JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

MASTER OF SCIENCE PROGRAM IN ENVIRONMENTAL ENGINEERING

MODELING OF NUTRIENTS LOADING AND TRANSPORTING PATH WAY USING SOIL & WATER ASSESSMENT TOOLS: A CASE STUDY OF FINCHA WATERSHED, WESTERN ETHIOPIA

BY: ZERIHUN KASSA

A THESIS TO BE SUBMITTED TO SCHOOL OF GRADUATE STUDIES OF JIMMA UNIVERSITY, FOR PARTIAL FULFILLMENT OF THE REQUIREMENTS OF MASTER OF SCIENCE DEGREE IN ENVIRONMENTAL ENGINEERING

MAY, 2018

JIMMA, ETHIOPIA

JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
CIVIL AND ENVIRONMENTAL ENGINEERING FACULTY
ENVIRONMENTAL ENGINEERINGDEPARTMENT

MODELING OF NUTRIENTS LOADING AND TRANSPORTING PATH WAY USING SOIL & WATER ASSESSMENT TOOLS: A CASE STUDY OF FINCHA WATERSHED, WESTETRN ETHIOPIA

MSc Thesis

BY

ZERIHUN KASSA

Main Advisor:Dr.Eng. Fekadu Fufa

Co-Advisor:Mr. Fayera Gudu

MAY, 2018

JIMMA, ETHIOPIA

DECLARATION

I, Zerihun Kassa, declare that this thesis is my own original workwith the exception of quotations or references which have been attributed to their sources or authors and that it has not been presented and will not be presented by me to any other university for similar or any other degree award.

Name of the student

Zerihun Kassa	....	....
Name	*signature*	*Date*

APPROVAL PAGE

We, the undersigned certify that the thesis entitled: "**Modeling of Nutrient Loading and Transport Pathways using SWAT model in Fincha'a watershed, Western Ethiopia**" is the work of Zerihun Kassa and we hereby recommend for the acceptance by school of Post Graduate Studies of Jimma University in partial fulfillment of the requirements for Degree of Master of Science in Environmental Engineering.

Dr. Ing. Fekadu Fufa (PhD) _______________ ________________

Main Advisor Signature Date

Fayera Gudu (MSc) _______________ ________________

Co-Advisor: Signature Date

As member of Board of Examiners of the M.Sc. Thesis Open Defense Examination, We certify that we have read, evaluated the thesis prepared by Zerihun Kassa and examined the candidate. We recommended that the thesis could be accepted as fulfilling the thesis requirement for the Degree of Master of Science in Environmental Engineering.

___________________ _____________________________________

External Examiner Signature Date

____ _________________

Internal Examiner Signature Date

______________________ _______________________________________

Chairperson Signature Date

ABSTRACT

Nutrients, particularly nitrogen (N) and phosphorus (P), are needed for plant growth and healthy ecosystems. In excess, however, they can impair surface water systems giving rise to a range of water quality problems like blooms of algae and the water hyacinth, depletion of oxygen levels and even suffocation or death of aquatic organisms and also increased nitrogen and phosphorus application on the land has enlarged N and P nutrients burdens to the lake through runoff and leaching. The objective of the study is modeling Nutrients (Nitrate-Nitrogen and phosphorus) loading and transporting in the Fincha watershed using Soil Water Assessment Tool (SWAT). The model was calibrated and validated using flow of Fincha'a gaging station. Sensitivity analysis showed curve number, Ground waterDelay, Moist bulk density *(Sol_BD)and* Threshold depth of water in shallow aquifer required for return flow (*GWQMN) were the most sensitive top four parameters. The model was calibrated using stream flow data from 1988 to 2002 and validated from 2003 to 2011.The*R^2 *and NSE values were used to examine model performance and the result indicates 0.93 and 0.79 to* R^2 *and 0.60 and 0.59 to NSE during calibration and validation respectively. This shows that there is good agreement between observed and simulated stream flow. From the simulation the annual total average of P and N were 17.5kg/ha/year and 78.6 kg/ha/year respectively. Surface runoff, lateral flow and percolation to the ground were the main transporting pathways for both Phosphorus and Nitrogen which depends on rainfall pattern, duration and intensity. Organic Phosphorus and organic N were dominantly transported through surface run off whereas NO3 was dominantly transported via percolation to ground water. The highest annual total P and total N load were contributed by sub basin 2, 4, 7 and 6,20,1 respectively. These Subbasins were mainly located in Jimma Rare Woreda, Jimma Geneti and Horo.*

Key Words: Nutrients Load and transporting pathway, SWAT model.

ACKNOWLEDGMENT

Above all, I thank the almighty God for His guidance and grace upon me during all my works and in all my life. Special acknowledgment and warmest appreciation is for my respected and diligent advisers, Dr.Ing Fekadu Fufa and Fayera Gudu (MSc), for their guidance, helpful moral support and scholarly advices me to complete my work successfully and their continuous and timely comments regarding the study.

I am also thanks Mr.Megersa Kebede who was with me from the very beginning of software set up to the end of my thesisand AtoAbashuGudeta who collected me data of Fincha'a Dam water

My gratitude also goes to the Ethiopian Road Authority (ERA) for their Financing of this program and supporting all times with work in partnership course carried out as part of agreements signed between Ethiopian Road Authority and Jimma University.

My special and great thanks goes to my beloved Wife Beki Mesfin who has been providing me with her love, support and encouragement the Necessary help during my academic careers. Without her consistent help and advice this wouldn't be real I am very proud to be part of such beautiful family.

Dedication

I dedicate this thesis to my Wife Beki Mesfin, and to my son Yerosan, for helpingme with affection, love and for their dedicated partnership in the success of my life.

Table of Contents

List of Tables

List of figures

ACRONYMS

AnnAGNPS	Annualized Agricultural Non-point Source Model
BMP	Best Management Practice
DEM	Digital Elevation Model
DMC	Double Mass curve
DO	Dissolved Oxygen
GIS	Geographical information system
HRU	Hydrologic Response Unit
LAT Q	Lateral flow
LULC	Land use land cover
NPERC	Percolation Nitrogen
NPS	Nonpoint source pollution
NSE	Nash-Sutcliffe efficiency
OAT	One-factor-At-a-Time
ORG N	Organic form of Nitrogen
ORGP	Organic form of Phosphorus
SED P	Sediment attached Phosphorus
SOLP	Soluble phosphorus form
SUR Q	Surface flow
SWAT	Soil and Water Assessment Tool
TMDLs	Total Maximum Daily Loads
TN	Total nitrogen
TP	Total phosphorus
USDA	United States Department of Agriculture
USDA-ARS	United State Department of Agriculture Agricultural Research Service

CHAPTER ONE: INTRODUCTION

1.1 Background

Nutrients such as nitrogen and phosphorus are vital to life on land and in water. Moderate input of nutrients to water systems may be beneficial for fish catches since it will increase the growth of macrophytes. However, an over-fertilization will lead to an excessive growth and the bacterial decay of organic matter may lead to oxygen depletion(Clark R. 2., 2001)

Non-point source of pollution is caused by the movement of water, over and through the ground, generally after a precipitation event (rainfall and/or snow). The runoff picks up and carries away natural and manmade pollutants, like from the agricultural sector is alleged to be the largest contributor to Non point Pollutant through runoff of nutrients, sediment, pesticides, and other contaminants eventually depositing them in lakes, rivers and coastal waters. Thus, the pollutants left on the surface from various sources accumulate in receiving water bodies. Nutrients, such as nitrogen and phosphorous, are a serious problem threatening water quality(Lindim C & Vieira, 2011). Non-point source pollution occurs when rainfall or irrigation water runs over land or through the ground, picks up pollutants and deposits them into rivers, lakes, or coastal waters or introduces them into ground water (Arnold, Allen, & Bermhardt, 1993).

Phosphorus as well as nitrogen contributes to enhanced algae growth, and subsequent decomposition reduces oxygen availability to benthic sea creatures like fish, shellfish, and crustaceans. Changes to nutrient loadings can also change the phytoplankton species composition and diversity. In extreme cases, eutrophication can lead to hypoxia or oxygen-depleted ‘dead zones’((Falkowski, 2011)and harmful algal blooms, which have been spreading (Diaz, 2008).

The quantity and quality of surface water, lakesand ground water constitute the water resources continuum of a watershed. Effective management of watersheds necessitates basic understandings of the numerous processes and interactions between the water resources continuum of a watershed, pollutant loadings, the receiving water bodies and effects of management practices.

Watershed models are cost effective tools to analyze the quantity and quality of water resources, in the planning, design, and operation of water use, distribution systems, and management activities (Muttiah, 2002).Watershed models have been extensively used in hydrological science and environmental management research for a number of important tasks, including estimating nonpoint source pollutant inputs to receiving water bodies and their source areas and predicting the effects of climate and land-use change on water quality(Rode, et al., 2010).

Watershed modeling can be a valuable tool for studying the relationships between conditions and the quality of water in a watershed(Liu, Zhang, Yuzhen, Hong, & Deng, 2008) .The modeling of environmental deterioration to better understand and manage natural resources, such as river basins and watersheds, is a continuous process. No matter what type of problem studied with Soil and Water Assessment Tool (SWAT), water balance is the driving force behind everything that happens in the watershed, in order to accurately predict the movement of pesticides, sediments, nutrients and hydrological cycle.

The importance of physically based, distributed and continuous time model like SWAT has increased with the advent of computationally efficient computers, Geographic Information Systems (GIS) software and availability of spatial input data(Borah, 2003).The extensive input data for the distributed watershed models are often generated from Geographic Information Systems (GIS) and regional or local surveys (Ewen, 2000).

Major components of the SWAT model include hydrology, weather, erosion, soil temperature, crop growth, nutrients, pesticides and agricultural management practices (Neitsch S. J., 2005). This model has the ability to predict changes in sediment, nutrient and pesticide loads with respect to the different management conditions in watershed.

The Soil and Water Assessment Tool (SWAT) model was developed by the U.S Department of Agriculture Agricultural Research Service (USDA-ARS)(Arnold J. W., 1998). It is a theoretical model that functions on a continuous time step. Agricultural components in the model include crop cycles from planting to harvesting, fertilization, tillage options, and animal production and have the capability to include point source loads .All model calculations are performed on a daily time step. The SWAT model predicts the influence of land-management practices on constituent yields from a watershed. It is the continuation of over 30 years of model development within the USDA-ARS(LIU, 2008).

Process-oriented models like the Soil & Water Assessment Tool (SWAT) (Srinivasan, 1998; Arnold J. G., 2005)incorporate current understanding of linkages between watershed properties and water quality responses, but they are also difficult to calibrate (Wang, 2012). Although evaluation of multiple responses simulated by spatially distributed process-based models over time and space is strongly encouraged (Wellen, 2015), such comprehensive evaluations are limited by the availability of spatial and long-term temporal data.

Similar study was done in order to model the flow and water quality dynamics of a coastal Mediterranean intermittent river using the Soil and Water Assessment Tool (SWAT 2005).Flow, sediment, nitrogen and phosphorus transport were simulated on the Vène experimental catchment, France. The model was sequentially calibrated at sub-catchment scale and validated both at sub-catchment and catchment scales. The results indicate that, while the model produces good results for flow simulation, its performance for sediment transport is less satisfactory. This in turn impacts on the nutrient transport module. The reasons behind these shortcomings are analysed, taking into account the length of the data records, their distribution and the equations used in the SWAT model(Chahinian, 2011).

Many regulations are in place to monitor point sources of pollution (i.e. industrial sites, waste water treatment plants, etc.), but it is well understood that these point sources are not the only factor in diminishing water quality values. Urban and agricultural runoff can contribute significant quantities of nutrients, chemicals, and sediments into stream networks, negatively impacting water bodies. To locate these “non-point” sources of pollution in a landscape, many watershed managers and researchers frequently use watershed scale models. One of the most commonly used watershed scale models being used is the USDA’s Soil & Water Assessment Tool (SWAT) model.

Fincha’a dam was constructed in 1973 as a strategy for fostering economic growth in Ethiopia through generation hydroelectricity, irrigation, fishery, and tourism (HARZA Engineering Company, 1975). Currently, of the 478 MW hydropower capacity generated in the country, this power plant generates 128 MW (Assefa, 2003), supplies water to a sugar factory downstream, and has created new economic activities such as fishery. But there has been no study conducted at this watershed that showsthe nutrients load and pathway to the Damat the recent.There for, the main aim of this study at Fincha Dam is to determine the transporting and loading of nutrients besides to identify the most prone area among the watershed of the dam.

1.2 Statement of the Problem

Freshwater is an indispensable natural resource for survival of human being and other species. The quantity and quality of freshwater influence human life, society stability and economy development. The increasing population and intensity with which land is used for crop production is reflected in changed land's surface and higher nutrient concentrations in many water bodies(Smith VH T. G., 1999).Such kind of problem of water pollution is being experienced by both developing and developed countries. Human activities give rise to water pollution by introducing various categories of substances or waste into a water body. The more common types of polluting substances include pathogenic organisms, oxygen demanding organic substances, plant nutrients that stimulate algal blooms, inorganic and organic toxic substances

The Excessive nutrients such as Nitrogen and Phosphorus cause eutrophication of water bodies leading to a number of environmental problems such as excessive growth of green algae and the water hyacinth, fish kills due to depletion in oxygen levels, release and accumulation of toxic substances and reduced water quality due to anaerobic conditions (Nyenje, 2010).Recently eutrophication has become a serious problem in the world. Its severity is increasing especially in the developing countries because of the rapid population growth and expansion of agriculture. According to a study conducted by UNEP, which is cited in Yang *et al*. (2008), about 30%- 40% of the lakes and reservoirs have been affected by eutrophication all over the world.

This also true in Africa eutrophication posses direct risks to public health because most large cities may depend entirely on surface water systems for drinking water supply. In the East African region for example, a number of large cities like Kampala in Uganda, Kisumu in Kenya and Mwanza in Tanzania depend on Lake Victoria for their daily water supply. The water quality of this lake has, however, deteriorated over the years due to excessive nutrient discharges from surrounding urban areas(Mwanuzi, 2013; Oguttu, 2008).

There for, eutrophication is an accelerated growth of algae on higher forms of plant life caused by the enrichment of water bodies by nutrients, especially by compounds of nitrogen and/or phosphorus. This may causes undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned. The sources of waterbodies eutrophication include nitrogen and phosphorus coming from diffuse and point sources, of which diffuse sources, mainly from agricultural activities, are more important (Lam QD, 2012).

Among the water bodies that are affected by eutrophication, Dams are one of them that are susceptible and exposed to the problem(Cunningham, 2008). Particularly, this problem can be augmented when the Dam is located in agricultural fields where there are poor management practices.This can create a number of water supply problems for cities depending on these fresh water bodies due to threats to public health when the affected water body is used for the city's water supply, fishing or recreation purposes. In fact, water supply based on these water resources may in a long run become unsustainable due to water quality deterioration.

In line with the above problems, this research going to simulate the nutrients loading and transporting pathway of the Fincha watershed, in addition it will identify the most prone area among the watershed.

1.3 Objective of the study

1.3.1 General Objective:

To model nutrient transporting pathway and Loadingof Fincha Watershed Using SWAT, Oromia national Regional state, Ethiopia.

1.3.2 Specific Objectives:

- To Determine the transporting pathway of N and P in the watershed
- To quantify the amount of N &P load to the nearby Fincha Dam.
- To identify the prone area responsible for high N and P load.

1.4. Study Questions

1. What are the transporting pathways of N and P in the watershed?

2. How much N and P are loaded to the Fincha Dam?

3. Which areas are significantly responsible for higher Nand P load?

1.5. Rationale of the Study

Water is the foremost part of all living things, and a major force constantly shaping the surface of the earth. It is also a key factor in air conditioning of the earth for human existence and in influencing the progress of civilization, (V.T.ChMow, 1988).In Third World countries where the agricultural sector plays a key role in their economic growth, the management of water resource is an item of high priority in their developmental activities, (K.Subramanian., 2008). In Ethiopia where about 85% of the population is engaged primarily in agriculture and depends heavily on available water resources, the assessment and management of available water resources is a matter of prime importance. Extensive modification of landscapes associated with increased human population, land development, and agricultural activities contributes to increased delivery of nitrogen and phosphorus to streams, rivers, estuaries, and ultimately to coastal waters (Perierls, Caraco, Pace, & Cole, 1992).

Water quality impairment in general, and diffuse pollution in particular, can be a serious problem in Ethiopia for reasons related to widespread sources of pollution, favoring hydrologic factors and lack of environmental services. The favorable hydro-meteorological factors are related to the nature of the rainfall climate and watershed characteristics. Many catchments in Ethiopia receive intense seasonal rainfall on steep slopes that have scarce vegetation cover. These factors enhance high surface runoff and transport of sediments and associated contaminants.

The advantage of prediction is that it can be used to alter the occurrences of detrimental conditions before they develop. Due to expense and intensiveness of long-term field study to quantify NPS pollutants, computer model simulations are increasingly more appealing. Forecasting information from model simulation is used in decision-making strategies designed to sustain agriculture. This information permits an alteration in management strategy prior to development of conditions that is detrimentally impact the agricultural productivity either of the soil or of quality of ground water. This ability optimizes the use of environment by sustaining its utility without detrimental consequences while preserving the esthetic qualities.

1.6 Scope of the Study

Geographically, the study will be bounded to Fincha Catchmentthat are (Guduru, Ababo Guduru, Abay Chomen, JimmaGanati and Horo)situated in the western part of Ethiopia, in Oromia National Regional State. The Vital focus of the study was limited to assessing the Nutrient (N and P) transport pathways and loading from watershed to Fincha Dam.Though it was not enough for calibration and validation, laboratory test of the collected water from August 8/8/2017 to September 8/8/2017 was done. Having these data, other researchers who will be interested in the area may do further research.

1.7 Limitation of the study

The main challenges in this study were lack of measured data of nutrients not from each watershed but also at the outlet or in Fincha'a Dam. Since from it's establishment to yet there was not a single stations that records the nutrient data thus it was not possible for the researchers to made calibration and validation, which might contribute its own impact on model prediction efficiency.

CHAPTER TWO: LITERATURE REVIEW

2.1 Nutrients Modeling

Nutrients such as nitrogen and phosphorus are vital to life on land and in water. Moderate input of nutrients to water systems may be beneficial for fish catches since it will increase the growth of macrophytes. However, an over-fertilization will lead to an excessive growth and the bacterial decay of organic matter may lead to oxygen depletion, especially at the deep bottoms of the sea. Due to this, there will be an alteration of the ecological community structure. Some species will be favoured while others will be disadvantaged in the altered environment. This is called eutrophication(Clark R. , 2001)

Eutrophication is one of the most prevalent global problems of our era. It is a process by which lakes, rivers, and coastal waters become increasingly rich in plant biomass as a result of the enhanced input of plant nutrients mainly nitrogen (N) and phosphorus (P)(Golterman, 1991) A recent issue of The Water Wheel (Water Research Commission, South Africa; issue September/October 2008) reports that 54% of the lakes/reservoirs in Asia are impaired by eutrophication, in Europe this is 53%, in North America 48%, in South America 41%, and in Africa 28%. The main nutrient sources are effluent discharges from domestic and industrial sources, and diffuse (non-point) sources. The non-point sources are transported by the surface runoff during the rainy seasons and by wind from the atmosphere.

2.1.1 Nitrogen

Nitrogen (N) is the most abundantly available element in the atmosphere, hydrosphere, and biosphere. However, it is the least readily available element to sustain life; and living organisms require it in large amounts. Less than 1% of the global N stock is available to more than 99% of living organisms(Galloway, 2003) .The nitrogen in our environment is almost entirely in the form of molecular nitrogen, which cannot be used by most organisms. Breaking the triple bond holding together the two nitrogen atoms requires a significant amount of energy. This strong bond can only be broken under high-temperature processes or by a small number of specialized nitrogen fixing microbes.

2.1.2Nitrogen Simulation Using SWAT Modeling

There is extensive spatial and temporal variability in soil nitrate concentrations, caused by local variations in the nitrogen cycle processes of mineralization, immobilization, nitrification, denitrification, leaching, and plant uptake etc. These processes are difficult to characterize at the watershed scale using measurements collected one time at a single site. For this reason, applications of physically based deterministic continuous models, including the SWAT model, have been commonly used to estimate nitrogen dynamics of a watershed (Krysanova, 2008)

The nitrogen cycle, modeled by SWAT, is a dynamic system that includes the water, atmosphere and soil. Nitrogen's ability to vary its valence state makes it a highly mobile element, and thus predicting the movement of different nitrogen compounds in the soil is critical to the successful management of this element in the environment. The three major forms of nitrogen in mineral soils are organic nitrogen associated with humus, mineral forms of nitrogen held by soil colloids, and mineral forms of nitrogen in solution. SWAT allows nitrogen to be added to the soil by fertilizer, manure, or residue application, fixation by symbiotic or non - symbiotic bacteria, and rain, while it can be removed from the soil by plant uptake, leaching, volatilization, denitrification, and erosion (Neitsch S. W., 2001). SWAT simulates the complete nutrient cycle for nitrogen and phosphorus. The nitrogen cycle is simulated using five different pools; two are inorganic forms (ammonium and nitrate) while the other three are organic forms (fresh, stable, and active).

In the soil, nitrogen (N) comes in both organic and inorganic forms. Inorganic N consists mostly of ammonium (NH4+) and nitrate (NO3-), and is already available to plants. Organic N (manure, crop residues and soil organic matter) must first be converted to inorganic forms before it can be taken up. This process is called mineralization, which is completed by soil microbes as a by-product of organic matter decomposition. The figure 1 below clearly depicting the inorganic and organic parts of the Nitrogen, since predicting the movement of nitrogen between the different pools in the soil is critical to the successful management of this element in the environment(Neitsch S. , 2002)

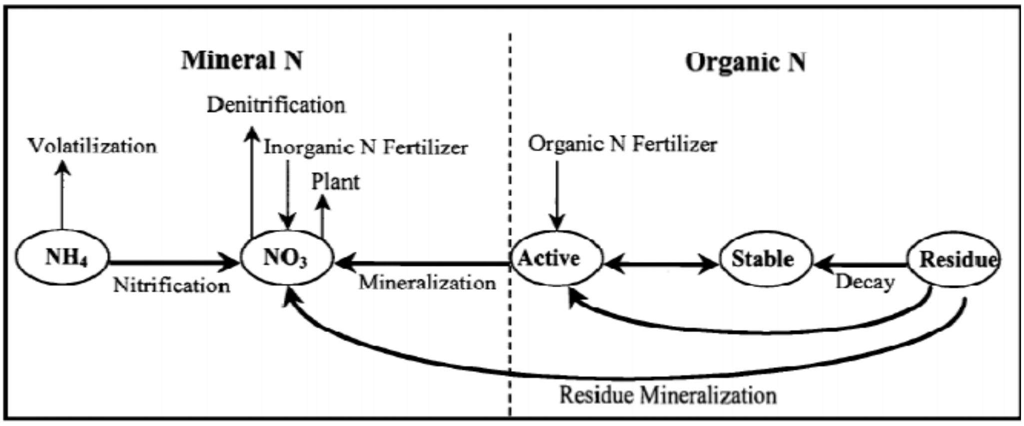


Figure 2.1SWAT soil nitrogen processes(**Source:(Neitsch S. J., 2005)**

2.1.3 Initialization of Soil Nitrogen levels

SWAT will initialize levels of Nitrogen in different pools if the users not define the amount of nitrate and organic nitrogen contained in humic substances for all layers at the beginning of the Simulation.

Initial nitrate levels in the soil are varied by depth using the relationship:

$$\mathrm{NO3}_{\mathrm{concentration}} = 7 * \exp\left({}^{-z}/_{100}\right) - - - - - - - - - - - - - - 1$$

Where $\mathrm{NO}_{3\mathrm{concentration}}$ is the concentration of nitrate in the soil at depth z(mg/kg or ppm),and z is the depth from the soil surface(mm).

2.1.4 Decomposition, Mineralization and Immobilization

The nitrogen mineralization algorithms in SWAT are net mineralization algorithms, which incorporate immobilization into the equations. The algorithms were adapted from the PA-PRAN mineralization model (Seligman, 1981).Once the soil organic and mineral nitrogen contents are defined**,** SWAT estimates the mineralization and immobilization based on the C:N ratio relationship. The kinetics of decomposition of crop residues and mineralization of nitrogen it contains are largely influenced by the quality of the plant materials, mainly the C:N ratio (Constantinides, 1994)

Decomposition from the residue fresh organic N pool, which will add to the humus active organic pool in the layer, is calculated by:

$$\mathrm{N}_{\mathrm{dec.ly}} = 0.2 * \delta_{\mathrm{ntr.ly}} * \mathrm{OrgN}_{\mathrm{frsh.ly}} - - - - - - - - - - - - - - 2$$

Where $N_{dec.ly}$ is the nitrogen decomposed from fresh organic N(kg N/ha),$\delta_{ntr.ly}$ is the residue decay rate constant, and $OrgN_{frsh.ly}$ is the nitrogen in the fresh organic pool (kg N/ha).

Mineralization from the humus active organic N pool that will be added to the nitrate pool in the layer is calculated as:

$$\mathrm{N}_{\mathrm{min.ly}} = \beta_{\mathrm{min}} * \sqrt{\left(\gamma_{\mathrm{tmp.ly}} * \gamma_{\mathrm{sw.ly}}\right)} * \mathrm{OrgN}_{\mathrm{act.ly}} - - - - - - - - - - - - -3$$

Where $\mathrm{N}_{\mathrm{min.l}}y$ is the nitrogen mineralized from the humus active organic N pool (kg N/ha),$\upbeta_{\mathrm{min}}$ is the rate coefficient for mineralization of the humus active organic nutrients, $\upgamma_{\mathrm{tmp.ly}}$ is nutrient cycling temperature factor for layer ,$\upgamma_{\mathrm{sw.ly}}$ is the amount of nitrogen in the active organic pool (kg N/ha).

Mineralization from the residue fresh organic N pool, which will add to the nitrate pool in the layer, is calculated with the equation:

$$\mathrm{N}_{\mathrm{min.ly}} = 0.8 * \updelta_{\mathrm{ntr.ly}} * \mathrm{orgN}_{\mathrm{frsh.ly}} -------------4$$

Where,$\mathrm{N}_{\mathrm{min.ly}}$ is the nitrogen mineralized from fresh organic N pool (kg N/ha),$\delta_{ntr.ly}$ is the residue decay rate constant, and $\mathrm{orgN}_{\mathrm{frsh.ly}}$ is the nitrogen in the fresh organic pool (kg N/ha).

2.1.5 Nitrification, Volatilization, Denitrification and Leaching

The microbial (Nitrosomonas) conversion of ammonium to nitrite (NO2_) and then to nitrate (NO3_) by the Nitrobacter is commonly known as nitrification. Nitrification is a biological process that slows when soil temperatures drop below 10oC. This is why ammonium-forming fertilizers should not be fall applied until soil temperatures are below 10oC. The losses of ammonia to the atmosphere, mainly from some surface applied nitrogen sources can occur through the process of volatilization. Ammonia is an intermediate form of nitrogen during the process in which applied fertilizer is transformed to NH4+. Soil pH values higher than 7.3 and high air temperatures increase volatilization losses. The total amount of ammonium lost to nitrification and volatilization is calculated in SWAT using a first-order kinetic rate equation developed by Reddy et al. (1979) and Godwin et al. (1984):

$$\mathrm{N}_{\mathrm{nit/volly}} = \mathrm{NH}_{4\mathrm{ly}} * \left(1 - \exp\left[\upeta_{\mathrm{nit.ly}} - \upeta_{\mathrm{vol.ly}}\right]\right) ------------5$$

Where $\mathrm{N}_{\mathrm{nit/volly}}$ is the amount of ammonium converted via nitrification and volatilization in layer (kg N/ha),$\mathrm{NH}_{4\mathrm{ly}}$ is the amount of ammonium in layer (kg N/ha),$\upeta_{\mathrm{nit.ly}}$ is the nitrification regulator and $\upeta_{\mathrm{vol.ly}}$ is the volatilization regulator.

Denitrification is the process by which bacteria convert nitrate (NO3_) to nitrogen gas (N2), which is lost to the atmosphere. Denitrifying bacteria use NO3_ instead of oxygen in their metabolic processes when the soil atmosphere lacks oxygen. Denitrification occurs in waterlogged soil with ample organic matter to provide energy for bacteria. For these reasons, denitrification generally is limited to topsoil. Denitrification can proceed rapidly when soils are warm and saturated for two or three days.

SWAT determines the amount of nitrate lost to denitrification with the equation:

$$N_{denit,ly} = No_{3ly} * (1 - \exp[-\beta_{denit} * \gamma_{tmp.ly} * OrgC_{ly}]) - - - - - - - - 6$$

Where $N_{denit,ly}$ is the amount of nitrogen lost to denitrification (Kg N/ha), No_{3ly} is the amount of nitrate layer(Kg N/ha), β_{denit} is the rate coefficient for denitrification, $\gamma_{tmp.ly}$ is the threshold value of nutrient cycling water factor for denitrification to occur.and $OrgC_{ly}$ is amount of carbon in the layer(%).

The risk of nitrate leaching down the soil profile is calculated in SWAT model as a function of the water discharge and residual soil nitrate in the profile. Nitrate is a soluble anion that does not adsorb to soil particles. Nitrate that moves below the root zone has the potential to enter either groundwater or surface water through tile drainage systems. The federal standard for the amount of nitrate allowed in drinking water is 10 ppm.

2.1.6 Nitrogen Deposition and Fixation

Deposition of atmospheric nitrogen can occur in rainfall. SWAT calculates the amount of nitrogen deposition in rainfall based on a user defined coefficient of nitrogen concentration in rain. SWAT also simulates nitrogen fixation by legumes when the soil does not supply the plant with the amount of nitrogen needed for growth. The nitrogen obtained by fixation is incorporated directly into the plant biomass and never enters the soil, unless plant biomass is added to the soil as residue after the plant is killed.

2.1.7 Nitrate Transport

The transport of nutrients from land areas into streams and water bodies is a normal resut of soil weathering and erosion processes.However,excessive loading of nutrients into streams and water bodies will accelerate eutrophication and render the water unfit for human consumption.

Most soil minerals are negatively charged at normal pH and the net interaction with anions such as nitrate is a repulsion from particle surfaces.This repulsion is termed negative adsorption or anion exclusion.

Anions are excluded from the area immediately adjacent to mineral surface due to preferential attraction of cations to these sites.This process has a direct impact on the transport of anions through the soil for it effectively excludes anions from the slowest moving portion of the soil water volume found closet to the particle surfaces(Jury, 1991).

Nitrate may be transported with surface runoff, lateral flow or percolation.To calculate the amount of nitrate moved with water,the concentration of nitrate in the mobile water is calculated.This concentration is then multiplied by the volume of water moving in each pathway to obtain the mass of nitrate lost from the soil layer.

$$\mathrm{Conce}_{\mathrm{NO\,3\,mobile}} = \mathrm{NO}_{3\mathrm{ly}} \left(1 - \exp\left[\frac{-\mathrm{w}_{\mathrm{mobile}}}{(1-\theta_c) * \mathrm{SAT}_{\mathrm{ly}} / \mathrm{W}_{\mathrm{mobile}}} \right] \right) ----7$$

Where, $\mathrm{Conce}_{\mathrm{NO\,3\,mobile}}$ is the concentration of nitrate in the mobile water for a given laayer(kg N/mm H_2o),$\mathrm{NO}_{3\mathrm{ly}}$ is the amount of nitrate in the layer (kg N/ha).$\mathrm{W}_{\mathrm{mobile}}$ is the amount of mobile water in the layer(mmH_2o),θ_c is the fraction of porosity from which anions are excluded,and $\mathrm{SAT}_{\mathrm{ly}}$ is the saturated water content of the soil layer(mm H_2o).The amount of mobile water in the layer is the amount of water lost by surface runoff,lateral flow or percolation:

$$\mathrm{W}_{\mathrm{mobile}} = \mathrm{Q}_{\mathrm{surf}} + \mathrm{Q}_{\mathrm{lat\,.ly}} + \mathrm{W}_{\mathrm{perc\,.ly}} \text{ for top 10mm} - - - - - - - - - - - - - 8$$

$$\mathrm{W}_{\mathrm{mobile}} = \mathrm{Q}_{\mathrm{lat\,.ly}} + \mathrm{W}_{\mathrm{perc\,.ly}} \text{ for lower soil} - - - - - - - - - - - - - - - - 9$$

Where $\mathrm{W}_{\mathrm{mobile}}$ is the amount of mobile water in the laye(mm H_2O),$\mathrm{Q}_{\mathrm{surf}}$ is the surface runoff generated on a given day(mm H_2O),$\mathrm{Q}_{\mathrm{lat.ly}}$ is the water discharged from the layer by lateral flow(mm H_2O) and $\mathrm{W}_{\mathrm{perc.ly}}$ is the amount of water percolating to the underlying soil layeron a given day(mm H_2O). Surface ruoff is allowed to interact with and transport nutrient from the top 10mm of soil.

2.1.8 Organic N in Surface Runoff

The organic N attached to the soil Particles via commercial fertilizer and livestock manure may be transported by surface runoff to the rivers and lakes.as cited by Neitsch(2002),the amount of organic nitrogen transported with sediment to the stream is calculated with loading function developed by McElroy et al.(1976) and modified by Williams and Hann(1976).

SWAT Calculates the movement of organic nitrogen in the surface as:

$$\mathrm{OrgN}_{\mathrm{surf}} = 0.001 * \mathrm{Conc}_{\mathrm{orgN} * {}^{\mathrm{Sed}}/_{\mathrm{area\ hru}}} * \varepsilon_{\mathrm{N:sed}} - - - - - - - - - - - 10$$

Where ,$OrgN_{surf}$ is the amount of organic Nitrogen transported to the main channel in surface runoff(kg N/ha),$Conc_{OrgN}$ is the concentration of organic nitrogen in the soil surface top 10mm(g N/metric tone soil),Sed is the sediment yield on a given day(metric tones).$Area_{hru}$ is the HRU area(ha),and $\varepsilon_{N:sed}$ is the nitrogen enrichment ratio.

There for, physically based deterministic models are useful tools that can be used to simulate spatial and temporal dynamics of nitrate-N within a watershed. These models can be used to identify relative importance of alternative best management practices (BMP) that can reduce nitrate-N water quality impacts. In this study, the SWAT model will be used to understand the sources, transport and fate of nitrate-N in the study area of Fincha'a watershed.

2.2 Phosphorus

Phosphorus (P) is an essential element for plant and animal production. Compared to other macronutrients, it is the least mobile element in plant and soils(Khan, 2001). P has high affinity to quickly combine with Ca, Fe, and Al ions to form insoluble compounds that precipitate out of solution, causing build-up near the soil surface and ready transport in surface runoff(Broberg, 1988). Enrichment of fresh water resources with P leads to eutrophication, which involves the increased growth of undesirable organisms such as cyanobacteria (blue-green algae), Agricultural nonpoint sources of P are primarily runoff from farm-fields and concentrated animal-feeding sites. Although both nitrogen and phosphorus contribute to eutrophication, phosphorus is the most limiting nutrient for the growth of aquatic organisms and thus the primary factor that must be controlled to prevent eutrophication of fresh water bodies. The increase in eutrophication of fresh waters can be controlled through decreasing P inputs to surface waters (Shigaki, 2006).

Establishment of economically and environmentally sound P management systems requires adoption of local management strategies that consider soil test phosphorus, P application methods, and transport factors such as hydrology and erosion(Mallarino, 2002). Since the buildup of P is most prevalent in areas where P from fertilizer and manure is applied in excess of crop needs, the problems of P losses are most severe in areas where soil P levels are highest and where water movement from soil to surface water is greatest.

2.2.1 Phosphorus Simulation Processes in SWAT Model

SWAT phosphorus modeling is based on point sources of P, soil applied organic and inorganic P fertilizers, and cycling of P in crop residue and microbial biomass. P cycling accounts for transformations in six soil P pools; three are organic (fresh organic, active and stable organic P) and another three are inorganic (minerals) pools (labile/solution, active, and stable pools).

The major P transformation processes include mineralization of fresh organic P and soil organic matter, and decomposition and immobilization. SWAT requires estimates for the initial mineral P and organic P concentrations in the upper soil layers for phosphorus simulation(Neitsch S. a., 2005a).

2.2.2 Mineral Pools of Phosphorus

SWAT initializes the active and stable mineral pools of Phosphorus based on labile Phosphorus.

i. Solution Pool: Also known as, the labile pool provides P for plant uptake, soluble P in surface runoff, and P leaching. Mineralized organic matter P and inorganic fertilizer P enter this pool. The initial value for this pool is a user-defined concentration. The initial Solution pool value, which is an input, sets both the active and stable P pools via fixed ratios.

ii. Active mineral pool: Interacts slowly with the stable pool and quickly with the solution pool. This pool represents P that is reversibly precipitated or adsorbed, but is less active than Solution P. It is about 1.5 times larger than the solution pool.

Active mineral pool concentrations (mg/kg) are given by:

$$\mathrm{P_{active\ \ mineral\ \ pool}} = \mathrm{P_{solution}} * \left[\frac{1-\mathrm{PAI}}{\mathrm{PAI}}\right] - - - - - - - - - - - - - - 11$$

Where, $P_{solution}$ is the amount of labile P (mg/kg) and PAI is the P availability index. PAI is estimated using the method outlined by Sharpley et al. (1984).

iii. Stable mineral pool: is the pool that is not readily available for plant uptake and reaches equilibrium very slowly with the active pool. This is the largest of the mineral P pools, about four times larger than the active pool.

Stable mineral pool concentrations (mg/kg) are given by:

$$\mathrm{P_{stable\ \ mineral\ \ pool}} = 4 * \left(\mathrm{P_{active\ \ mineral\ \ pool}}\right) - - - - - - - - - - - 12$$

2.2.3 Organic Pools of Phosphorus

i. Phosphorus in the fresh organic pool is the sum fresh Organic P from animal manure added to the solution pool and organic P from crop residue set to 0.03% of the initial amount of residue on the soil surface. The SWAT model assumes animal manures are composed of relatively soluble mineral and readily degradable organic forms.

ii. Organic P concentration (P hum) in mg/kg is calculated with the assumption of an 8:1 N to P ratio in humic substances using:

$$\text{Organic } P_{\text{humic}} = 0.125*(N_{\text{humic}}) ----------------13$$

Where,N_{humic} is the concentration of humic organic nitrogen in the soil layer (mg /kg).

2.2.4 Mineralization, Decomposition and Immobilization

The P mineralization calculations also include immobilization and are based on(C.A.JONES, 1984) .The fresh organic P associated with crop residue and microbial biomass and active organic P pool associated with soil humus are two P reservoirs considered by the model for mineralization. Temperature factor (γ_{temp}) and water factor (γ_{water}) are two parameters regulating the impact of temperature and water availability on P mineralization and decomposition. These factors are calculated as follows:

$$\gamma_{\text{temp}} = 0.9\left(\frac{T_{\text{soil}}}{T_{\text{soil}} + \exp[9.93 - 0.312 * T_{\text{soil}}}\right) -----------------14$$

$$\gamma_{\text{water}} = \frac{SW}{FC} ---------------------------15$$

WhereT_{soil} the temperature of the soil layer (°C),SW water content of the soil layer (mm) and FC water content of the soil layer at field capacity (mm).Temperature of the soil layers should be above 0°C for mineralization and decomposition to occur. The minimum value of γ_{water} water allowed by the model is 0.05.

$$\text{Organic } P_{\text{active}} = \text{Organic } P_{\text{humus}} \left(\frac{\text{Organic } \mathbf{N} \text{ active}}{\text{Organic } \mathbf{N} \text{ active} + \text{Organic } \mathbf{N} \text{ stable}}\right) --- 16$$

$$\text{Organic } P_{\text{stable}} = \text{Organic } P_{\text{Humus}} \left(\frac{\text{Organic N stable}}{\text{Organic N stable} + \text{Organic N active}}\right) --17$$

Where Organic P_{active} is the amount of P in the active organic pool (kg P ha^{-1}),Organic P_{stable} stable is the amount of P in the stable organic pool (kg P ha^{-1}),Organic P $_{humus}$ is the concentration of Humic organic P in the soil layer (kg P ha^{-1}), $Organic\ \boldsymbol{N}\ active$ is the amount of nitrogen in the active organic pool (kg N ha^{-1}), and $Organic\ \boldsymbol{N}\ active$ is the amount of nitrogen in the stable organic pool (kg N ha^{-1}). The amount of P mineralized from the humus active organic pool is calculated as follows and is added to the solution P pool in the soil layer.

$$P_{\text{mineral \_active}} = 1.4(\beta_{\text{mineral}})(\gamma_{\text{temp}}\ \gamma_{\text{water}})^{0.5}(\text{Organic}P_{\text{active}}) ----18$$

Where $P_{mineral\ \_active}$ is the P mineralized from the humus active organic P pool (kg P ha $^{-1}$), and $\beta_{mineral}$ is the rate coefficient for mineralization of the humus active organic nutrients. Mineralization and decomposition from the residue fresh organic P pool is calculated as:

$$\mathrm{P_{mineral}} = 0.8\ (\delta_{\mathrm{ntr}})(\mathrm{Organic\ P_{fresh}}) ----------------19$$

$$(\mathrm{P_{decay}}) = 0.2\ (\delta_{\mathrm{ntr}})(\mathrm{Organic\ P_{fresh}}) ----------------20$$

Where $P_{mineral}$ is the amount of P mineralized from the fresh organic P pool (kg P ha^{-1}) and added to the solution P pool, P_{decay} is the amount of P decomposed from the fresh organic pool (kg P ha^{-1}) and added to the humus organic pool, and δ_{ntr} is the residue decay rate constant δ_{ntr} is calculated as:

$$\delta_{\mathrm{ntr}} = \beta_{\mathrm{residue}}\ \gamma_{\mathrm{ntr}} \left(\sqrt{\gamma_{\mathrm{temp}}\ \gamma_{\mathrm{water}}}\right) ----------------- 21$$

Where, $\beta_{residue}$ is the rate coefficient for mineralization of the residue fresh organic nutrients and γ_{ntr} the nutrient cycling residue composition factor for the soil layer is calculated as:

$$\gamma_{\mathrm{ntr}} = \mathrm{Min} \begin{cases} \exp\left(-0.693\left(\frac{\varepsilon_{\mathrm{C}}:\mathrm{N} - 25}{25}\right)\right) \\ \exp\left(-0.693\left(\frac{\varepsilon_{\mathrm{C:P}} - 200}{200}\right)\right) \\ 1 \end{cases} -------------- 22$$

Where, $\varepsilon_{C:N}$is the C: N ratio on the residue in the soil layer and $\varepsilon_{C;P}$is the C: P ratio on the residue in the soil layer. The C: N ratio of the residue is calculated as:

$$\varepsilon_{\mathrm{C:N}} = \frac{0.58\ \mathrm{rsd}}{\mathrm{Organic\ N_{fresh\ +\ NO_3}}} -----------------23$$

Where, $rsd$is the amount of residue in the soil layer (kg ha^{-1}), 0.58 is the fraction of residue that is carbon, and NO_3 is the amount of nitrate in the soil layer (kg N ha^{-1}). The C: P ratio is calculated as:$\varepsilon_{\mathrm{C:P}} = \left(\frac{0.58\ \mathrm{rsd}}{\mathrm{Organic\ \ P_{fresh}\ \ + P_{Solution}}}\right) -----------24$

2.2.5 Inorganic Phosphorus Sorption

The inorganic P pool, originating either from mineralization of organic P or P applied directly as inorganic fertilizer, is simulated considering plant uptake and conversion to active and stable forms of inorganic P. The movement of P between the solution (labile) and active mineral pools are estimated using the following equilibrium equations (S.L. Neitsch et al., 2009).

$$P_{soluble\ /active} = P_{so\ lution} - (\text{mineral})(P_{active})\left(\frac{PAI}{1-PAI}\right) - - - - - - - - 25$$

$$\text{IF}\quad P_{solution} > (\text{mineral})(P_{active})\left(\frac{PAI}{1-PAI}\right)$$

$$P_{Soluble\ /active} = 0.1(\text{P soluble}) - \text{Mineral Pactive}\frac{PAI}{1-PAI} - - - - 26$$

$$\text{IF } P_{solution} < \text{Mineral } P_{active}\left(\frac{PAI}{1-PAI}\right)$$

Where, $P_{\text{solution/active}}$ is the amount of P transferred between the soluble (labile) and active mineral pool (kg/ha), $P_{solution}$ is the amount of labile P (kg P ha^{-1}), and PAI is P availability index. A positive value of $P_{\text{solution/active}}$ indicates transfer of P from solution to the active mineral pool, and a negative value indicates that P is transferred from the active mineral pool to solution (labile) pool. Phosphorus availability index controls the equilibrium between the solution and active mineral pool and specifies what fraction of fertilizer P is in solution after the rapid reaction period.

In estimating slow sorption of P (where sorbed P is the stable pool), SWAT assumes that the stable mineral pool is four times the size of the active mineral pool. The movement of P between the active and stable pools is calculated using the following equations (S.L. Neitsch et al., 2009).

$$P_{active\ /stable} = \beta_{eqP}(4 \text{ mineral } P_{active} - \text{mineral } P_{satble}) - - - - - - 27$$

$$\text{If mineral } P_{stable} < 4 \text{ mineral } P_{active}$$

$$P_{active\ /stable} = (0.1\beta_{EQp})(4\text{mineral } P_{active} - \text{mineral } P_{satble}) - - - - 28$$

$$\text{If mineral } P_{stable} > 4 \text{ mineral } P_{active}$$

Where, $P_{active\ /stable}$ is the amount of P transferred between the active and stable mineral pools (kg P ha^{-1}), and β_{EQp} is the slow equilibrium rate constant (0.0006 d^{-1}). A positive value of $P_{active\ /stable}$ indicates transfer of P from the active mineral pool to the stable mineral pool, and a negative value indicates transfer of P from the stable mineral pool to the active mineral pool.

2.2.6 Phosphorus In stream

SWAT model users have an option to include or exclude in-stream processes in SWAT simulations. When the in-stream component is included, the model routes the state variables through additional algorithms that have been adapted fromQUAL2E, a steady-state stream water-quality model developed by These QUAL2E additional algorithms are included to simulate in-stream processes otherwise not considered by SWAT. The differences between the algorithms used in SWAT and QUAL2E are predominantly related to model characteristics of being a dynamic (SWAT) or steady state model (QUAL2E). The steady-state constituent concentrations are calculated in the QUAL2E model using a mass transport equation that includes advection, dispersion, dilution, constituent reactions and interactions, and source and sink components (Brown and T.O.J.Barnwell, 1987).

2.3 Water shade Management

watershed management can be characterized as a continuous, geographically defined, integrated, collaborative process of creating and implementing plans, programs, and projects designed to sustain and enhance watershed and related eco-system functioning. Holistic watershed management should include broad stakeholder engagement to aid in defining specific watershed management goals and related actions that support attainment of those goals. Setting watershed management goals and assessing attainment of those goals must be based on the application of sound science and appropriate tools and technology (EPA, 2008).

2.4. Models

A watershed model simulates hydrologic processes in a more holistic approach compared to many other models that primarily focus on individual processes or multiple processes at relatively small-or field-scale without full incorporation of a watershed area. Watershed-scale modeling has emerged as an important scientific research and management tool, particularly in efforts to understand and control both point and non-point source pollutant(Golmar Golmohammadi, 2014).

2.4.1 Hydrological model selection criteria

There are various criteria, which can be used for choosing the right hydrological model for a specific problem. These criteria are always project dependent, since every project has its own specific requirements and needs. Further, some criteria are also user-depended (and therefore subjective). Among the various project-dependant selection criteria, there are four common, fundamental ones that must be always answered(Cunderlik, 2003):

- Required model outputs important to the project and therefore to be estimated by the model (Does the model predict the variables required by the project such as long-term sequence of flow?)
- Hydrologic processes that need to be modeled to estimate the desired outputs adequately (Is the model capable of simulating single-event or continuous processes?),

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

2.4.2over View of SWAT

SWAT, developed by the United States Department of Agriculture (USDA) – Agricultural Research Service (ARS) in early 1990s (Arnold J. W., 1998), is a continuous, semi distributed hydrologic model that runs on a daily time step. Hydrologic response units (HRUs), defined by combinations of land cover and soil combinations, are the computational elements of SWAT. The daily water budget in each HRU is computed based on daily precipitation, runoff, evapotranspiration, percolation, and return flow from the subsurface and groundwater flow. Runoff volume in each HRU is computed using the Soil Conservation Service (SCS) curve number method.

The interface of SWAT model is compatible with ArcGIS that can integrate numerous available geospatial data to accurately represent the characteristics of the watershed. In SWAT model, the impacts of spatial heterogeneity in topography, land use, soil and other watershed characteristics on hydrology are described in subdivisions. There are two scale levels of subdivisions; the first is that the watershed is divided into a number of sub-watersheds based upon drainage areas of the attributes, and the other one is that each sub-watershed is further divided in to a number of Hydrologic Response Units (HRUs) based on land use and land cover, soil and slope characteristics. The SWAT model simulates eight major components: hydrology, weather, sedimentation, soil temperature, crop growth, nutrients, pesticides, and agricultural management (Neitsch S. J., 2005).Major hydrologic processes that can be simulated by this model include evapotranspiration, surface runoff, infiltration, percolation, shallow aquifer and deep aquifer flow, and channel routing(Arnold J. W., 1998). Stream flow is determined by its components surface runoff and ground water flow from shallow aquifer.

2.4.3 Application of SWAT model

(Paiet al.,2011) described modeling approach for prioritizing 12-digit hydrologic unit code sub watersheds in the Illinois River Drainage Area in Arkansas (IRDAA) watershed utilizing SWAT model output for sediment, total phosphorus (TP), and nitrate-nitrogen (NO3-N). The model was Calibrated and validated at seven locations for total flow, base flow, and surface runoff and at three locations for water quality outputs. A multi-objective function consisting of percent relative error (RE),Nash-Sutcliffe efficiency (NSE), percent bias (PBIAS), coefficient of determination (R2), and ratio of the root mean square error to the standard deviation of measured data (RSR) was used to guide model evaluations.

(Gebreyesus, 2012)Evaluated the effectiveness of different scenarios in reducing runoff, sediment and soil nutrients losses using the SWAT model for the Mai-Negus catchment, northern Ethiopia. The baseline scenario at the catchment outlet simulated the highest erosion in terms of runoff, sediment yield, total nitrogen (TN) and phosphorus (TP) losses as 168 mm, 42,000 t year-1, 22,400 and 1,360 kg year-1, respectively.

The study that examined the applicability of the SWAT model to simulate the sediment yield from the Fincha watershed (area 3,251 km2), Ethiopia. The automated calibration process was used to calibrate the model parameters using time series data from 1987 to 1996. Data from 1997 to 2006 were used to validate the model using the input parameter set. The results of the model calibration and validation showed reliable estimates of monthly sediment yield with R2 = 0.82 and ENS = 0.80 during the calibration period and R2 = 0.80 and ENS = 0.78 during the validation period. This study showed that the SWAT model is capable of predicting sediment yields and hence can be used as a tool for water resources planning and management in the study watershed(Abdi, 2012).

The SWAT model application was calibrated and validated in some parts of Ethiopia, frequently in Blue Nile basin. (Setegn, 2009a)used SWAT to model the hydrological water balance of the Lake Tana basin in Ethiopia with the objective of testing the performance of the SWAT model for stream flow prediction. These authors calibrated and validated on four tributaries of Lake Tana using SUFI-2, GLUE and ParaSol algorithms. This paper reported that the SWAT model was more sensitive to HRU definition thresholds than to sub-basin discretization. Further, the paper reported that more than 60% of the observed river discharge falls within the 95% confidence bounds.

(Gessese, 2008)used the SWAT model performed to predict the Legedadi reservoir sedimentation. According to this study, the SWAT model performed well in Predicting sediment yield to the Legedadi reservoir. The study further put that the model proved to be worthwhile in capturing the process of stream flow and sediment transport of the watershed of the Legedadi reservoir.

(Mekonnen et al.,2009) developed a generic rainfall-runoff model better suited to Ethiopian catchments. They used a spectrum analysis method to extract the relationships between different temporal scales of available daily rainfall and runoff series that reflect the temporal and spatial scales of 25 discharges in two watersheds in Ethiopia. The paper reported that frequencies in rainfall and stream discharge longer than 50 days had a sufficient coherence to warrant model calibration.

The literature reviewed and presented above showed that SWAT is capable of simulating hydrological and erosion process interms of terms of runoff, sediment yield, total nitrogen (TN) and phosphorus (TP) with reasonable accuracy and can be applied to large and complex watersheds.

2.4.4SWAT Model Calibration

Calibration is an intensive exercise used to establish the most suitable parameter in modeling studies and an iterative process that compares simulated and observed data of interest (typically stream flow data) through parameter evaluation. The exercise is vital because reliable values for some parameters can only be found by calibration (Beven, 1989).The model parameters changed during calibration are broadly classified into physical and process parameters. Physical parameters represent measurable properties of the basin such as surface area and slope of the basin.

2.4.5 SWAT Model Validation

Model validation is the process of rerunning the simulation, using a different time-series for input data, without changing any parameter values which may have been adjusting during calibration. Validation can also occur during the same time-period as calibration, but at a different spatial location.

2.4.6 Assessment of Model performance

The performance of SWAT is evaluated using statistical measures to determine the quality and reliability of predictions when compared to observed values. During calibration and validation of a hydrological model it is necessary to assess the performance of the model. This is done by statistically comparing the model output and observed values using various statistical measures. These measures include the coefficient of determination (R2) and Nash-Sutcliffe Efficiency.

The coefficient of determination (R^2) described the proportion of the variance in the measured data explained by the model. R^2 ranges from 0 to 1, with higher values indicating less error variance, and typically values greater than 0.5 are considered as cited by Moriasi et al., (2007).The Nash-Sutcliffe efficiency (NSE) indicates how well the plot of observed versus simulated data fits the 1:1 line. It generally ranges from $-\infty$ to 1. Higher value of NSE indicates better accuracy of model prediction whereas lower NSE indicates poor model prediction. In general, model simulation can be judged as satisfactory if NSE >0.50.

CHAPTER THREE:METHODS AND MATERIALS

3.1 Methods

This study was dealing about nutrients load and transporting mechanisms and stream flow to Hydropower Reservoirs with the application of a physically based watershed model SWAT version 2012. This chapter describes the study area, the input data, their source and the methodology adopted to evaluate the nutrients and stream flow to hydropower reservoir of the Fincha’a watershed.

SWAT simulation run was carried out using a set of input variables, then a sensitivity analysis was performed to identify the most parameters that influence the streamflow forcalibration and validation of SWAT model in the basin. The efficiency of the model was assessed by comparing simulated and observed streamflow. The results from software works, visual identification results interpreted and report preparation follows.

3.1.1 Description of the Study Area:

Finchaa is located in Horro Guduru Wollega zone, Oromia national regional state, western Ethiopia between 9°10'30" to 9°46'45" North latitude and 37°03'00" to 37°28'30" East longitude (Figure 3.1). Finchaa is located about 47 km from the zonal capital Shambu and 280km from capital town of Oromia and Ethiopia Addis Ababa. About 178,000 people live in the watershed area (Assefa, 1994). Finchaa sub-basin is a part of Blue-Nile river basin which contains three watersheds (Finchaa, Amerti and Neshe) watershed. The sub-basin has an area of 5,210 km^2. It covers 6 woredas; Abay Chomen, Guduru, Ababo Guduru, Jimma Rare, Jimma Horo, and Jimma Geneti. Finchaa dam was constructed at the Finchaa River in 1973 as a strategy for fostering economic growth in Ethiopia through generation of hydroelectricity, irrigation, fishery, and tourism (HARZA, 1975). At that time the dam was the largest hydro-electric Project in the country.Elevation in the watershed ranges between 902 m asl to 3157 m asl and with mean elevation of 2078m asl.

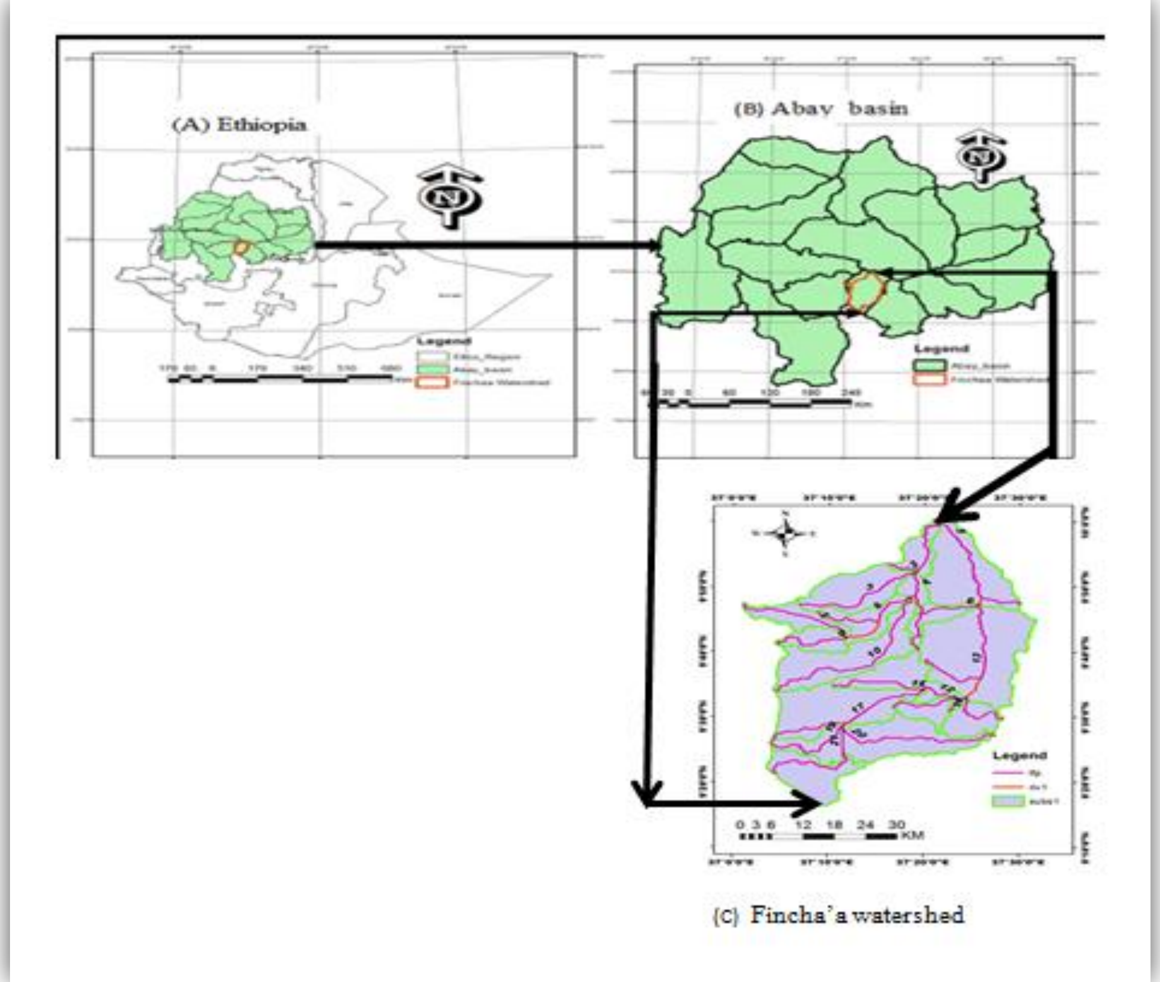


Figure 3.1Location of the Study area.

3.1.2 Climate of the area

3.1.2.1 Rainfall of the Watershed

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), WoinaDega (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 WoinaDega climate. Weather data of station Shambu, Fincha, Combolcha and Hareto were collected from National Meteorological Agency. Of the four stations Shambu and Fincha were principal stations while Combolcha and Hareto were third stations. The former two stations have Precipitation, maximum and minimum temperature, Wind speed, relative humidity and solar radiation. Accordingly, from both principal and third stations data from 1986 to 2016 were collected. The annual precipitation of the study area were presented on the fig: 2 the maximum rainfall was 2150.5 mm while the minimum was 1109.7mm.Most of the rainfall of the study area were between June to September which is influenced by the seasonal migration of inter-tropical convergence zone (ITCZ).

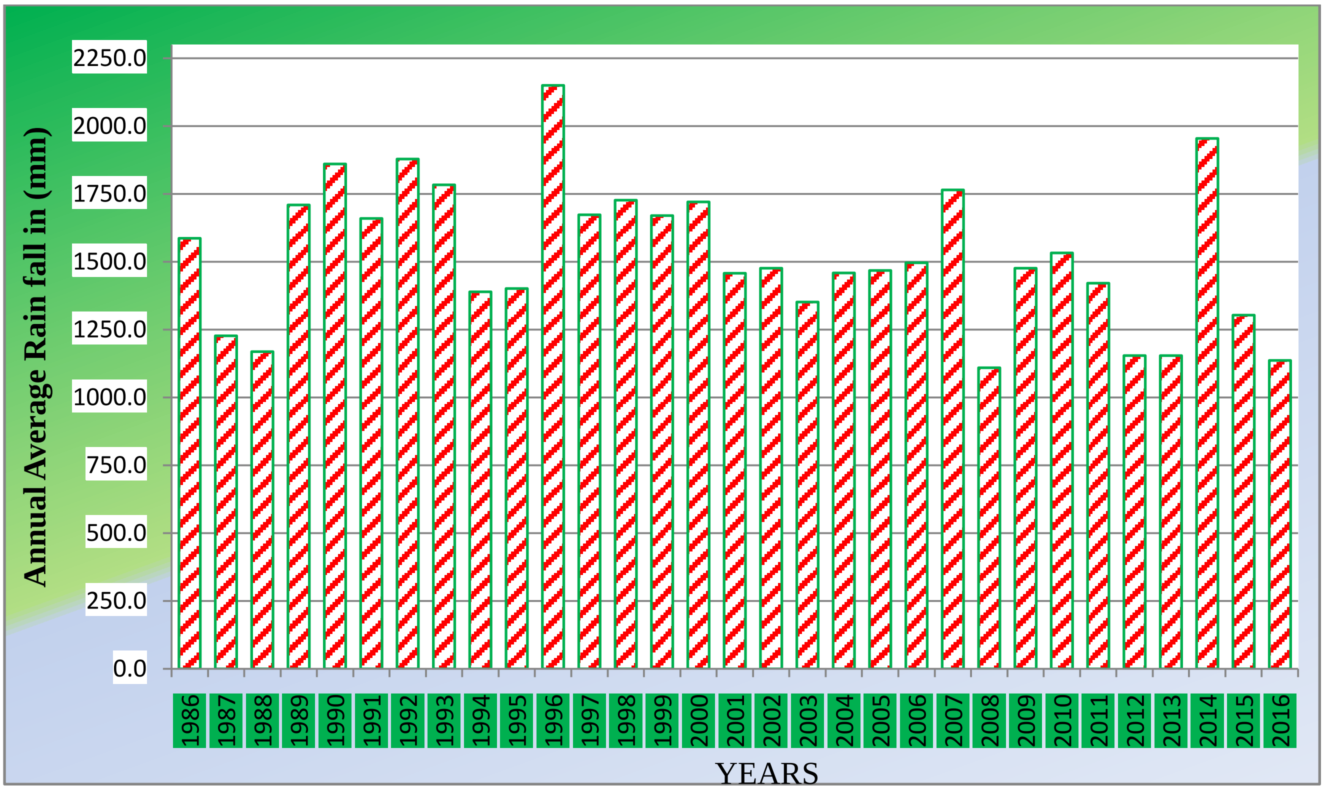


Figure 3.2the annual average rainfall of Fincha'a watershed from 1986 to 2016.

3.1.2.2 Temperature

The highest temperature observed in the north western part of the basin and the lower temperature observed in the highlands of the central and eastern part of the basin. Finchaa Sub-basin is located in the moist humid climatic zone of the Blue Nile basin. The annual maximum and minimum temperature in the sub-basin varies between 19.5^{0}C – 31.5^{0}C and 6^{0}C – 16^{0}C respectively. Temperature is higher in the northern lowlands with a maximum of 290C – 31.50C and minimum of 140C - 160C. The mean monthly temperature of the area varies from 14.60C to 17.70C.

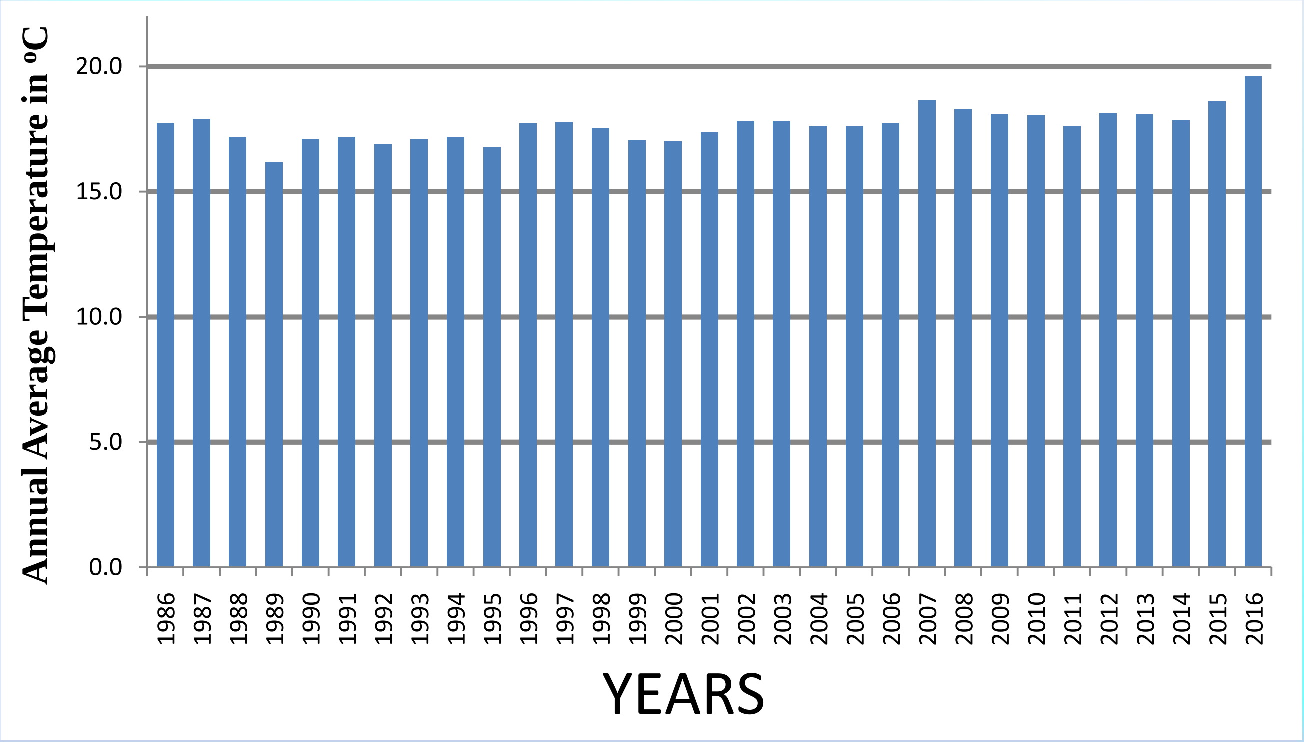


Figure 3.3Annual Average Temperature of the study area

3.1.3 Land use Land Cover data

The land use in Finchaa sub-basin is dominated by cultivation and irrigated agriculture. The major land form of the watershed includes flat, gently sloping to undulating plains, hills, and mountains. The western part of the watershed is characterized by mountainous, highly rugged and rolled topography with steep slopes and the lower part is characterized by valley floor with flat to gentle slopes. Shrub land, grazing land, forest, woodland and wetland/swamp are land cover types in the watershed.

3.1.4 Soils Data

The catchment has a wide range of soil type mainly dominated by clay and loam soil (Bezuayehu, 2006). The largest portion of the watershed is characterized by red to reddish brown friable Luvisols and black heavy clay vertisols. Most of the soil of the irrigated land is Luvisols and the rest is vertisols. Vertisols is found mostly in the lower areas near the Finchaa River and at the upper ends of the interfluves commonly associated with swamps and temporary wetlands on the plains with good to moderate fertility. The dominant soils in the basin are Cambisols and Nitosols, with the occurrence of Arenosols, Luvisols, Vertisols and Phaeozems

3.1.5 Fincha Dam Area

Finchaa lake/Dam is one of the biggest man made body of water in Ethiopia, it is locally known as Chomen Lake. Finchaa reservoir has an area of 1318 km^2 where as its River originates from the Chomen and Finchaa swamps on the highlands. The hydropower reservoir covers approximately one-third of the watershed area. Many streams join Finchaa River, the main tributaries being Sahel,Laga Magal,Erer,Jaben,Dildila Aba galan from the southern parts ,Hagamsa, Korke, Fakare and Boye from the western side and Sargo-Gobana, Aware, Sombo, and Andode from the eastern side. The Reservoir initially stores 185 million cubic meters, after the water is diverted from Amerti River to the Finchaa reservoir through a tunnel the storage capacity of the Finchaa reservoir was raised from 185 to 460 million cubic meters of water and the capacity of hydroelectric power generation was raised from 100MW to 134MW. According to studies done by the Oromia Agricultural Development Bureau (OADB, 1996) and (Assefa, 1994) showed that Finchaa Reservoir has inundated large areas of different land use types and evicted several people from their original places.

3.1.6 Study Design

The study followed longitudinal research design type, to answer the objectives of study questions besides it involved in site observation to achieve the defined objectives. Therefore,descriptive, quantitative and qualitative types of research approach were undertaken.

3.1.7 Data Type, Data source ad Data collection procedure

Both primary and secondary data were used in this study to achieve the specific objectives of the study. Meteorological elements such as precipitations, Wind speed, Relative humidity, sunshine hour and Daily average temperature) from 1986 to 2016 were collected from National Meteorology Agency.

Hydrological data like stream discharges and spatial data such as Digital Elevation Model, Soil, Land use/ Land cover Secondary data were collected from Ministry of Water, Energy and Irrigation respectively.

Table 3.1Location of Meteorological Stations, the data year and Flow within and Around the Watershed

S.No	Stations	Latitude	Longitude	Elevation	Meteorological & Hydrologic parameters		
					Class	Year	Flow
1	Shambu	9.5712	37.12117	2460	Principal	1986-2016	No data
2	Hareto	9.35	37.12	2260	Third	1986-2016	No data
3	Combolcha	9.5023	37.4727	2341	Third	1986-2016	No data
4	Fincha	9.57	37.37033	2248	Principal	1986-2016	1986-2011

3.1.8 Water Quality data Collection and preparation

Among different parameters of water quality test, nutrients are the main due to their impacts both on the users and water bodies. This nutrient data of Fincha’a Dam were needed in order for calibration and validation of the model. Even though the establishment of this dam was early, there is no a single data of nutrients measured neither by a government nor by an individuals. To achieve the objective of the study in particular the water quality data of the study area namely Nitrogen and phosphorus, the researcher collected data of water from the reservoir/dam. Unless the observed data of nutrients, it is impossible to calibrate and validate the output of the model.   So it is a challenging problem of modeling the nutrients load and transport pathway in the study area in specifically and in Ethiopia as a general due to lacking of measured data.

Though it was not enough for calibration and validation, laboratory test of the collected water from August 8/8/2017 to September 8/8/2017 was done to develop the relationship between the simulated output of nutrients and flow data.

Ato Abashu:Observer of the Fincha Dam

Zerihun

Figure 3.4 During data collection.

Ato Abashu Collected daily data for 30 days from different site of the dam starting from august 8/8/2017 to September 8/8/2017.

1) Conducting laboratory test

   After the sample was collected the laboratory work was followed. The sample from the field was stored in refrigerator for a certain period, when it was not possible to test the sample as soon as it brought from the site in order to obtain good output for the result. A number of parameters were measured for both nitrogen and phosphorus. Total nitrogen (TN), Nitrate (NO_3^-) and Ammonia (NH_3) for nitrogen species and Total phosphorus (TP) and Ortho-Phosphate (PO_4^{-3}) for phosphorus species were measured. The study was employed a kit methods (LCK-138) and the result was obtained based on time and temperature requirement for each parameters. Total nitrogen (TN) and Total phosphorus (TP) were read direct from the sample whereas Nitrate (NO_3^-), Ammonia (N_3H_4) and Ortho-Phosphate (PO_4^{-3}) were filtered before placing into digestion pit. The procedure to determine phosphorus and nitrogen was attached as annex to the end of this document. The result was obtained for all intended species of phosphorus and nitrogen. As mentioned on the heading of this title, the result was not sufficient to make calibration So, the model was calibrated and validated only by stream flow .calibrating and validating the model by stream flow, was assumed as calibrating and validating phosphorus and nitrogen. During field observation.

Figure 3. 5Reservoir area of Fincha'a watershed (image taken during Field visit).

3.1.8.1 Data Preparation

The data from various sources were prepared as suitable to input to fit the model requirements. The DEM data that was in the form of pixels was adjusted appropriately to relevant co-ordinates and then mosaic to cover the study area. The land use data was clipped and projected to fit the DEM and soil data of the study area also too. In addition, the key land use types of the area were identified, coded to match the SWAT land use database. Regarding the hydro-meteorological data (discharge and meteorological), which were gathered were organized, processed and arranged vertically to fit the model data requirement.

3.1.9 Filling Missing Meteorological Data

Sometimes, the rainfall amount at a certain rain gauge station for a certain day(s) may be missing due to the absence of some observer or instrumental failure. In such cases, it might be needed to estimate the missing rainfall amount by approximating the value from the data of the nearby rain gauge stations. The following methods are generally adopted for computing the missing rainfall data.

Three rain gauge stations as close to and as evenly spaced around the station with the missing record (i.e. station X) as possible, are, first of all, chosen. The rainfall data for these three stations (i.e. 1, 2, and 3) on the day for which the data at the station X is missing are now collected. The average annual rainfall values at all the four stations should also be known.

Now, if the average annual rainfall at each of these three index stations differs within 10% of the average annual rainfall of the station X (i.e. the station with missing data), then a simple arithmetic average of the precipitations (corresponding to the missing precipitation) at the three index stations will give us the estimated quantity. Thus, if N1, N2, N3 and Nx represent the average annual normal rainfalls at stations 1, 2, 3 and X respectively; and P1, P2, P3 and Px represent their respective precipitation data of the day for which the data is missing at station X; then we have:

$$\boldsymbol{P_x} = \mathbf{(P\_1+P\_2+P\_3)/3} \quad \text{---} \ \mathbf{29}$$

[Provided N_1, N_2 and N_3 differ within 10% of N_x]

However, when the average annual precipitation at any of the three stations differs from tha-tat the station in question by more than 10%, the normal ratio method is used. In this method, the amounts at the three index stations are weighted by the ratios of their average annual precipitation values. Hence, the missing precipitation data Px, in such a case, will be given by

$$\boldsymbol{P_{x=\frac{1}{3}}\left(P_1\frac{N_x}{N_1}+P_2\frac{N_x}{N_2}+P_3\frac{N_x}{N_3}\right)-----------------30}$$

[Provided any of N1, N2 andN3 differs from Nx by more than 10%] (Garg, 2005).

Based on mentioned above the normal ratio method was conducted to fill missing climatic variables of the study area.

3.1.10 Consistency analysis of rainfall data

According to Garg (2005), a significant change may occur in and around a particular rain gauge station. Such change occurring in a particular year will start affecting the rain gauge data, being reported from that particular station. After a number of years, it may be felt that the data of that station is not giving consistent rainfall values. In order to detect any such inconsistency, and to correct and adjust the reported rainfall values, a technique, called double mass curve method, was adopted in this study**.**

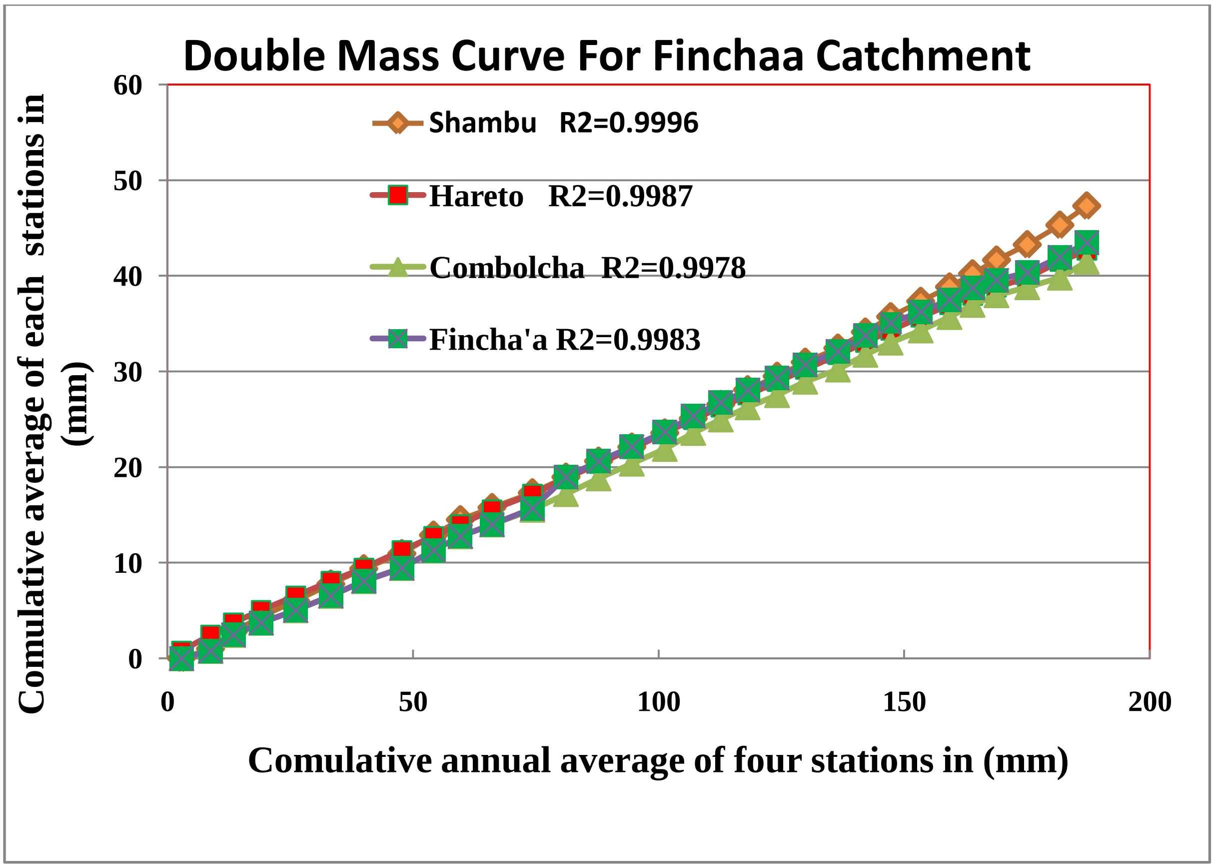


Figure 3. 6Consistency checking for the four Rainfall stations within and around the catchment.

3.2 Materials

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

- Arc GIS 10.3
- Arc SWAT
- SWAT-CUP
- PCP STAT
- Dew02.exe
- Microsoft Excel
- DEM, Meteorological, Hydrological map and data. The following flow chart shows the overall activities of SWAT process.

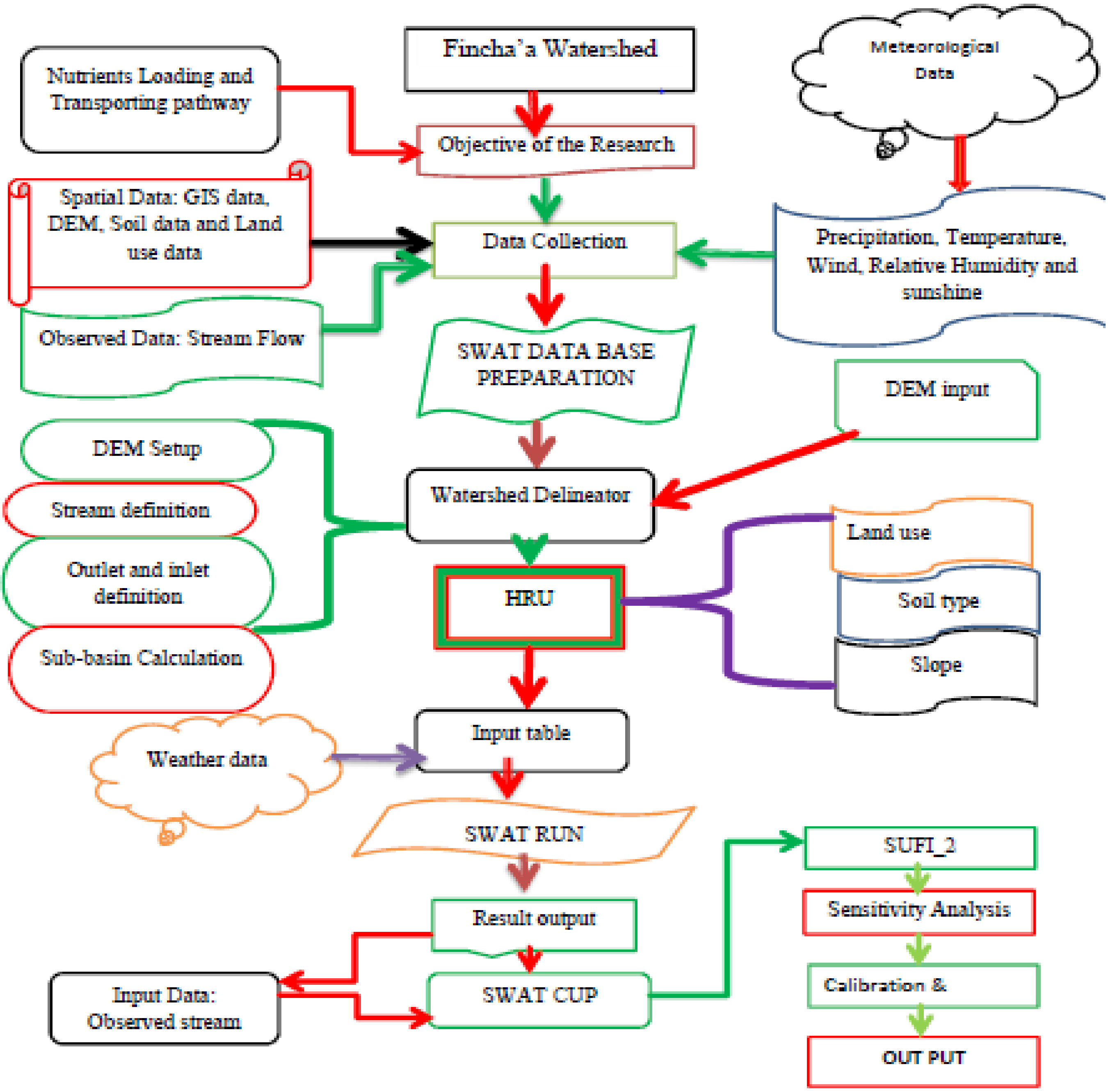
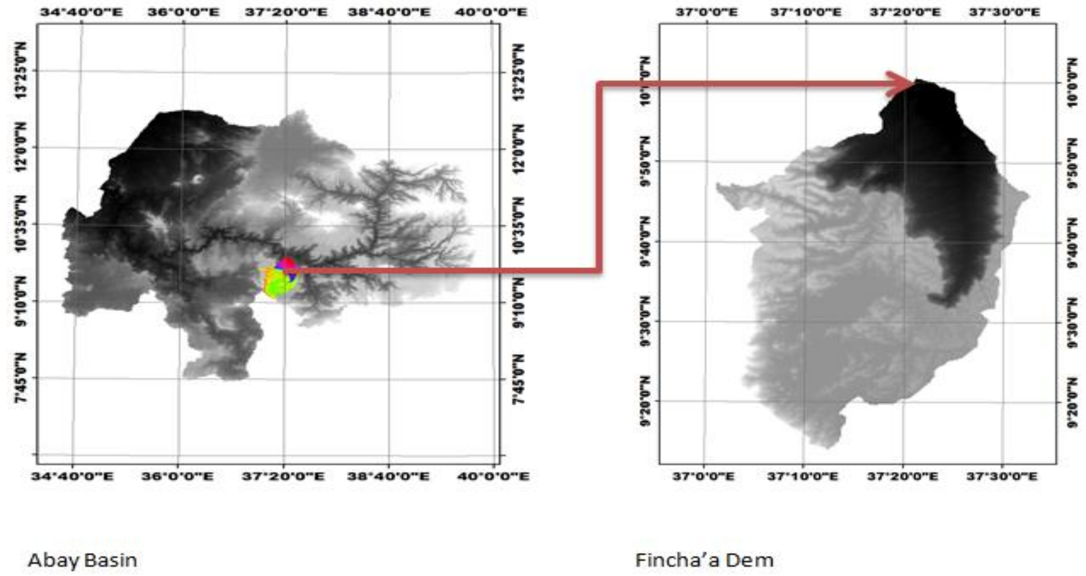


Figure 3.7Flow Charts of Arc SWAT Processing Steps

3.3 SWAT Model Setup

3.3.1 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 projectedinto 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.



Abay Basin

Fincha’a Dem

Figure 3.8 Digital Elevation Model of the study area.

3.3.2 Stream definition

The stream definition and the size of sub-basins were carefully determined by selecting threshold area or minimum drainage area required to form the origin of the streams. In this section, initial stream network and sub-basin outlets were defined. This was achieved by using critical area.

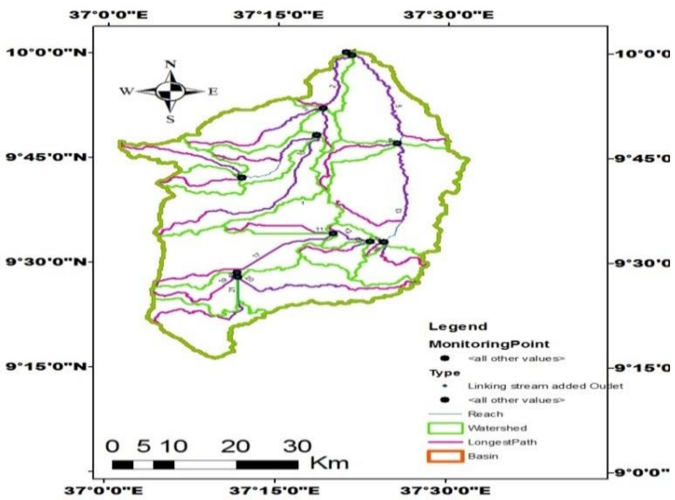


Figure 3.9Streams and sub-basins in the Watershed

3.3.3 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 use, 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 20 percent soil and 10 percent slope threshold were used as an adequate for most applications and 156 Hydrologic response units were used.

3.3.4 Land use

According to table(23.2) and Figure(3.10),the land use in Finchaa sub-basin is dominated by agriculture and moderately cultivated which accounted 38.07 and 35.64 percent respectively. Land Use/ land cover is one of the highly influencing the hydrological properties of the watershed. The prepared land-use /land cover was given as input to the model data of the SWAT to describe the HRU of the watershed. Therefore, the impact of each type of LULC was considered in this model to calculate Nutrients load in the basin. The default LULC of the SWAT model was linked to LULC map through the look up table which was linked to the LULC Database. The major land uses of the study area are as follows:

Table 3.2Original land use/land cover types and redefined according to the SWAT code and their aerial coverage.

Land use_ land cover Original	land use according to SWAT database	SWAT code	Area	
			ha	% Watershed
Moderately cultivated	Agricultural Land-Generic	AGRL	93345.300	35.64
Agriculture	Agricultural Land-Row Crop	AGRR	99706.4100	38.07
Irrigated Farm land	Corn	CORN	5062.6800	1.93
Degraded Savanna	Range-Grasses	RNGE	30398.5800	11.61
Water body	Water	WATR	30582.6300	11.68
Swamps/Wetland	Wetlands-Non-Forested	WETN	2103.0300	0.8
Afro alpine Belt	Forest-Evergreen	FRSE	325.7100	0.12
URBAN	Residential	URBN	380.6100	0.15

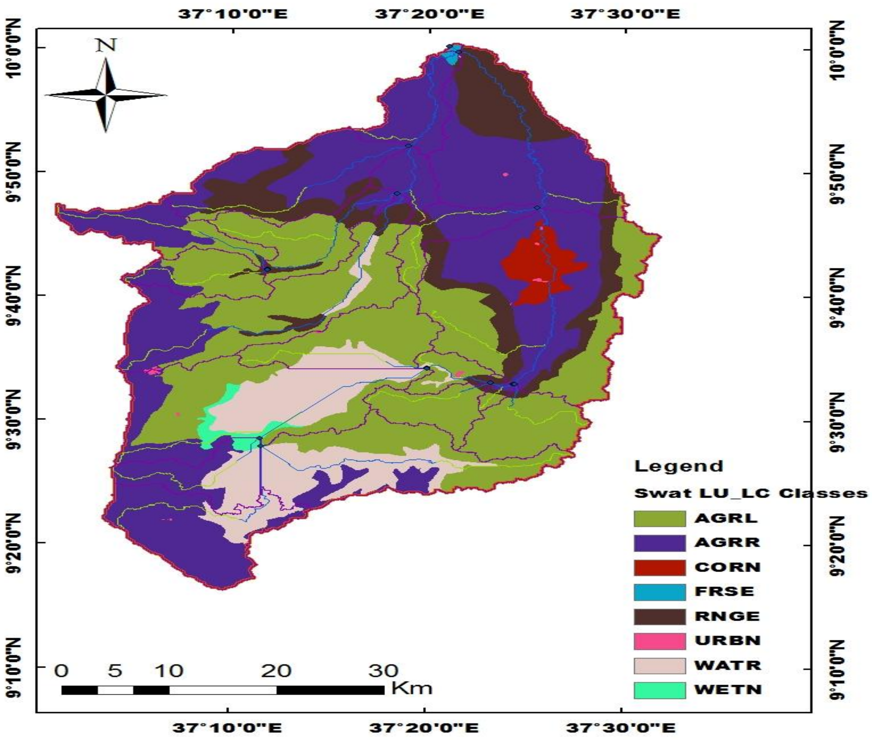


Figure 3.10Map of the major land use/ land cover types of Finchaa watershed

3.3.5 Soil Data

Soil data is also one of the major input data for the SWAT model with inclusive and chemical properties. Soil physical attributes were initially stored to the SWAT's soil database through an Edit database interlace and relevant information required for hydrological modeling. To integrate the soil map with SWAT model, manually define was used. For this study the soil map was integrated or defined by double clicking in the Soil data SWAT column in the SWAT Land Use /soil/slope definition Classification. Accordingly, Eutric Nitosols, Eutric Cambislos and Cambic Arenosols were the dominated soils that cover large area of Fincha'a watershed respectively thus major soil types in the sub-basin are shown in table (3.3) and Figure (3.11) below.

Table 3.3Soil type of the study area with their aerial coverage

Soil Types	Area	
	Ha	%
Cambic Arenosols	29056.77	11.09
Chromic Luvisols	1749.69	0.67
Chromic Vertisols	17197.65	6.57
Dystric Cambisols	10559.43	4.03

Eutric Cambislos	41832.54	15.97
Eutric Nitosols	114782.4	43.83
Haplic Phaeozems	28225.8	10.78
Humic Cambisols	582.48	0.22
WATER	17918.19	6.84
Total	**261904.9500**	**100**

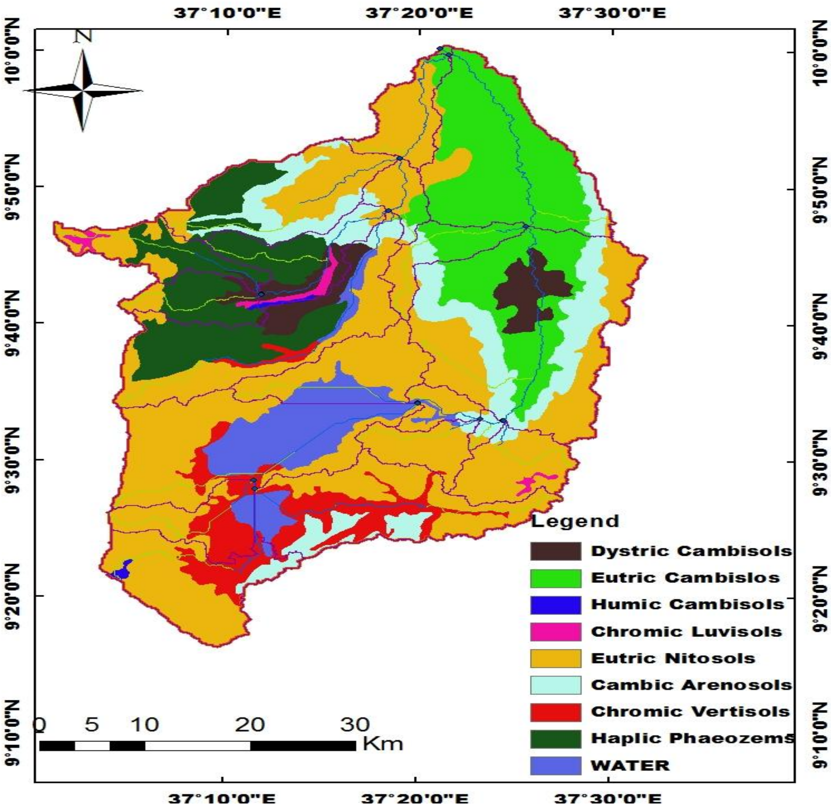


Figure 3.11Map of the major soil types of Finchaa watershed

3.3.6 Slope

HRU analysis in ArcSWAT includes division of HRUs by slope classes in addition to land use and soils. This is particularly important if sub-basins are known to have a wide range of slopes occurring within them.

Slope is derived from inputted DEM, so that the model uses this slope for the development of HRU in addition to LULC and soil input parameters. Arc SWAT allows the integration of land slope classes (up to five classes) when defining hydrologic response units. There are possibilities to choose simply a single slope class, or choose multiple classes. For this study multiple slope discretizations has been selected. Table (3.4) shows the distribution of the slope in the study area accordingly, 45.13% and 24.3% of the area have slope between 0 to 8 and 8-16 respectively which was shown by fig (3.12).

Table 3.4Distribution of Slope Steepness in the Fincha'a Watershed

Classes	Percent Slope	Area [ha]	% Watershed Area
1	0-8	118204.2	45.13
2	8-16	63638.01	24.3
3	16-30	50863.23	19.42
4	>30	29199.5100	11.15
	Total	261904.95	100

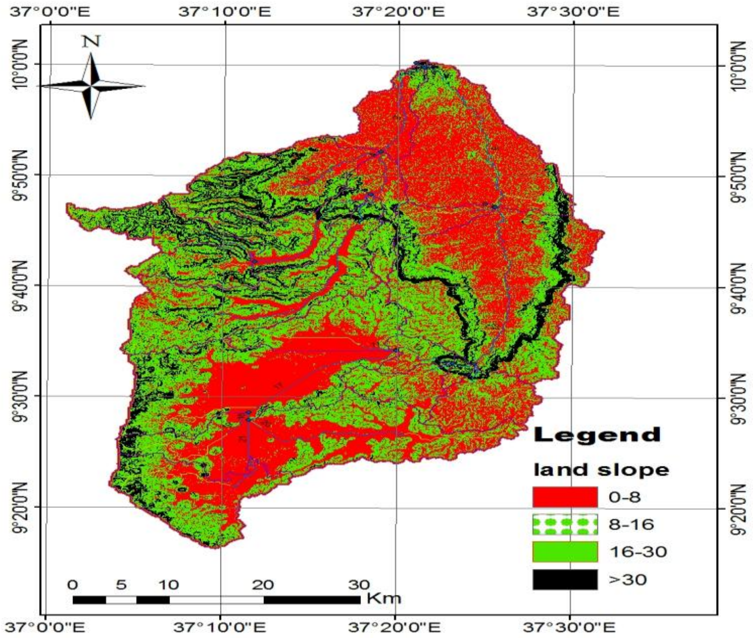


Figure 3.12Map of Slope classes used in the SWAT of the Finchaa watershed

3.4 Weather Data and Writing Input Files

It is vivid that shortages of climatic data are common in developing countries but more serious in Ethiopia to analysis country wide climate trends. Since Arc SWAT software uses many parameters of Meteorological data, so in order to overcome from shortages of synoptic weather data using of weather generator do solve the problem. It solves the problem of Lack of full and realistic long period climatic data by generating data having same statistical properties as the observed ones. SWAT built in weather generator called WGEN that is used to fill the gaps, for generating missing data. The data required for this study was collected from-four stations within and around the study area: Combolcha, Finchaa, Hareto and Shambu. SWAT requires daily precipitation, maximum and minimum temperature, solar radiation, wind speed, and relative humidity as inputs. Fig (3.13) shows the average maximum and minimum temperature and fig (3.14) shows the monthly rainfall distribution of the study area.

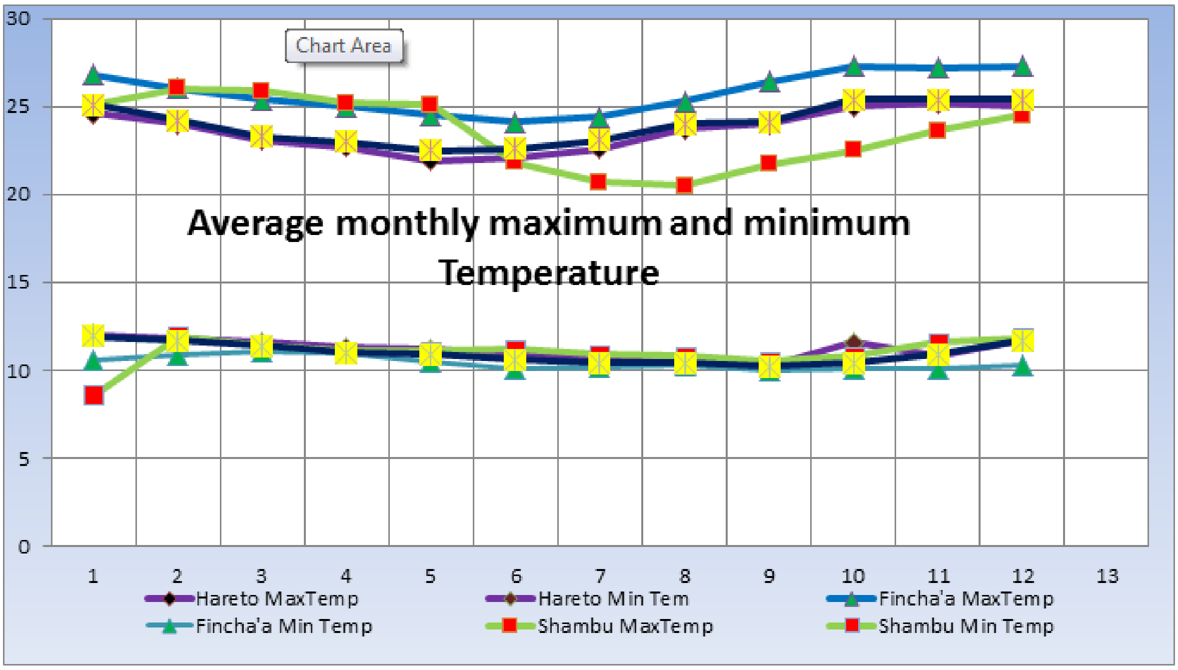


Figure 3.13Average monthly minimum and maximum temperature patterns of different stations (1988-2016)

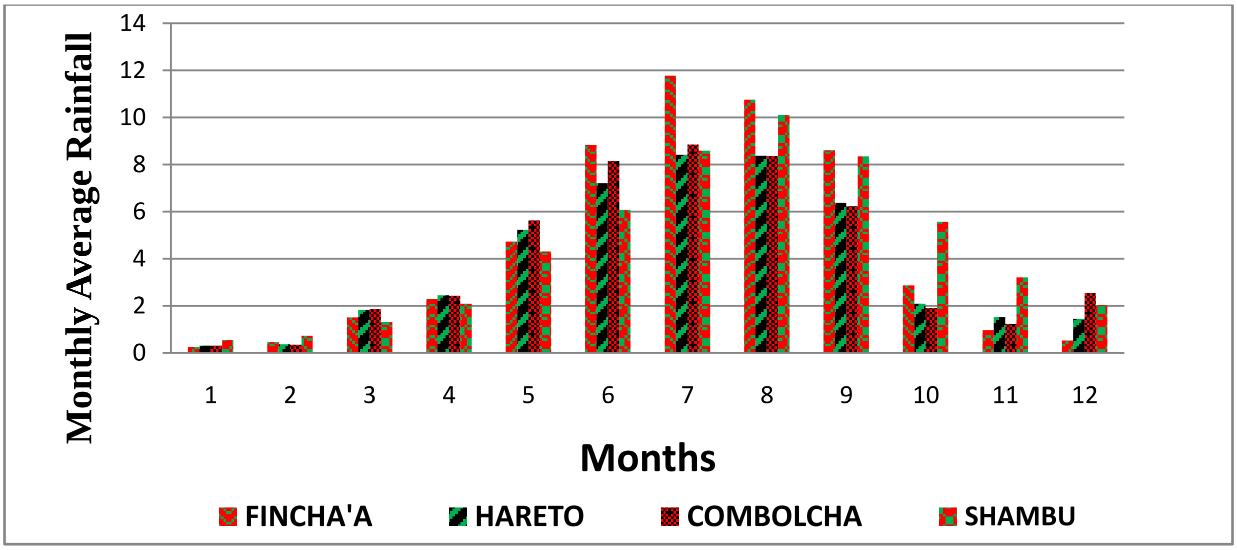


Figure 3.14Monthly Rainfall distributions used for weather writings input

3.5 Edit SWAT Input

The edit SWAT input menu allows to edit the SWAT model databases and the watershed databases files containing the current inputs for the SWAT model. To edit any parameters they should be added to the watershed configuration during the watershed discretization. The edits made to the parameters using the ArcSWAT interface are reflected only in the current SWAT project. If the parameters are not defined in the watershed a dialog box notifies the warning.

3.6 Simulation

The SWAT Simulation menu allows finalizing the setup of input for the SWAT model, to run the SWAT model and to read the SWAT output by importing files to database and saving to the place of interest or by opening the outputted. The simulation of Fincha'a sub-basin were accomplished through using Arc SWAT 2012.At the last Running SWAT check take Place for output visualization. Finally, the other key aspects of the SWAT simulation performed for the watershed accordingly, monthly output time step with skewed normal distribution of rainfall of 31 years (1986 -2016) were simulated, two years were used for the model warming up.

3.7 SWAT_CUP

SWAT-Cup is a computer program used for calibration of SWAT model. The program links SUFI2, PSO, GLUE and PARASOL procedures to swat model. Any calibration/uncertainty or sensitivity program is linked to SWAT using this generic interface.

The degree to which all uncertainties are accounted for is quantified by a measure of p-factor which is the percentage of measured data bracketed by the 95% prediction uncertainitiey-95ppu. The 95ppu is calculated at 2.5% and 97.5%levels of the cumulative distribution of an output variable obtained through Latin Hypercube sampling. SUFI2 Sequential Uncertainty Fitting Ver.2, the parameter uncertainty in driving variables (e.g., rainfall), conceptual model, paraters, and measured data. In SUFI 2, the assessment of the sensitive parameters is measured using the t _stat values where the values are more sensitive for a larger in absolute t _ stat values. P_ values are used to determine the significance of the sensitivity where the parameter becomes significance if the P-values are close to zero.

3.8. Model Sensitivity Analysis, Calibration and Validation

The heterogeneity of environmental variables such as soil types, land uses, topographic features, and weather parameters need to be considered for the effective simulation of spatially varying properties of a watershed. Spatially discrete and temporally continuous data are often not available. Satisfactory physical representation of physically based spatially distributed models, like SWAT, is limited by the amount of information available. Thus, the application of complex distributed models over large areas using insufficient input data has led to the inclusion of model sensitivity analysis, calibration and validation as methodological frameworks of the models (Folle et al, 2005) has suggested a procedural approach of parameter screening, spatial parameterization, and parameter sensitivity analysis to reduce the SWAT model calibration parameters (Muleta and Nicklow, 2005; Vachaud and Chen, 2002).

3.8.1. Sensitivity analysis

Sensitivity analysis is the process of determining the rate of change in model output with respect to changes in model inputs (parameters).Two types of sensitivity analysis are generally performed by SWAT-CUP: local, by changing values one at a time and global, by allowing all parameter values to change. The two analyses, however, may yield different results. Sensitivity of one parameter often depends on the value of other related parameters; hence, the problem one- at- a- time analysis is that the correct values of other parameters that are fixed are known. The disadvantage of global sensitivity analysis is that it needs a large number of simulations. Both procedures, however, provide insight into the sensitivity of the parameters and are necessary steps in model calibration. The most sensitive input parameters were identified using the SWAT model inbuilt procedures (van Griensven, 2005).

The sensitivity analysis tool in SWAT-Cup 2012 was used in ranking parameters based on their influence in governing flow as well nutrients. It is an important step in the modeling process in order to identify the parameters of calibrating.

The sensitivity analysis is done by varying parameters value and checking how the model rea cts. If small change on a given parameter value results on a remarkable change on the model output, the parameter is said to be sensitive to the model.The result of sensitivity here is dependent on the estimates of average changes in the objective function resulting from changes in each parameter while all other parameters are changing.Multiple regression analysis is used to get the statistics of parameter sensitivity, t-stat and p-stat. A t-stat is then used to identify the relative significance of each parameter.A t-stat is measure of the precision with which the regression coefficient is measured. It is calculated as the ratio of coefficient of a parameter to its standard error. P-stat value is determined by comparing the t-stat parameter with the values in the student's t-distribution table. The student's t-distribution describes how the mean of a sample with certain number of observation is expected to behave. The larger p-value suggests changes in the predictor are not associated with changes in the response whereas smaller p-value suggests changes in predictor's value are related to the changes in the response variable. Finally, the larger in absolute value of t-stat and the smaller the p-value denotes the more sensitive parameter.

At the beginning, 20 hydrological flow related parameters were identified and imported into the file of par_info.txt found in sufi2.in directory from the data base of the absolute-SWAT_values.txt with their absolute min and max range. After iterations, sensitivity analysis for the parameters that may have a potential influence on Fincha'a watershed was performed according to the ranges of their variation. The adjustment of the parameters was done, keeping other unchanged. The changes were made a number of times with in its allowable range for the sensitivity test. Out of the twenty streams flow parameters the 16 most sensitive ones were chosen for calibration processes.

These weredepending on the hydrological process contributing to surface runoff (CN2, SOL_K, CH_N2.rte and SOL_AWC), Ground water (GW_REVAP, GW_DELAY, ALPHA_BF, REVAPMN, and GWQMN), Average Slope (SLSUBBSN and HRU_SLP) and Base flow alpha facto and Channel effective hydraulic conductivity (ALPHA_BNK and CH_K2) and evaporation process (ESCO, EPCO) were selected. Then the model parameters used in the sensitivity analysis of stream flow were selected and the method algorithm for analysis was defined. In the project the Latin Hypercube One factor At a Time (LH-OAT) sensitivity analysis method was used. It is combination of the One-factor-At-a-Time (OAT) design for simulation and Latin Hypercube (LH) sampling Three hundred times were iteration done, in order to obtain good parameter value estimation.

Table 3.5Sensitivity analysis parameters of flow in Finchaa watershed

No.	Input parameter	Description of parameter
1	CN2	SCS curve number for moisture condition
2	GW_DELAY	Ground water Delay (days)
3	SOL_BD	Moist bulk density
4	GWQMN	Threshold depth of water in shallow aquifer required for return flow (mm)
5	SOL_K	Saturated Hydraulic conductivity (mm/hr)
6	ALPHA_BNK	Base flow alpha factor for bank storage
7	SURLAG.bsn	Surface runoff lag time (days)
8	ALPHA_BF	Base flow alpha factor (days)
9	CH_K2	Effective hydraulic conductivity of the main channel (mm/hr)
10	SLSUSBBSN.hru	Average slope length (m)
11	HRU.SLP	Soil evaporation compensation factor
12	SOL_AWC	Soil available water capacity (mm H20/ mm soil)
13	OV_N.hru	Plant evaporation compensation factor
14	CH_N	Manning’s roughness coefficient for main channel
15	GW_REVAP	Ground water ‘revap’ coefficient
16	ESCO_hru	Soil evaporation compensation factor

3.8.2 Calibration

Model inputs and values of parameters are associated with a number of uncertainties. Therefore model calibration is an important task to improve the result of model simulation. It is a process in which parameter adjustment are made in order to simulate as closely as possible the hydrological behavior of the watershed. A proper model calibration is necessary to consider a good fit between simulated and observed watershed runoff volume, the peak flow, and the base flow since the movement of nutrients like Nitrogen and phosphorus are influenced by this process. This hydrological process is very important for assessing the water quality parameters of Fincha’a sub-basin and Fincha’a dam nutrients level.

Calibration can be performed in two ways: either manually or automated. In ArcSWAT2012 Manual Calibration Helper used for making adjustment to parameters across a user defined group of HRUs or sub basins. Auto calibration and Uncertainty of Arc SWAT 2012 is used for automated calibration. It has two dialogue boxes namely Auto-Calibration Input and Auto-Calibration Output. The former allows performing the automatic model calibration by selecting a simulated model and a subbasin which a discharge outlet located at the point. The latter provides option to refine to the out parameters for an analysis.

All these objectives are considered during model calibration because a single objective function cannot establish a reasonable match between simulated and observed data. Most calibrations are supported by sensitivity analysis which avoids performing calibration on non-effective parameters.

3.8.3. Model validation

The model validation is the process of demonstrating the given site-specific model is capable of making sufficiently accurate simulations and In order to utilize the calibrated model for estimating the effectiveness of future potential management practices. Model validation is a means of checking ability of the model to simulate the hydrological response of a basin for another range of time periods or conditions than those for which the model was calibrated .Validation was also done to compare the model outputs with an independent data set without making further adjustment of the parameter values. Model validation is comparison of the model outputs with an independent data set without making further adjustment which may be adjusted during calibration process.

3.8.4 Model performance evaluation

To evaluate the model simulation outputs in relative to the observed data, model performance evaluation is necessary. There are various methods to evaluate the model performance during the calibration and validation periods. For this study, two methods were used: Coefficient of determination (R2) and Nash and Sutcliffe simulation efficiency (ENS)

The coefficient of determination (R^2) described the proportion of the variance in the measured data explained by the model. R^2 ranges from 0 to 1, with higher values indicating less error variance, and typically values greater than 0.5 are considered as cited by Moriasi et al., (2007).

$$R^2 = \frac{\left[\sum_{i=1}^{n}\left(Q_i^{sim} - Q_{mean}^{sim}\right)\left(Q_i^{obs} - Q_{mean}^{obs}\right)\right]^2}{\sum_{i=1}^{n}\left(Q_i^{sim} - Q_{mean}^{sim}\right)^2\left(Q_i^{obs} - Q_{mean}^{obs}\right)^2} \text{-------------------------} 31$$

Where,

Q_{mean}^{sim} = mean of simulated values, Q_{mean}^{obs} = mean of observed values

The Nash-Sutcliffe efficiency (NSE) indicates how well the plot of observed versus simulated data fits the 1:1 line. It generally ranges from $-\infty$ to 1. Higher value of NSE indicates better accuracy of model prediction whereas lower NSE indicates poor model prediction. In general, model simulation can be judged as satisfactory if NSE >0.50, (Moriasi, 2007).

NSE is computed as shown below:

$$NSE = 1 - \left[\frac{\sum_{i=1}^{n}\left(Q_i^{obs} - Q_i^{sim}\right)^2}{\sum_{i=1}^{n}\left(Q_i^{obs} - Q^{mean}\right)^2}\right] \text{-----------------------------------} 32$$

Where, Q_i^{obs} = Observed stream flow in m^3/s , Q_i^{sim} = Simulated stream flow in m3/s , Q^{mean} = Mean of n values , *and n* = number of observations.

CHAPTER FOUR: Result and Discussion

4.1 Results

Thirty one (31) years of weather and climate data were used for the success of this study. The rainfall distribution of the area was similar with the seasonal rainfall characteristics of the Country. As it is shown on the Figure (4.1) average Monthly rainfall simulated from October to January were less than the other months since the season is dry season which is influenced by the movement of Inter Tropical Convergence Zone(ITCZ) from northern hemisphere to southern.

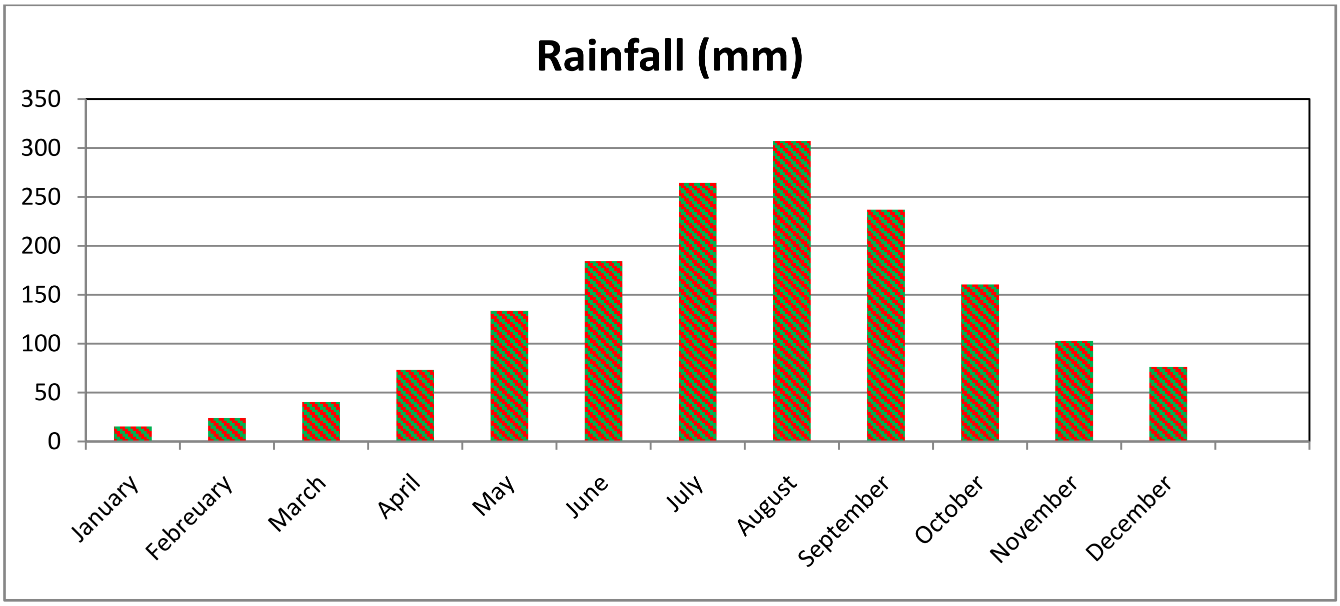


Figure4. 1Monthly Rainfall of Fincha'a watersheds

4.2 Sensitivity Analysis

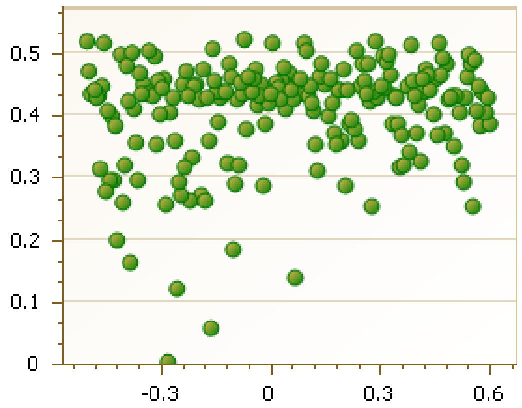
Sensitivity analysis was performed on flow parameters of SWAT on monthly time steps with observed data. For this analysis, 20 parameters were considered and only 16 Parameters were identified to have significant influence in controlling the stream flow in the watershed. The result of the sensitivity analysis indicated that these 16 flow parameters were sensitive to the SWAT model i.e. the hydrological process of the study watershed mainly depends on the action of these parameters. Curve number (CN2), ground water delay (GW-Delay), moist bulk density(SOL_BD) , Saturated Hydraulic conductivity(SOL_k) and (GWQMN) were identified to be highly sensitive parameters. The other parameters such as from 6 to 8 were identified as medium important parameters while the rest of the parameters were slightly importantTable (4.2).

Table 4.1Ranked Flow Sensitivity parameter of Fincha'a Sub-basin, based on t-stat and p-value

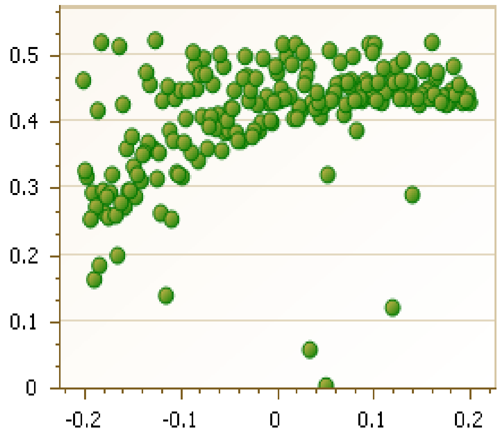
No.	SWAT Input parameter	t-test	p-test	Ranking
1	CN2	8.56	0.00000	1
2	GW_DELAY	-8.56	0.0000	2
3	SOL_BD	2.99	0.0000	3
4	GWQMN	2.47	0.0001	4
5	SOL_K	2.05	0.0004	5
6	ALPHA_BNK	1.92	0.0006	6
7	SURLAG.bsn	1.82	0.0046	7
8	ALPHA_BF	1.64	0.0001	8
9	CH_K2	1.4	0.16	9
10	SLSUSBBSN.hru	-1.4	0.16000	10
11	HRU.SLP	1.35	0.18000	11
12	SOL_AWC	-1.04	0.300	12
13	OV_N.hru	1.03	0.3100	13
14	CH_N	-0.96	0.34000	14
15	GW_REVAP	-0.64	0.52	15
16	ESCO_hru	0.23	0.82	16

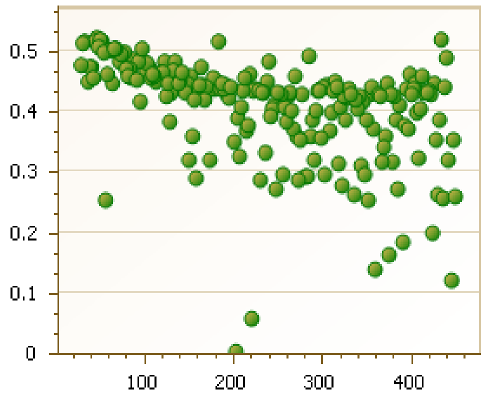
From the most sensitive parameters, five of the were shown by dot plot as seen below

1.CN2

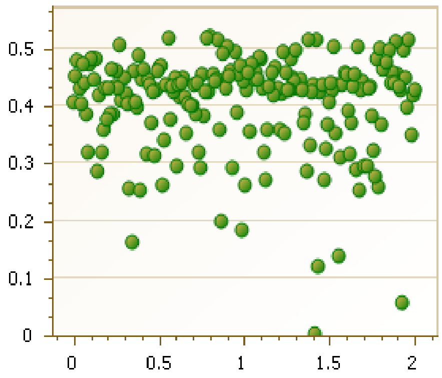


2.GW_Dealy

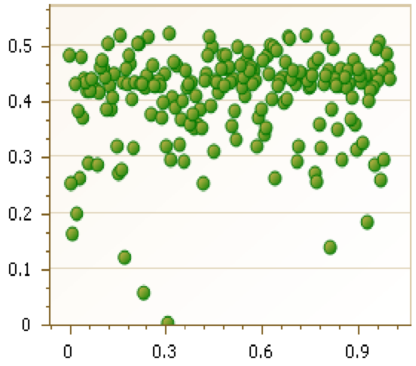




3. SOL_BD



4. GWQMN



5. SOL_K

Figure4. 2Dot plot of five most sensitive parameters

4.3 Calibration of stream flow

The movement of surface water with the associated pollutants is governed by hydrologic processes. The model calibration for stream flow has been done between the observed and simulated discharge values for 14 years' time-steps during 1988 – 2002 on the monthly basis. Initially two year of flow data during 1986 and 1987 were taken as the warming period and the rest of the periods were used for the model calibration. The model was calibrated using 16 parameters which were recorded as the sensitive parameters were used for the stream flow measurement.The simulated stream flow was calibrated against monthly average flow with those selected sensitive parameters ordered in table (4.2) by the SWAT-CUP2012 calibration sub-model of SWAT-CUP SUFI2. The coefficient of determination R^2 and the Nash- Sutcliffe equation has been applied for model testing between simulated and observed flows and calculated on monthly basis was 0.83 and 0.79 respectively.The time series data of the observed and simulated flows on monthly basis were plotted for visual comparison to explore the similarity within the peak values resulting from the procedures of SUFI-2 and the scatter plot of monthly stream flow showing a well-fitting relationship of the observed and simulated values for calibration shown in figure (4.4).

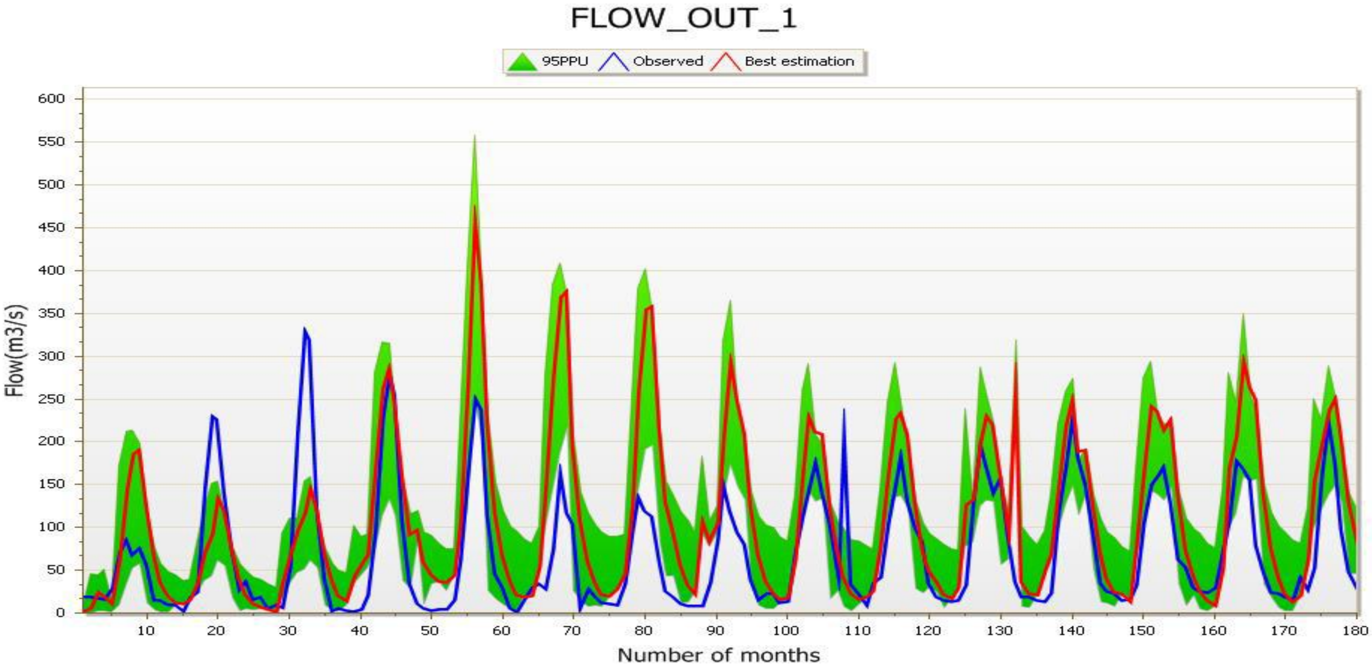


Figure4. 3Calibration results of monthly observed and simulated flows of Fincha'a watershed

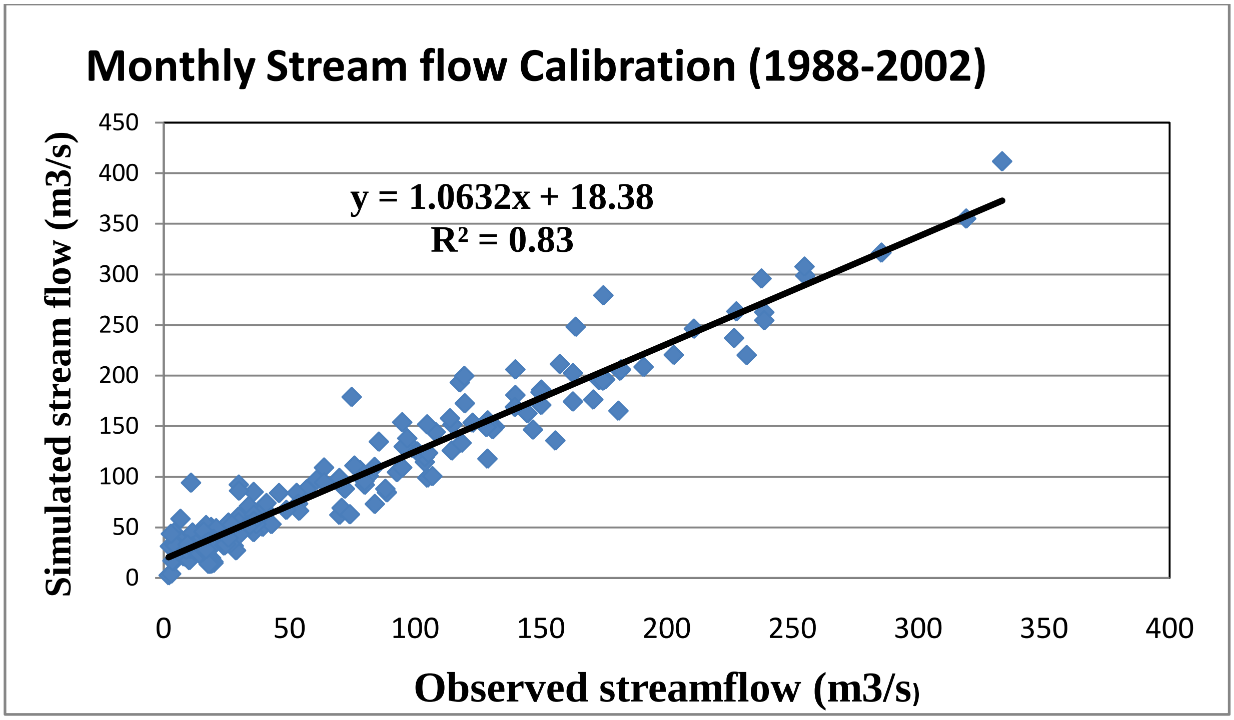


Figure4. 4Scatter plot of observed and simulated stream flow for Fincha'a water-shed during calibration period.

4.4 Stream Flow Validation

After calibration finished, the model was validated using data of flow from 2003 to 2011 for nineyears. Validation proved that the performance of the model for simulated flows in periods different from the calibration periods.

The coefficient of determination (R^2 = 0.60) and the Nash-Sutcliffe (NS=0.59) shows a satisfactory agreement between the observed and simulated values. The time series data of the observed and simulated flows on monthly basis were plotted for visual comparison to explore the similarity within the peak values resulting from the procedures of SUFI-2 Figure (4.5) and the scatter plot showing the observed and simulated values for validation was shown in figure (4.6).

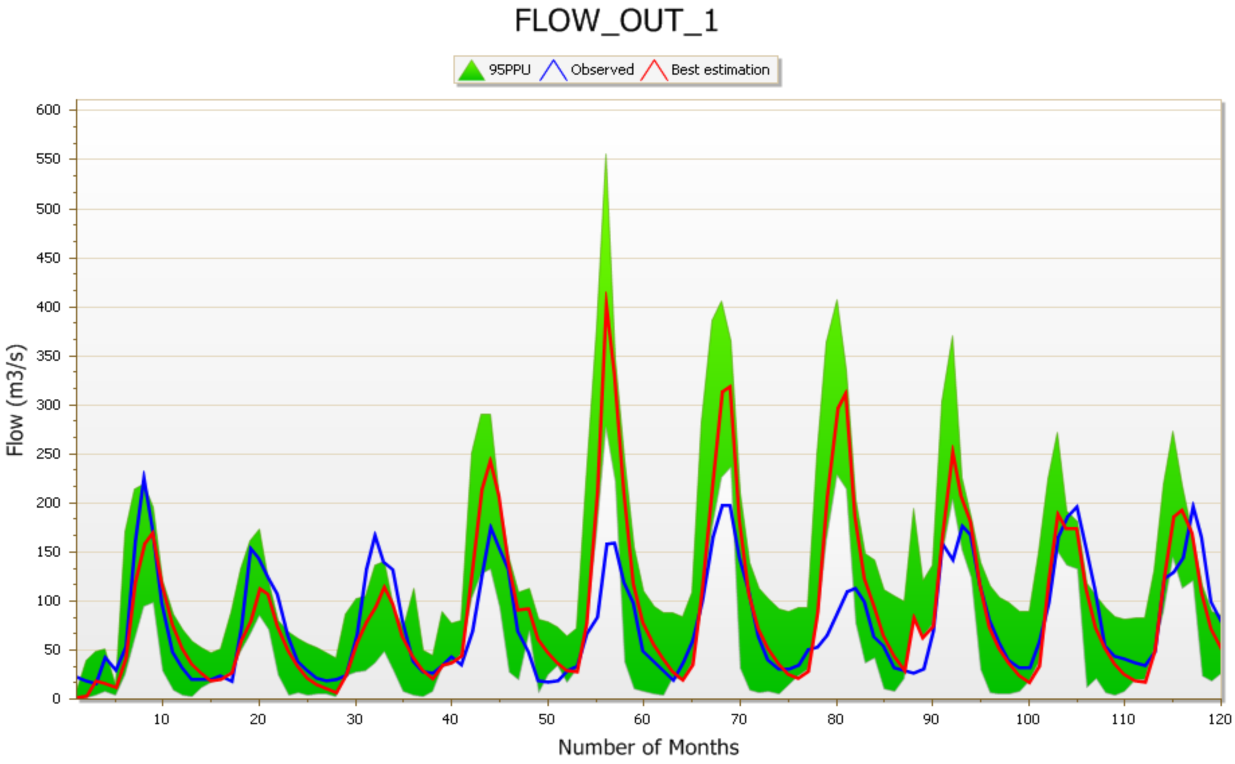


Figure4. 5Validation result of monthly observed and simulated flows of Finchaa watershed.

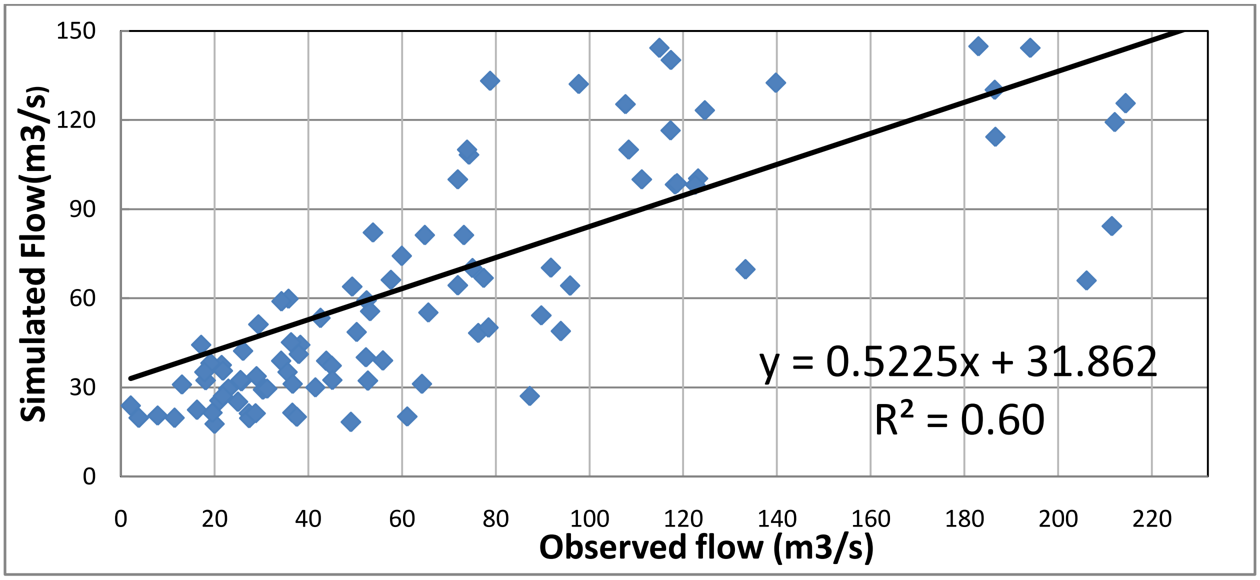


Figure4. 6Scatter plot of observed and simulated stream flow for Finchaa watershed during Validation period.

4.5 Surface Runoff

Surface runoff or overland flow occurs whenever the rate of precipitation exceeds the rate of infiltration and occurs along a sloping surface. Surface runoff refers to the portion of rainwater that is not lost to interception, infiltration, and evapotranspiration (Solomon, 2005). Since water quality depends on the total runoff in the watershed, detail considerations of each hydrologic condition of different LULC and a soil is very important. The nutrient loading on the rivers and lake depends on the total runoff the watershed. And the total runoff depends on the actual hydrologic condition of each LULC and soil present in the watershed. Based on the Figure (4.7), the annual average surface runoff the catchment was 351.7mm. In 2002 and 2005,572 mm and 529mm of runoff were recorded in the catchment which were the maximum the study area while

72.8mm was the minimum that recorded in 1992.

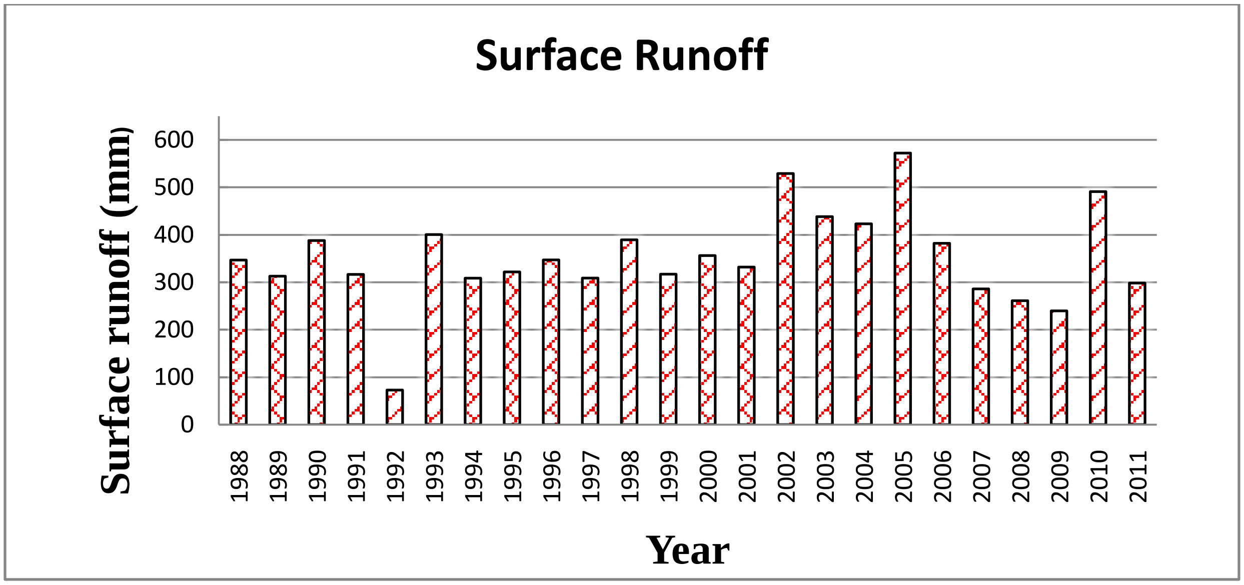


Figure4. 7Annual surface runoff of the Fincha'a Catchment.

4.6 Nitrogen Load and Transport Pathways

According to Thompson (2011), Nutrient fluxes from landscapes to stream reach are complex processes involving water flow and chemical processes. Different water flow pathways are main driving forces for nutrient transport. As a result, catchment characteristics, such as topography, soil type and underlying geology have great influences on runoff generation processes and affect nutrient leaching in turn. For example, more nutrients are found to be transported into streams in highly permeable soil covered land due to short residence time and low nutrient retention (Rode et al., 2009). Through altering hydrological behaviors, climate change in terms of temperature and precipitation also affects nutrient transport and transformation processes (Bouraoui et al., 2004).In addition to the soil characteristics, Rode(2009) said Diffuse sources (e.g. fertilizer inputs in agricultural land) are main nutrient inputs, many studies have been undertaken to investigate land use impacts on river nutrient loads by running different land use scenarios.

SWAT assumes the movement and transformations of nitrogen for two mineral species (ammonium and nitrate) and for three organic species (active, stable and fresh) in soil nitrogen pools (as N).The SWAT model simulation of nitrogen can account for transport and transformation processes in the soil profile and the shallow aquifer, roughly up to a depth of 20 m (Neitsch et al., 2005). As mentioned previously under (3.1.8),there is no measured data of Nitrogen and phosphorus in streams,Dams and lakes at national level in Ethiopia according to ministry of water,irrigation and mining of the country told me during data collection,so calibration and Validation of water quality was not possible.Rather the model was calibrated and validated by flow because hydrological processhas direct impact on nutrient loading and transport pathways from the watershed to Fincha'a Dam. Thus, Calibrating and validating stream flow were the driving force for calibrating and validating of P and N. The stream flow calibration results were in agreement with the measured and predicted at the gaging station of Fincha'a watershed with the R^2 and NSE of 0.83 and 0.79 respectively while the validation showed satisfactory rank with R^2 and NSE 0.6 and 0.58 respectively.

4.7 Transporting Pathway of nitrogen

Based on the Figure (4.8),the means via which nitrogen transported to the Fincha'a dam was through surface water flow, lateral flow and percolating. The Average annual nitrate carried by surface runoff from the catchment area to Fincha'a dam was 2kg/ha/year which contribute 5% of the transporting means nitrate that was exported through lateral flow was the least which was 3%.But large amount of the Nitrate exported to the Dam through Percolating that accounts 35.7kg/ha/year(92%).

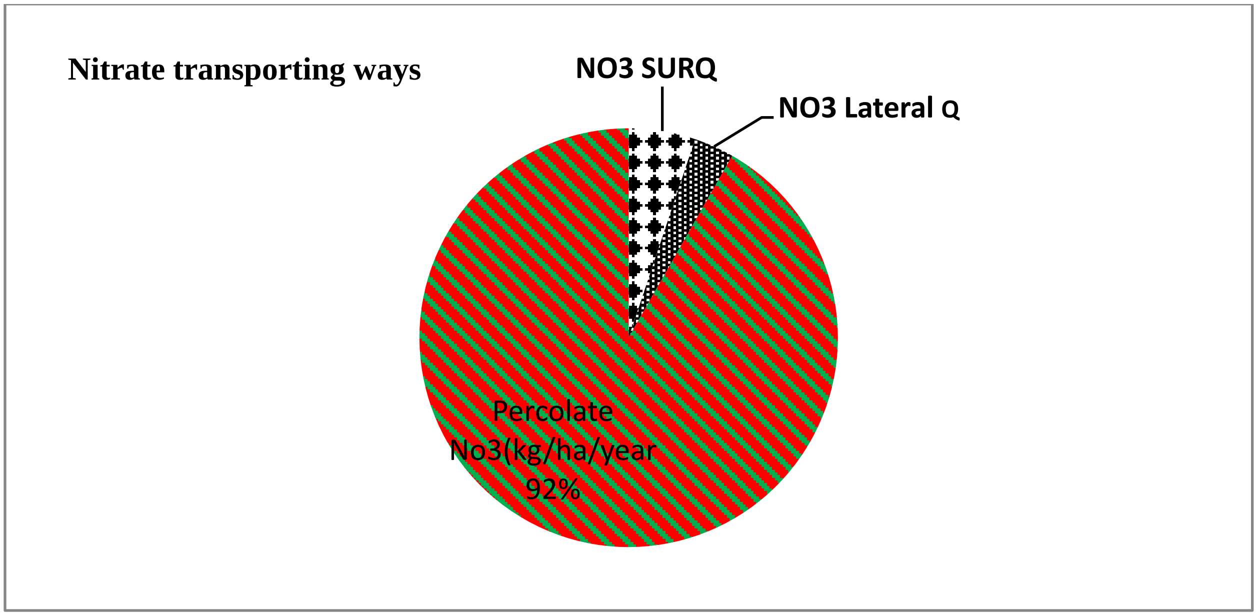


Figure4. 8Nitrate transporting way at Fincha'a Dam

4.8 Nitrogen load

The average nitrate loss through surface flow of the catchment was 2kg/ha/year that accounts 2.6%. Of the nitrogen load that exported from the watershed was via lateral flow which is 1.6%. From the total nitrogen simulated at the study area, Organic nitrogen and percolating nitrate were contributing the dominant rank and numerically, the annual averages of them were 37.75 kg/ha/year and 35.27kg/ha/year respectively Table (4.2).

Table 4.2 Annual Nitrogen losses from watershed to Fincha'a Dam

Year	Surface Q NO3 (kg/ha)	Lateral Q NO3(kg/ha)	Percolate NO3(kg/ha)	Organic Nitrogen(kg/ha)	Total Nitrogen (kg/ha)	% of total in each year
1988	1.11	0.49	9.2	27.17	37.97	2.08
1989	0.7	0.64	15.85	30.11	47.3	2.59
1990	4.34	0.79	19.84	38.75	63.72	3.48
1991	2.04	1.27	34.23	28.0	37.82	2.07
1992	0.93	0.79	24.27	44.3	40.12	2.19
1993	1.25	0.95	34.49	60.5	97.19	5.32

1994	1.59	0.83	21.99	34.71	59.12	3.23
1995	2.26	1.18	27.84	38.7	69.98	3.83
1996	1.93	1.22	33.64	39.05	75.84	4.15
1997	1.72	0.96	25.22	48.07	75.97	4.15
1998	1.8	1.39	43.18	38.85	85.22	4.66
1999	2.38	0.98	27.68	39.63	70.67	3.86
2000	1.01	1.61	47.68	33.65	83.95	4.59
2001	1.4	1.28	38.15	38.72	79.55	4.35
2002	1.7	1.46	45.2	51.79	100.15	5.48
2003	2.78	1.43	40.09	35.23	79.53	4.35
2004	1.4	1.2	36.62	46.42	85.64	4.68
2005	3.35	1.75	51.79	37.1	93.99	5.14
2006	1.64	1.37	42.02	38.86	83.89	4.59
2007	1.49	1.44	43.79	39.31	86.03	4.70
2008	3.78	1.07	35.99	42.79	83.63	4.57
2009	1.25	1.6	47.69	33.06	83.6	4.57
2010	4.35	1.15	38.21	61.56	105.27	5.76
2011	1.26	1.76	61.82	37.53	102.37	5.60
Average	2.0	1.19	35.27	40.2	78.6	
Total	47.46	28.61	846.48	963.86	1886.41	100.00
%	2.6	1.6	44.2	51.2	100.0	

4.8.1 Organic N

Three organic (fresh organic nitrogen from crop residue and microbial biomass, active and stable organic nitrogen from the soil humus) pools of nitrogen are simulated by the SWAT model. According to the findings, the organic nitrogen form was identified as the major load of nitrogen species in the study area. The maximum organic N load was found on the year 2010 which accounts 61.56kg/ha and the minimum Organic N load was 28.0kg/ha during the year of 1991 figures (4.18). The annual total average of Organic load in the Fincha'a catchment was simulated 40.2kg/ha that accounts 51.2% of total nitrogen load in the catchment Figure (4.9).

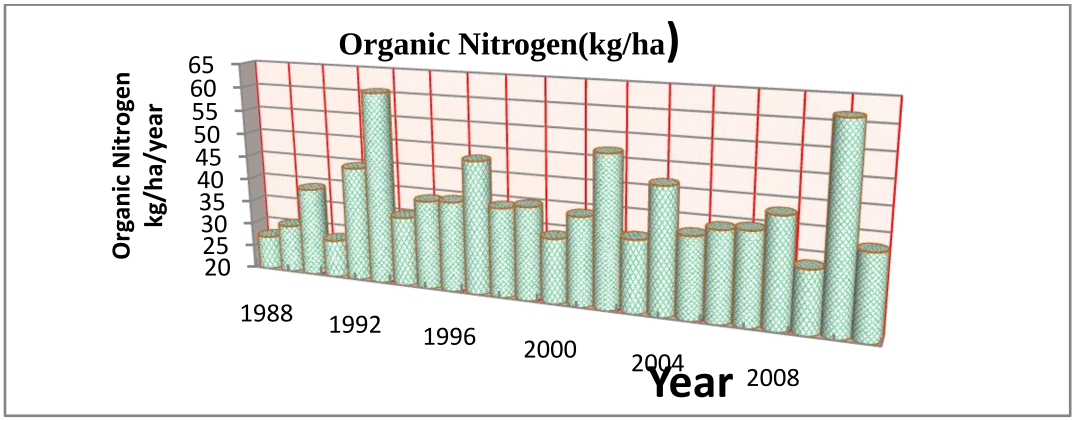


Figure4. 9Annual Organic Nitrogen load

4.8.2 Total Nitrogen

In this case, total nitrogen is the sum of both organic nitrogen and nitrate-N, which in all soil layers simulated by SWAT at outlet of watershed. Nitrogen in the soil humus is divided into active and stable pools. The average annual total nitrogen load from the Fincha'a watershed was 78.6 kg/ha/year. In 2010 and 1988, maximum and minimum amount of Total nitrogen load were found at study area which are 105.27kg/h and37.97 kg/ha/year respectively.As discussed under Figure (4.10), the most contributing of total nitrogen was organic nitrogen and those transported through percolating was taking the rank.

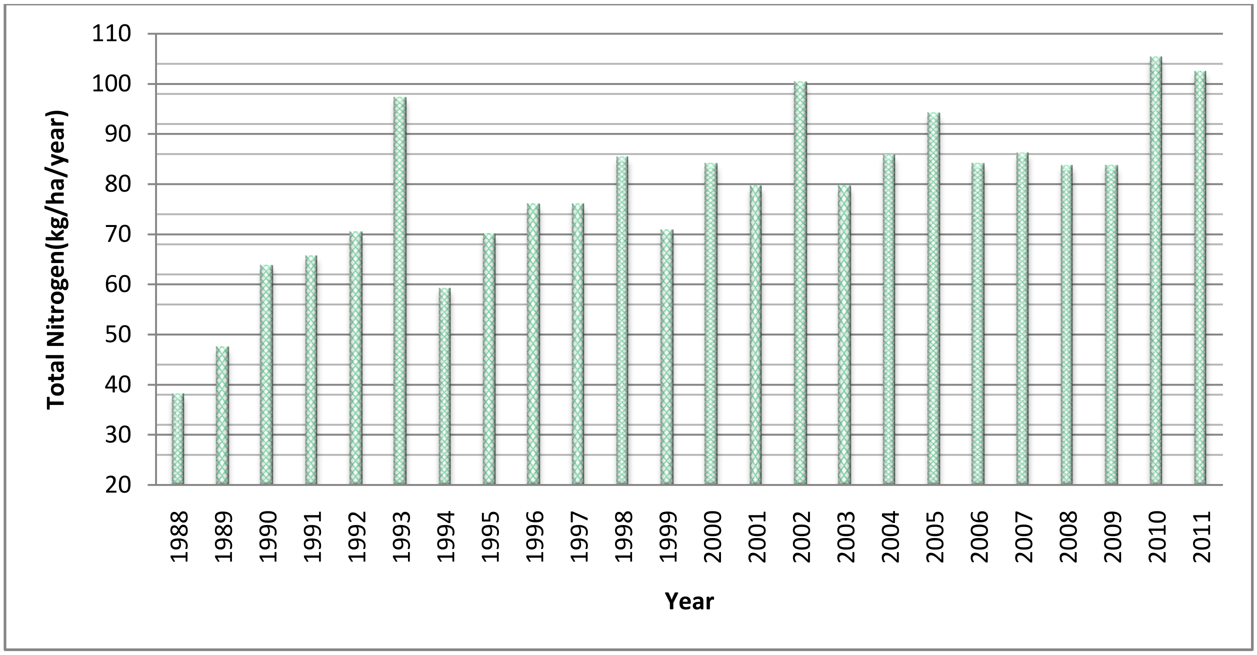


Figure4. 10 Average Total Nitrogen load

4.9 Phosphorus transport pathways

Nutrient fluxes from landscapes to stream reach are complex processes involving water flow and chemical processes (Thompson et al., 2011) thus different water flow pathways are main driving forces for nutrient transport. Among different nutrients intrudes to rivers, lakes and other water body from land surface, attention for this study was given to Phosphorus (P) and Nitrogen(N).

Loss of phosphorus not only from agricultural land but also from any surface of the earth is largely controlled by the hydrological phenomenon such as surface runoff. Through runoff P transported as particulate (sediment bound) or dissolved (soluble) form. P cycling accounts for transformations in six soil P pools; three are organic (fresh organic, active and stable organic P) and another three are inorganic (minerals) pools (labile/solution, active, and stable pools). The major P transformation processes include mineralization of fresh organic P and soil organic matter, and decomposition and immobilization. SWAT requires estimates for the initial mineral P and organic P concentrations in the upper soil layers for phosphorus simulation (Neitsch, 2005a) so, SWAT monitors six different pools of p in soils, three pools in organic forms of p while the other three pools are; fresh organic p associated with crop residue and microbial biomass, and active and stable organic p pools related with soil humus. These characteristics enhance to build up of phosphorus particulate near the soil surface that is readily transport by surface run off. Surface run off is the major mechanism by which p is exported from the most catchments (Neitsch et al.., 2009). In addition to the afro-mentioned, the research done at Gilgel Gibe watershed (Adela Y. and Behn C., 2015) assures that there were positive correlation between runoff and total phosphorus loss (R^2=0.89,P-value=0.001).

Phosphorus transport processes simulated in SWAT include surface runoff in solution, losses of P attached to sediment and leaching of soluble P. The amount of soluble P removed in runoff is predicted using solution P concentration in the top 10 mm of soil, the runoff volume and a partitioning factor. Sediment transport of P is simulated with a loading function as described in the SWAT theoretical documentation (Neitsch et al., 2005b).

Having quoting the above findings of scientific facts as supportive base, the researchers studied Fincha'a watershed nutrients transport as general to Fincha'a Dam in particularly. Accordingly, the investigation showed that 7.2kg/ha/year which accounts 41.3% of p was transported from the catchment to the Dam in the form of organic phosphorus(Org p) . Sediment attached P (adsorbed) which accommodates around 10.3 kg/ha/year of transport path that holds 58.3%. The soluble P which was 0.07kg/ha/year the least transport mechanism that accounts only 0.4% Table (4.3).

Table 4.3Annual phosphorus loss in the Fincha'a Dam.

Year	ORGP(kg/ha)	SOLP(kg/ha)	SEDP(kg/ha)	Total P(kg/ha)
1988	6.55	0.09	11.05	17.68
1989	7.17	0.06	10.67	17.90
1990	8.19	0.08	11.69	19.96
1991	6.83	0.05	10.33	17.21
1992	3.90	0.03	7.40	11.33
1993	10.37	0.10	13.87	24.34
1994	7.11	0.07	10.61	17.80
1995	7.49	0.06	10.99	18.53
1996	7.42	0.07	10.92	18.40
1997	8.28	0.08	11.78	20.15
1998	7.04	0.05	10.54	17.63
1999	7.31	0.07	11.31	18.70
2000	6.47	0.06	9.07	15.60
2001	6.61	0.06	9.21	15.88
2002	8.12	0.11	10.72	18.95
2003	6.62	0.07	9.22	15.91
2004	7.39	0.08	9.99	17.47
2005	7.25	0.09	9.85	17.20

2006	7.05	0.10	9.65	16.80
2007	6.41	0.05	9.01	15.47
2008	6.78	0.09	9.38	16.24
2009	6.51	0.05	8.11	14.66
2010	9.60	0.10	11.20	20.89
2011	7.06	0.06	8.66	15.78
Average	7.2	0.07	10.3	17.5
Sum	173.53	1.73	245.23	420.48
Percent	41.3	0.4	58.3	100

4.9.1 Phosphorus load

Based on the simulated data, the annual average loss of Org P from Fincha'a catchment was 7.2 kg/h/year which accounted 41.3% among the other forms of phosphorus transported. There were maximum load of OrgP during 1993 and 2010 that accounted 10.37 kg/ha/year and 9.6kg/ha/year respectively. This might be happened due to high rainfall which led to high amount of surface runoff and sediment load besides agricultural activities in the boundary of the catchment Figure (4.11) Even though the amount of soluble phosphorus is less among the two forms of phosphorus exported to the dam, it accounted 0.4 %.

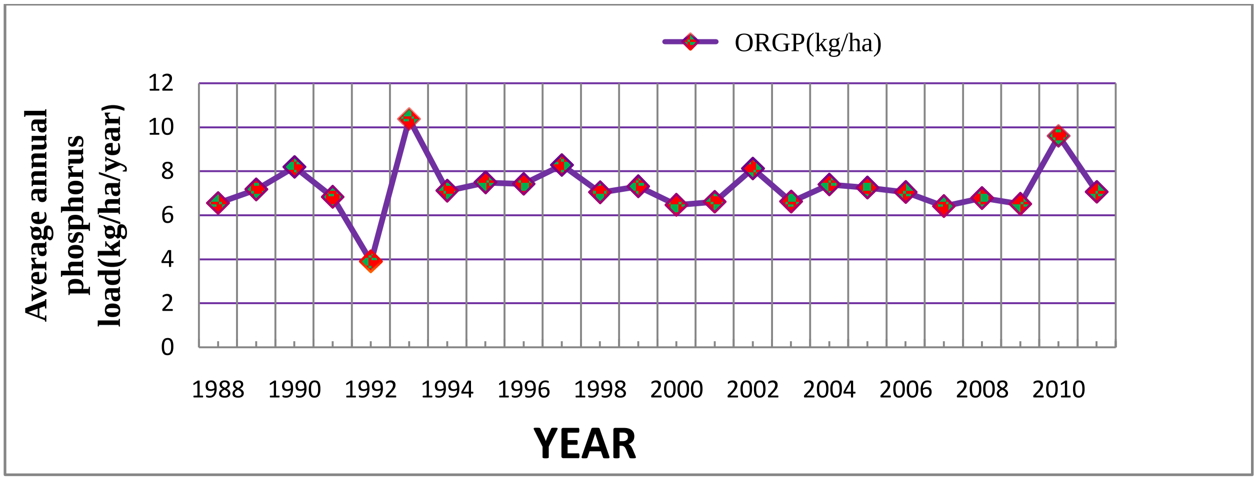


Figure4. 11Annual Load of Org P

4.9.2 Sediment P

is a mineral form of phosphorus that attached to sediment and transported by surface run off towards to the Dam. The annual average Sed P loss in the Fincha'a catchment was identified as 10.3(kg/h/year) with coverage of 58.3% of the other form of P loss. The high amount of sediment form of P was loaded during 1993, 1997, 1999 and 2010 were (13.8, 11.78, 11.31and 11.20)kg/ha/year) respectively Figure(4.12).

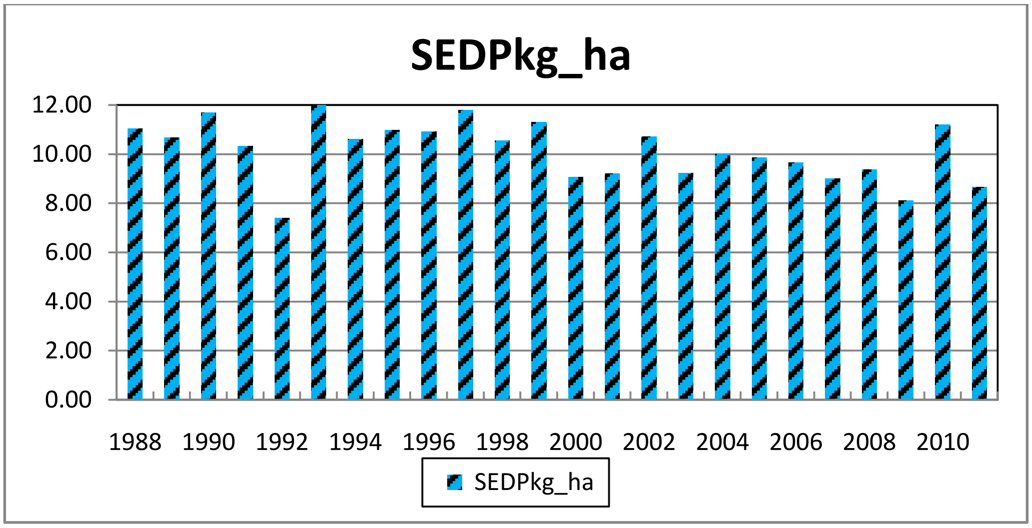


Figure4. 12Annual Sed P load

4.10 Prone Sub-Basins

The study area was classified into 21 subbasins and 156 Hydrologic response unit (HRU).Each subasins was contributing different amounts of both phosphorus and nitrogen loads to its outlet and moving distant to Fincha'a Dam.

4.10.1 Spatial Distribution of Nitrogen on Fincha'a sub-basin

4.10.1.1. Spatial distribution of organic Nitrogen

The high amount of Organic N was exported from sub basins number 6,20,1,3,9 and 2 which accounts 8.94,7.7,6.5,6.4,6.4 and 6.4% respectively and sub-basin 21 and 17 were among the most least contributing sub-basins as indicated in Figure (4.13). Based on average sub basin value of organic N, the distribution of N nutrient mostly concentrated from sub-basin 1 to 10.As it is seen on Figure (4.14) the highest amount of organic nitrogen was contributed from the southern parts of the catchment. In average northwest part of the catchments were exporting the highest than the other parts of the watershed.

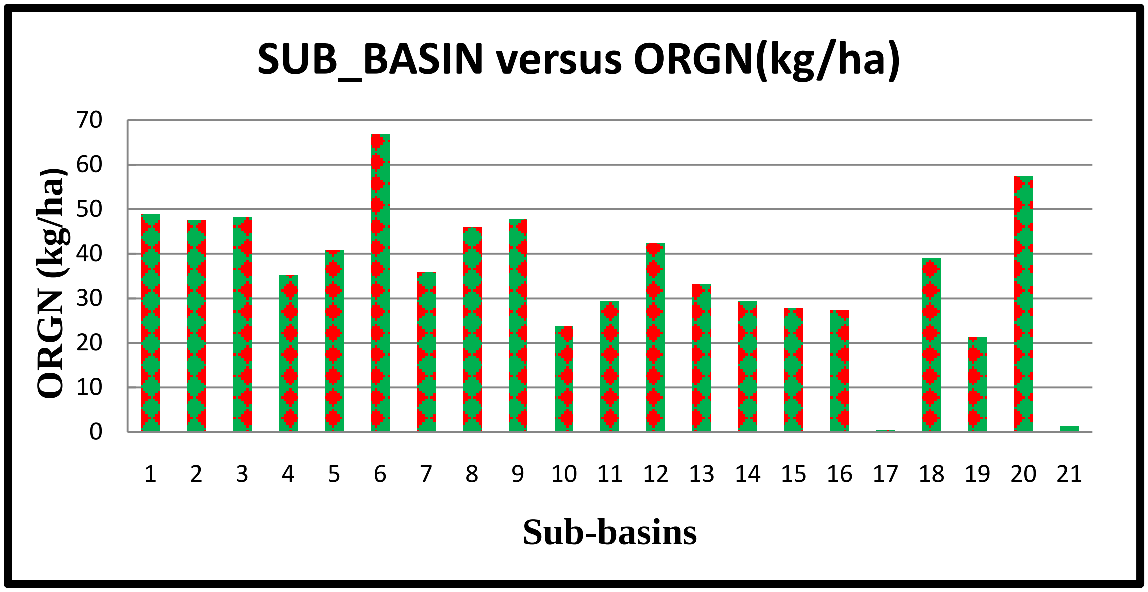


Figure4. 13Sub-basin versus ORGN concentration that enters to the dam.

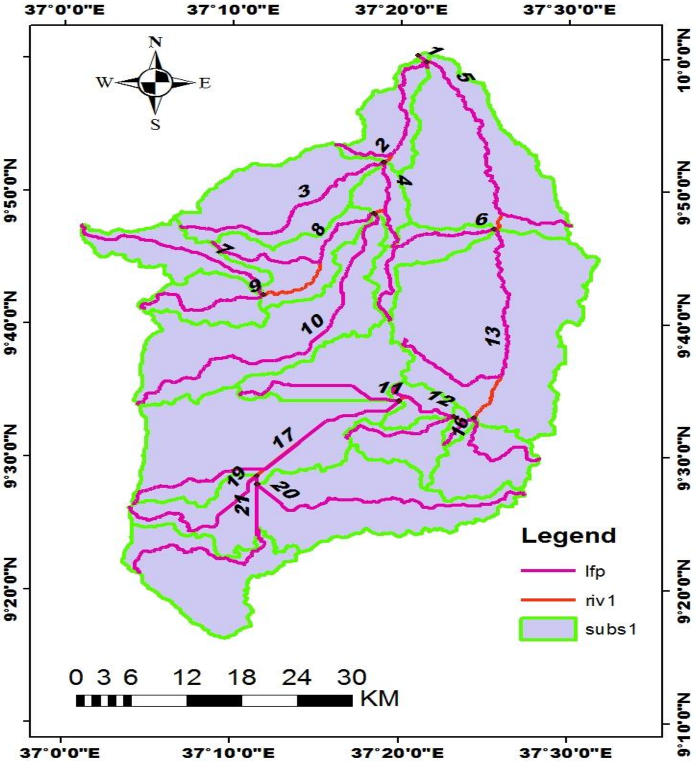


Figure4. 14Map that shows the sub-basin distribution of the Fincha'a catchment.

According to table (4.4): 52.4% of the sub-basins were exporting more than 40kg/ha, 38.1% of them contributing ORGN nitrogen load to the Dam in average 30kg/ha and few sub-basins were exporting around 10kg/ha in averagewhen these result compare with the result of research done in lake victoria, the former were the highest. The highest amount of nitrogen that contributed by two sub-basins to lake victoria were0.112-0.237kg/haand 1.003-1.339kg/ha (R.J. Kimwaga,et al., 2012)

Table 4.4over all loads of ORGN and contributing sub-basin

ORGN(kg/ha)	Contributing sub-basin
=>40	1,2,3,5,6,8,9,11,12,18,20
20-40	4,7,10,13,14,15,16,19
<=20	21,17

4.10.1.2 Spatial distribution of NO_3 load

SWAT estimate the nitrate load at various pathways e.g. export with runoff, lateral flow, and percolation and it is calculated as a function of the volume of water and the average concentration of nitrate in the soil layer. The study was found that NO3 was transported by Surface flow, lateral flow and ground water percolation. This all mechanistic agents were transporting nitrate from sub basin to the destination point. Based on Figure (4.15), the most prone area or sub-basins were exporting 35kg/ha which contributes 62% and the least were contributing 9% when these results were compared with the research done by Folle then the former were high (Muleta and Nicklow, 2005) since the highest result of Folle was 22.6kg/ha.

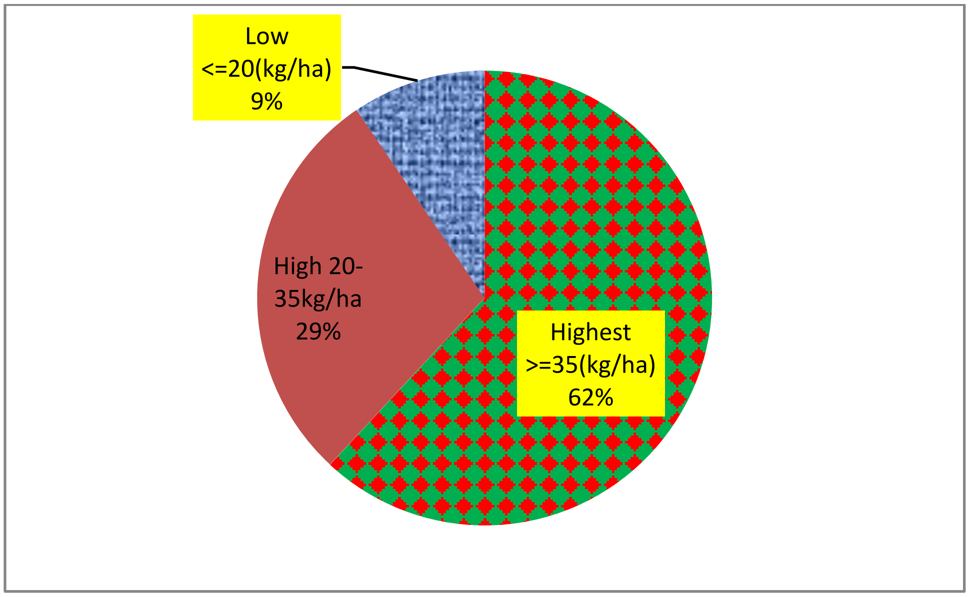


Figure4. 15 Classifying Nitrate with prone area.

According to Table (4.5)**,**the spatial distribution of P, and N were not homogeneous across a watershed, other parts of the watershed contribute little to overall load .This may be some areas of a watershed are more prone to erosion and some of the area may be well manageable. This assumption has agreement with the study done by Ballantine and his fellow workers. (Ballantine al., 2009).

Table 4.5The most prone sub-basin in exporting Nitrate

NO3(kg/ha)	Contributing sub-basin
=>35	4,6,9,11,14,15,16,17,18,19,20,21
20-35	3,5,7,8,10,12
<=20	1,2

4.10.2 Spatial distribution of Phosphorus on the Fincha'a Subbasin

Table(4.6) ,shows phosphorus average Subbasin load from Fincha'a watershed to dam in general but particularly it identifies the load of ORGP, Soluble phosphorus and phosphorus those attached to sediment.

Table 4. 6 Spatial distribution of Phosphorus at Fincha'a Subbasin

Subbasin	ORGP(Kg/ha)	SOLP(kg/ha)	SEDP(kg/ha)	TP
1	0.02	0.09	0.42	0.53
2	0.58	0.12	3.72	4.42
3	0.58	0.09	3.38	4.05
4	0.58	0.11	3.55	4.24
5	0.43	0.10	2.91	3.44
6	0.53	0.08	3.22	3.83
7	0.84	0.06	3.81	4.71
8	0.52	0.04	2.77	3.33
9	0.63	0.04	3.40	4.08
10	0.64	0.05	3.46	4.15
11	0.37	0.02	2.33	2.72
12	0.45	0.03	2.96	3.44
13	0.56	0.07	3.11	3.75
14	0.46	0.06	2.56	3.08

15	0.45	0.03	2.96	3.44
16	0.43	0.03	2.88	3.33
17	0.37	0.02	2.03	2.43
18	0.01	0.08	0.9	0.99
19	0.47	0.05	2.30	2.82
20	0.30	0.02	1.72	2.05
21	0.70	0.06	3.32	4.08

4.10.2.1 ORGP (kg/ha)

Depending on the table(4.7),the leading amount of organic phosphorus were 0.84,0.7,0.64 and 0.63kg/ha which were loaded from Subbasin 7,21,10 and 9 respectively.57.1% of the Subbasins were contributing between 0.45-0.84kg/ha while the medium class of the Subbasins were contributing 0.01 to 0.1 kg/ha. The reason behind those contributing more organic phosphorus might be the effect of erosion, land status of the study area were playing a crucial role.´

Table 4. 7Spatial classification of ORGP (kg/ha)

ORGP(kg/ha)	Contributing Subbasins	%
0.01-0.1	18,1	9.5
0.1-0.45	5,11,12,15,16,17,20	33.3
0.45-0.84	2,3,4,6,7,8,9,10,13,14,19,21	57.1

4.10.2.3 SOLP (Kg/ha)

Of the ORGP,SOLP and SedP, soluble phosphorus was less in amount than others.0.12,0.11 and 0.1kg/ha were exported from Subbasins 2,4 and 5 respectively, As it is vividly seen from Figure(4.16),Subbasin 1 to 6 were contributing more than the rest of the Subbasins.

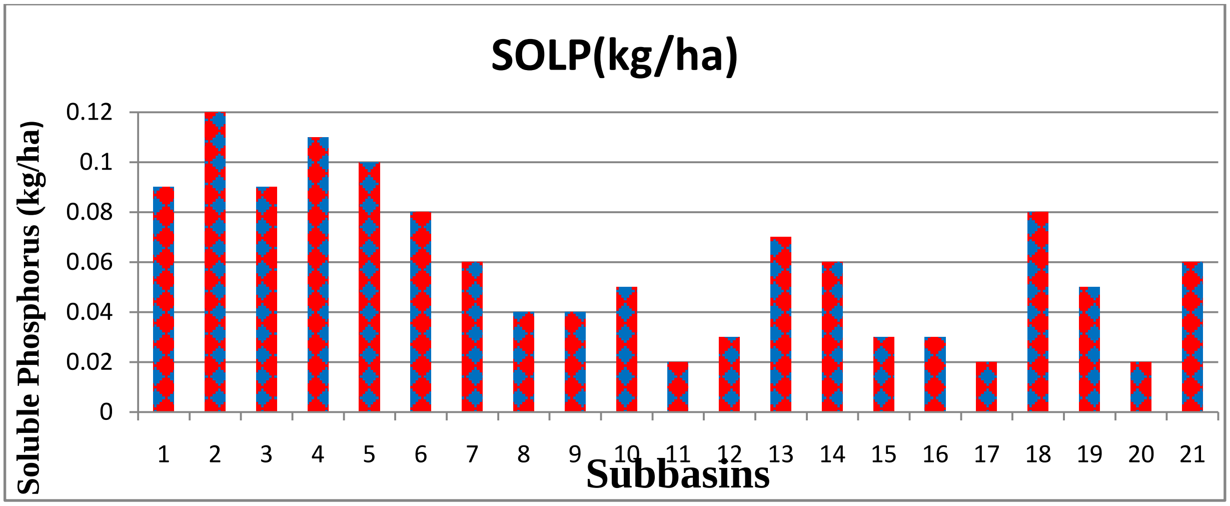


Figure4. 16 spatial distribution of soluble phosphorus

Based on the table (4.8) and figure (4.18), 14.3% of the sub basins were contributing 0.42 -1.8 kg/ha of Sedp to the Fincha'a dam or outlet, those contributing Subbasins were 1, 18 and 20 of them Subbasin 20 were the most prone area.47.6% of the Subbasins were contributed between 1.8 to 3.18kg/ha of SedP of these Subbasins 13 and 12 were more contributed than the others.

Table 4. 8SedP load versus contributing Subbasins

SedP(kg/ha)	Contributing Subbasins	percentage
0.42 -1.8	1,18,20	14.3
1.8-3.18	5,8,11,12,13,14,15,16,17,19	47.6
3.18-3.85	2,3,4,6,7,9,10,21	38.1

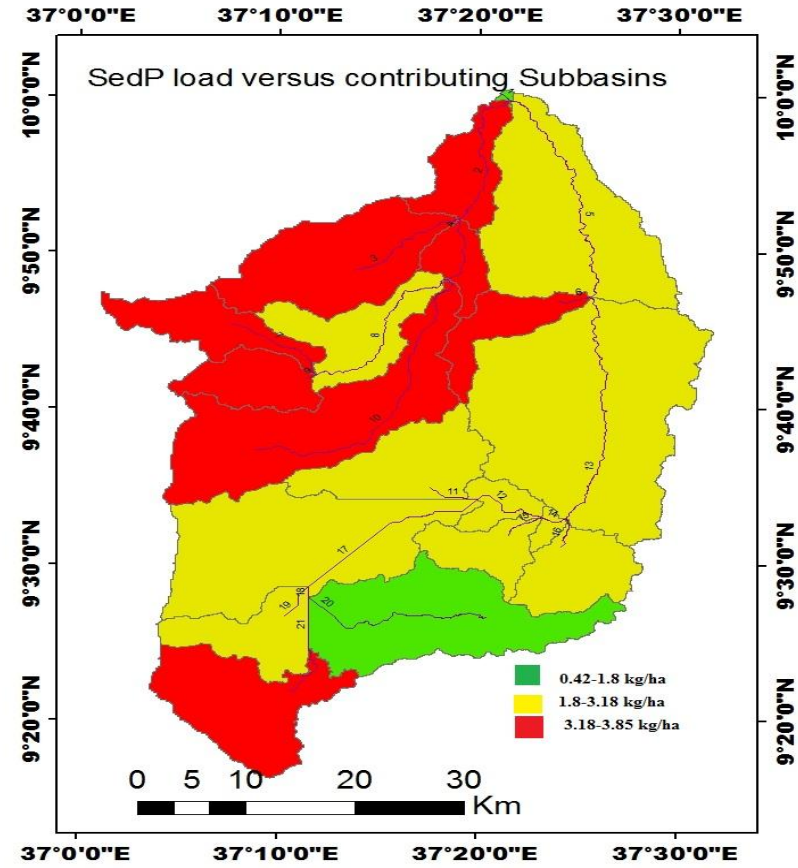


Figure4. 17 spatial distribution of Sediment attached phosphorus (SedP)

CHAPTER FIVE: CONCLUSION AND RECOMENDATIONS

5.1. CONCLUSIONS

In broad sense, today, not only through the media outcry but also via practical life, peoples are worrying about Pollution. There are different types of pollution in general but this study did give attention particularly on Water Pollution.It is a mere to handle point source pollutants of water resource but it may not be easy to control and manage the non-point pollutants thus it is the prime agenda of the world's communities. Agricultural fertilizers and other inputs of agricultural activities are playing a pivotal role in deteriorating the quality of water including from the source to periphery. Even though many researchers were conducted the effect and transporting way of nutrients on the water bodies, still more remain to develop efficient method that explicitly put the phosphorus and nitrogen fate. This study wants to assure the usefulness of hydrological modeling for investigating the load and transport pathways of nutrients and hydrologic response analysis at various spatial and temporal scales. It is frank that, there are no perfect hydrological models, but it is more representative than other methods in order to determine the load and transporting pathways of nutrients on a certain watershed.

GIS and SWAT version 2012 were helpful tools for the study area in order to evaluate the spatial and temporal loading and transporting pathways for nutrients like nitrogen and phosphorus from Fincha'a watershed. Being using SWAT 2012, researchers could analysis the effect of Climate trends and land use, Water quality analysis,and sediment yield, to plan dam construction, to manage flood risk, and so on. Over all it is a reasonable annual predictor of the watershed responses for assessing the impacts of different management systems on water resources and non-point source pollution.

From the simulation of hydrological process,the effect of precipitation, surface runoff and total water yield on phosphorus and nitrogen loading and its transport pathways was evaluated. Based on the finding of Fincha'a watershed, P and N load, transport pathways and prone area was identified using SWAT model. From the simulation the annual total average of P and N were 17.5kg/ha/year and 78.6 kg/ha/year respectively. Surface runoff, lateral flow and percolation to the ground were the main transporting pathways for both Phosphorus and Nitrogen which depends on rainfall pattern, duration and intensity. Organic Phosphorus and organic N were dominantly transported through surface run off whereas NO3 was dominantly transported via percolation to ground water. The highest annual total P and total N load were contributed by sub basin 2, 4, 7 and 6,20,1 respectively. These Subbasins were mainly located in Combolcha Woreda, Jimma Geneti and Horo.

Model was calibrated and validated by gauged flow and the result of SWAT model performance during calibration and validation was found to be 0.83, and 0.79, 0.60 and 0.59 respectively for R^2 and NSE. This shows good agreement between the simulated flow and observed stream flow. Though measured data of Nutrients were not present, Nutrient Dynamics and hydrological process that were simulated by SWAT used as the analysis of the findings.

5.2 RECOMMENDATIONS

From the model's result the pollutants loading were from the upper catchments of the study area, which were through surface runoff, percolation and lateral flow taken to the Fincha'a Lake. Even though it is not taken into consideration, the sustainability of the lake will be under questions. If the loading of these nutrients continues it will be resulted in lake eutrophs besides an activities that are performing near the lakes also a witness of high sediments and nutrients are eroded to the lake thus in order to overcome from such fate the following recommendations forwarded to the concerned bodies to plan landuse and water use for optimization of the environmental benefit through surface runoff control, erosion protection, nutrient loading control, flood protection and water availability:-

- Nutrients are mainly loaded to the water resource via surface run off. Hence, it is recommendable to apply best management plan which is simple, economical and adaptable over the study catchment for managing severe impact of surface run off on water resources like promoting "Daagaa" among the communities.
- The amounts of nutrient loading were very high in the study area these may be depending on the increasing population which increases agricultural practice through using agricultural inputs like fertilizer application. Therefore, Communities should be educated by developmental agent (DA) about the effect of the unwise use of fertilizers with agricultural practices versus the impact what would it causes not only the nearby environment, natural resources and ecosystem but also on the Fincha'a lake.
- To classify the level of the lake into different classes of eutrophication, data of recorded water quality in general and nutrients in particular are crucial but there was no recorded nutrient data still now at the country level as other hydrological data. This is a challenging part to calibrate and validate the model efficiency and to use the model as a tool for analyzing nutrient loading and transport pathways at catchment level of Ethiopia. So, it is better to adapt nutrient gauging at catchment level and water resource level by concerning organization.
- 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 be installed uniformly within the watershed.

- The specified sub basins which are critical areas or most prone areas were Jimma geneti Jimma Rare and Horo woreda thus the responsible and concerned bodies should give special attention and apply best management practices continuously over those areas for bidirectional benefits.

REFERENCE

Abdi, B. A. (2012). Simulation of Sediment Yield using SWAT Model in Fincha Watershed, Ethiopia. . *Kasetsart J. (Nat.Sci).*, 46 : 283 – 297.

Arnold, J. G. (2005). : SWAT2000: current capabilities and research opportunities in. *Hydrological Processes*, 19, 563-572.

Arnold, J. G. (2012). WAT Model Use, Calibration, and Validation. . *Transactions of the ASABE.*, 55(4): 1491-1508.

Arnold, J. W. (1998). Large Area hydrologic Modeling and assessment,Part I:Model development,. *J.of American Water Resource Association*,, 34,11,73-89.

Arnold, J., Allen, P., & Bermhardt, G. (1993). A comprehensive surface ground water flow model. *J.Hydrol.*, 142,47-69.

Ballantine, D. D. (2009,). Mobilization and transport of sediment- associated phosphorus by surface runoff. . *Water Air Soil Pollution.*, 311-320.

Beven, K. J. (1989). Changing ideas in Hydrology. The Case of Physically - Based Models. *Journal of Hydrology,Catchments, Tanzania. Proceedings of the 3rd International SWAT conference,Zurich,*, 105: 157 - 172.

Bezuayehu, T. (2006). People and dams:Environmental and socio-economic impacts of Fincha’a hydropower dam, western Ethiopia. . *Tropical Res. Manag. Paper No. 75. Wageningen University and Research Center. Wageningen, The Netherlands*.

Borah, D. M. (2003). Watershed-scale hydrologic and non-point source pollution models:Review of mathematical bases. *Trans.ASAE* , 46:1553-1566.

Bouraoui F, G. B. (2004;). Impact of climate change on the water cycle and nutrient losses in a Finnish catchment.. *Climatic Change* , 66: 109-126.

Broberg, O. G. (1988). Particulate and dissolved phosphorus forms in freshwater:Composition and analysis. *Hydrobiologia*, 170:61-90.

BROWN, L. &. (1987). The Enhanced Water Quality Model QUAL2E and QUAL2E-UNCAS Documentation and User Manual. *U.S>Environmental protection Agency*.

C.A.JONES, C. (1984). A Simplified Soil and Plant PhosphorusModel:I. *Documentation*, 48,800-805.

Chahinian, N. T.-G.-L. (2011). Flow and nutrient transport in intermittent rivers: a modelling case-study on the Vène River using SWAT 2005. *Hydrol. Sci. J.* , 56(2), 268–287.

Clark, R. 2. (2001). Marine Pollution. Bath Press Ltd., Bath, Avon.

Constantinides, M. J. (1994). Nitrogen miniralization from leaves and litter of tropical plants:Relationship to nitrogen,lignin and soluble polyphenol concentrations. *Soil Biology and biochemistry.*, 26:49-55.

Cunderlik, J. (2003). Hydrological model selection for CFCAS project, Assessment of water resource risk and vulnerability to change in climate condition, University of Western Ontario.

Cunningham, W. a. (2008). rinciples of Environmental Science: Inquiry and Applications, 4th ed. *McGraw Hill, USA.*, PP. 241-245.

Diaz, R. R. (2008). Spreading dead zone and consequences for marine ecosystems. *J.science:*, 321:926-9.

Diaz-Ramirez, J., Martin, J., & William, H. (2013,). Modelling phosphorus export from humid subtropical agricultural fields:A case study using the HSPF model in the Missippi Alluvial plain. *J.Earth science. Clim.Change.*, 4.

EPA. (2008). *Handbook for developing watershed plans to restore and pretect our waters.* Washington,D.C.:U.S: EPA841-B-08-002.

Ewen, J. a. (2000). SHETRAN:Distributed river basin flow and transport modeling system. *J.Hydrol.Eng*, 5:250-258.

Falkowski, P. a. (2011). Ocean deoxygenation:Past,recent,and future. *J.EOS*, 92:409-10.

Galloway, J. a. (2003). The nitrogen cascade. *Bioscience*, 53:341-356.

Gebreyesus, B. T. (2012). Management strategies for reducing soil degradation through modeling in a GIS environment in northern Ethiopia catchment. *Nutr. Cycl. Agroecosyst,*, 92: 255–272.

Gessese, A. (2008). Prediction of sediment inflow for Legedadi reservoir using SWAT watershed and CCHE1D sediment transport models. *Faculty of Technology, Addis Ababa University*.

Golmar Golmohammadi, S. P. (2014). Evaluating Three Hydrological Distributed Watershed Models. 1,20-39.

Golterman, H. D. (1991). *Eutrophication of lakes,rivers,and coastal seas.,in Htzinger,O.,ed.,The handbook of Environmental Chemistry,Vulome5(Part A):*. Berlin,Springer-Verlag,.

Jury, W. W. (1991). *Soil physics,5^th edition.John Wiley and Sons,Inc.* New York,N.Y.

K.Subramanian. (2008). *"Engineering Hydrology,"3rd Edition.* McGraw-Hill,New York.

Khan, S. a. (2001). A Simple Soil test for detecting sites taht are nonresponsive to nitrogen fertilization. *Soil Sci.Soc.Am.J*, 65:1751-1760.

Kitaka, N. (2000). Phosphorus supply to a shallow tropical lake and its consequences-Lake Naivasha,keniya.Department of Biology. *Leicester,University of Leicester*, 190.

Krysanova, V. J. (2008). Advances in ecohydrolical modelling with SWAT-a review. *Hydol.Sci.J/Sci.Hydrol.*, 53:939-947.

L., H. (1995). *Sources of Euthrophication:hydrological pathways of catchment nutrient export.Man's influence on Freshwater Ecosystes and Water Use(proceedings of a Boulder Symposium),july.* IAAHS Publ.no.230.

Lam QD, S. B. (2012). Assessing the spatial and temporal variations of water quality in lowland areas,Northern Germany. *Journal of Hydrology*, 438-439:137-147.

Lindim C, P., & Vieira, J. (2011). Analysis of spatial and temporal patterns in a large reservoir using water quality and hydrodynamic modeling. *Eco.Model*, 222,2485-2494.

Liu, J., Zhang, L., Yuzhen, Z., Hong, H., & Deng, H. (2008). Validation of an agricultural non-point source(AGNPS) pollution model for a catchment in the Jiulong river watershed,China. *J.Environ.Sci.China*, 20,599-606.

Mallarino, S. a. (2002). Phosphorus indexig for cropland:Overview and basic concepts of the lowa phosphorus index. *J.Soil Water Conserv.*, 57:440-447.

Moriasi, D. N. (2007). Model Evaluation Guidelines for Systematic Quantification of Accuracy in Watershed Simulations. . *Transactions of the ASABE*,, 50(3):885−900.

Muleta, M. K. (2005). Sensitivity and uncertainty analysis coupled with auto-mated calibration for a distributed watershed. . *J. Hydrol. (Amsterdam)*, 306(1–4),127–145.

Muttiah, R. R. (2002). Scale-dependent soil and cimate variability effects on watershed water balance of the SWAT model. *Journal of Hydrology.*, 256:264-285.

Mwanuzi, F. A. (2013). Simulation of pollution buffering capacity of wetlands fringing the Lake Victoria:. *Environment international, , v. 29*, , p. 95-103.

Neitsch, S. (2002). Soil and Water Assessment ToolTheoretical Documentation. *Texas,Texas water Resources institute,College Station.*

Neitsch, S. a. (2005a). Soil and Assessment tool theoretical documentation,version 2005. *Temple, TX.USDA Agricultural Research Service and Texas A&M Blackland Research Center.*

Neitsch, S. J. (2005). Soil and Water assessment tool theoretical documentation,version 2005. *Temple,TX.USDA Agricultural Research Service and Texas A&M Blackland Research center.College Station,TX.*

Neitsch, S. W. (2001). *Soil and Water Assessment Tool(SWAT) Theoretical documentation,USD Agricultural Research service,*. Temple,Texas,.

Nyenje, P. F. (2010). Eutrophication and nutrient release in urban areas of sub-Saharan Africa — A review. *Science of the Total Environment., v. 408*, p. 447-455.

Oguttu, H. B. (2008). Pollution menacing lake victoria: Quantification of point sources around Jinja Town,Uganda:. *Water Sa,, v. 34,* , p. 89-98.

Pease, L., Odour, P., & Padmanabhan, G. (2010). Estimating Sediment,nitrogen,and phosphorous loads from the pipestem creek watershed,north Dakota,Using AnnAGPS. *Comput.Geosci.UK*, 36,282-291.

Perierls, B., Caraco, N., Pace, M., & Cole, J. (1992). Human influence on river nitrogen. *Nature*, 350,386-387.

Rode, M., Arhonditsis, G., Balin, D., Kebede, T., Krysanova, V., van Griensven, A., et al. (2010). New challengs in integrated water qualitt modeling . *Hydrol.process.*, 24,3447-3461.

Seligman, N. H. (1981). A simulation model of annual pasture production limited by rainfall and nitrogen.Simulation. *PAPRAN*.

Setegn, S. S. (2009a). patial delineation of soil erosion vulnerability in the Lake Tana Basin, Ethiopia. *Hydrological Processes,Hydrol. Process*.

Shigaki, F. a. (2006). Animal-based agricultur,phosphorus management and water quality in Brazi:Options for the future. *Scientia Agricola*, 63:194-209.

Smith VH, T. G. (1999). Eutrophication:impacts of excess nutrient inputs on freshwater,marine,and terrestrial ecosystems. *Environmental pollution*, 100:179-196.

Solomon, H. (2005). GIS-Based Surface Runoff Modeling and Analysis of Contributing Factors; a Case study of the Nam Chun watershed, Thailand. *MSc Thesis, ITC, the Netherlands*.

Srinivasan, R. A. (1998). Hydrologic modeling of the United States with the soil and water assessment tool. *International Journal of Water Resources Development.*, 14,315-325.

Thompson SE, B. N. (2011;). Relative dominance of hydrologic versus biogeochemical factors on solute export across impact gradients. . .*Water Resources Re-search* , 47.

V.T.ChMow, D. a. (1988). "Applied Hydrology,". *McGraw-Hill,New York*.

Wang, G. a. (2012). A review on parameterization and uncertainty in modeling greenhouse. *Geoderma,*, 170, 206-216.

Wellen, C. K.-D.-R. (2015). : Evaluation of the Current State of Distributed Watershed Nutrient Water Quality Modeling. *Environmental science & technology,*, 49, 3278-3290.

APPENDIX

Appendix I. Observed data of Nutrients

4.1.1 The graphical presentation of measured Total nitrogen

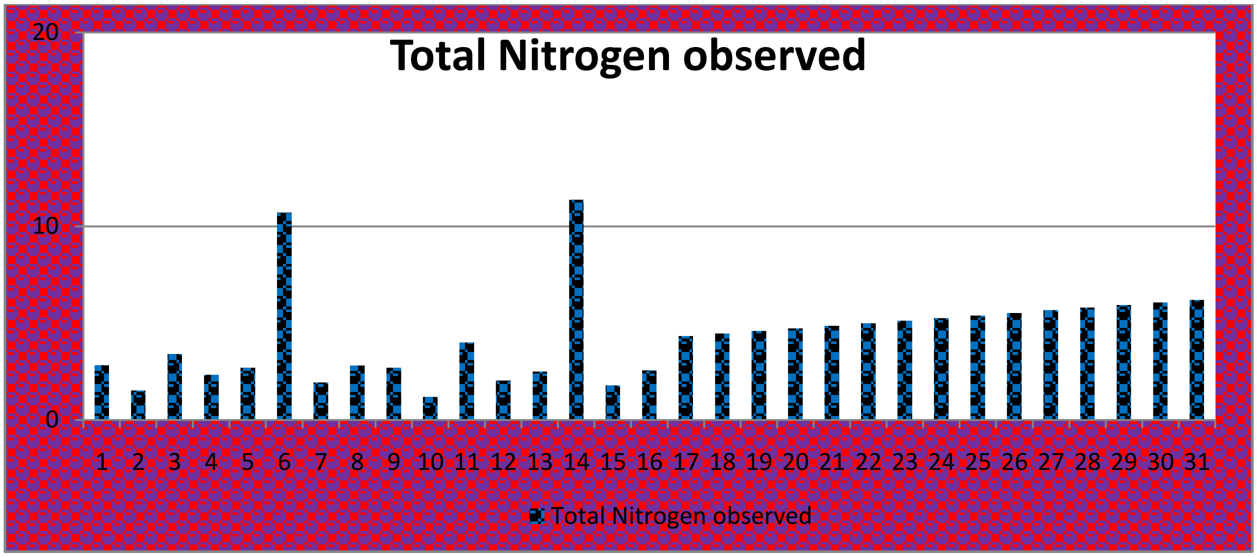
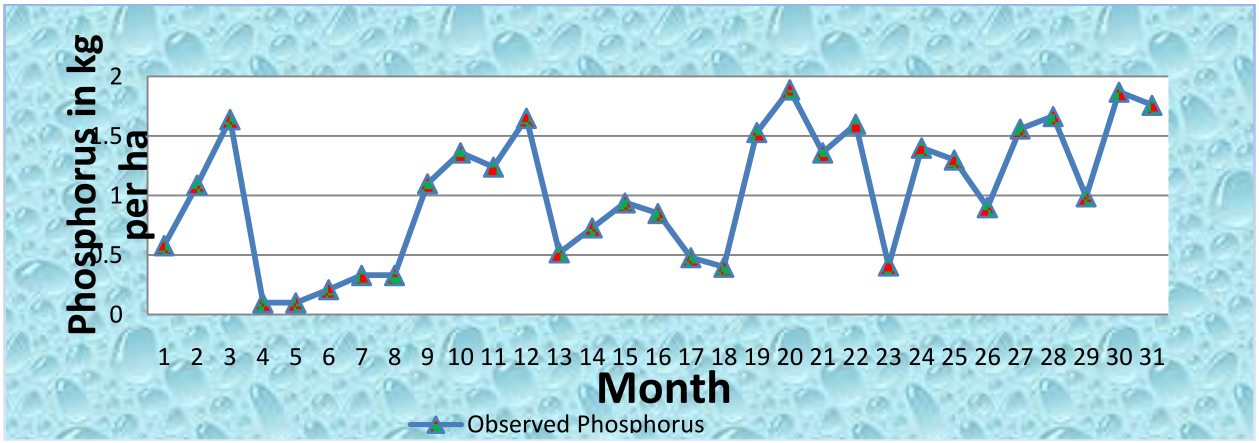
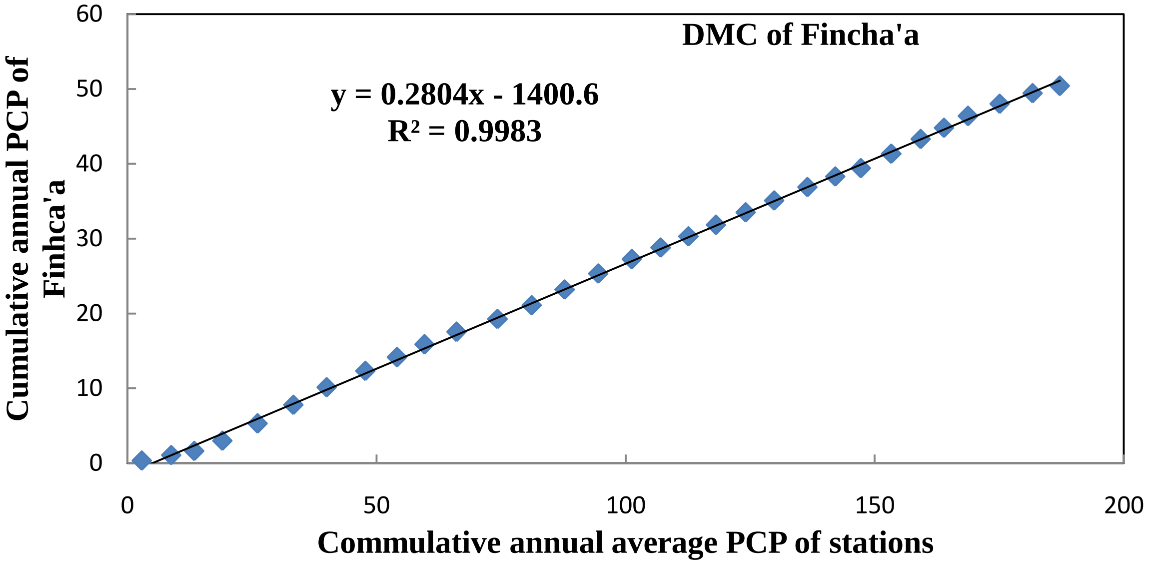
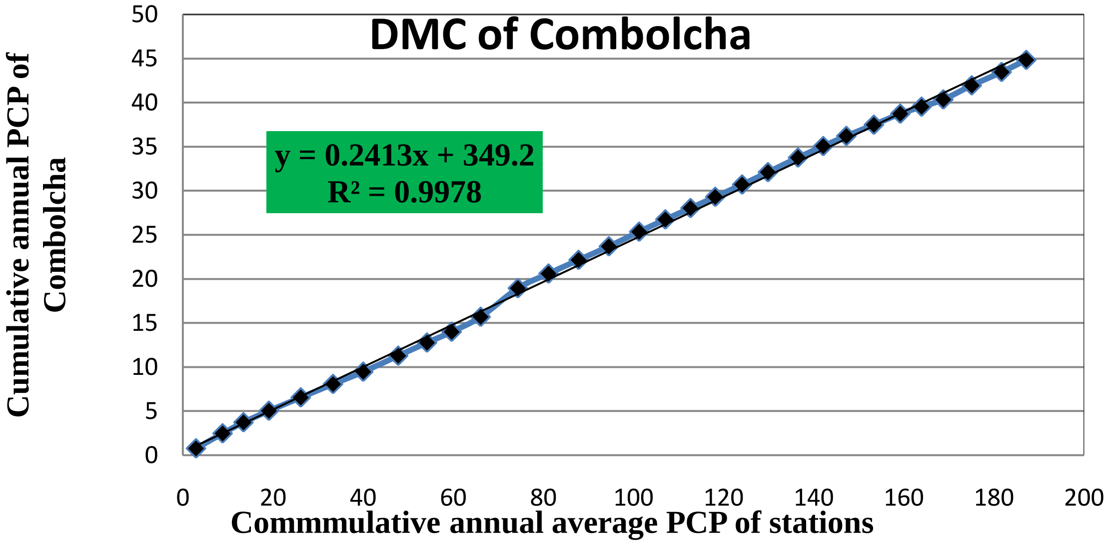


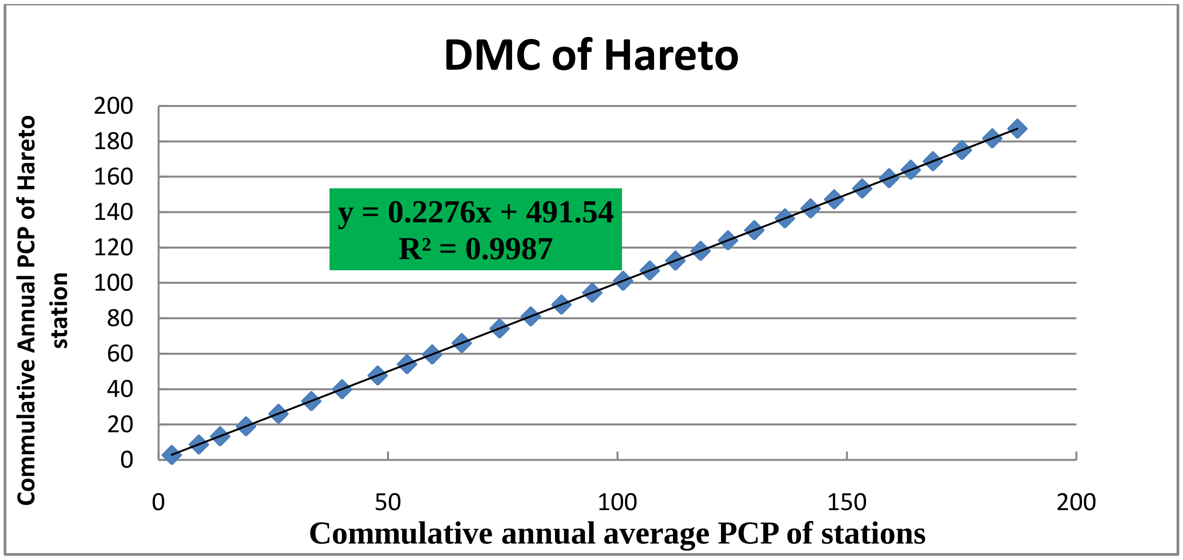
Fig:2, Total nitrogen observed at Fincha’a Dam

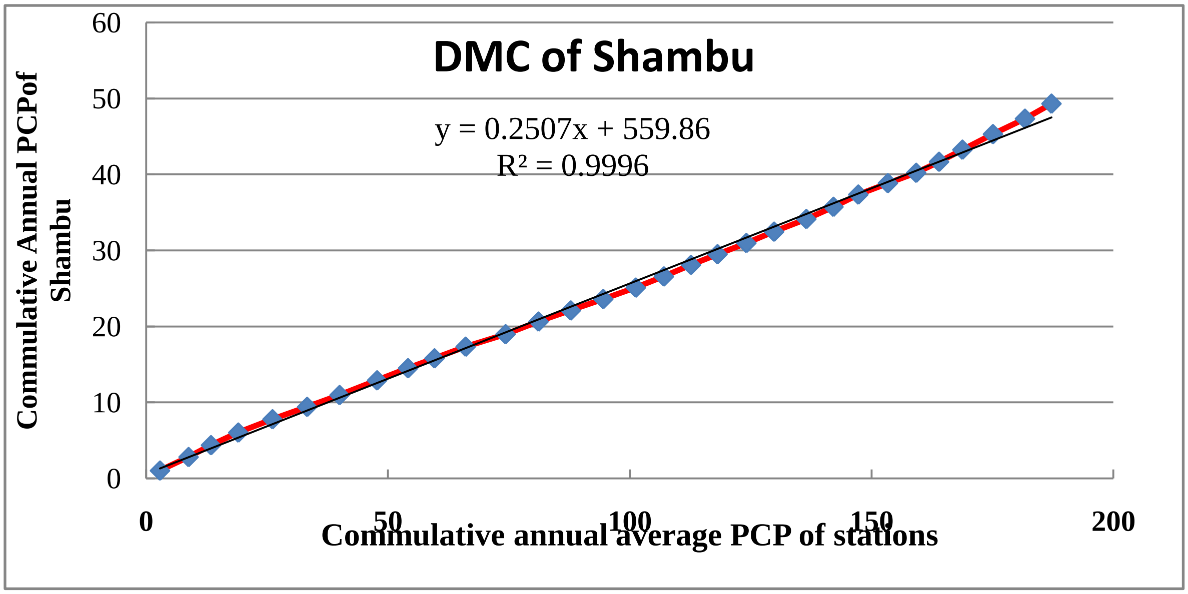


Appendix II.Consistency checking for each Rainfall stations.









Appendix III:

Weather Generator parameters (WGEN) used by the SWAT model,
Symbols and Statistical Analysis of Daily Precipitation and Solar radiation Data

(1986_2016) Input of Shambu 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

Month	PCP_MM	PCPSTD	PCPSKW	PR_W1	PR_W2	PCPD
Jan.	16.35	2.3678	7.8253	0.0754	0.4603	4.06
Feb.	20.35	3.4974	8.1541	0.098	0.3554	3.9
Mar.	40.82	4.056	4.2976	0.1277	0.5556	7.26
Apr.	65.81	6.0213	4.0311	0.1601	0.6177	9.45
May.	131.05	8.4538	3.0403	0.2376	0.7127	14.71
Jun.	186.36	8.7531	2.2259	0.3419	0.7958	19.9
Jul.	264.02	9.8933	1.6704	0.4751	0.8577	25.16
Aug.	311.44	11.2673	2.1437	0.7838	0.8682	27.42
Sep.	249.57	9.7358	2.0419	0.6423	0.8674	26.03
Oct.	172.84	9.1346	2.4969	0.2208	0.8108	18.58
Nov.	93.35	7.0617	3.087	0.1419	0.6871	10
Dec.	61.4	6.16	5.8234	0.0893	0.691	7.52

Appendix IV

```
This      file      has       been      generated      by            the          program   'dew02.exe'
Input     Filename  =         dew021.txt
Number    of        Years     =                   31
Number    of        Records   =                11320

Number    of        NoData    Values
tmp_max   =                0
tmp_min   =                1
hmd       =                1
```

Average Daily Dew Point Temperature for Period (1986 - 2016)

Month	tmp_max	tmp_min	hmd	dewpt
Jan	22.58	10.48	50.45	6.77
Feb	23.29	11.18	46.64	6.21
Mar	24.43	11.32	50.75	8.08
Apr	24.87	12.05	52.83	9.12
May	25.3	12.22	64.89	12.72
Jun	24.33	11.83	79.75	15.47
Jul	23.28	11.41	85.71	15.81
Aug	23.21	11.53	86.55	15.99
Sep	23.09	11.29	82.2	15.01
Oct	22.63	11.07	69.45	11.96
Nov	22.12	10.44	61.3	9.49
Dec	22.28	10.32	55.24	7.99

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