL_K	Channel effective hydraulic conductivity.	7	±25%
8	ALPHA_BF	Base flow alpha factor	8	0 – 1
9	CN2	Moisture condition curve number	9	±25%
10	GWQMN	Threshold depth of water in the shallow aquifer for return flow to occur	10	0 – 5000
11	SOL_AWC	Available water capacity	11	±25%
12	CH_N2	Manning's "n" value for the main channel	12	0-0.3


FLOW_OUT_1
95PPU
Observed
Best estimation
150
120
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140
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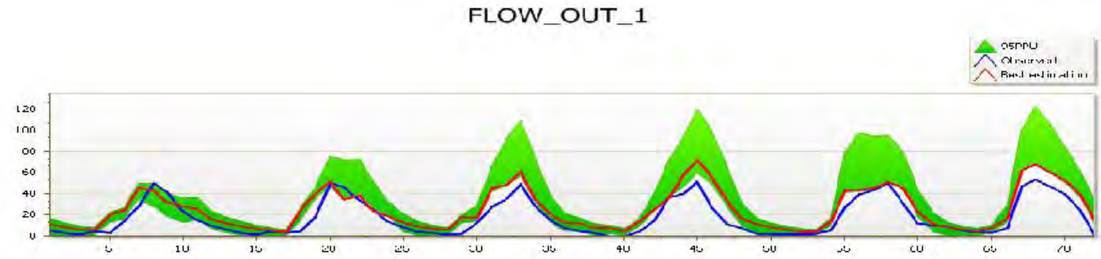
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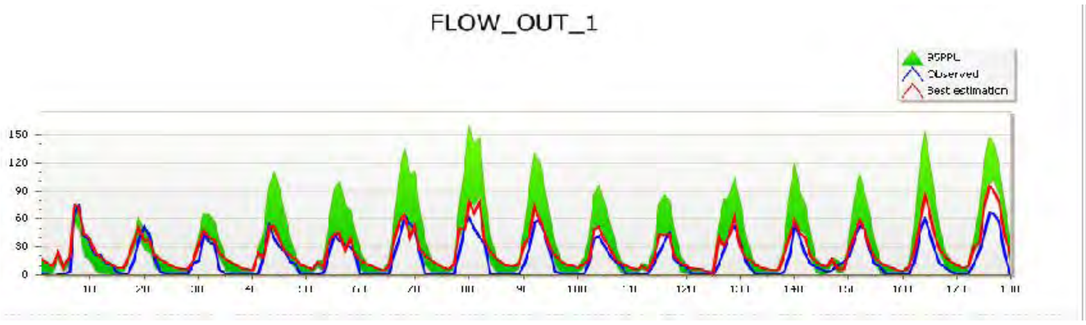
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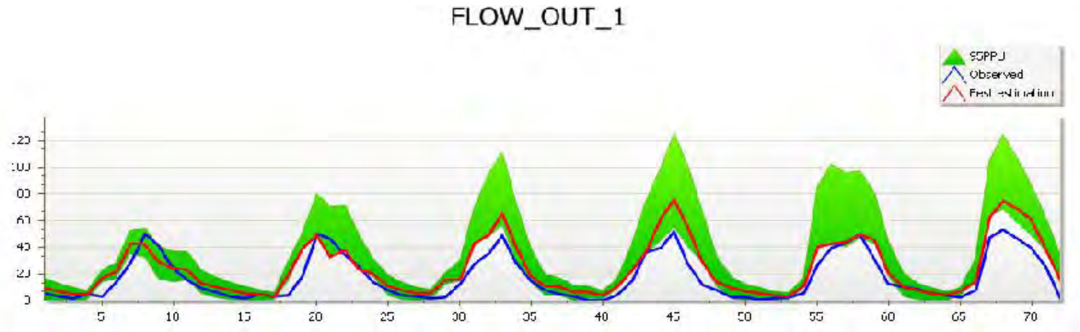
FLOW_OUT_1
95PPU
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Best estimation
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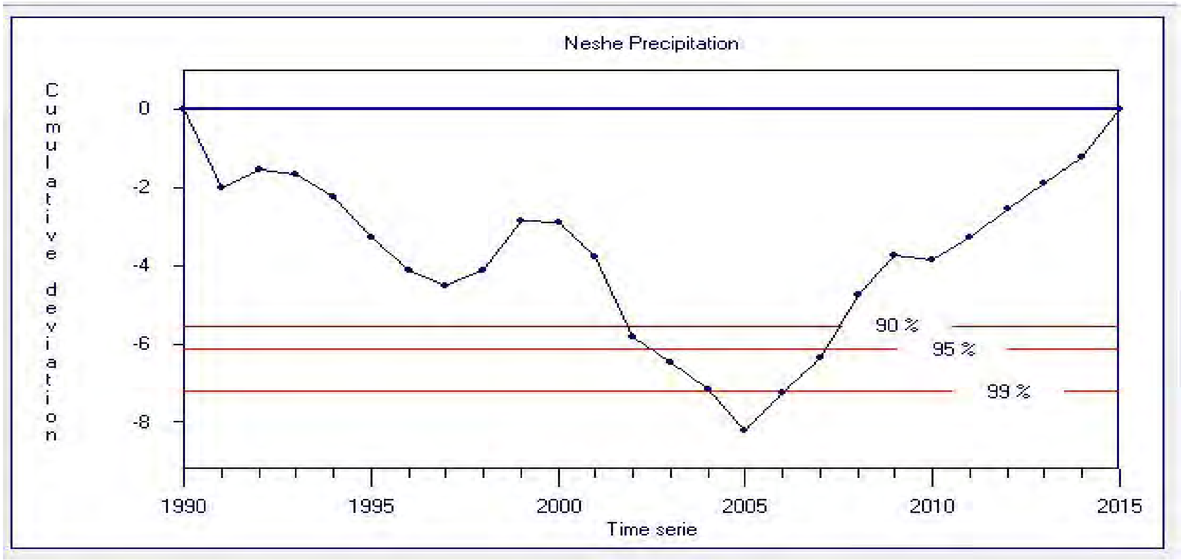
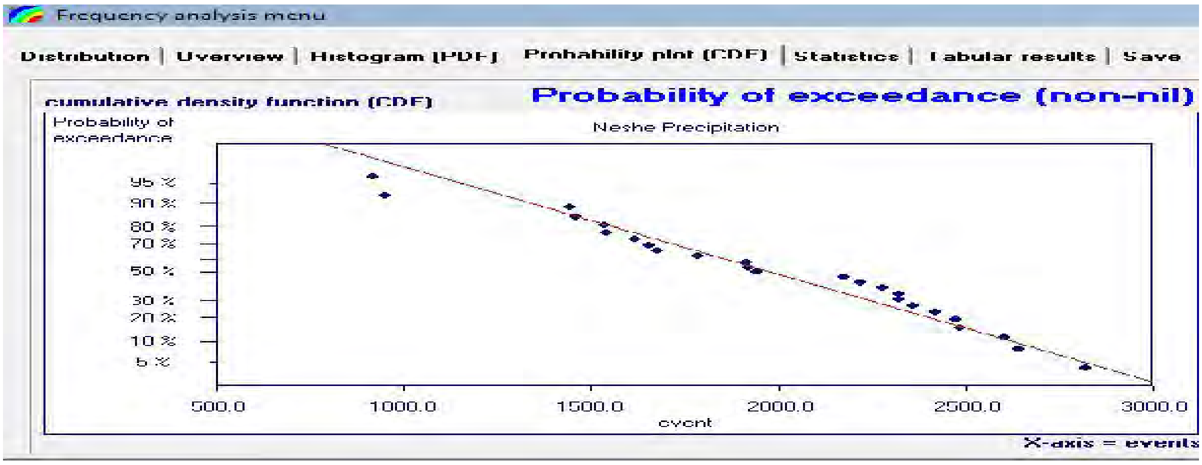
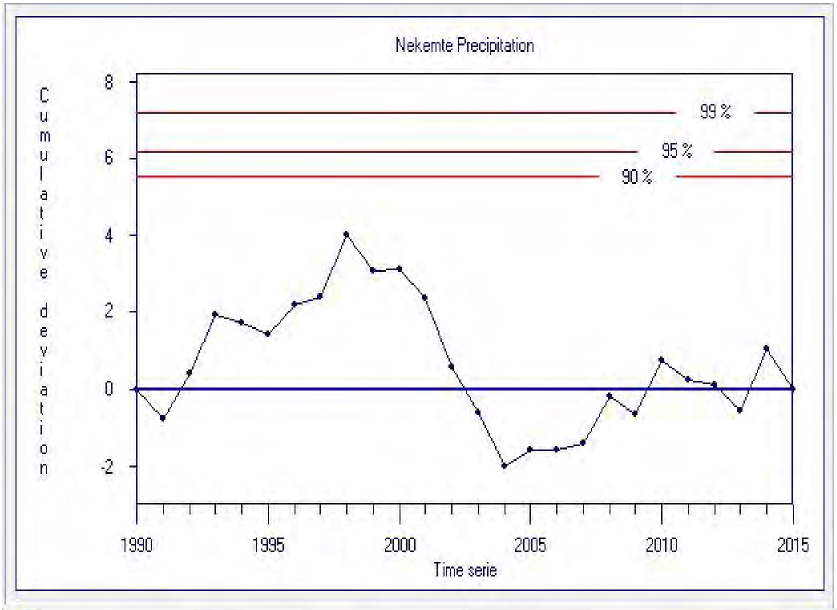
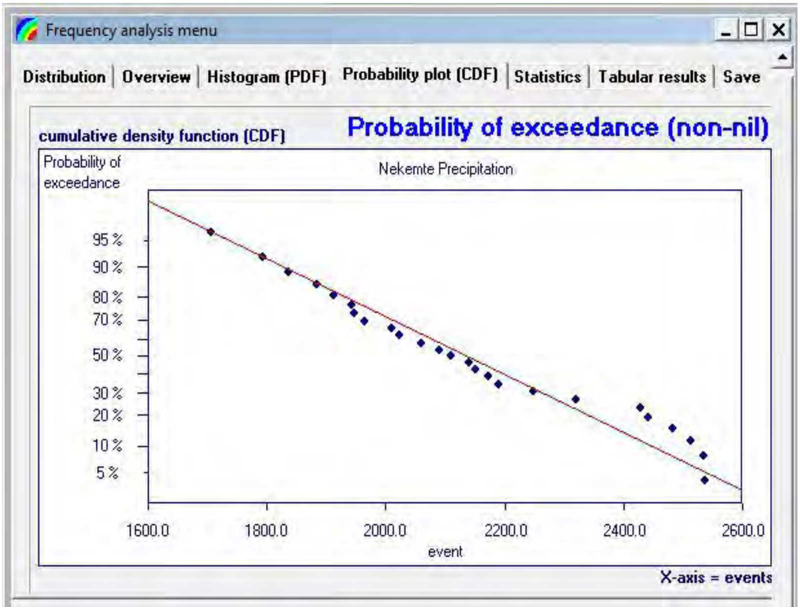
70

No.	Station name	Type of station	R^2
1	Shambu	Meteorological	0.96
2	Alibo	Meteorological	0.99
3	Debre Markos	Meteorological	0.97
4	Nekemte	Meteorological	0.93
5	Neshe	Hydrological	0.97
6	Fincha	Hydrological	0.97






Nekemte Precipitation
Cumulative deviation
8
6
4
2
0
-2
99 %
95 %
90 %
1990
1995
2000
2005
2010
2015
Time serie


Frequency analysis menu
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Probability plot (CDF)
Statistics
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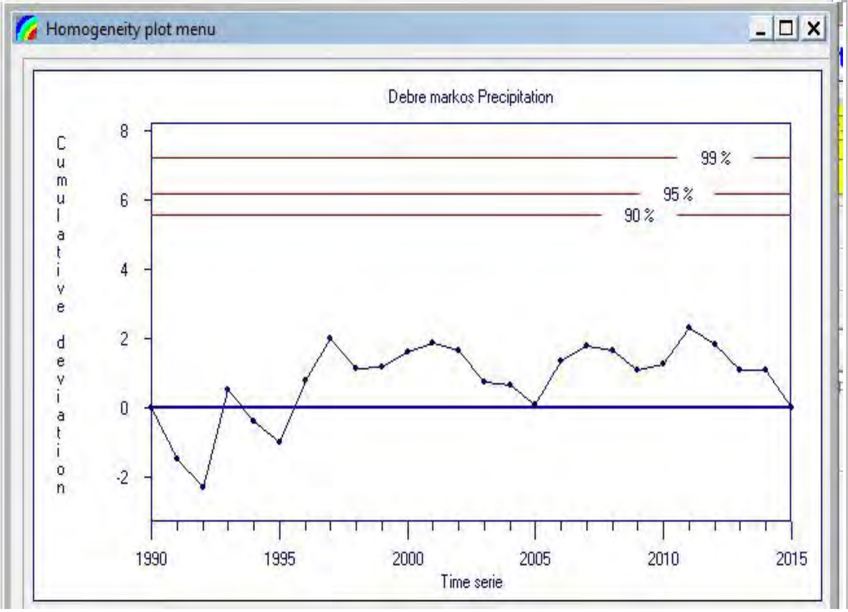
Save
cumulative density function (CDF)
Probability of exceedance (non-nil)
Probability of exceedance
Nekemte Precipitation
95 %
90 %
80 %
70 %
50 %
30 %
20 %
10 %
5 %
1600.0
1800.0
2000.0
2200.0
2400.0
2600.0
event
X-axis = events


Homogeneity plot menu
Debre markos Precipitation
Cumulative deviation
8
6
4
2
0
-2
99 %
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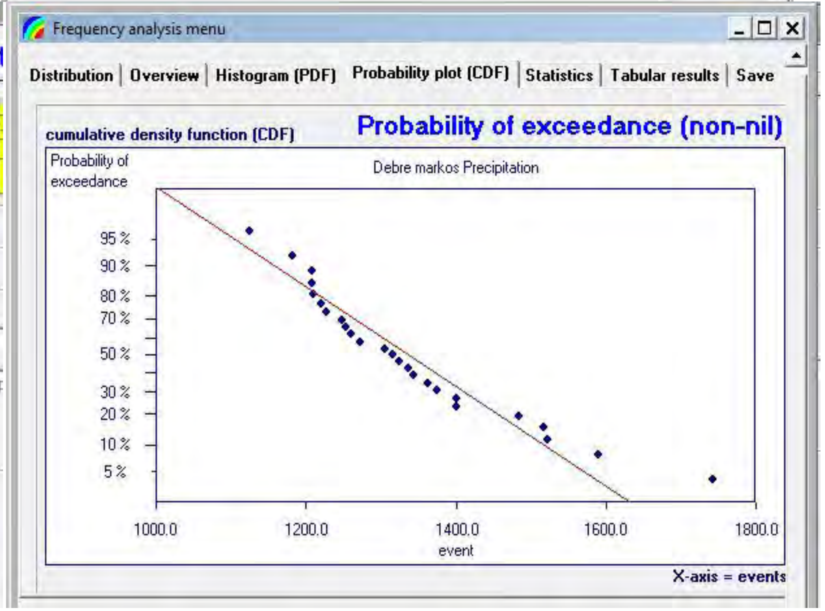
90 %
1990
1995
2000
2005
2010
2015
Time serie


Frequency analysis menu
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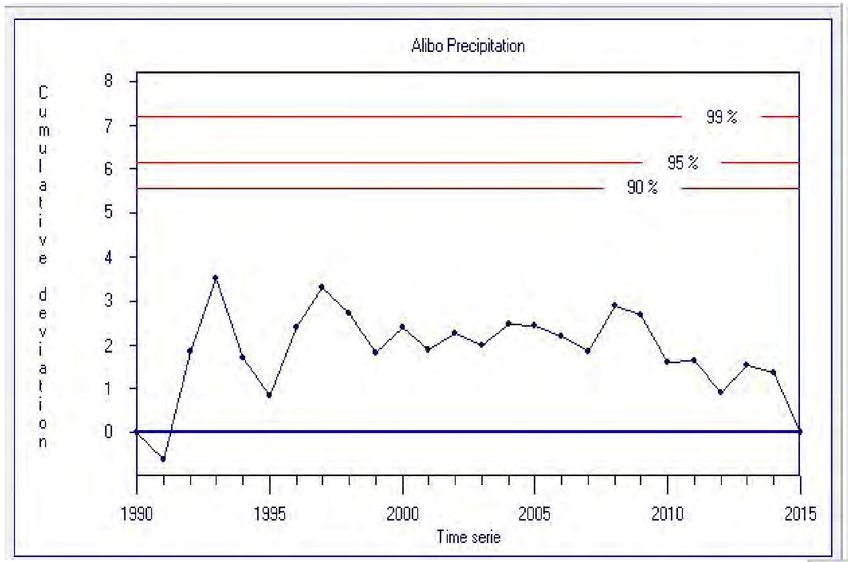
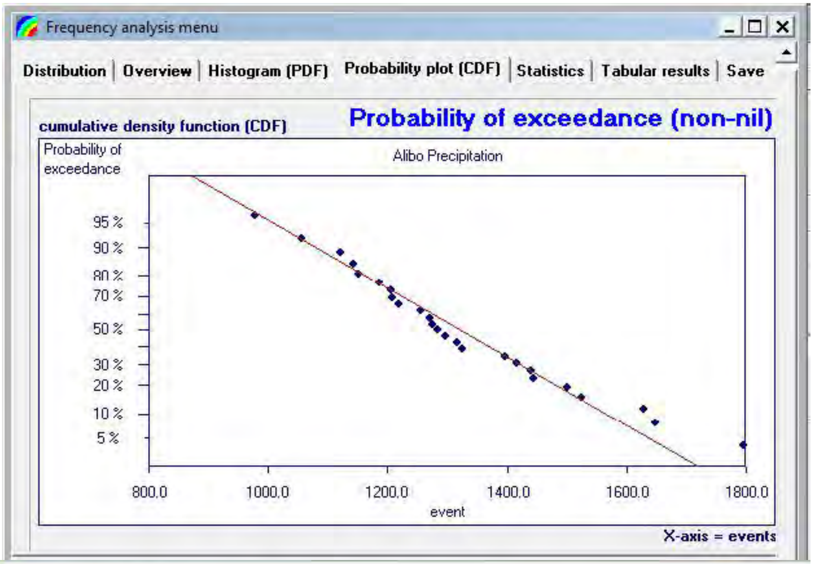
cumulative density function (CDF)
Probability of exceedance (non-nil)
Probability of exceedance
Debre markos Precipitation
95 %
90 %
80 %
70 %
50 %
30 %
20 %
10 %
5 %
1000.0
1200.0
1400.0
1600.0
1800.0
event
X-axis = events


Alibo Precipitation
Cumulative deviation
8
7
6
5
4
3
2
1
0
99 %
95 %
90 %
1990
1995
2000
2005
2010
2015
Time serie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Probability plot (CDF)
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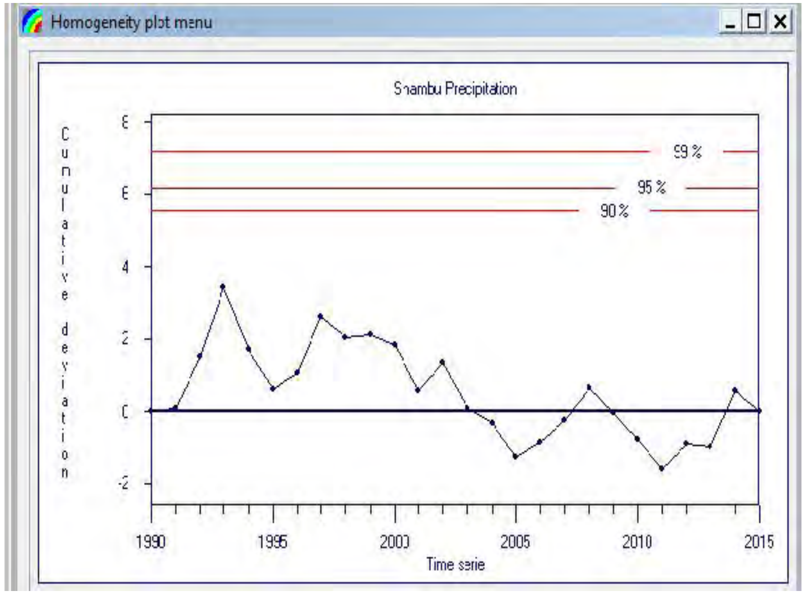
cumulative density function (CDF)
Probability of exceedance (non-nil)
Probability of exceedance
Alibo Precipitation
95 %
90 %
80 %
70 %
50 %
30 %
20 %
10 %
5 %
800.0
1000.0
1200.0
1400.0
1600.0
1800.0
event
X-axis = events


Homogeneity plot menu
Shambu Precipitation
Cumulative deviation
8
6
4
2
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99 %
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90 %
1990
1995
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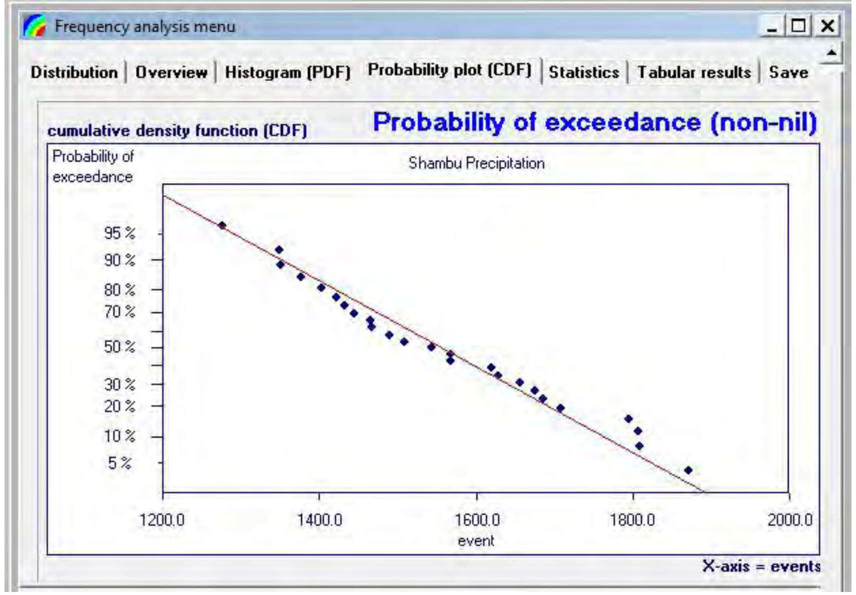
2010
2015
Time serie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Probability plot (CDF)
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Tabular results
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cumulative density function (CDF)
Probability of exceedance (non-nil)
Probability of exceedance
Shambu Precipitation
95 %
90 %
80 %
70 %
50 %
30 %
20 %
10 %
5 %
1200.0
1400.0
1600.0
1800.0
2000.0
event
X-axis = events