JIMMA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
JIMMA INSTITUTE OF TECHNOLOGY
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
DEPARTMENT OF WATER SUPPLY AND ENVIRONMENTAL ENGINEEERING
ENVIRONMENTAL ENGINEERING POST GRADUATE PROGRAM

Modeling of Nutrient Loading and Transport Pathways using SWAT model in Didessa Catchment, South-West Ethiopia

By

Adisu Befekadu Kebede

A thesis submitted to the School of Graduate Studies of Jimma University in Partial fulfillment of the requirements for the Degree of Masters of Science in Environmental Engineering

October, 2017

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Main advisor: Dr.-Ing. Fikadu Fufa (PhD)
Co-Advisor: Wakjira Takala (MSc)

October, 2017

Jimma, Ethiopia

Declaration

I, Adisu Befekadu, declare that the content of this thesis is entirely my original work with the exception of quotations or references which have been attributed to their sources or authors. This thesis has not been previously submitted to any other university for requirements of degree.

Adisu Befekadu Kebede ________________ ________________

Signature Date

APPROVAL SHEET

The undersigned certify that the thesis entitled: **“Modeling of Nutrient Loading and Transport Pathways using SWAT model in Didessa Catchment, South-West Ethiopia”** is the work of Adisu Befekadu and we here by 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. Fikadu Fufa (PhD) ______________ ______________
Main Advisor Signature Date

Wakjira Takala (MSc) ______________ ______________
Co-Advisor: Signature Date

As member of Board of Examiners of the MSc. Thesis Open Defence Examination, We certify that we have read, evaluated the thesis prepared by Adisu Befekadu 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.

Dr.Tasisa Kaba(PhD) ____________________ ______________
External Examiner Signature Date

Mr. Megersa Kebede (MSc) ____________________ ______________
Internal Examiner Signature Date
Mr. Fayera Gudu (MSc) ______________________ ______________
Chairperson Signature Date

Abstract

Pollution of surface water with harmful chemicals and eutrophication with excess nutrients are serious environmental concerns. Eutrophication is a problem that alters the ecological integrity of any water resources at global, regional and local scale including Ethiopia. It is resulted primarily due to phosphorus and nitrogen that exported and loaded from agricultural fields. This lends the need of knowing the nutrient loading and transport mechanism that will occur with spatial and temporal extent. Thus, effective information regarding the nutrient load and transport mechanisms are important to hydrologists, water use planners, watershed management and decision makers for sustainable water resource projects and planet ecosystem.

Consequently, this study was aimed at Modeling Phosphorus and Nitrogen loading and its transport pathways and to identify the prone sub basin that were responsible for a significant Phosphorus and Nitrogen load in Didessa catchment. Soil and Water Assessment Tool (SWAT) model was used to determine the nutrient loading and its transport pathways. The input data used were digital elevation model, land use/land cover map, soil map, stream flow data and metrological data. The data were obtained from Ministry of water, irrigation and electricity. Simulation of SWAT was used in identifying the most vulnerable sub basin to the hydrological process. The model was calibrated and validated using the Stream flow of Didessa near Arjo gaging station. Sensitivity analysis shows curve number, ALPHA-BNK and CH-K2 are the most sensitive top three parameters.

The model was calibrated using stream flow data from 2000 to2008 and validated from 2009 to 2014. The R^2 *and NSE values were used to examine model performance and the result indicates 0.84 and 0.80 to* R^2 *and 0.65 and 0.54 to NSE during calibration and validation respectively. Following this, the pathways of Phosphorus and Nitrogen were identified and found that the organic form of Phosphorus and Nitrogen was the dominant exporting mechanism in the study area and accounts around 58.89% and 82.26% of the total path. For the all forms of Phosphorus and Organic N, surface run off was the dominant means of transport agent. The three ways by which NO3 transport was found as surface run off, lateral flow and through percolation to ground water. The average annual surface run off contribution in study duration was found as 774.13 (mm). The average annual loading of total Phosphorus and total Nitrogen were identified as 20.01kg/h and 22.22kg/h in the study area during study period. The most three annual surface runoff contributing, sub basins are 11, 23 and 5 whereas sub basins 11, 3 and 5 contributes the highest sediment yield. The sub basin 17,23,3 and 16, 17, 22 were identified as the three highest loading of total P and total N respectively.*

Key Words: Didessa sub basin, Phosphorus and Nitrogen modeling, SWAT model, Transport pathway, Water quality

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Acronyms

AGNPS	Agricultural Non-Point Source model
BMPs	Best Management Practices
DEM	Digital Elevation Model
DMC	Double Mass Curve
DO	Dissolved Oxygen
ETB	Ethiopia Birr
GIS	Geographical Information System
GPS	Geographical Positioning System
GUI	Graphical User Interface
HRU	Hydrological Response Unit
LAT Q	Lateral Flow
LULC	Land Use Land Cover
MoWIE	Ministry of Water, Irrigation and Electricity
N	Nitrogen
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
P	Phosphorus
PBIAS	Percent Bias
RP	Reactive P
RPRD	Research Publication and research development
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
UP	Unreactive P
USEPA	U.S. Environmental Protection Agency

CHAPTER ONE
INTRODUCTION

1.1. Background

Water is an important resource for life. Entire living organisms on earth need water for life. Today, the quality of water becomes a major problem that needs serious attention. Good quality water has become an expensive item, because many water sources has been polluted by waste coming from the various human activities. This leads to declining quantity of water sources that could not meet the ever growing need.

Sustainable management of water resources throughout the world has been a raising demand recently (Tilman, 2007).To achieve goals of any water quality management, programmer must contain evaluation of pollution loads from various sources. Pollution of surface water with harmful chemicals and eutrophication of rivers and lakes with excess nutrients are serious environmental concerns. The U.S. Environmental Protection Agency (USEPA) estimated that 53% of the 27% assessed rivers and streams miles and 69% of the 45% assessed lakes, ponds, and reservoirs acreage in the nation are impaired (USEPA, 2010).According to United States Environmental Protection Agency (USEPA) it is reported that nutrient enrichment is the major cause for impairment of lakes and other water bodies in the United States (USEPA, 1994). The most common water pollution concerns in U.S. Rivers and streams are sediment, nutrients (Phosphorus and Nitrogen) and pathogens.

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 (Jembere *et al*., 2016). In its pathway through the soil-rock complex until reaching the river channel, the water carries everything that can be mobilized by its physical or chemical action, including the soluble and particulate products that result from interaction with the biota (Sioli, 1975). Among these products there are nitrogen and phosphorus compounds. Phosphorus (P) and Nitrogen(N) are an essential element for plant and animal growth and its input has long been recognized as necessary to maintain profitable crop and animal production. Phosphorus inputs can also increase the biological productivity of surface waters by accelerating eutrophication. Eutrophication is an accumulation of excessive nutrient mainly N, P in slow moving water resulting an excessive algal growth in receiving water bodies (Shalamu *et al*., 2012). This process can be greatly accelerated by human activities that increase nutrient loading rates to Water (Sharpley et al., 2003). Eutrophication restricts water use for fisheries, recreation, industry, and drinking because of increased growth of undesirable algae and aquatic weeds and the oxygen shortages caused by their death and decomposition.

Non-point source pollution from agricultural, forest, and urban lands can contribute to water Quality degradation. The impact of agricultural practices on water quality has received considerable attention during the last two decades, with a number of studies indicating agricultural chemicals to be one of the main sources of nonpoint source pollution (NPS) (Gilley and Risse, 2000; Harmel *et al*., 2004; Yu *et al*., 2004).

Intensive agricultural practices are identified to release significant amounts of nutrients, especially nitrogen (N) and phosphorus (P), fecal bacteria, and sediment to receiving water bodies (Gillingham and Thorold, 2000; Monaghan *et al*., 2005). For example, excess application of animal manure and inorganic fertilizers has been shown to increase nitrate nitrogen concentration in groundwater (Burkart and Stoner, 2002; Babiker *et al*., 2004), and excessive usage of poultry litter is linked to higher P concentration in runoff (Edwards and Daniel, 1992; USEPA 2000). In addition, sediment loss from top soil containing relatively large amounts of nutrients can threaten water quality and decrease the productive capacity of the land (USEPA, 2003).

The Didessa catchment is one of the major catchments that significantly contributes to the livelihoods of millions of people around south west Ethiopia area and cover a total area of 14887 km2. This catchment is critical national significance as it has great potentials for irrigation; high value crops and livestock production and others. It is therefore necessary to evaluate the existing trend and quality of surface water in time and space and its pollutant movement for proper planning in the near future.

Despite the fact that the Didessa sub-basin study area provides the largest amount of the Blue Nile River flows and the cultural agricultural practice in the catchment dominantly on going with using inorganic and organic fertilizer, most studies related to the Blue Nile River have focused on the northern part of the Blue Nile Basin. This makes the Didessa sub-basin is less studied areas, and a key to better understanding the overall hydrological regime of the Blue Nile. However, surface application of manures or direct transfer of P from broadcast manure to runoff is still not dealt with adequately in most models (Pierson *et al*., 2001; Sharpley *et al*., 2002).

Therefore, continuous physics-based distributed models are better suited for the accurate simulation of spatial and temporal patterns in surface runoff, sediment, chemicals, and nutrients and their associated transport pathways (Borah and Bera, 2003).

Total Maximum Daily Loads (TMDLs) are developed by states to improve water quality. The TMDL requires identifying and quantifying pollutant contributions from each source to devise source-specific pollutant reduction strategies to meet applicable water quality standards. A TMDL quantifies pollutant sources and maximum allowable loads to the contributing Point and nonpoint sources so that the water quality standards are attained to protect drinking water, aquatic life, and other water uses (USEPA, 1998).Once the necessary pollutant reduction levels are identified through establishment of TMDLs, control measures such as best management practices (BMPs) are to be implemented. Water quality simulation models can assist with TMDL development through simulating loads to receiving water bodies under various BMPs. Models in combination with observational data from historical and current monitoring programs will provide the information for TMDL waste/load allocations implementation strategies.

Commonly, water quality assessment at the watershed scale is accomplished using two techniques: (a) watershed monitoring and (b) watershed modeling. Hydro-ecological models have become very popular tools for assessing and managing water resources and nutrient transports at catchment scale in the last decade (Eugenio *et al*., 2017).Watershed models provide a tool for linking pollutants to the receiving streams. Models provide quick and cost-effective assessment of water quality conditions, as they can simulate hydrologic processes, which are affected by several factors including climate change, soils, and agricultural management practices.

There are a large number of predictive models in literatures capable of simulating several management practices ranged from simple lumped parameters to physically based complex models in varying temporal and spatial scales (Tilman, 2007). As a result of continuous water quality monitoring is extremely expensive, time consuming and spatially impractical at catchment level, mathematical modeling has become a primary technology for analyzing diffuse source pollution. Model would be used to assess pollutant loadings allowed to be discharged in to receiving water bodies when measured data are insufficient to picture pollution within water shade (Taffese *et al*., 2014).

The Soil and Water Assessment Tool (SWAT) model has been widely used worldwide in simulating hydrology and water quality at the watershed scale. There are many aspects that need to be fixed and enhanced to improve the accuracy of the model when it is applied to steep terrain watersheds (Jong *et al*., 2009).

However, nothing has done to model the pollutant loading and transport pathways in the Didessa catchment using SWAT model. Therefore, this research was shown the loading and transport pathways of phosphorus and nitrogen using SWAT model.

1.2. Problem of Statement

Pollution of surface water with harmful chemicals and eutrophication of rivers and lakes with excess nutrients are serious environmental concerns. Eutrophication is typically described as the phenomenon of (toxic) algal blooms in surface waters, leading to light and oxygen depletion in the water, fish kills, loss of biodiversity, and overall deterioration of water quality, due to excessive inflow of nutrients (Stevenson, 1986; Mourad, 2008).There is a knowledge gap with respect to the amount of nutrient loading and transport mechanism, and its effect on water quality in watershed on different temporal and spatial scale within the catchment. Many societies have experienced water shortage and quality degradation as a result of population growth, increased urbanization and industrialization, increased energy use, increased irrigation desertification global warming lead to eutrophication of the water resources (Singh and Woolhiser,2002).

The magnitude of pollutant loaded and transported mechanism within and from the watershed/catchment become a serious concern for planning, design and implementation of numerous national development projects in the area and the watershed management practice.

Also assessment of pollutant transport and loading in reservoirs, irrigation command and hydropower systems are considerable essential for land and water management; there is no published research that studies this issue in the Didessa catchment.

Furthermore excess nutrients, particularly nitrogen (N) and phosphorus (P) from agricultural land 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. This can create a number of water supply problems for communities depending on these fresh water bodies due to threats to public health when the affected water body is used for the communities' 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.

Despite the fact that the Didessa sub-basin study area provides the largest amount of the Blue Nile River flows and is comparatively well equipped with lengthy hydrological and meteorological data series, most studies related to the Blue Nile River have focused on the northern part of the Blue Nile Basin (Bizuneh, 2011). This makes the Didessa sub-basin is less studied areas, and a key to better understanding the overall Pollutant status in the regime of the Blue Nile. To properly understand environmental risks and manage nutrient pollution in these watersheds, it is necessary to have knowledge of the transport mechanism and loading quantity to the discharge points.

This approach justifies the inclusion of slopes, management practices and drainage area in methods to estimate the P and N transport easily in the catchment. Although few studies are undergoing on the catchment, previously no any study was done on the area in line with the objective at hand. Rapidly expanding of agricultural activities in the catchment will lead to more problems in future if it will not properly managed. Hence the outcome of this study will be base for other researcher to investigate related studies further in the future. Therefore, the main purpose of this study is to assess the P and N transport pathways and loading conditions in Didessa catchment using SWAT model as a tool.

1.3. Objective

1.3.1. General Objective

The Main objective of the study is to Model the phosphorus and Nitrogen loading and transport Pathway in the Didessa catchment using SWAT model.

1.3.2. Specific Objectives

- To check the simulating efficiency of the SWAT model.
- To identify the dominant phosphorus and nitrogen transport pathways.
- To quantify the amount of phosphorus and nitrogen load to the outlet of water resources and
- To identify the prone area responsible for high phosphorus and nitrogen load.

1.4. Research Questions

The main study questions that were centered to answer in the study were the following:

1. What is the simulating efficiency of the SWAT model?
2. Through which route P and N will be dominantly transported?
3. How much P and N will be loaded to the water resources in the study period?
4. Which areas will significantly responsible for higher P and N load?

1.5. Justifications of the Study

Ethiopia has embarked on extensive water resources development plan since few years back. Though the development activities encompass all major river basins of the country, the huge agricultural and hydroelectric power potentials in the Abay (Upper Blue Nile) Basin have attracted considerable attention (Tena *et al*., 2016). Hence, there are currently a number of water resources development projects in the construction and planning phases in Didessa Sub-basin of the Abbay Basin.

A nutrient-stressed situation in a watershed does not occur instantaneously; rather, it is a phenomenon which develops through time. It has been a common practice to evaluate nutrient problem after symptoms of water scarcity have begun to manifest themselves. It is, of course, very useful to make water quality analysis even after water quality deterioration has manifested itself, as it would lead to seeking a win–win situation among different water users (demand sites) in the watershed. However, assessing the overall water pollutant loading and the existing and planned demand centers in the basin ahead of time would help in limiting developments only to the carrying capacity of the resource, while considering the sustainability issues which need to address the right of the future generation to make their lives from the resource.

A sustainable agriculture requires a delicate balance between crop production, natural resources uses, environmental impacts, and economics. The goal of sustainable agriculture is to optimize food production while maintaining economic stability, minimizing the use of finite natural resources, and minimizing impacts upon environment. Still, an agricultural activity remains as a single greatest contributor of NPS pollutants to soil and water resources (Humenik *et al*., 1987; Kavlock *et al*., 1994).

Identifying the environmental impact of Non-Pont Source pollutant at a global, regional and localized scale is a key component to achieving sustainable agriculture. Assessment involves determination of changes of some constituents over time .This change can be measured in real time or predicted with a model. Real time Measurement reflect the activities of the past, whereas, model prediction are glimpses into the feature based upon the simplified set of assumptions.

However, the advantage of prediction is that it can be used to alter the occurrences of detrimental conditions before they develop. Predictive models provide the ability to get answers to what if questions. Due to expense and intensiveness of long-term field study to quantify Non-Pont Source 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 which is detrimentally impact either the agricultural productivity of the soil or 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. Significance of the study

Given that the effects of nutrient loading on water resources are the result of complex interactions between diverse site-specific factors and offsite conditions, standardized types of responses will rarely be adequate. Reductions in nutrients are needed to limit algae blooms that die and sink to the bottom of the bank of water bodies and consume oxygen, resulting in hypoxic zones where fish and shellfish cannot survive (Hirsch, 2012). Evaluating the environmental impact of NPS pollutant at a global, regional and local scale is a key component to achieving sustainable agriculture.

Currently, the government of Ethiopia is working different types of project to benefits the community as whole from water resource. Arjo-Didessa Irrigation project is one of the ongoing huge projects in the Didessa catchment. Such project should be sustainable environmentally and socially by compromising future generation. Pollutant transport from agricultural land and domestic waste can affect Water resource quality and quantity.

The provision of prognoses for the nutrient loading changes with spatial and temporal and their interaction with the hydrological process is getting a great issue for the future development, for risk assessment and decision making program. Hence, this study generally will contribute the following major significances:

1. Understanding the consequences of nutrient loading quantity and spatial variation is a vital component for sustainable water use development and planning for careful development of new option fertilizer application to the well-being of the community.
2. It has a special relevance for policy makers, natural resource managers, stake holders and decision makers as a pioneer and base line to provide direction for a management and decision process for catchment treatment and to develop appropriate water resource and land management regulation.
3. Likewise, through conservation of the resources the community will get goods and services from the watersheds on which they live, including water for personal consumption, irrigation and hydropower, recreation and tourism; and maintenance of biodiversity.
4. The existing and future water resources projects of the basin will be sustained as the result of nutrient loading and transport direction determination through provision of

best management system to the catchment. As Didessa is located on the upstream of number of tributaries, and will reach Renaissance Dam projects after long path, handling Didessa catchment will sustain the downstream projects.

5. The other importance of this study is to recommend the applicability of the model for prediction of P and N load after testing the model forecasting efficiency over the study area.
6. Additionally, to propose possible mitigation measures that should have to apply to control P and N load that loaded via major paths after the main route identification. Finally, to hypothesize the appropriate means of watershed management for all stakeholders to monitor the corresponding water resources effectively.
7. As baseline information which will serves the study area, Didessa-sub basin.

1.7. Scope of the Study

This study was geographically limited to Didessa sub- basin, situated in the south-western part of Ethiopia. Generally, the study has addressed issues related to the phosphorus and nitrogen loading and transport pathways that were assumed to take place in the Didessa catchment and the effect of these loading had on the hydrological process, but the best monitoring approach is not conducted.

1.8. Limitation

The challenges encountered in this study were lack of measured nutrient data to perform calibration and validation, which has its own impact on model prediction efficiency. Lack of up-to date gauged and recorded both spatial and temporal data, the availability and accessibility of quality data within scheduled study period was the main limitation of the study.

1.9. Dissemination of the Findings

The research will be presented for the post graduate studies of Jimma Institute of Technology, Faculty of Civil and Environmental Engineering, Environmental Engineering stream and would be publically defended in the presence of examiners. Up on the completion of the research presentation, the paper would be disseminated using internationally known Journals of Environmental Engineering related in country and continental level. In addition the findings would be presented to the community, stake holders, and managers, governmental and non-governmental organizations through different Workshops.

1.10. Overall study Structure

This thesis was categorized into 5 chapters. Chapter 1 focuses on the background of the study, statement of the problem, objective of the study, study question, justification of the study, significance of the study, scope of the study. Chapter 2 was dealt with the literature review. Chapter 3 would discuss methods followed and the material used to finalize the paper. Chapter 4 covers result and discussion. Chapter 5 main conclusion of the study finding and corresponding recommendation

CHAPTER TWO
LITERETURE REVIEW

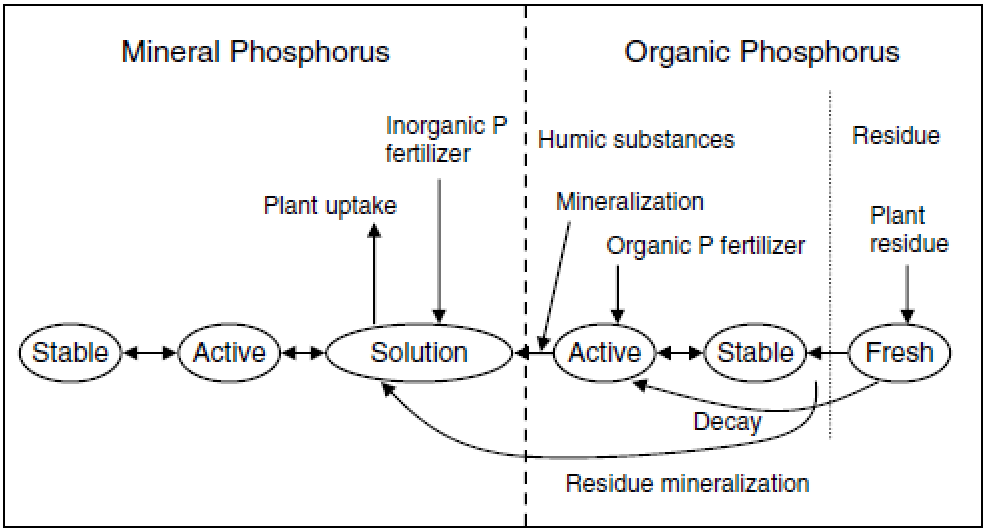
2.1. Introduction

This chapter reviews the various relevant literatures, which are related to this study. First the Phosphorus and Nitrogen pollution, impacts of phosphorus and Nitrogen pollution and Effect of Eutrophication are discussed. Then pollutant models with emphasis on soil and Water Assessment Tool (SWAT).

2.2. Phosphorus

Phosphorus (P) is a major nonpoint source of pollutant that causes Eutrophication in surface waters. It is also essential nutrient for life and is the 11th most abundant in the earth crust (Tewodros *et al*., 2014). Under normal water flow, roughly two third of the total phosphorus load to lakes and rivers comes from non-point sources such as runoff from pasture and crop lands, atmospheric deposition and stream bank erosion(Tewodros *et al*., 2014). However, phosphorous loading contributed from pasture, grazing and crop land is largest source of non-point phosphorous. Phosphorus has two main forms: dissolved (soluble) and particulate (attached to or a component of particulate matter).

Phosphorus can be added to the soil matrix in the form of inorganic P fertilizer, organic P fertilizer, and P present in plant residue. Soil P is divided into six pools. Three of the pools are characterized as mineral P, and three are characterized as organic P (Chaubey *et al*., 2006). Soil inorganic P is divided into solution, active, and stable pools. Transformations of soil P among these six pools are regulated by algorithms that represent mineralization, decomposition, and immobilization. The solution (labile) pool is considered to be in rapid equilibrium (days to weeks) with active pools that subsequently are considered to be in slow equilibrium with stable pools (Sharpley *et al*.,1984, Jones *et al*., 1984, Neitsch *et al*., 2009).



(Neitsch, 2009)

Figure 2.1: Various pools of P and their interactions in soil matrix

Initial amounts of soluble (labile) and organic P contained in humic substances for all soil layers can be either specified by the model user or designated with SWAT model default values. The model initially sets concentration of solution (labile) P in all layers to 5 mg P kg soil for unmanaged land under native vegetation and 25 mg P kg soil for cropland conditions (Neitsch *et al.*, 2001a).

The active mineral pool P (*A*ctive-mineral-pool) concentration (mg kg-1) is initialized as

$$Pactiv_{-mineral-_{pool}} = Psolution(1 - PAI/PAI)\ldots\ldots\ldots(2.1)$$

Where *P* solution is the amount of labile P (mg P kg–1) and *PAI* is the P availability index *PAI* is estimated using the method outlined by (Sharpley *et al.*, 1984).

The stable mineral pool P (*P* Stable-active mineral) concentration (mg P kg–1) is initialized as: $Pstable - mineral - pool = 4(Pactive - mineral - pool)\ldots\ldots\ldots\ldots$ (2.2)

Organic P concentration (*P* humic_organic) is calculated assuming an N to P ratio in Humic substance of 8 to 1 and is calculated as

$$Phuman - organic = 0.125(Nhuman - organic)\ldots\ldots\ldots\ldots\ldots (2.3)$$

Where N humic_organic is the concentration of humic organic nitrogen in the soil layer (mg kg-1). Phosphorus in the fresh organic pool is set to 0.03% of the initial amount of residue on the soil surface (kg ha-1).

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 temperature) and water factor (γ water) are two parameters regulating the impact of temperature and water availability on P mineralization and decomposition.

The amount of P present in active and stable organic pools associated with humus
is calculated as:

$$OrganicPactive = organicPhumus \left[\frac{organicNactive}{organicNactive + organic\ Nstable}\right] \ldots\ldots..2.4$$

$$Organic\ P\ stable = organic\ Phumus \left[\frac{organic\ Nstable}{organicN\ active + organic\ N\ stable}\right] \ldots\ldots.2.5$$

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 $_{\text{humus}}$ is the concentration of Humic organic P in the soil layer (kg P ha^{-1}), $Organic$ N $active$ is the amount of nitrogen in the active organic pool (kg N ha^{-1}), and $Organic$ 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.

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.

$$\mathrm{P_{mineral\_active}} = 1.4(\beta_{\mathrm{mineral}})(\gamma_{\mathrm{temp}}\,\gamma_{\mathrm{water}})^{0.5}(\mathrm{OrganicP_{active}}) \ldots\ldots\ldots (2.6)$$

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:

$$\mathrm{P_{mineral}} = 0.8\ (\delta_{\mathrm{ntr}})(\mathrm{Organic\ P_{fresh}}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.7)$$

$$\left(\mathrm{P_{decay}}\right) = 0.2\ (\delta_{\mathrm{ntr}})(\text{Organic } \mathrm{P_{fresh}}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.8)}$$

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:

$$\delta_{\mathrm{ntr}} = \beta_{\mathrm{residue}}\gamma_{\mathrm{ntr}}\left(\sqrt{\gamma_{\mathrm{temp}}\gamma_{\mathrm{water}}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.9)}$$

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

$$\gamma_{\mathrm{ntr}} = \mathrm{Min}\begin{cases} \exp\left(-0.693\left(\frac{\varepsilon_{\mathrm{C:N}} - 25}{25}\right)\right) \\ \exp\left(-0.693\left(\frac{\varepsilon_{\mathrm{C:P}} - 200}{200}\right)\right) \\ 1 \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.10)}$$

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:

$$\varepsilon_{\mathrm{C:N}} = \frac{0.58\ \mathrm{rsd}}{\text{Organic } \mathrm{N_{fresh+\ NO_3}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.11)}$$

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:

$$\varepsilon_{\mathrm{C:P}} = \left(\frac{0.58\ \mathrm{rsd}}{\text{Organic } \mathrm{P_{fresh}}\ + \mathrm{P_{Solution}}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2.12)}$$

2.2.1. 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 (Neitsch *et al.*, 2009).

$$P_{soluble/active} = P_{solution} - (\text{mineral})(P_{active})\left(\frac{PAI}{1-PAI}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (2.13)$$

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

$$P_{Soluble/active} = 0.1(\text{P soluble}) - \text{Mineral Pactive}\frac{PAI}{1-PAI} \ \ldots\ldots\ldots (2.14)$$

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

Where, P 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 (Neitsch *et al.*, 2009).

$$P_{active/stable} = \beta_{eqP}(4 \text{ mineral } P_{active} - \text{mineral } P_{satble}) \ldots\ldots\ldots \ \ldots\ldots\ldots (2.15)$$

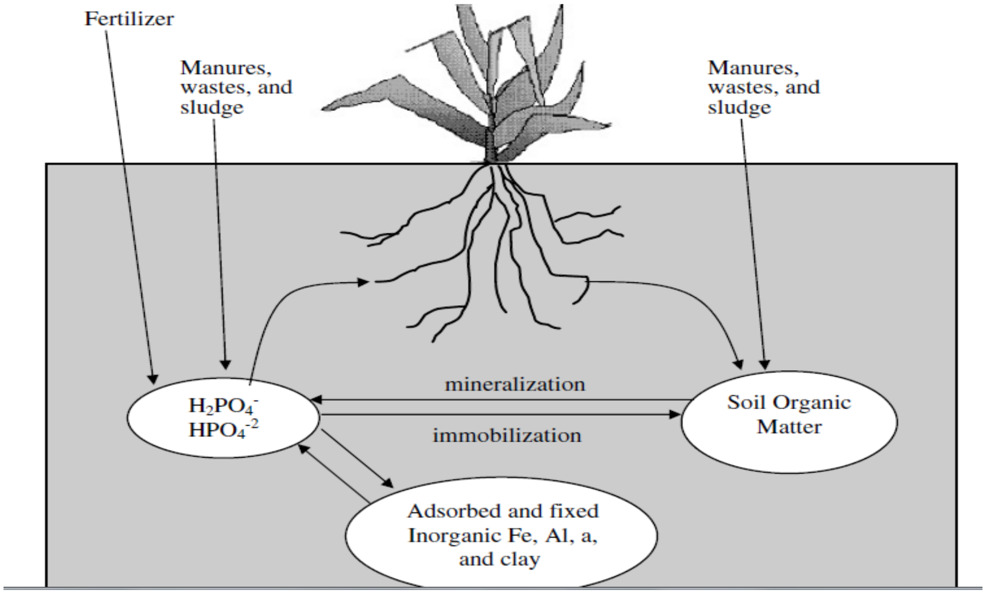
$$\text{If mineral } P_{stable} < 4 \text{ mineral } P_{active}$$

$$P_{active/stable} = (0.1\beta_{EQp})(4\text{mineral } P_{active} - \text{mineral } P_{satble}) \ldots \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.16)$$

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

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.

Among the natural sources, rocks of the drainage basin constitute the main phosphate source (Sioli, 1975). After the phosphate release, by the weathering of primary minerals of the rock, its distribution in the aquatic ecosystems occurs in the dissolved and particulate forms (Mash mango B. *et al.*, 2013). The more important artificial sources of phosphate are domestic and industrial sewers, detergents, agricultural fertilizers and particulate material of industrial origin, contained in the atmosphere.



(Neitsch *et al.*, 2009)

Figure 2.2: Phosphorus cycle process using SWAT model

2.2.2. Transport Mechanism of Phosphorus

2.2.2.1. Surface Transport of Phosphorus

Surface runoff is considered to be the main pathway for P losses (Sharpley *et al.* , 1994). In many agricultural catchments, leaching of P comes from a small part of the area during a few storm events (Pionke *et al.*, 1997) or during snowmelt.

Flat topography and the presence of preferential flow pathways in structured clay soils or light textured sandy soils with low P sorption capacity may also lead to increased P leaching losses (Djodjic and Bergstrom 2005a).Reactive P (RP) and unreactive P (UP) differ in mobility in the transport pathways; surface runoff, matrix and preferential subsurface drainage (Djodjic and Bergstrom, 2005b).

Unreactive P (UP) is mainly transported with surface runoff, whereas RP losses have been assumed to be associated with slow matrix flow (Djodjic and Bergstrom, 2005b). Unreactive P mainly consists of particulate P, but it may also include dissolved organic P and inorganic polyphosphates (Ron Vaz *et al*. 1993). Bioavailable P is mainly inorganic orthophosphates, but certain soluble organic P compounds may act as sources of plant available P (Wild and Oke, 1966) after enzymatic hydrolysis (Tarafdar and Classen, 1988).

2.2.2.2. Subsurface Transport of Phosphorus

In addition to the intrinsic soil phosphorus, the infiltration process assists in bringing more phosphorus material to the soil from the land surface. Normally soils with higher cracking potential are characterized by large crack volumes that accelerate the removal of water with the dissolved phosphorus from the surface to the lower soil horizons where it will join the lateral flow or tile flow and finally reach the surface water (Dils *et al*., 1996).

2.2.2.3. In-stream Transport of Phosphorus and Nitrogen

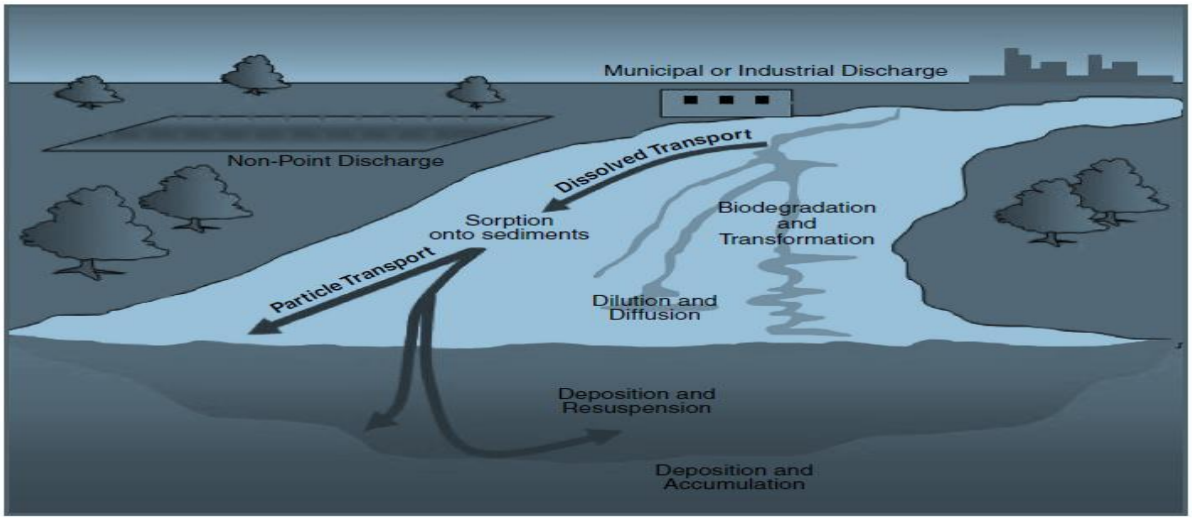
Phosphorus exists in a dissolved and particulate state within a stream system. Temporal and spatial changes of these two phosphorus forms in a river occur due to a combination of physical, chemical and biochemical. Therefore by examining the characteristics of water flow, sediment transport and chemical reactions occurring in a stream system, the movement of phosphorus a through a stream can be understood processes (Rauch *et al*., 1998).

2.3. 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. The nitrogen in our environment is almost entirely in the form of molecular nitrogen, which cannot be used by most organisms. This strong bond can only be broken under high-temperature processes or by a small number of specialized nitrogen fixing microbes (Galloway *et al*., 2003).

The main natural sources of nitrogen for the aquatic ecosystems are: rain, organic and inorganic material of allochthonous origin and fixation of molecular nitrogen (Wetzel, 2001). The human intervention in the nitrogen biogeochemical cycle occurs through three main paths: atmospheric emissions, mainly through the burning of fossil fuels, that come back to the ecosystems by precipitation; agricultural practices, with the use of nitrogen fertilizers, whose portion not assimilated by the cultures is leached for the groundwater, notably in the form of nitrate; release of domestic sewers and industrial effluents in the water bodies, without previous treatment (Odum, 1988). From the aquatic ecosystems point of view, the first two paths act as diffuse sources of nitrogen, while the last is characterized as a punctual source. Soil nitrogen (N) is simulated in the SWAT model and is partitioned into five N pools, with two being inorganic (ammonium-N [NH_4-N] and nitrate-N [NO_3-N]) and three being organic (active, stable, and fresh).

The SWAT model simulates movement between N pools, such as mineralization, decomposit ion and immobilization, nitrification, denitrification, and ammonia volatilization. Other soil N processes such as N fixation by legumes and NO_3-N movement in water are also included in the model. All soil N processes are simulated in the SWAT model using relationships described in the model's theoretical documentation (Neitsch *et a*l., 2001a).Once N enters channel flow, the SWAT model partitions N into four pools: organic N, NH_4-N, nitrite-N (NO_2-N), and NO_3-N. The SWAT model simulates changes in N that result in movement of N between pools. The algorithms used to describe N transformations in channel flow were adapted from the QUAL2E model by SWAT model developers (Neitsch *et al*., 2001a).



(Neitsch *et al*., 2009)

Figure 2.3: N and P Process in stream considered by SWAT model.

2.3.1 Transport Mechanism of Nitrogen

Nitrate load calculations indicate that the annual nitrate load is directly related to river flow. Thus in high rainfall seasons, more nitrate is transported into the river from the watershed than in low rainfall months. During dry seasons, nitrate tends to build up in soils, largely as a result of reduced plant uptake, and is washed into streams at larger rates during subsequent wet seasons (Goolsby *et al*. , 1999).

The mechanisms involved in soluble transport are straightforward, and include an initial desorption or dissolution bound by soil particles, followed by water movement from source soil to a stream or river that later intercepts a sensitive water body. The process takes place in the most upper layer, 2 cm, of the soil profile (Cample *et al*., 2001). The loss of nitrogen to surface and ground water resources has been cited as one of the major causes of water resources contamination on all continents (Vitousek *et al*., 1997).

2.4. Impact of Phosphorus and Nitrogen

Both natural processes, such as precipitation inputs, erosion, weathering of crustal materials, as well as the anthropogenic activities associated to agricultural, domestic and industrial activities can change the chemical characteristics of rivers (Malmqvist, 2002). Rivers are landscape integrating components and receive the whole load of transported material from the drainage basin in which they are inserted. The risk for future discharges of pollutants as a result of accidents and management changes must also be taken into account.

In its pathway through the Soil-rock complex until reaching the river channel, the water carries everything that can be mobilized by its physical or chemical action, including the soluble and particulate products that result from interaction with the biota (Sioli, 1975). Among these products there are nitrogen and phosphorus compounds. Phosphorus (P) and Nitrogen(N) are an essential element for plant and animal growth and its input has long been recognized as necessary to maintain profitable crop and animal production. Phosphorus and Nitrogen inputs can also increase the biological productivity of surface waters by accelerating Eutrophication. Eutrophication is an accumulation of excessive nutrient mainly N, P in slow moving water resulting an excessive algal growth in receiving water bodies (Shalamu *et al.*, 2012).

2.5. Effect of Eutrophication

However, human activities have resulted in excessive loading of phosphorus and Nitrogen into many freshwater. The dissolved phosphorus present in continental aquatic ecosystems has its origin in natural and artificial sources. Eutrophication is one of the most prevalent global problems of our era. It is a process by which water resources increasingly rich in plant biomass as a result of the enhanced input of plant nutrients mainly N and P. The adverse effects of the process is it increases in phytoplankton, production of harmful secondary metabolites, and total depletion of dissolved oxygen and alteration of the ecological integrity of freshwater resources (Beyene *et al*., 2009).

2.6. Watershed Management

Management of soil P and N (especially in high-input agricultural systems) has focused on issues like whether to apply fertilizer, at what rate, evaluating placement and residual effects, and comparing relative effectiveness of water-soluble versus insoluble sources. Models operating with a time-step of a growing season and an empirical relationship between yield and soil P status are adequate to gain insights into crop responsiveness to alternative fertilizer P sources and their residual effects (Probert, 1985).

In the last two decades, NPS (nonpoint source pollution) has become a topic for research that resulted in the development of numerous models and modeling techniques (Leon, *et al*., 2000). Most models simulate hydrologic, chemical and physical processes involved in the transport of sediment, nutrients and pesticides (Leon *et al.*, 2000, Dolan *et al*., 1981). The difficulty in modeling NPS is the problem of identifying sources and quantifying the loads. Moreover, sediment from agricultural land transports fertilizer which affects negatively the receiving water bodies such as lake and rivers are leading to serious Eutrophication problems.

The Agricultural Non-point Source model (AGNPS) is a non-point source pollution model developed by the US Department of Agriculture, Agricultural Research Service (Young, 1987). It calculates upland erosion, overland runoff volume, pollutants from point source inputs at each grid cell in the catchment and route to the next grid cell when the overland flow concentrated enough. The agricultural non-point source (AGNPS) model was tested and validated in Kori gauged-watershed, south Wello zone, Ethiopia (Mohammed *et al*., 2004).

2.7. Modeling approach

Models can be classified in to different categories. Empirical models developed from regression of observed data where as physical based models are developed based on the physics such as conservation of mass and momentum. Deterministic model provides same result for two equal sets of input data while stochastic model result in different output (Refsgaard, 1996). Lumped models consider a system as black box and everything is spatially averaged as a single system.

However, distributed models consider the heterogeneities by dividing the system in to smaller groups. For this study the program SWAT (Soil and Water Assessment Tool) is selected due to its continuous time scale, distributed spatial handling of parameters and integration of multiple processes such as climate, hydrology, nutrient and pesticide, erosion, land cover, management practices, channel processes, and processes in water bodies has an important tool for water shed scale studies. The Model is a basin-scale, continuous-time model and is designed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions.The model is physically based, computationally efficien t, and capable of continuous simulation over long time periods.(Arnold *et al*., 1998),(P. W.

Gassman *et al*., 2007). The model was applied for Nutrient impact assessment in different parts of the world. It is also readily and freely available model.

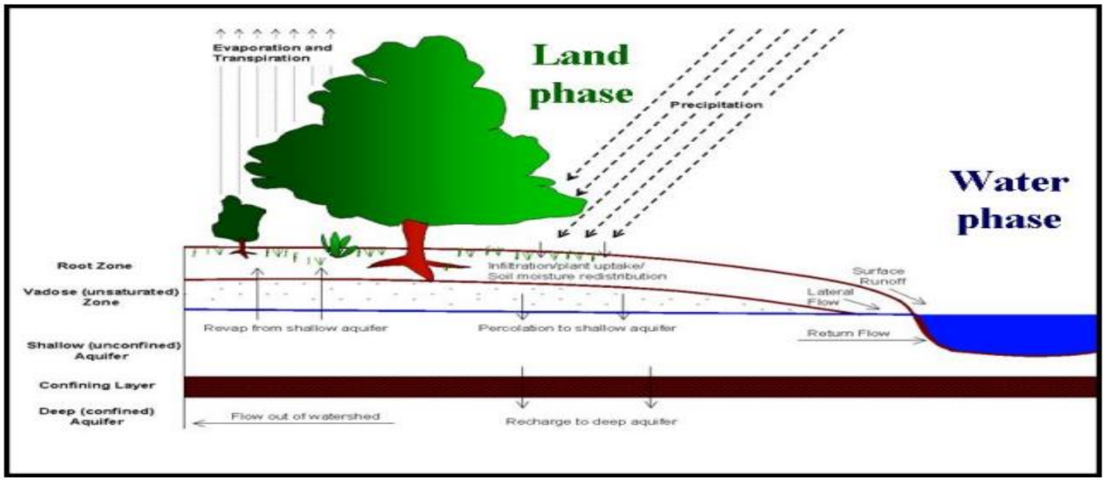
2.8. SWAT model description

Soil and Water Assessment Tool (SWAT) is a physical process based model developed by Dr. Jeff Arnold in Texas to simulate the process at catchment scale on daily time step (Neittsch *et al.,* 2005). Among semi-distributed hydrological models, SWAT model was originally developed for prediction of discharge from ungagged basins (Arnold *et al.* 1998). SWAT model with a spatial database has been successfully used to simulate flows, sediment, and nutrient loadings of a watershed (Rosenthal and Hoffman 1999). SWAT has been extensively used in many countries worldwide for discharge prediction as well as for soil and water conservation (Patel and Srivastava 2013).

The objective of SWAT model development was to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time. It divides a catchment or basin in to sub-basins by hydrological response unit (HRU) based on soil type, land use and management practice. Thus, dividing the basin into HRU will simulate the hydrological process in detail. SWAT simulates the hydrology of a watershed in to two phases, the land and water or routing phases of the hydrologic cycle. The land phase of the hydrologic cycle controls the amount of water, sediment, nutrient and pesticide loadings to the main channel. The routing phase of the hydrologic cycle defines the transport of water, sediment, nutrient and pesticide through the channel to the outlet of the sub basin.

The hydrological cycle simulated by SWAT is based on water balance as the driving force including precipitation, soil water content, surface runoff, evapotranspiration, water entering the vadose zone from the soil profile and return flow from groundwater. The HRU water balance is represented by four storage volumes; snow, soil profile, shallow aquifer and deep aquifer. Flow, sediment, nutrient and pesticide loadings from each HRU in a sub-basin are summed and routed through channels, ponds and/or reservoirs to the watershed outlet. The model supplies several options for calculation of surface runoff and evapotranspiration.

For this reason, SWAT is increasingly being used to support decisions about alternative water management policies in the areas of land use change, climate change, water re-arrangement, and pollution control. There are numerous applications of SWAT model all over the world,(Dhami and Pandey, 2013).



(Neitsch *et al*., 2009)

Figure 2.4: Hydrological cycle representation in SWAT Model.

The SWAT model soil erosion algorithm uses the Modified Universal Soil Loss Equation (MUSLE) equation to estimate the total amount of sediment delivered to the stream network within a watershed (Williams, 1975).

The SWAT model calculates sediment yield for each HRU and every single day with rainfall and runoff using the following MUSLE equation:

$$SYLD = 11.8 * (Qsurf * qp)0.56 * K * LS * C * P * CFRG$$

where SYLD is the sediment yield to the stream network in metric tons, Qsurf is the surface runoff volume in mm, qp is the peak flow rate in m3/s, K is the soil edibility factor which is a soil property available from the Soil Survey Geographic (SSURGO) data, LS is the slope length and gradient factor, C is the cover management factor and can be derived from land cover data, P is the erosion control practice factor which is a field specific value and CFRG is the coarse fragment factor. The SWAT model no longer uses a sediment delivery ratio to calculate sediment yield at the HRU level.

2.8.2. Phosphorus Simulation Processes in SWAT Model

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 *et al*., 2005a).

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). Plant use of phosphorus is estimated using the supply and demand approach. Losses of P in base flow and subsurface losses are considered in calculating total loads. The in-stream P transformation and routing processes of SWAT are taken from QUAL2E – The Enhanced Stream Water Quality Model (Brown and Barnwell, 1987).

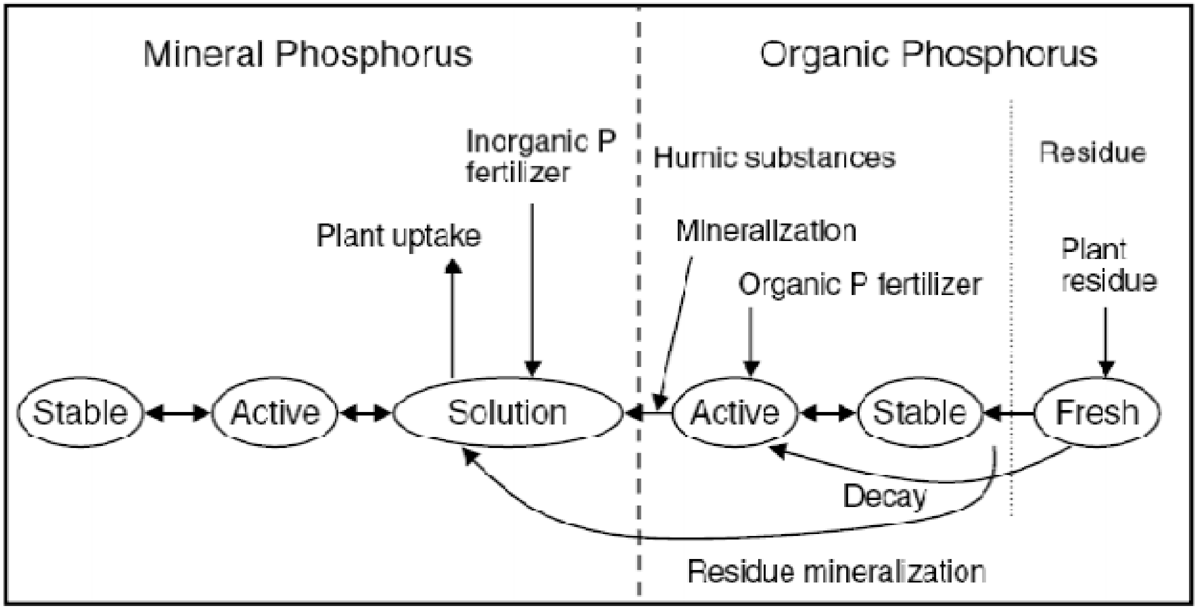


Figure 2.5: SWAT phosphorus pools and phosphorus cycle processes (Neitsch *et al*., 2009)

2.8.3. Nitrogen Simulation Processes in SWAT Model

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. Two inorganic (NH4+ and NO3−) and 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 (Neitsch *et al*., 2002; Neitsch *et al*., 2005).

The soil nitrogen content, both organic nitrogen and nitrate-N, in all soil layers needs to be defined by the user or estimated by the SWAT model for simulation of nitrogen. Nitrogen in the soil humus is divided into active and stable pools. SWAT describes nitrogen transport and loss processes by simulating nitrogen availability, transport, and attenuation processes using mechanistic functions. The model describes the spatial and temporal variations of sources and sinks within a watershed on a continuous time frame.

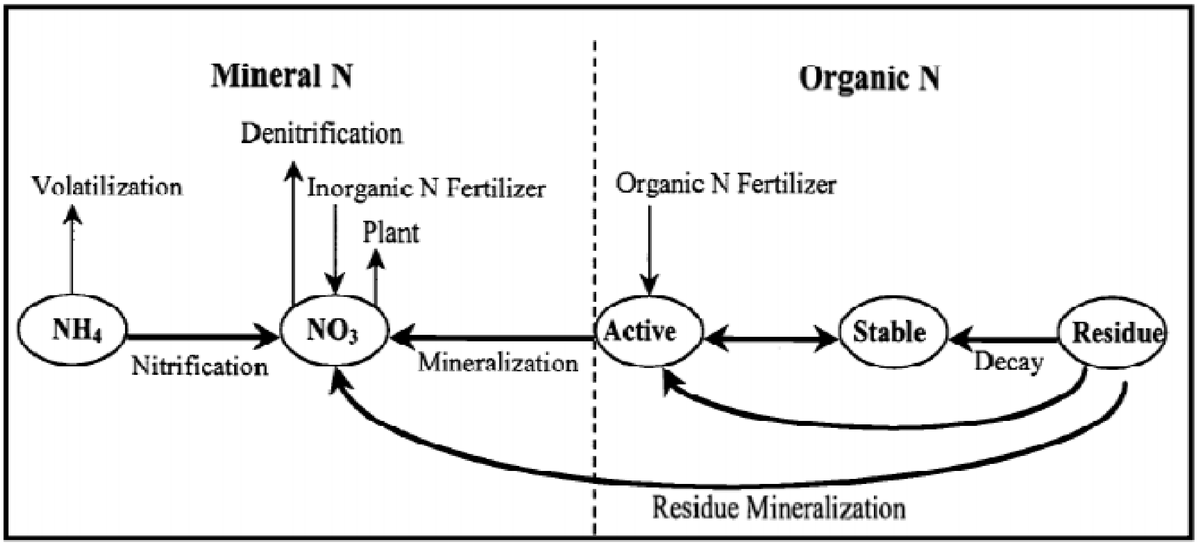


Figure 2.6: SWAT soil nitrogen processes (Source (Neitsch *et al*., 2005))

CHAPTER THREE

METHODS AND MATERIALS

3.1. Study Area

The study area is situated in Abay/Nile River basin to the south direction called as Didessa Sub-basin, which is situated in the south-western part of Ethiopia, in Oromia National Regional State. The drainage area lies under the four administrative zones of Oromia national regional state of Ethiopia Such as: Jimma Zones in the most upper and middle part, Buno Bedele Zone and East Wollega Zone in the middle part and WestWollega in the lower part down to its confluence to the Blue Nile River. It is geographically located between $35^0 48^{’}$14” and 37^0 03’57” East longitudes and between $7^0$42’06” and 9^0 12’29” North latitude (figure 3.1).

Drainage area coverage at the outlet of delineated watershed was nearly 14,867 km^2 and Didessa River has 363 km longest flow path. The topography or elevation of the watershed ranges from 1032m to 3169m above mean sea level. The majority of the area is characterized by a humid tropical climate with heavy rainfall and most of the total annual rainfall is received during one rainy season called kiremt. The maximum and minimum temperature varies between 21.1 – 36.50c and 7.9 -16.80c, respectively. The mean annual rainfall in the study area ranges between 1509 mm in the southern to 2322 mm in the northern catchments.

Didessa watershed Sub basin has a number of tributary that contributes its flow to Blue Nile River which made its flow volume the largest of other sub-basin to Nile River. The Wama, Dabana, Dabus, and Anger are some of the tributaries of Didessa River. The big irrigation project for sugar factory including the proposed dam is under construction in the catchment. The sub basin of the irrigation project is bordered by Omo-Gibe River basin on eastern side and Baro Akobo River basin on SW side. The total area of the catchment at the proposed dam is about 5,632.64 km^2.

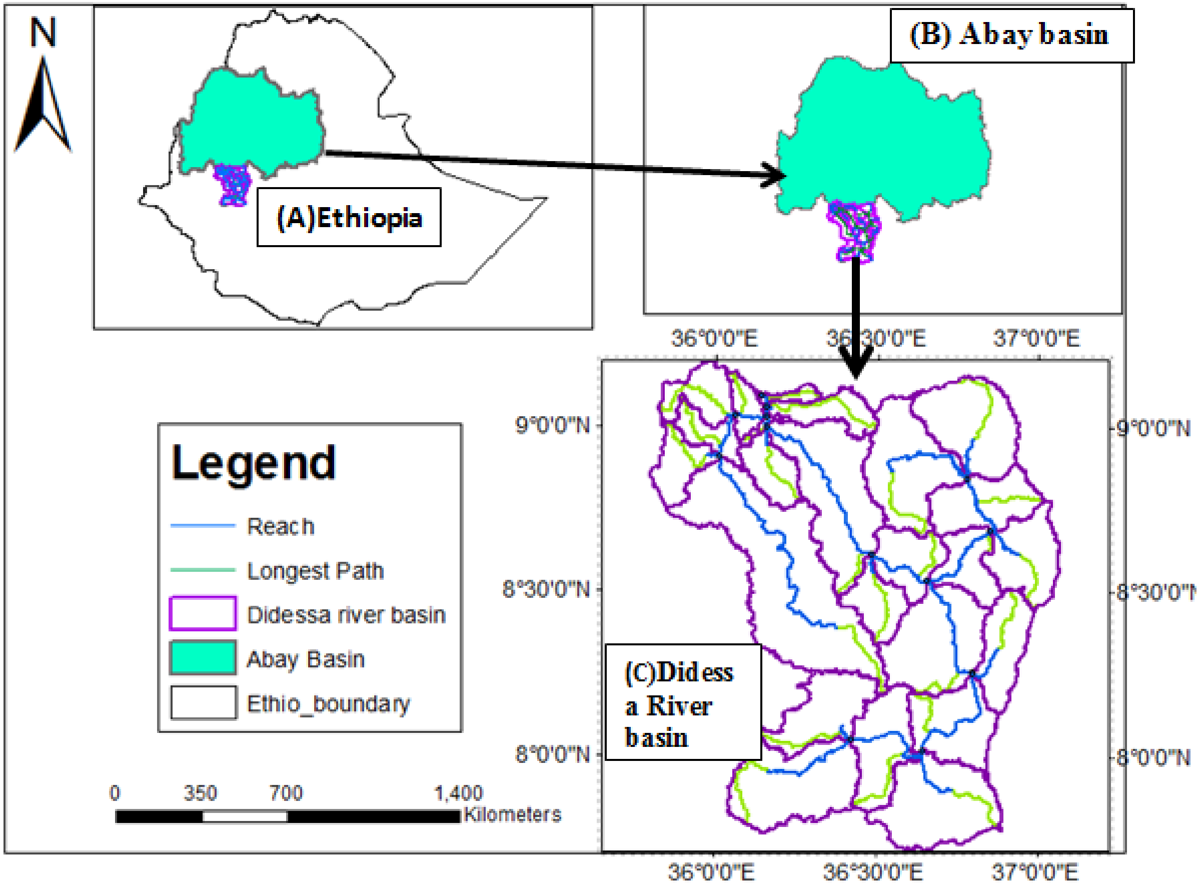


Figure 3.1 **:** Location of the Study area

3.2. Research design

The study was followed a kind desktop longitudinal research design type to answer the fundamental study questions and the defined objectives.

The methodology of this work has the following components:

Data collection, Data processing, Running model, Sensitivity Analysis, Calibration and validation of the model and Model result analysis. For this purpose SUFI-2 calibration and Uncertainty analysis algorithms were used. Finally, calibration, validation of stream flow and appropriate systems to check the performance of the model with observed data and analysis of nutrient loading and transport pathway was done relative to calibrated hydrologic processes. The overall methodology of the study was presented in figure 3.2.

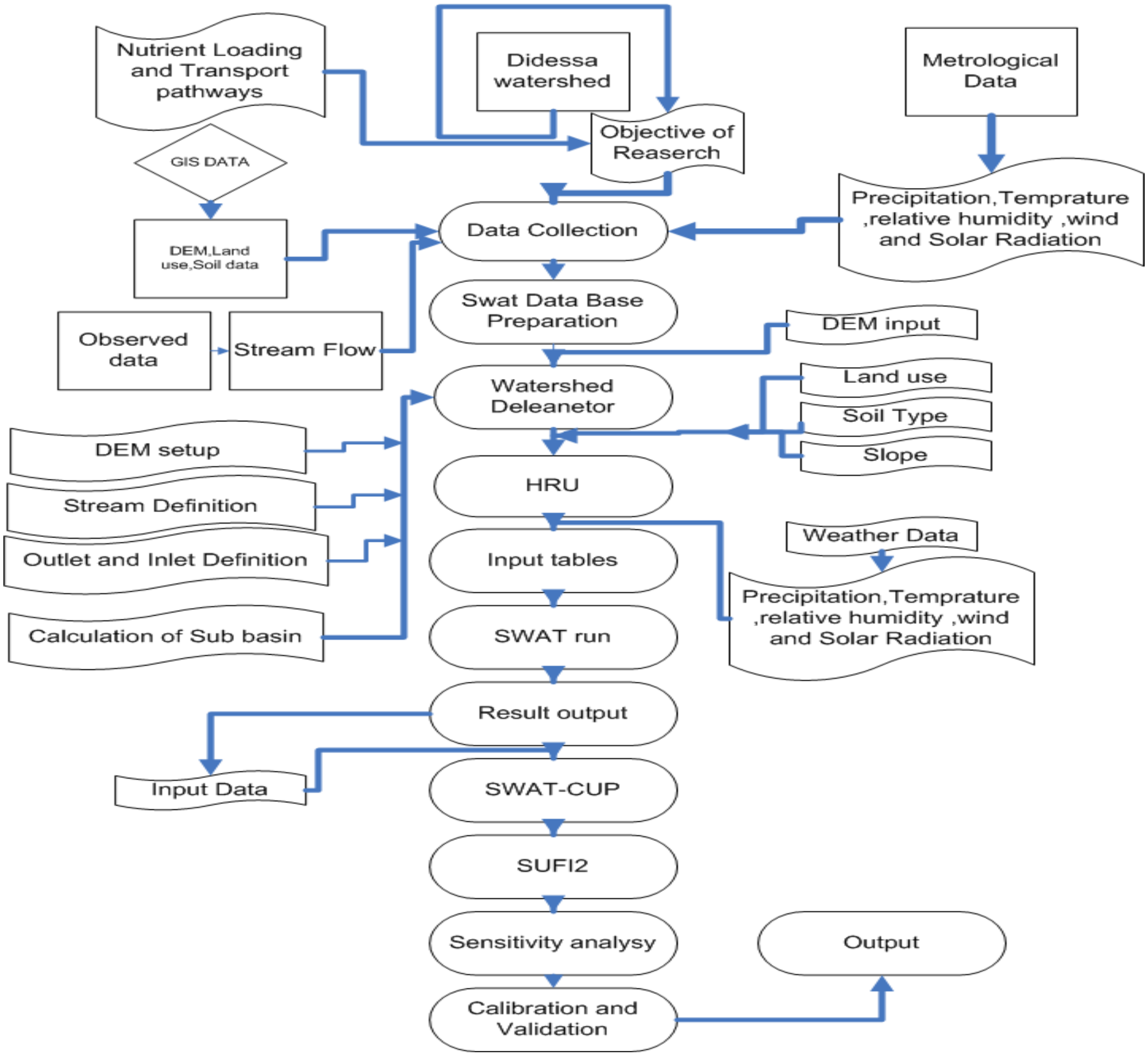


Figure 3.2: Flow chart of Arc SWAT processing steps

3.3. Materials

The main tools (materials) used for input data preparation, analysis are: ArcGIS, Arc SWAT 2012, SWAT CUP2012, PCPSTAT, Dew02.exe, Microsoft Excel, DEM, Meteorological, Hydrological map and data. ArcGIS was used for creating and using maps, managing geographic information in a database and execution of GIS processing tools (such as clipping, overlay, and spatial analysis). SWAT model was used for setting up the study project, delineating the study area, analyzing HRU, writing all input tables, editing inputs and simulating all inputs.

3.4. Data Type and Data source

A.Data Type

The major data types that are used in this study include climate/metrological, hydrology, soils, land use/land cover data, Nutrient data (Nitrogen and phosphorus) and Digital Elevation Model. The climate variables required are daily precipitation, maximum and minimum air temperature, solar radiation, wind speed and relative humidity.

The secondary data types such as temporal data which includes precipitation, temperature, wind speed, relative humidity, sunshine, and stream discharge and spatial data such as Digital Elevation Model, Soil, Land use/ Land cover are used.

B.Data Sources

The secondary data was collected from different sources. The temporal data (hydro-meteorological and stream discharge data was gathered from Ethiopia National Metrological agency/Meteorological Sub stations and from Ministry of Water, Irrigation and Electricity respectively. DEM data was gathered from Ministry of Water, Irrigation and Electricity, under GIS Department. The soil and Land data of the study area was taken from Ministry of Water, Irrigation and Electricity. The SWAT Input Data Types and their Corresponding Sources are summarized by in table (3.1).

Table 3.1: SWAT input data types and corresponding sources

Data Type	**Source**	**Scale/Period**	**Description**	**Remark**
Weather	National Meteorological Agency of Ethiopia	1990-2015	Daily precipitation, Maximum and minimum temperature, mean wind speed and relative humidity	Many of the Station have long period missing.
Hydrology	Ministry of Water, Irrigation and Electricity of Ethiopia	1990-2015	Daily and monthly flow data	Many of the station have long period Missing.
Land use/cover	Ministry of Water, Irrigation and Electricity of Ethiopia	1998	Land use classification map	

Data Type	Source	Scale/Period	Description	Remark
Soils	Ministry of Water, Irrigation and Electricity	1998	Soil classification map	
Terrain	Ministry of Water, Irrigation and Electricity	30mx30m resolution	Digital Elevation Model	
Nutrient	Partly from Abay basin nekemte branch And partly lab test		Nitrogen and phosphorus	

3.5. Data Collection procedure

The data required for model input was collected through field work (sample of raw water for nutrient test was collected from site daily for 30 days) and the secondary data needed for desk study which also include the temporal and spatial data was collected from the sources.

3.6. Model Input Data Preparation

3.6.1 .Metrological data

Meteorological data is needed by the SWAT model to simulate the hydrological conditions of the basin. The meteorological data which was gathered from previous source was organized, processed and arranged/transposed vertically to fit the model data requirement. The meteorological data collected were precipitation, maximum and minimum temperature, relative humidity, wind speed and sunshine hour's five stations (Nekemte, Bedele, Arjo, Agaro and Dembi) from the year 1990 -2014. Among the five conventional gauging stations, Nekemte and Bedele have been used as weather generator stations to fill missing data for the conventional meteorological stations. Location details of weather monitoring station were tabulated in table (3.2) and figured in figure (3.3).

Table 3.2: Location Details of the Weather Monitoring Stations

Weather Station	Coordinate			Remark
	Longitude	Latitude	Altitude	
Agaro	36.60	7.85	1666	
Arjo	36.50	8.75	2565	
Bedele	36.33	8.45	2011	Used as weather generator station
Dembi	36.45	8.07	1925	
Nekemt	36.46	9.08	2080	Used as weather generator station

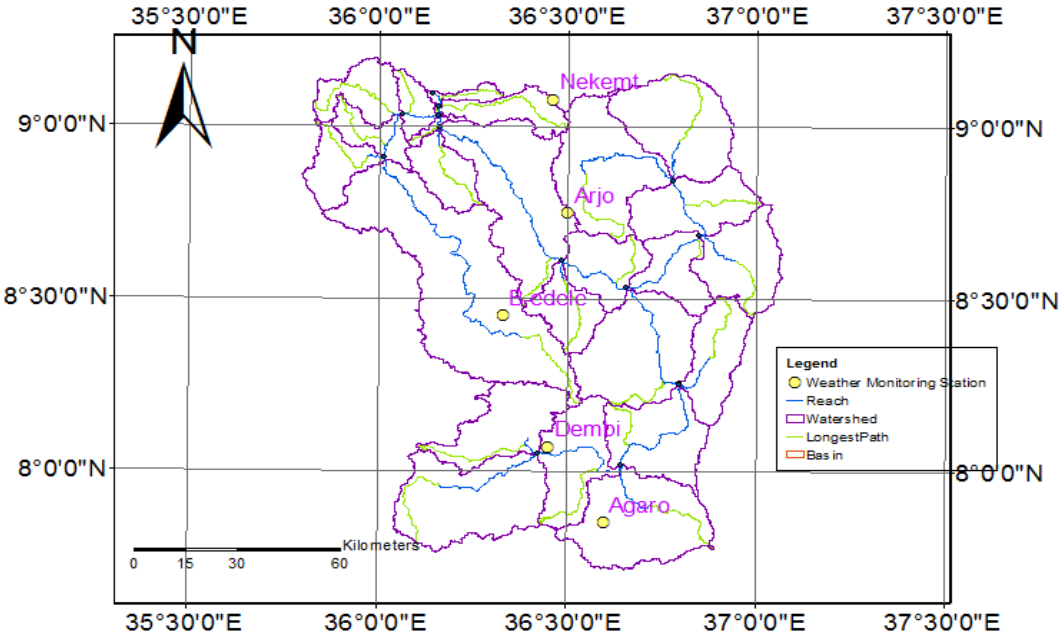


Figure 3.3: Location of Weather monitoring station in study area.

A. Filling Missing Data

Data were missing from a particular station (gauging site) or representative metrological datum are necessary at a point of interest. There are different methods for filling the missing data, statistically XLSTAT2015 tool were used for the rainfall and other metrological parameter in this study. Regression imputation, which substitutes the values using available observed data developing the corresponding regression equation to predict the missed value from nearest station were applied for filling data. Mean imputation which replaces missing values with arithmetic mean of available data for temperature were used by XLSTAT2015. Concerning the weather generator data file preparation, the dew point temperature and corresponding standard deviation of average daily maximum and minimum temperature and humidity data was prepared using dew02.exe and spreadsheet pivot table. Likewise, the solar and wind speed data was prepared using Excel pivot table and then added to user weather generator database. Finally the statistical parameter of daily precipitation data was prepared using the pcpSTAT and then added to weather generator data bases

The arc SWAT model requires a daily solar radiation but the data acquired from National Meteorological Agency was in sunshine hour which was measured in a three hour interval four times per day. Thus, the sunshine hours are cumulated per day and converted to the solar radiation using the empirical formula. The empirical equation according to angstrom (Allen, *et al.*, 1998) was used to estimate the daily solar radiation records for Nekemte and Bedele station. The angstrom formula relates the solar radiation with the extraterrestrial radiation and relative sunshine to be used for the SWAT model as given in equation 3.1.

$$RS = \left(A + B * \frac{n}{N}\right) * Ra \qquad 3.1$$

Whereas: $a -$ is a regression constant, expressing the fraction of extraterrestrial (Ra) radiation reaching the earths on overcast days (n=0) and a+b fraction of extraterrestrial radiation reaching the earth on clear days (N+n).

In order to use the above equation, the coefficient has to be determined first. This requires a linear transformation of equation 3.1 with the parameter a representing y-intercept and b representing the gradient.

$$\frac{Rs}{RA} = a + b * n/N \qquad 3.2$$

B. Consistency

Visual observation and Double mass curve (DMC) was used to check the consistency for adjustment of inconsistent data. This technique is based on the principle that when each recorded data comes from the same parent sample, they are consistent. A group of five base stations in the neighborhood of the station was selected.

A double-mass curve is a graph of the cumulative catch at the rain gage of interest versus the Cumulative catch of one or more gauges in the region that has been subjected to similar hydro meteorological occurrences and is known to be consistent (Gebrie, 2016). Accordingly the double-mass curve of selected station Rainfall was drawn to check consistency of the

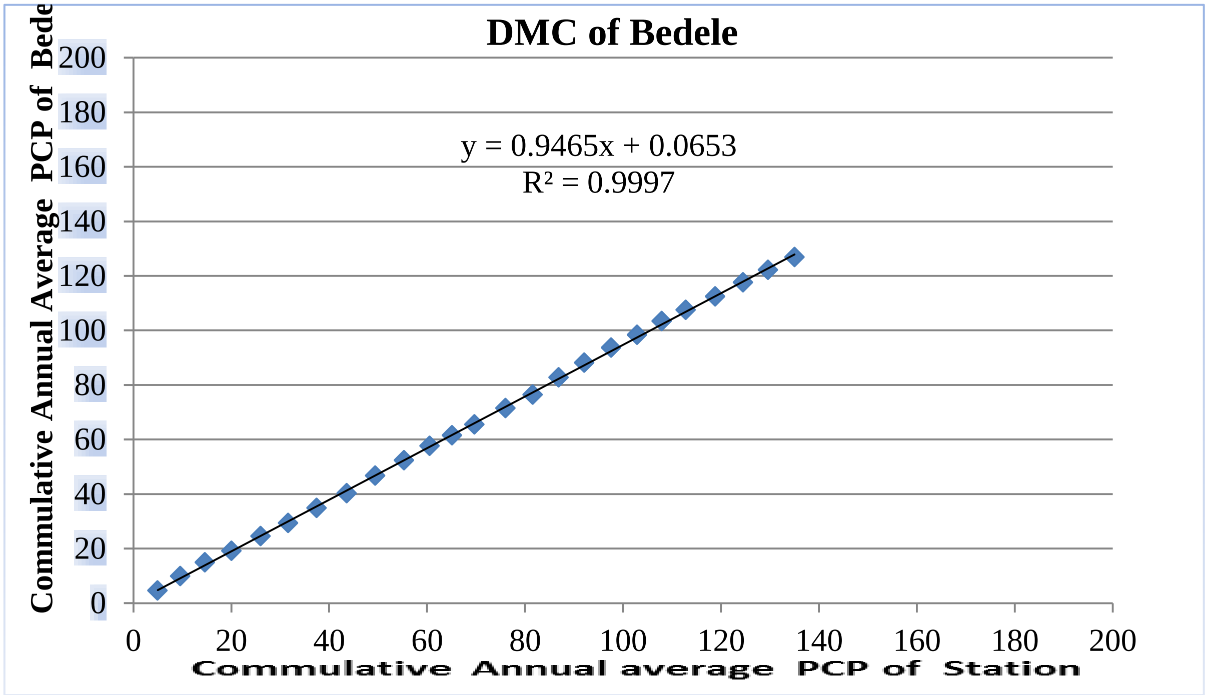


Figure 3.4: DMC of Bedele rainfall station

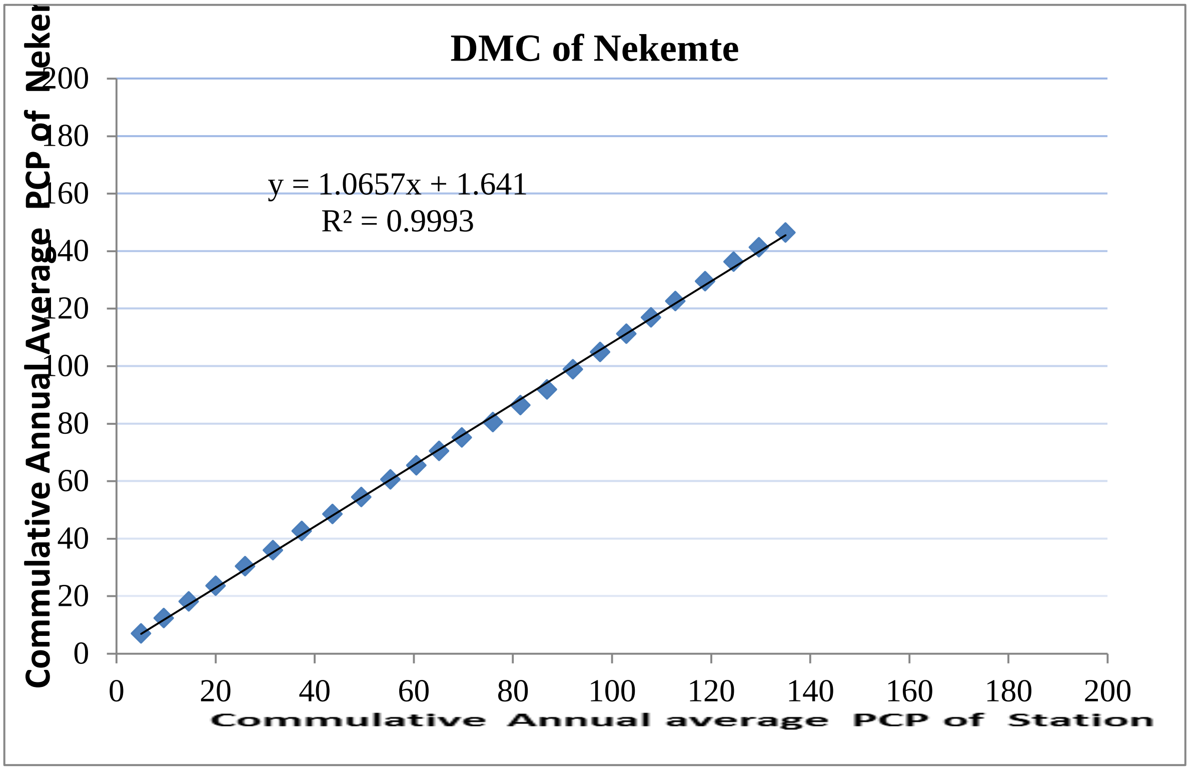


Figure 3.5: DMC of Nekemt rainfall station

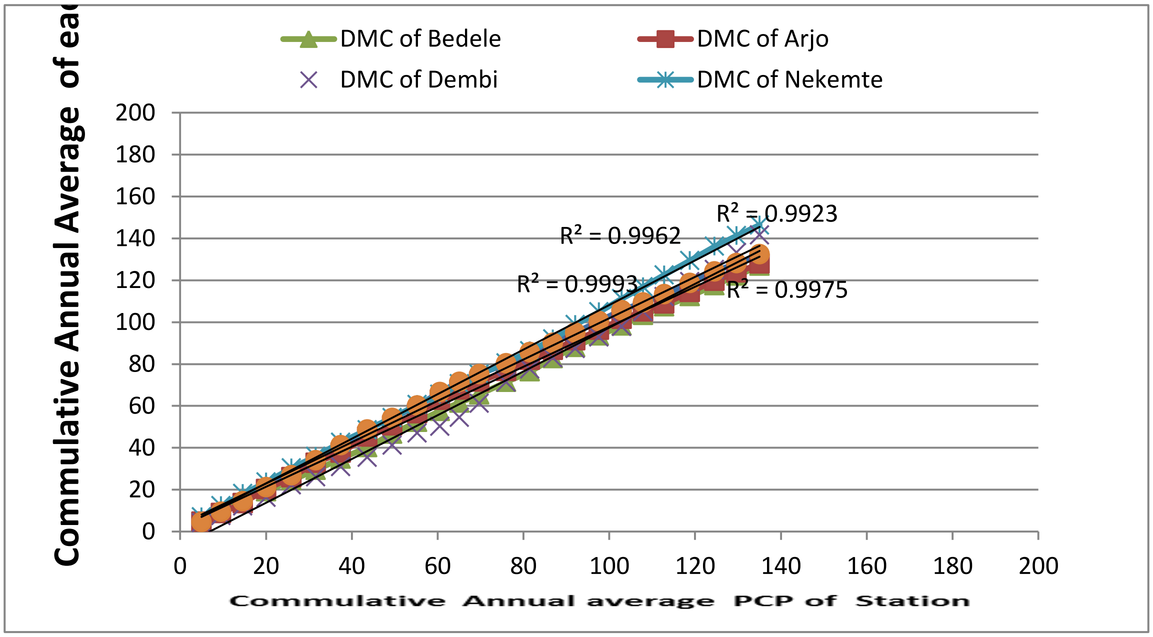


Figure 3.6: Consistency checking for the five rainfall stations

3.6.2. Hydrological Data

The stream flow data of the Didessa watershed was required for calibrating and validating the model. Therefore, daily and Monthly stream flow data at different gauging stations in Didessa Sub-basin (1990-2014) were collected from the Hydrology Department of Ministry of Water, Irrigation and Electricity of Ethiopia. Most of the stations have short records and/or many missing data, which hinders the use of these stations for model calibration. Hence, a flow monitoring station called Didessa near Arjo, with relatively long period of recorded data has been used for model calibration and validation.

Table 3.3: Geographical Location of Didessa near Arjo Gauging Station

Flow Gaging Station	Coordinate		Catchment Area(km2)	Sub-basin number
	Longitude	Latitude		
Didessa near Arjo	$36^{0}25'0''$ E	$8^{0}41'0''$ N	14867	13

Specifically the location was found in sub basin 13 of watershed of Didessa Sub-basin across the river near Bedele to Arjo Bridge.

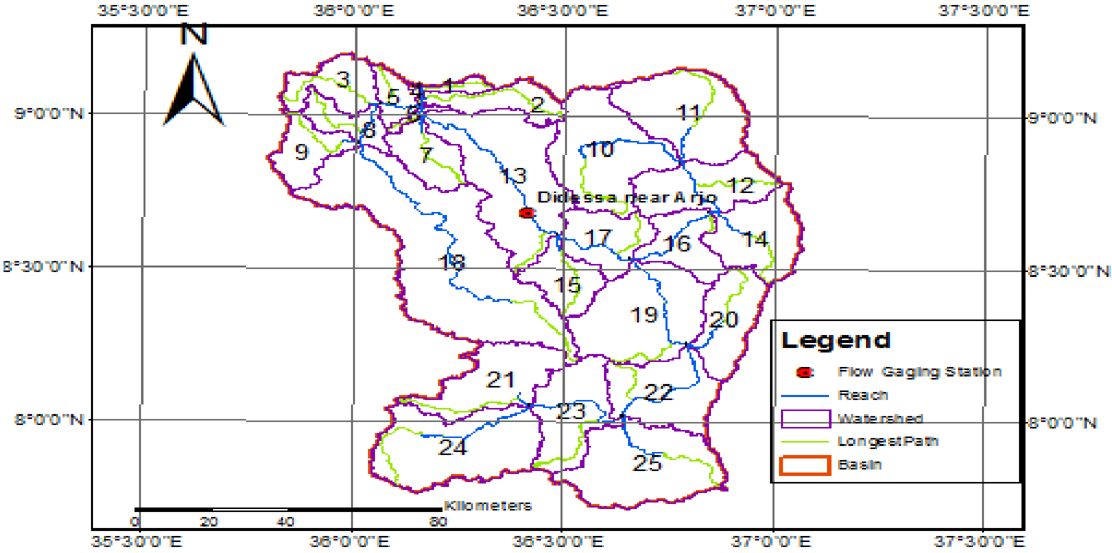


Figure3.7: Flow gaging station and Delineated watershed of study area

3.6.3. Digital Elevation Model (DEM)

The topography is defined by DEM, which describes the elevation of any point in a given area at a specific spatial resolution, which is used for watershed delineation. A Digital Elevation Model of 30 m by 30m, in the Grid format and projected was used in this study and the original DEM in geographic coordinate system was obtained from Ethiopian Ministry of water, Irrigation and Electricity, Under GIS Department. The minimum and maximum elevation of the Study area above mean sea level was between 1032m and 3169m respectively with mean of 2101msal.

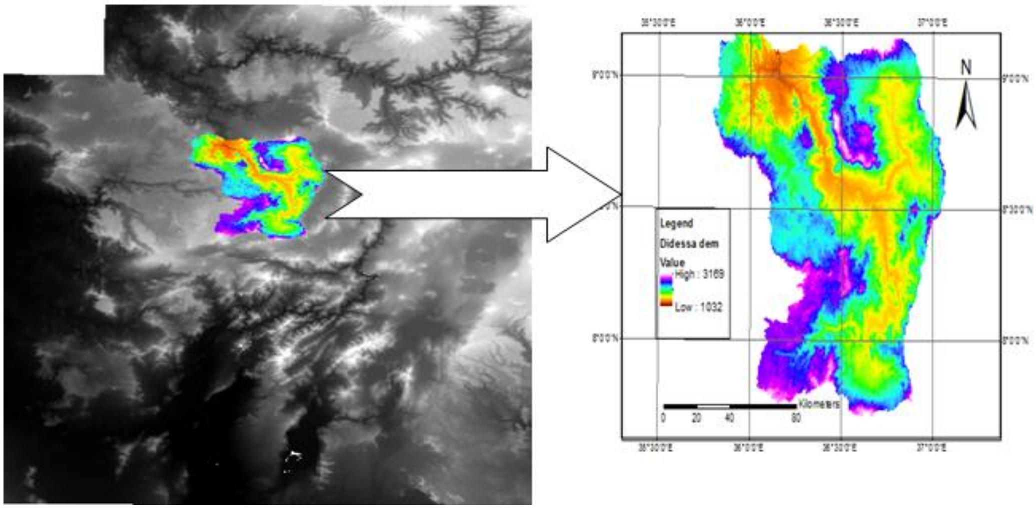


Figure 3.8: Elevation Map of Didessa Sub basin

3.6.4. Land Use/Land Cover

The land use land cover map gives the spatial extent and classification of the various land use land cover classes of the study area. The LULC data combined with the soil cover data generates the hydrologic characteristics of the basin or for the study area, which in turn determines the excess amounts of precipitation, recharge to the ground water system and the storage in the soil layers. The land use shape file (see Figure 3.9) has been collected from Ministry of Water, Irrigation and Electricity of Ethiopia.

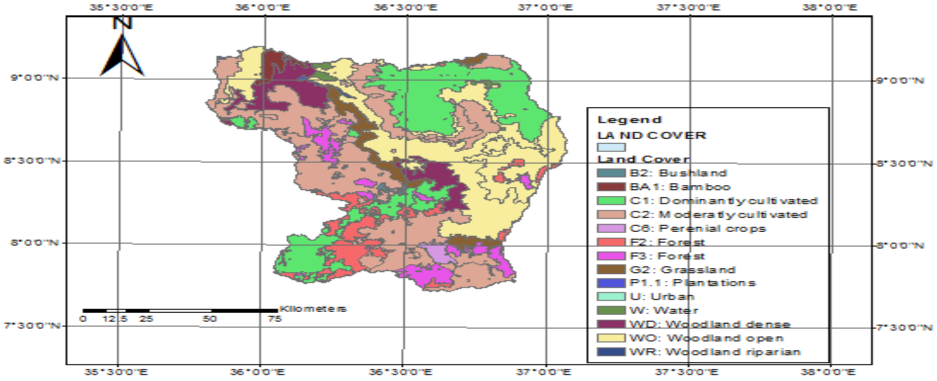


Figure 3.9: Original land use of Didessa from MoWIE

Didessa Sub-basin is predominantly covered with moderately cultivated land cover, followed by open Woodland and Dominantly cultivated practices. The central and southern parts of the basin are predominantly cultivated.

SWAT model needs some adjustments of land data to process and generate HRUs.However, there are some differences between SWAT data base and land use/land cover shape file, and some adjustments of the data prior to use in SWAT had to be done. So, accordingly land use adjustment was done to fit SWAT data base and 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 runoff, sediment load and Nutrient Load in the basin.The major land uses of the study area are presented in table 3.4.Original land use /land cover types and redefined according to the SWAT code and their aerial coverage are shown in table (3.4).

Table 3.4: Original land use/land covers types and redefined according to the SWAT code and their percentage coverage.

S.N	Original land use	Redefined land use according to SWAT database	SWAT code	Area %coverage
1	Bush Land	Range-Brush	RNGB	0.37
2	Bamboo	Cassava	CASS	1.16
3	Dominantly Cultivated	Agricultural Land-Generic	AGRL	20.28
4	Moderately cultivated	Agricultural Land-Row Crops	AGRR	29.80
5	Perennial crops	Corn	CORN	0.84
6	Forest	Forest-Mixed	FRSTE	11.49
7	Grass Land	Range-Grasses	RNGE	3.74
8	Plantations	Forest-Evergreen	FRSE	0.08
9	Water Bodies	Water	WATR	0.63
10	Urban	Residential	URBN	0.15
11	Woodland dense	Wetlands-Mixed	WETL	6.71
12	Woodland open	Wetlands-Forested	WETF	24.60
13	Woodland Riparian	Wetlands-Non-Forested	WETN	0.16

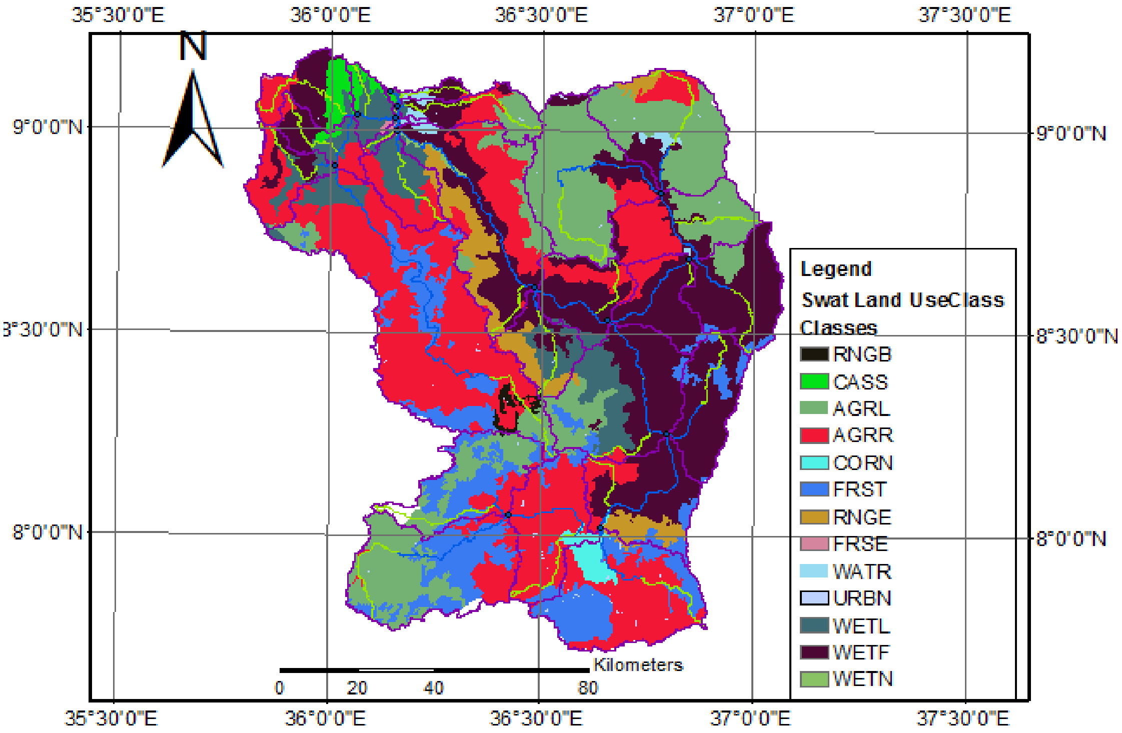


Figure 3.10: SWAT Land use of Didessa Sub-basin

3.6.5. Soil types

Soil data is one of the inputs that the SWAT model needs in modeling the watersheds. SWAT requires soil properties and land use land cover information to simulate loads in the hydrological components. The soil data have been collected in shape file format from the GIS department of the Ministry of water, Irrigation and Electricity of Ethiopia.

According to the data obtained from MOWIE soil classes in Didessa basin, ten soil types were identified. From these classes, Dystric Nitosols are the dominant soil types followed by dystric combisols and Eutric nitosols as shown in figure (3.11). Before integrating these soils into SWAT data base, soil was prepared to fit swat data base.

Table 3.5: Didessa basin soil class with their respective percentage coverage

S.N	Soil Types	%coverage
1	Chromic Vertisols	1.10
2	Dystric Combisols	11.70
3	Dystric Nitisols	66.83
4	Eutric Combisols	0.00
5	Eutric Fluvosols	1.64
6	Eutric Nitosols	5.37
7	Haplic Alisols	3.56
8	Dystric Leptosols	0.85
9	Haplic Arisols	5.31
10	Eutric Vertisols	3.64

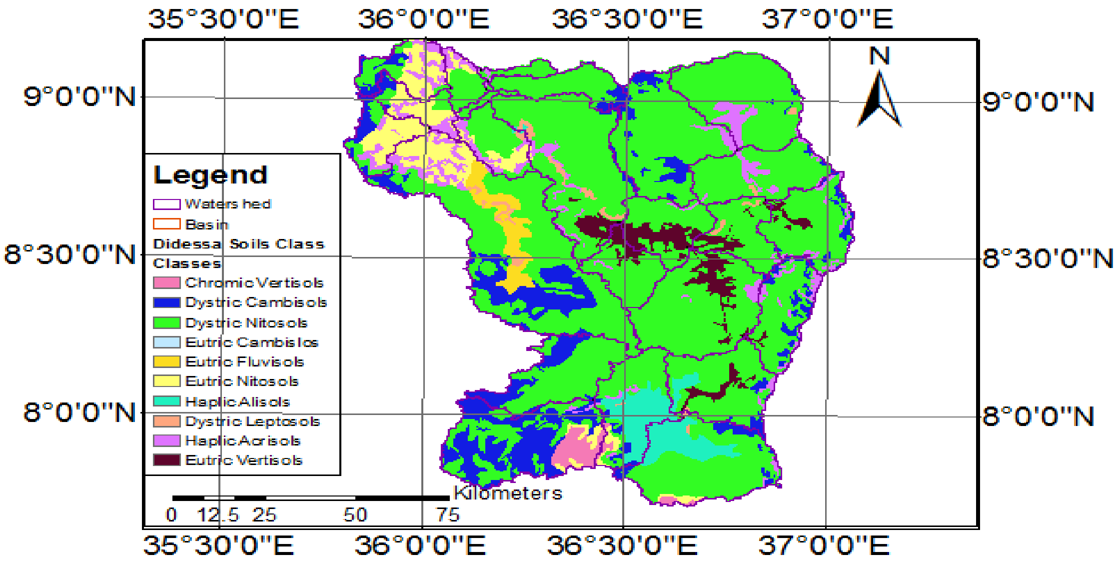


Figure 3.11: Soil Map of Didessa river Basin

3.6.6. Nutrient data preparation

The nutrient data of the Didessa watershed was required for calibrating and validating the model. To address the objective of the study specifically the water quality data such as Phosphorus, nitrogen and sediment data were required by SWAT model for calibration of the simulated output. But one of the challenging problems of modeling the nutrient load and transport pathway in the catchment of Ethiopia is the lack of measured data through the country. There are no measured water quality data continuously for Didessa sub-basin particularly.

Laboratory test have been done for nitrogen and phosphorus for the sake of relationship development b/n simulated output of nutrient and flow data. The laboratory test had been done for 30 days from august fifteen to September fifteen of 2017 for rainy season.

1) Sampling the raw water from the site

In order to conduct laboratory test for water quality parameter, the sample was taken from the river daily in the morning before 10:00am continuously for 30 days.

The samples were taken from Didessa River near Arjo to Bedele Bridge relatively at well mixed point in the flowing river.

Figure 3.12: sampling point for water quality test

Due to the river was very full at the season, it was difficult to find the access path to go through, the bank of the river and even the river was fully occupied by different wild animals that attack people. As information was taken from local people and those professionals from Abbay basin nekemte branch, taking the sample at the rainy season is very difficult, due to the river is already covered by crocodiles and not easy to access the river, as it was already recovered by forest and taking care is very important.

So, considering the above factors, different techniques were developed. The rope with plastic bottle was used to take the sample from the river flowing through the channel. As to the river channel is very wide, three bottles were used.one liter from center and a liter of two bottles from both side of the channel were taken and the composite sample were made to make the sample representative sample. Different materials/tools used for sample collection were:

a) **Plastic bottle** **b) Rope**

Figure 3.13: materials used for sample collection

2) 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 ($NO3^{-}$) and Ammonia (N_3H_4) 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 ($NO3^{-}$), Ammonia (N_3H_4) and Ortho-Phosphate (PO_4^{-3}) were filtered before placing into digestion pit. A number of material and procedures for laboratory work used were: beaker, measuring cylinder, funnel, filtering paper. 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. It was only two months of data, (August/2017 =15 days result and September/2017 =15 day result). All data was tested in 2017, which is not in the study period.

But, the result was unfeasible and inadequacy to make calibration, even to develop relationship with simulated output. Due to the limitation the result was not used in this document and the result was attached as annex at the back of this paper. So, the model was calibrated and validated only by stream flow .calibrating and validating the model by stream flow, was used for analysis of phosphorus and nitrogen. Most of discussion focused on the relationship and impact of the hydraulic process on the nutrients were deeply analyzed.

3.7. SWAT Model Setup

The model is built completely in a GIS environment using a SWAT extension (www.brc.tamus.edu/swat/arcswat.html). Arc SWAT extension of ArcGIS version creates an Arc Map project file that contains links to retrieved data and incorporates all customized GIS functions into Arc Map project file. The project file contains a customized Arc Map Graphical User Interface (GUI) including menus, buttons, and tools.

All processes were performed through the interface in Geographic Information System (GIS) for SWAT version Arc SWAT 2012 interface with ArcGIS 10.3. The SWAT project setup in volved was: (1) Watershed delineation (2) sub basin discretization (3) HRU Analysis and definition (4) Weather Data Definition (5) SWAT Simulation (6) Read SWAT Result (7) sensitivity analysis, and (8) calibration and validation.

The detail steps that were followed to create a SWAT project under Arc Map environment are conceptualized in the figure (3.13): Following these procedures, the model input data, DEM (Digital Elevation Model), land use map, soil map and weather data were geo-processed step by step to set up the model for the study area.

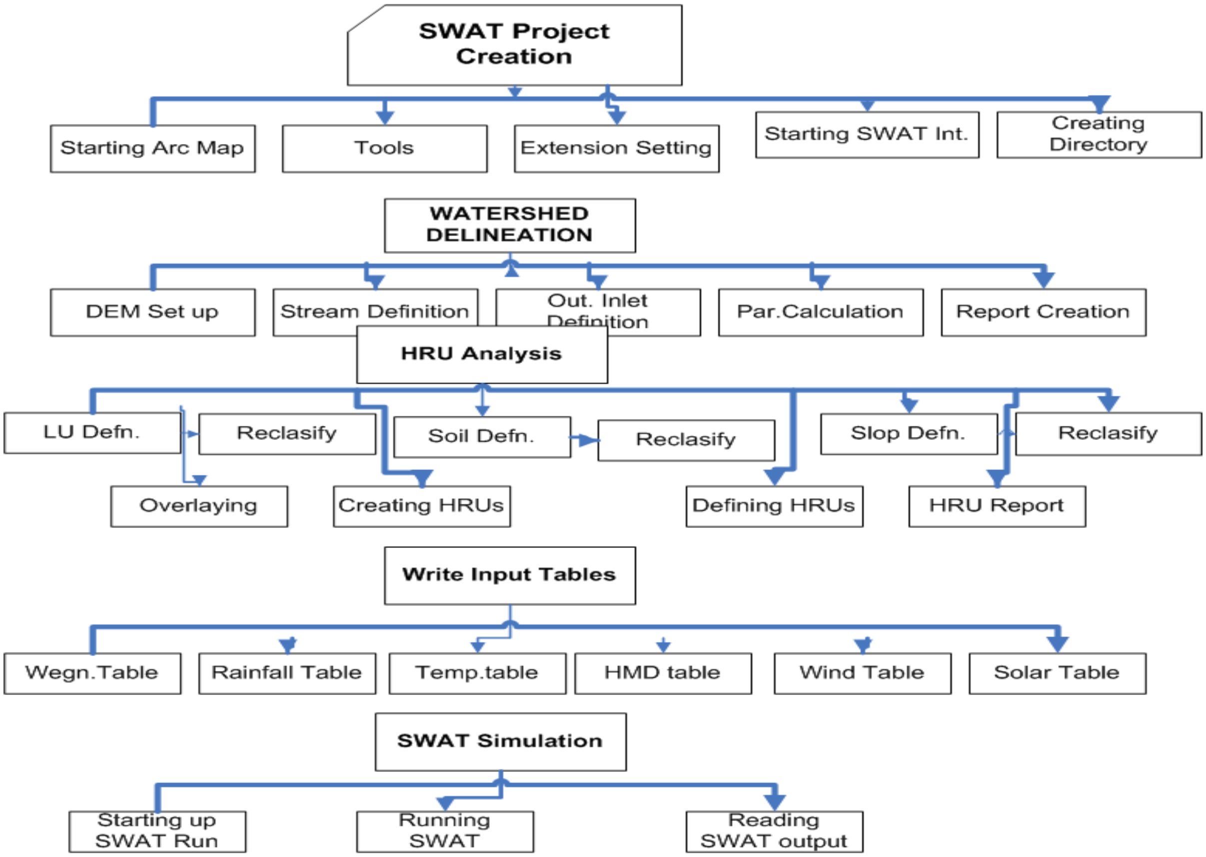


Figure 3:14: Sequential flow followed to run model

3.7.1. Watershed Delineation

The first step in creating SWAT model input is delineation of the watershed from a DEM. A watershed delineation tool was used to delineate the sub-basins based on DEM data. Subsequently, a stream network was also generated using DEM data. Inputs entered into the SWAT model were organized to have spatial characteristics.

Before going in hand with spatial input data i.e. the soil map, LULC map and the DEM were projected into the same projection called UTM Zone 37N, which is a projection parameters for Ethiopia. The watershed delineation processes include, DEM setup, stream definition, outlet and inlet definition, watershed outlets selection and definition and calculation of sub-basin parameters. For the stream definition the threshold based stream definition option was used to define the minimum size of the sub basins. 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. Choosing the threshold value of 29000 hectares, the Didessa watershed was delineated in to 25 sub watersheds having an estimated total area of 14,867 km2.A watersheds was separated into a number of sub basins, for modeling purposes (see Figure 3.15). Accordingly, the basin was divided into 25 sub-basins.

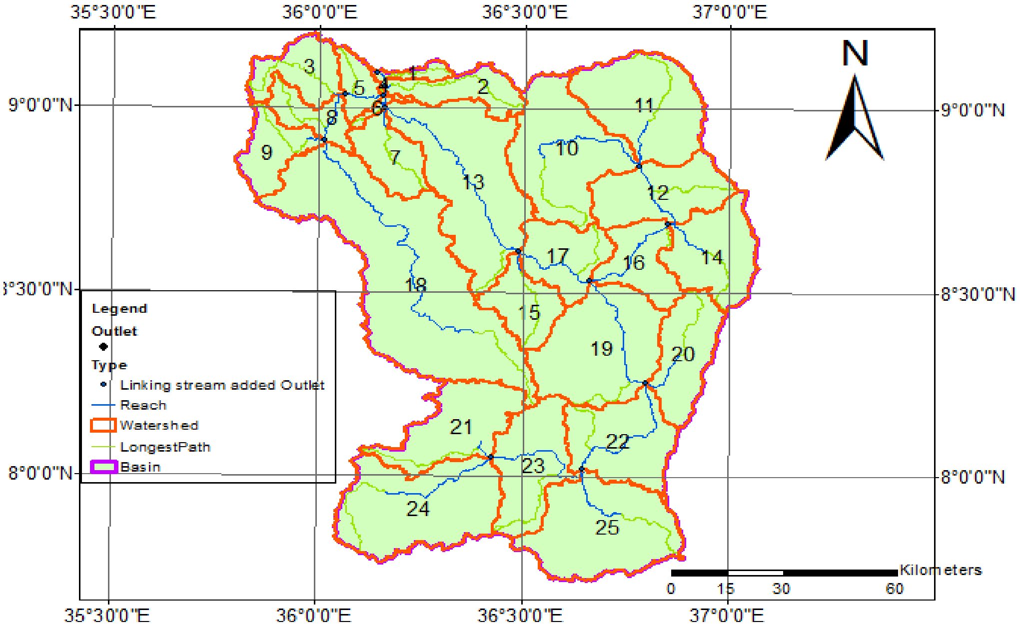


Figure 3.15: Delineated Didessa watershed

3.7.2. Hydrological Response Units Analysis (HRUs)

In the standard SWAT sub-basin, discretization was made based on the slope, soil and land use percentage thresholds. Sub-basins are divided into hydrologic response units (HRUs).HRU is the smallest unit in SWAT defined based on a unique combination of slope, soil type and land use. Using the SWAT Model, Didessa watershed was divided in to 25 sub-basin and 253 HRUs, determined by unique inter section of the LULC, slope and soil within the watershed. The land area in a sub-basin was divided into HRUs. The HRU analysis tool in Arc SWAT helped to load land use, soil layers and slope map to the project. The delineated watershed by ArcSWAT and the prepared land use and soil layers were overlapped 100%. The HRU analysis of Land use and Soil were presented in the table (3.6) and (3.7) respectively.

Table 3.6: SWAT Land use/land covers Analysis

S.N	Land use/Land cover according to SWAT database	SWAT code	Area	
			Area(ha)	%coverage
1	Range-Brush	RNGB	5513.0702	0.37
2	Cassava	CASS	17252.8956	1.16
3	Agricultural Land-Generic	AGRL	301465.1041	20.28
4	Agricultural Land-Row Crops	AGRR	443024.2007	29.80
5	Corn	CORN	12422.1029	0.84
6	Forest-Mixed	FRSTE	170799.2767	11.49
7	Range-Grasses	RNGE	55573.1231	3.74
8	Forest-Evergreen	FRSE	1234.9422	0.08
9	Water	WATR	9345.8804	0.63
10	Residential	URBN	2274.1075	0.15
11	Wetlands-Mixed	WETL	99672.3444	6.71
12	Wetlands-Forested	WETF	365641.4588	24.60
13	Wetlands-Non-Forested	WETN	2407.7933	0.16
		Total	1486626.3000	100%

The procedure includes: defining the land use data sets first and then the land use layer was reclassified in SWAT. Soil data sets are also defined and then reclassified.

Table 3.7: SWAT Soil class Analysis

S.N	Soil Types	Coverage	
		Area	%coverage
1	Chromic Vertisols	16228.3932	1.10
2	Dystric Combisols	168968.0431	11.70
3	Dystric Nitisols	997313.4896	66.03
4	Eutric Combisols	11929.396	0.80
5	Eutric Fluvosols	24547.5084	1.64
6	Eutric Nitosols	79901.3216	5.37
7	Haplic Alisols	53219.4558	3.56
8	Dystric Leptosols	12648.9254	0.85
9	Haplic Arisols	79355.4453	5.31
10	Eutric Vertisols	54407.3319	3.64
	Total	1486626.3000	100

HRU analysis in SWAT includes divisions of HRUs by slope classes in addition to land use and soils map. The multiple slope option (an option which considers different slope classes for HRU definition) was selected. Based on multiple slope option four class slopes (0-4, 4-8, 8-12 and above 12) was selected for entire watershed and HRU was analyzed as in Table (3.8) and Figure (3.16).

Table 3.8: Slope Classification of Didessa Catchment.

Classes	Slope Range	Coverage	
		Area(ha)	% coverage
Class1	0-4	67691.6497	4.55
Class2	4-8	174242.9769	11.72
Class3	8-12	225623.6867	15.18
Class4	Above12	1019067.99	68.55

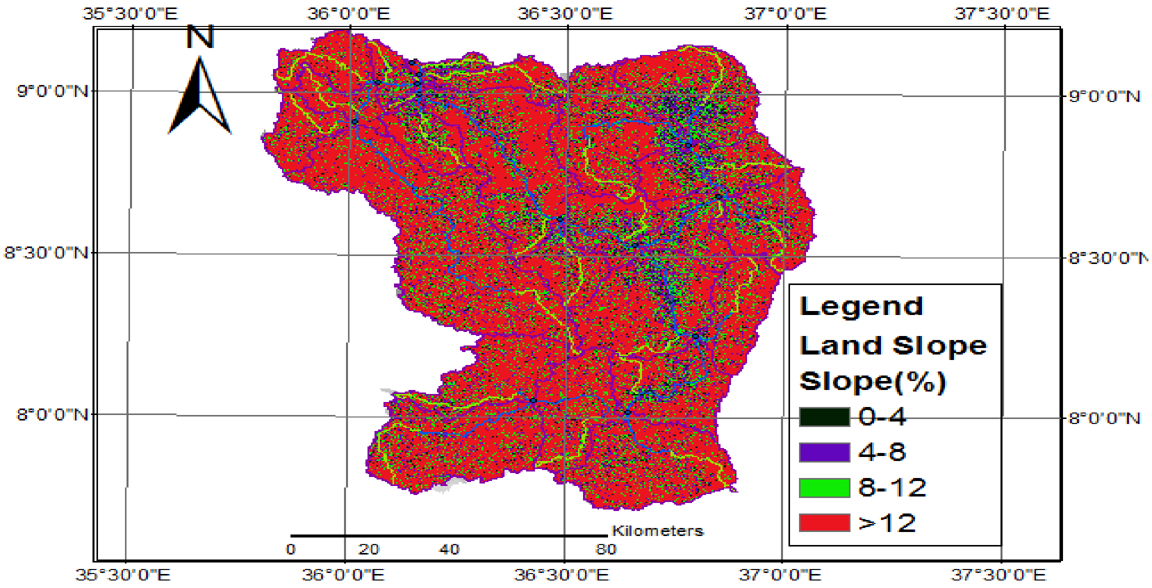


Figure 3.16: Slope Distribution of Didessa Watershed

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 were made to be overlaid for HRU definition. Recommended thresholds of percentage for land cover, soil and the slope area were applied to limit the number of HRUs in each sub watershed. For this specific study a 10% threshold value for land use, 10% for soil and 10% for slope were used. The HRU distribution in this study was determined by assigning multiple HRU to each sub-basin.

3.7.3. Writing Input Tables

Meteorological data (precipitation, minimum and maximum temperature, relative humidity, solar radiation and wind speed) and location of Meteorological stations were prepared based on SWAT table format and integrated with the model using weather data input wizards for the period of (1990-2014).Five metrological station (Agaro, Arjo, Bedele, Dembi and Nekemt) was used as weather station data. Nekemte and Bedele Meteorological station data were used as weather generator. The weather data was loaded using the first command in the write input tables menu item of the Arc SWAT. The weather generator data containing the location of the weather generator station (WGEN user) was loaded first followed by the weather stations location into the working project and assign weather data to the sub watersheds. The write command becomes active after weather data is successfully loaded.

3.7.4. Simulation

The simulation part of Didessa sub-basin was completed using Arc SWAT interface in SWAT 2012 Model. SWAT simulation run was carried out on the period of 1990-2014 climate data. Two years were taken for warm up period. The warm up period is important to make sure that there are no effects from the initial conditions in the model.

The lengths of warm up period differ from watershed to watershed. It is mainly depend on th e objective of the study. The simulate output data imported to database and the simulation results were saved in different files of SWAT output format. The file that saved in table out Microsoft access format contains different SWAT parameters output. It was used for SWAT model calibration and result discussion, since some of the observations of the watershed's be havior are obtained by measuring these parameters.

3.8. SWAT_CUP

SWAT-Cup is a computer program used for calibration, validation and uncertainty analysis for SWAT model. The program links SUFI2, PSO, GLUE, PARASOL and MCMC 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 F itting Ver.2, the parameter uncertainty in driving variables (e.g., rainfall), conceptual model, parameters, and measured data. In SUFI 2, the assessment of the sensitive parameters is mea sured using the t _stat values where the values are more sensitive for a larger in absolute t _ s tat 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.

3.8.1. 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 (Muleta 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).

3.8.2. 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 general procedures followed during sensitive parameters analysis shown in figure (3.17)

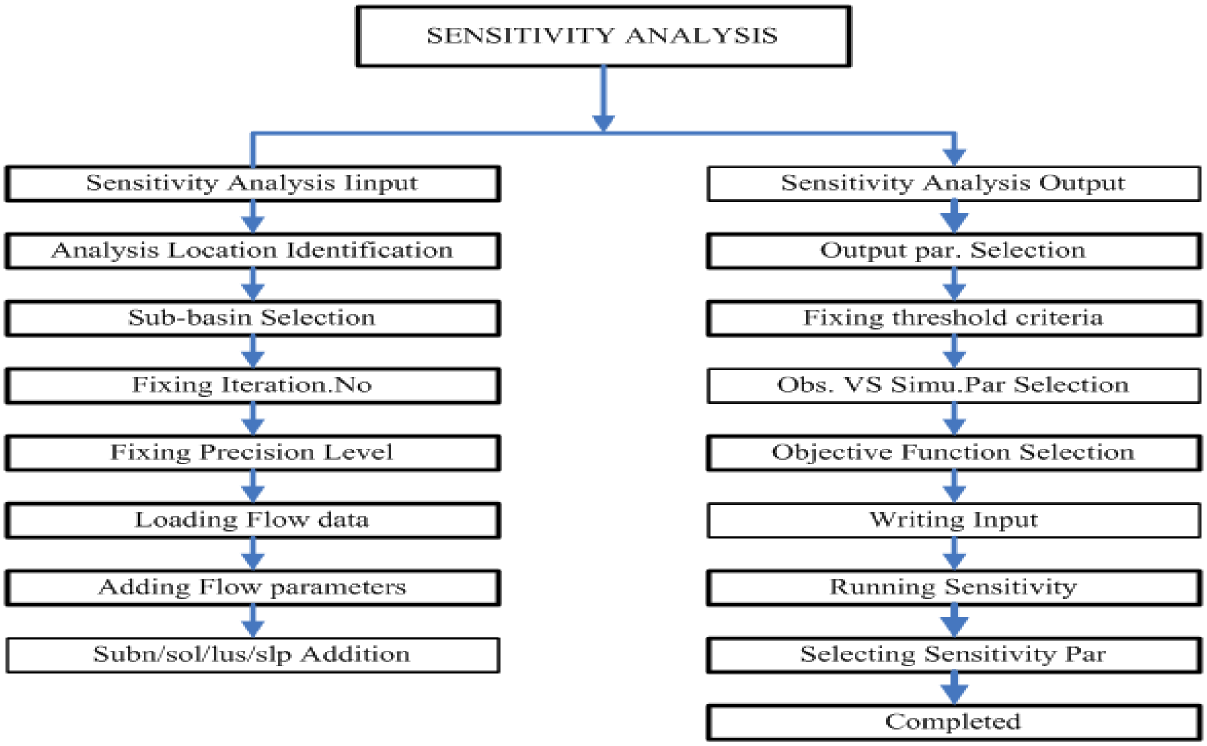


Figure 3.17: Order followed to identify sensitive parameters

The sensitivity analysis tool in SWAT-Cup 2012 was used in ranking parameters based on their influence in governing flow or water quality (sediment and Nutrient). This is an important step in the modeling process as it helps in identifying the parameters to calibrate which otherwise become very complex and computationally time consuming.

The sensitivity analysis is done by varying parameters value and checking how the model reacts. 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-vale. A t-stat is then used to identify the relative significance of each parameter.

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-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.

Initially, 21 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 Didessa River was performed according to the ranges of their variation. The adjustment of the parameter was done, keeping other unchanged. The changes were made a number of times with in its allowable range for the sensitivity test.

The sensitivity analysis of the Didessa River of the SWAT model input parameter utilized 21 number of SWAT input parameters and 15 were selected. Table (3.9) shows the description o f this parameters.These parameters were selected from various references including by (Arno ld *et al*., 2012, Chaubey and White, 2005). Based on this, hydrological process contributing to surface runoff (CN2, SOL_K, and SOL_AWC), Ground water (GW_REVAP, GW_DELAY, ALPHA_BF, REVAPMN, and GWQMN), Average Slope (SLSUBBSNand HRU_SLP) and Base flow alpha facto and Channel effective hydraulic conductivity (ALPHA_BNK and CH_K2) and evaporation process (ESCO, EPCO) were selected.

The analysis was done by the global sensitivity analysis using SWAT_CUP 2012. In a global sensitivity analysis, parameter sensitivities are determined by calculating the number of multiple regression systems, which regresses the Latin hypercube generated parameters against the objective function values. A number of iterations (500) were made to obtain good parameter value estimation.

Table 3.9: description of sensitive parameter

No.	Input parameter	Description of parameter
1	CN2.mgt	SCS curve number for moisture condition ii
2	ALPHA_BNK.rte	Base flow alpha factor for bank storage

No.	Input parameter	Description of parameter
3	CH_K2.rte	Channel effective hydraulic conductivity
4	SLSUBBSN.hru	Average slope length
5	HRU_SLP.hru	Average slope steepness
6	SURLAG.bsn	Surface runoff lag coefficient
7	SOL_K .sol	Soil conductivity
8	SOL_AWC .sol	Available soil water capacity
9	ALPHA_BF.gw	Base-flow alpha factors
10	GW_DELAY.gw	Groundwater delay
11	ESCO.bsn	Soil evaporation compensation factor
12	REVAPMN.gw	Threshold depth of water in shallow aquifer for revap to occur
13	EPCO.bsn	Plant evaporation compensation factor
14	OV_N.hru	Manning’s “n” value for overland flow
15	GWQMN.gw	Threshold depth in shallow aquifer required for return flow

3.8.3. Calibration and Validation

Model calibration is a means of adjusting model parameters to a given set of local conditions, thereby reducing the uncertainty of prediction and minimizes the deviations between the observed and predicted values. Once the parameters to be optimized were identified through the sensitivity analysis, the model was calibrated. Model calibration is performed by careful selection of the values for the input parameters with in their range through comparison of model outputs with observed data under the same condition for a given set of assumed condition (Arnold, *et al.*, 2012).

Calibration is an effort to better parameterize a model to a given set of local conditions that establish the most suitable parameter in modeling studies and an iterative process that compares model predictions(output) for a given set of assumed condition and observed data of interest (typically stream flow data, sediment data and nutrient data) through parameter evaluation

There are manual and automatically or both calibration systems for the distributed hydrologic model. Manual calibration is the trial and error process of model parameter adjustment. After the parameter adjustment, simulated and observed watershed behavior is compared to visualize the match between them. Automatic calibration on the other hand uses mathematical search algorithm that seeks to minimize differences between selected features of modeled and observed behaviors by systematic trial iterations in the values of the model parameter.

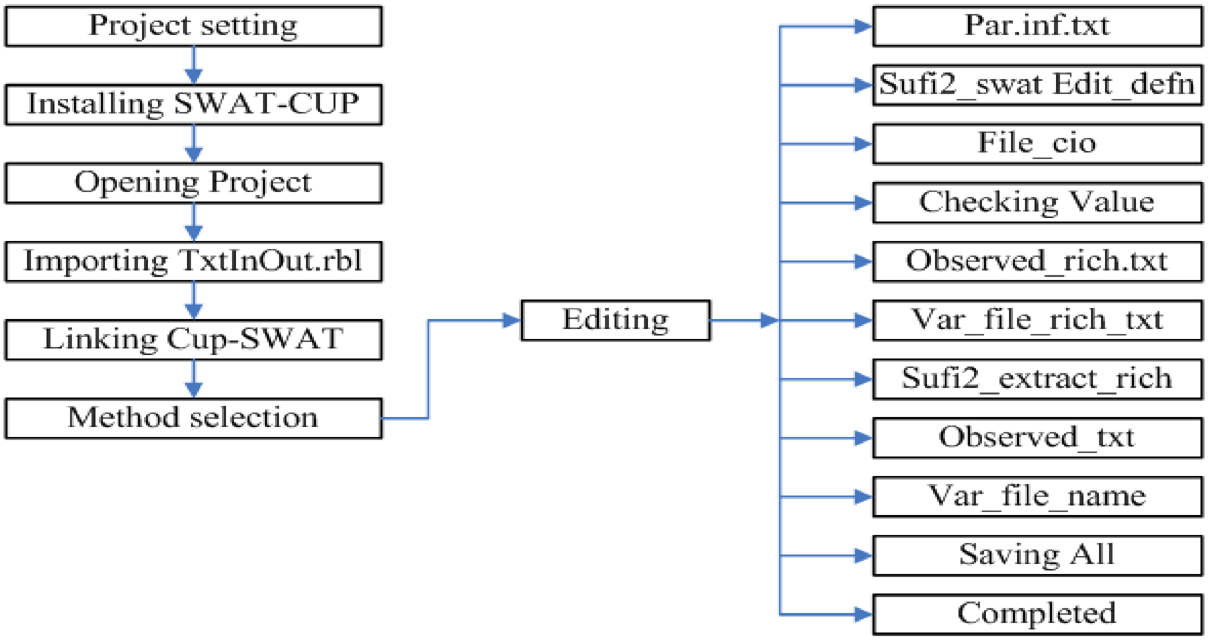


Figure 3.18: Steps followed to undergo auto calibration (Abbas Pour, 2005)

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 involves running a model using parameters that were determined during the calibr ation process and comparing the prediction to observed data not used in the calibration.Once optimal parameter values were chosen via the manual routine, each calibrated models was the n run over a new period. The two statistical model performance measures were used in calibration and validation procedure for stream flow by SWAT-CUP model. The conceptual flow for validation is as follow.

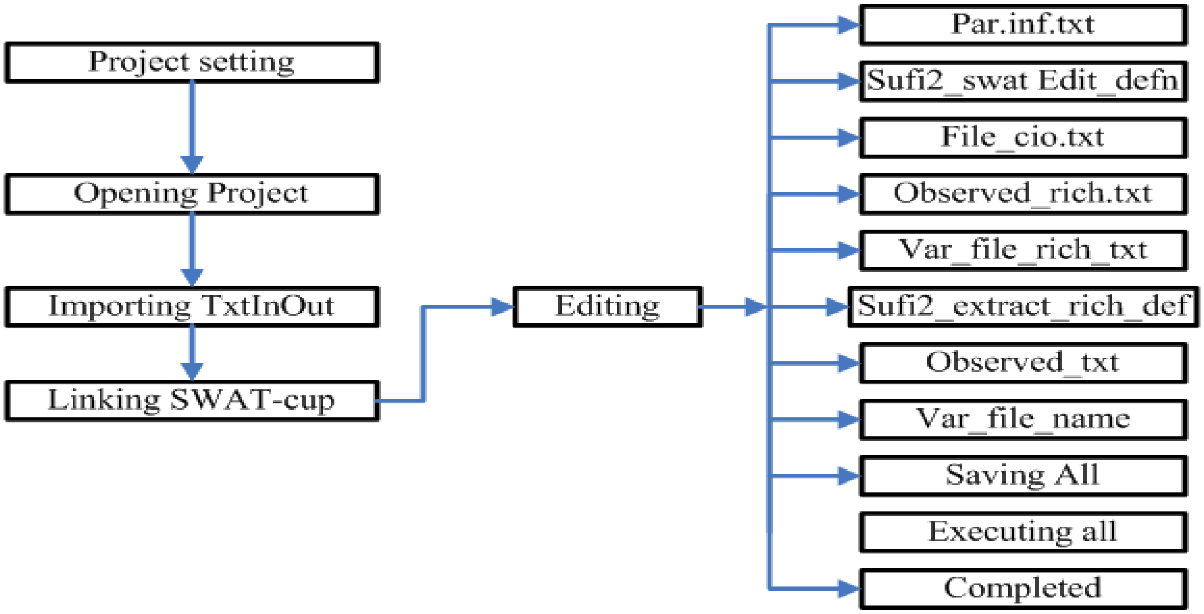


Figure 3.19: Series of steps followed during validation (Abbas Pour, 2005)

Calibration and validations are following procedural approach for calibrating multiple parameters. Accordingly hydrology is calibrated first for most, followed by sediment calibration and finally water quality is calibrated based on objective function.

Depending on the availability and quality of the discharge (stream flow) data, modeling period was classified into the warm up period, calibration period and model validation period. Developing the initial SWAT parameters, the model was run for the 25 year (1990-2014) climatic data with the default parametric values. The output of the model is then used to prepare an input to the SWAT- CUP2012. The available flow data of 15 years (2000-2014) at Didessa near Arjo gauging station was used to run the default calibration.

For the default calibration 15 flow parameters were used and the simulation was run for 500 times. By developing the graph of the observed flow and the simulated flow from the default calibration, the study period was divided into the calibration and validation period. Accordingly, warm up period of 2 years (1998-1999), calibration period of 9 years (2000-2008) and validation period of six years (2009-2014) were selected.

Here, since there was no recorded nitrogen, phosphorus data, at the country level, the nutrient were not calibrated. These are because of their direct relationship between the flow/run off, and the nutrient, the impact was discussed. The Result was discussed based on limited measured data and calibrated stream flow specifically to answer the objective.so, the relationship was developed for nutrients and other hydrological parameter after the model was validated by stream flow.

3.8.4. Model Performance Evaluation

To conclude representative model, performance evaluation is an essential measure to verify the Efficiency of the model. From different methods of model performance evaluation, coefficient of determination (R2) and Nash and Sutcliffe simulation efficiency, ENS (Nash Sutcliffe, 1970) were used. (1) NSE (Nash-Sutcliffe efficiency) and (2) R^2correlation between observed and simulated flows were the two statistical reports for calibration and validation. The NSE (Nash-Sutcliffe efficiency) is computed as the ratio of residual variance to measured data variances. The NSE simulation coefficient indicates how well the plot of observed versus simulated values fits the 1:1 line. The Nash-Sutcliffe is calculated using Eq. (3.3):

$$\mathrm{NSE} = 1 - \left[\frac{\sum_{i=1}^{n}\left(Q_i^{obs} - Q_i^{sim}\right)^2}{\sum_{i=1}^{n}\left(Q_i^{obs} - Q^{mean}\right)^2}\right] \quad 3.3$$

Where,Q_i^{obs} =Observed stream flow in m3/s; Q_i^{sim} = simulated stream flow in m3/s; Q^{mean} = Mean of n values; *n* = number of observations

The NSE can range from $-\infty$to +1, with 1 being a perfect agreement between the model and real (observed) data. The simulation results were considered to be good if NSE ≥ 0.75, and satisfactory if 0.36 ≤ NSE ≤ 0.75(Griensven and Bauwens, 2003).

The coefficient of determination R^2 value is an indicator of the strength of the linear relationship between the observed and simulated values. It ranges from 0.0 to 1.0, with higher values indicating better agreement. The R^2 is calculated with Eq. (3.4)

$$\mathbf{R^2} = \frac{\left[\sum_{i=1}^{n}\left(Q_i^{sim} - Q_{mean}^{sim}\right)\left(Q_i^{obs} - Q_{mean}^{obs}\right)\right]^2}{\sum_{i=1}^{n}\left(Q_i^{sim} - Q_{mean}^{sim}\right)^2\left(Q_i^{obs} - Q_{mean}^{obs}\right)^2} \qquad 3.4$$

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

CHAPTER FOUR

RESULT AND DISCUSSION

4.1. Land use, Soil and HRU Summary

Based on land use data obtained, thirteen land use classes were derived. Agricultural land-raw crops(AGRR) (Moderately cultivated),Wetlands Forested(WETF) (Woodland open),Agricultural land Generic(AGRL) (Dominantly cultivated),Forest- mixed(FRSTE) (Forest) were the four dominant land use classes that accounts 29.8%, 24.6%, 20.28% and 11.49% coverage respectively in the Didessa river basin. The other land use classes' accounts 13.84% together and the detailed description of each land use were tabulated in chapter three of this document.

Ten soil types were identified. Dystric nitosols are the very dominant soil type that distributed in the central, upper and lower parts of study area. Its coverage accounts 66.03%, which followed by Dystric combisols and Eutric nitosols with coverage of 11.7% and 5.37% respectively. The other soil information was discussed in chapter three of this document.

The overland slope derived from DEM was classified into four slopes classes (0-4%), (4-8%), (8-12%) and above 12% for sake of assessing level impact of these slope classes on initiation of erosion responsible for sediment, nutrient and agricultural chemicals load to the nearby water resource. Accordingly, the findings of this assessment imply that high amount of P, N and sediments were exported via surface runoff from sub-basins found around the edge of the catchment having high elevation or slope greater than 12%.

4.2. Sensitivity Analysis

Stream flow Sensitivity analysis was done to determine parameter for which it is important to have more accurate value and understand the behavior of the system being modeled. The Auto calibration was done by varying the values of the sensitive parameter with in their permissible value. The best parameters obtained were compared to the predicted flows. Accordingly, 21 parameters were analyzed and ranked according to (Lenhart et al., 2002) and found that 15 parameters were considered as the most sensitive parameters as in table (4.1).

Table 4.1: Selected sensitivity parameters of Flow and its fitted value in SUFI2

No.	Input parameter	Min_ Value	Max_Value	Fitted value
1	CN2	-0.2	0.2	0.142
2	ALPHA_BNK	0	1	0.806
3	CH_K2	0.025	250	178.445
4	SLSUBBSN	10	150	65.125
5	HRU_SLP	0	1	0.076
6	SURLAG	0.05	24	9.121
7	SOL_K	-0.8	0.8	0.254
8	SOL_AWC	0	1	0.386
9	ALPHA_BF	0	1	0.702
10	GW_DELAY	30	450	32.63
11	ESCO	0	1	0.339
12	REVAPMN	0	500	444.375
13	EPCO.	0	1	0.059
14	GWQMN	0	2	10.469
15	OV_N	0.01	30	1.218

The SCS runoff curve number (CN2) was found to be among the most sensitive parameters for a Didessa River Basin and OV_N was the least sensitive parameter, which have direct sensitivity impact on nutrient prediction. This sensitivity was ranked based on statistical parameter of t-stat and p-value as shown in table (4.2).

Table 4.2: Ranked Flow Sensitivity parameter of Didessa Sub-basin, based on t-stat and p-value

No.	SWAT Input parameter	t-stat	p-Value	Ranking
1	CN2	12.053	0.000	1
2	ALPHA_BNK	11.606	0.000	2
3	CH_K2	-5.896	0.000000008	3
4	SLSUBBSN	-4.360	0.000016785	4
5	HRU_SLP	3.376	0.000808214	5
6	SURLAG	1.917	0.05594755	6
7	SOL_K	1.628	0.104400046	7
8	SOL_AWC	-1.602	0.110049056	8
9	ALPHA_BF	-1.352	0.177131863	9
10	GW_DELAY	1.338	0.181643988	10
11	ESCO	-0.495	0.620589702	11
12	REVAPMN	0.2686	0.788351488	12
13	EPCO	0.1064	0.915297032	13
14	GWQMN	0.0712	0.942794457	14
15	OV_N	0.043	0.966048807	15

The ranking was based on sensitivity ranking t-stat and p-value number, as the absolute value of the larger the t-stat value was indicated the most sensitive parameter and the lower value of p-value was indicate the most significant parameter. So, the larger the t-stat value and the lower the p-value were limiting the parameter as most sensitive and ranking was based on this value for all parameter. The other studies conducted in the Didessa basin also showed similar result as the curve number was most sensitive parameter for stream flow calibration (Tesfa gebrie, 2016).The dot plot of the 5 sensitive parameters were shown in figure (4.1).

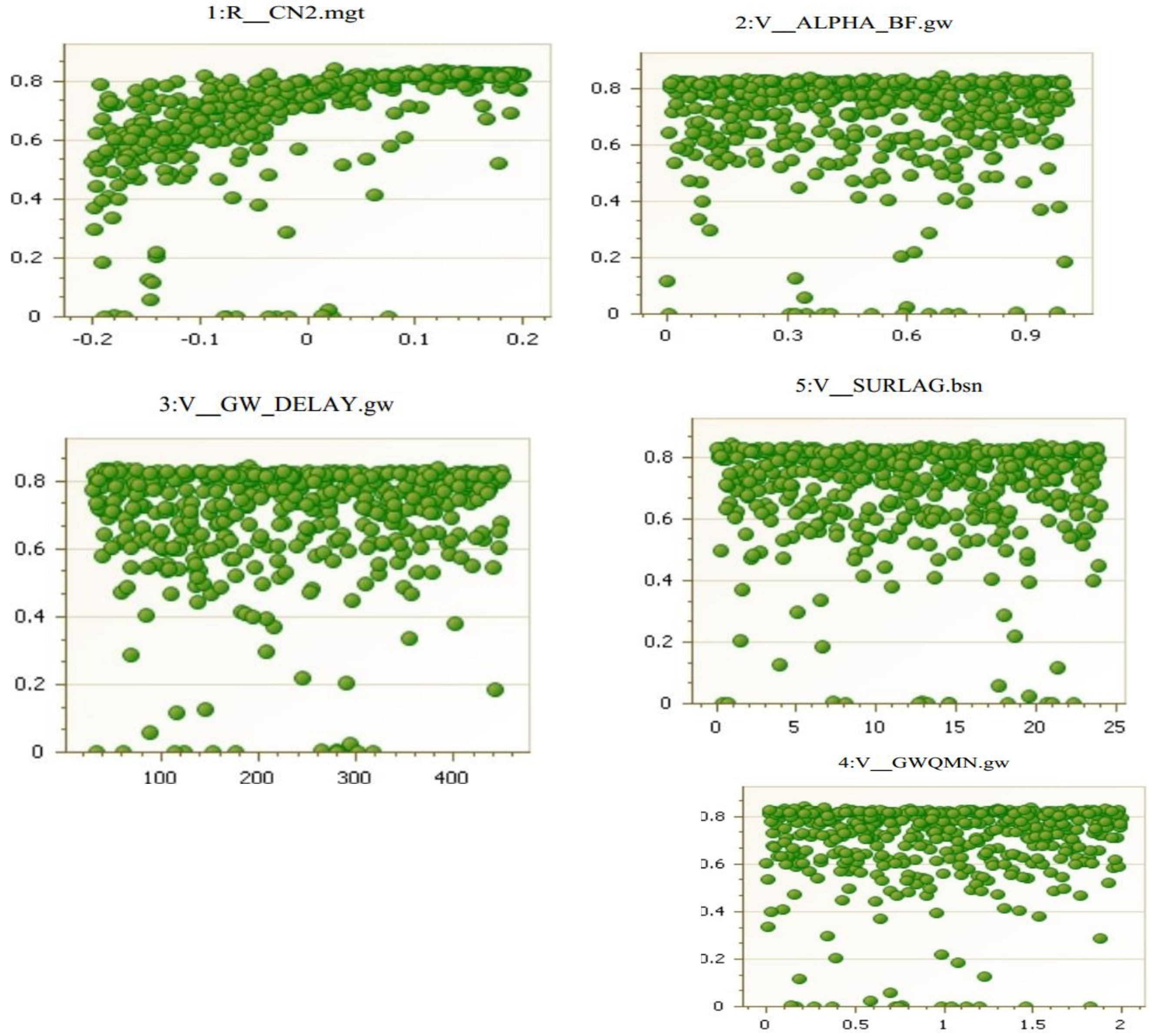


Figure 4.1: Dotplot of five most sensitive parameter

4.3. Stream Flow Calibration

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 calibration was done for the period of (2000-2008) for nine years with two years (1998-1999) keeping for model warm up or to initiate the model. The graphical methods, flow hydrography (figure 4.3) and scatter plot (figure 4.2) and values of statistical parameters of coefficient of determination (R^2) and Nash-Sutcliffe efficiency (NSE) were used as an indication of calibration acceptance.

The calibration results showed good agreement between measured and predicted flow at the gaging station Didessa near Arjo of sub-watershed with an R^2 and NSE 0.84 and 0.65 respectively.

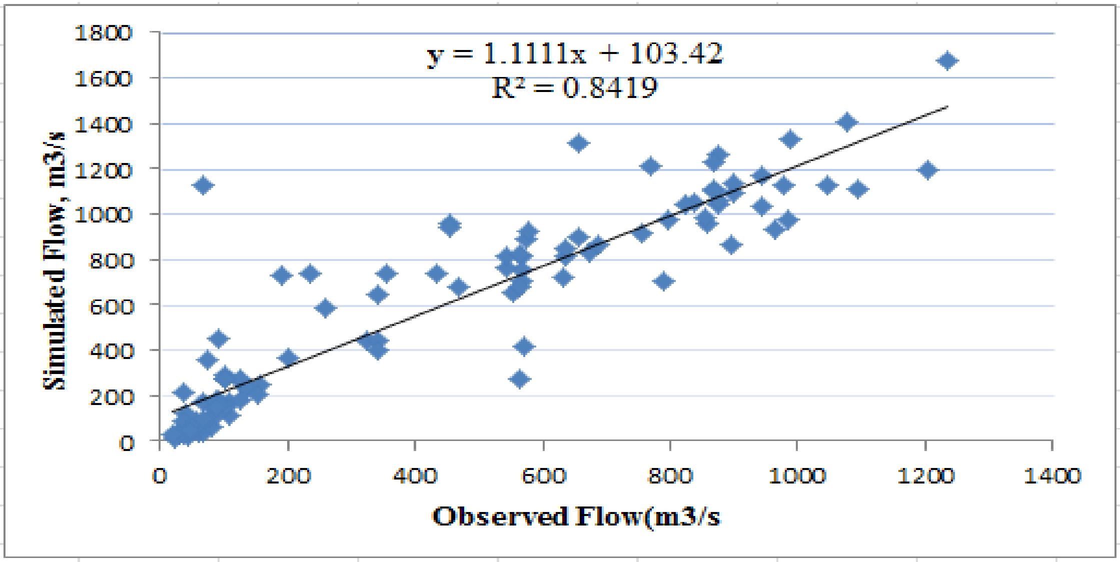


Figure 4.2: Regression correlation of observed and simulated monthly stream flow during calibration

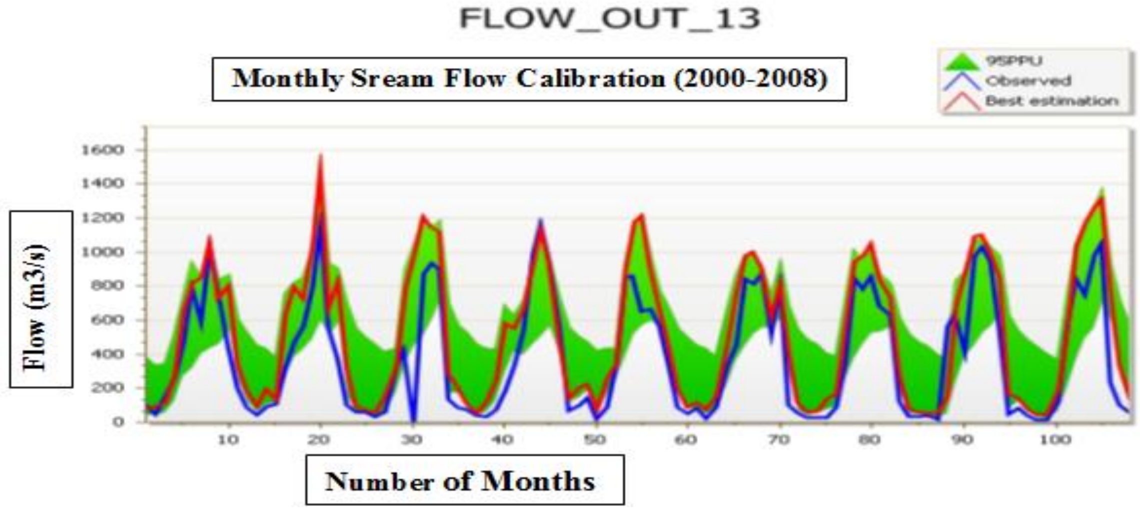


Figure 4.3: Hydrograph of observed and simulated monthly stream flow during calibration

4.4. Stream flow Validation

The model validation was done using stream flow data set for the period of six years (2009-2014). The same number of simulation in the calibration was used during validation process. Statistical analysis of model performance during validation using regression plot indicates a good relationship between simulated and measured stream flow. The R2 value of 0.8 obtained indicate a good model fit during validation. In addition the objective function NSE of 0.54 indicates the model performance during validation was satisfactory.

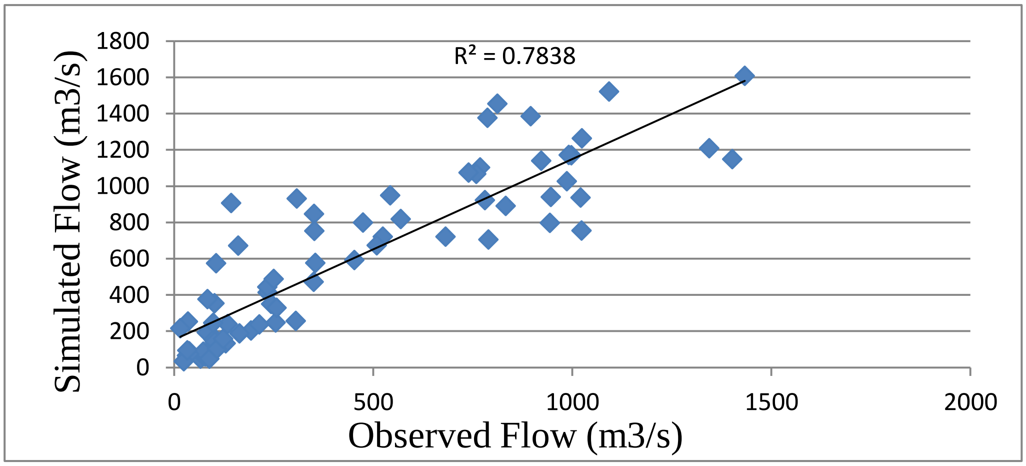


Figure 4.4: Regression correlation of observed and simulated monthly stream flow during validation.

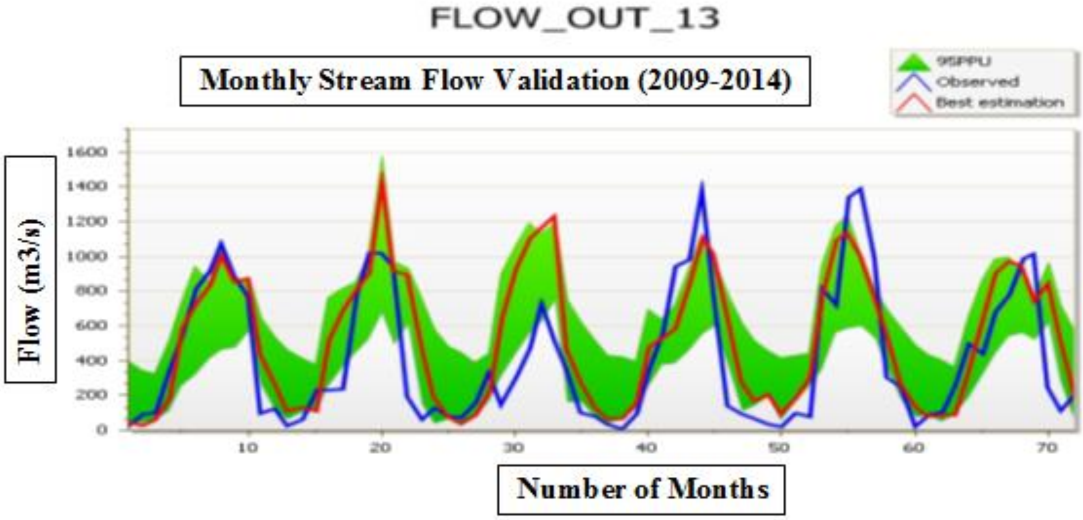


Figure 4.5: Hydrograph of observed and simulated monthly stream flow during validation

Even if the calibration and validation results are in acceptable range, the value was low especially for NS .The reason might be number of data used during both calibration and validation was small and maybe there were inaccurate measuring during field data collection.

4.5. Surface Runoff

At catchment scale, surface runoff is the major agent for driving sediment, nutrients and agricultural chemicals towards the flowing surface water resources. The average annual surface run off contributed was computed as 774.13 mm. The figure (4.6) shows, the maximum amount of surface run off generated from the catchment in the year of (2001) with the volume of (929.5mm), with (14 %) contribution.

The minimum runoff generation was seen in the year (2003), which was about (572.64mm) (8.43 %). The possible reason might be the slope condition, change in hydrological condition, soil physical and chemical nature, alteration of land use and land cover and level of effective watershed management methods applied over the area.

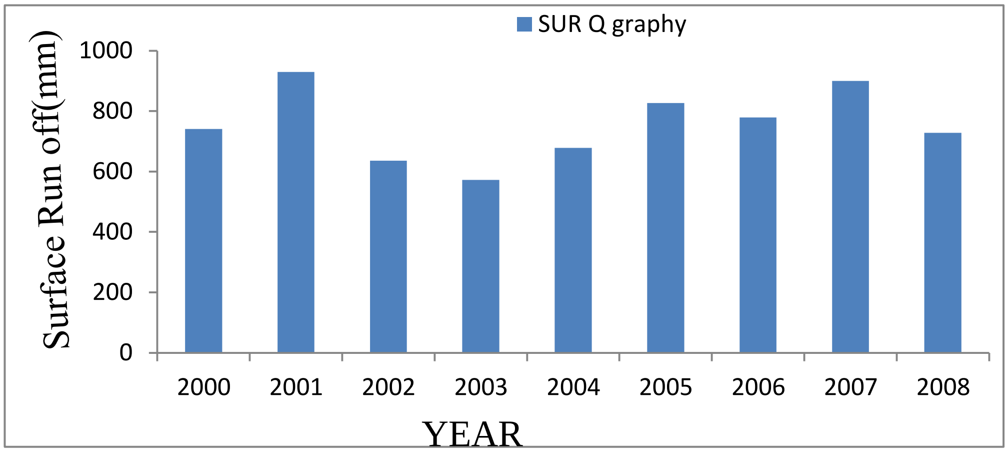


Figure 4.6: Annual surface runoff of Didessa river basin (2000-2008)

Based on Simulated output of precipitation and surface Run off, the result strongly shows the close relationship with (R^2=0.89) as indicated in scatar plot of figure 4.5.This shows Changes in precipitation be explained 89% of the variation in surface runoff (figure 4.7) as more than 89% of precipitation from the catchment converted to surface run off. It was seen a very close linear relationship between precipitation and contributed run off as in figure (4.7) and (4.8).This might be due to overland slope, ineffective land cover, and dominant agricultural practice and soil type vulnerability to erosion effect due to dominant soil type of study area were dystric Nitisols, which is well drained tropical soil with more than 30% clay in their subsurface horizon (Geleta, 2010).

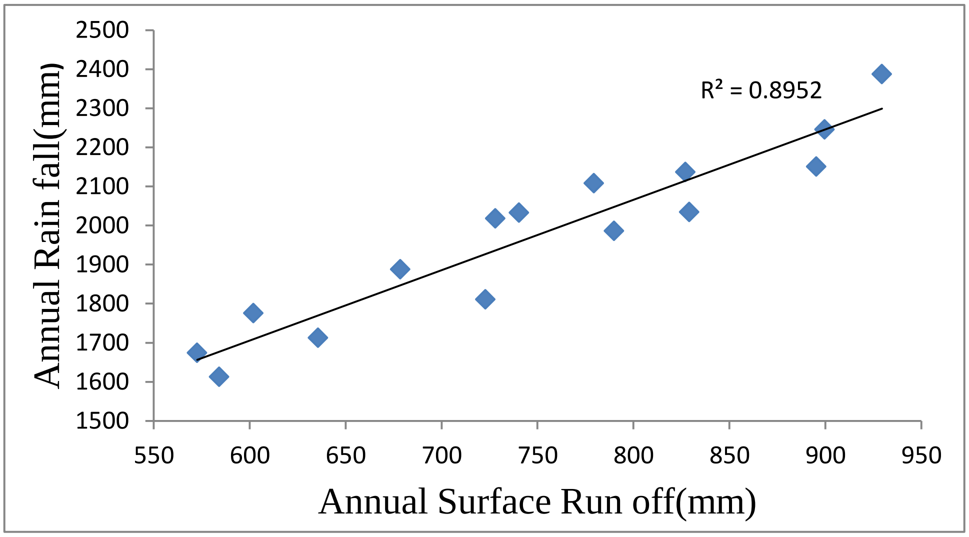


Figure 4.7: Scatar plot of annual run off and annual rainfall

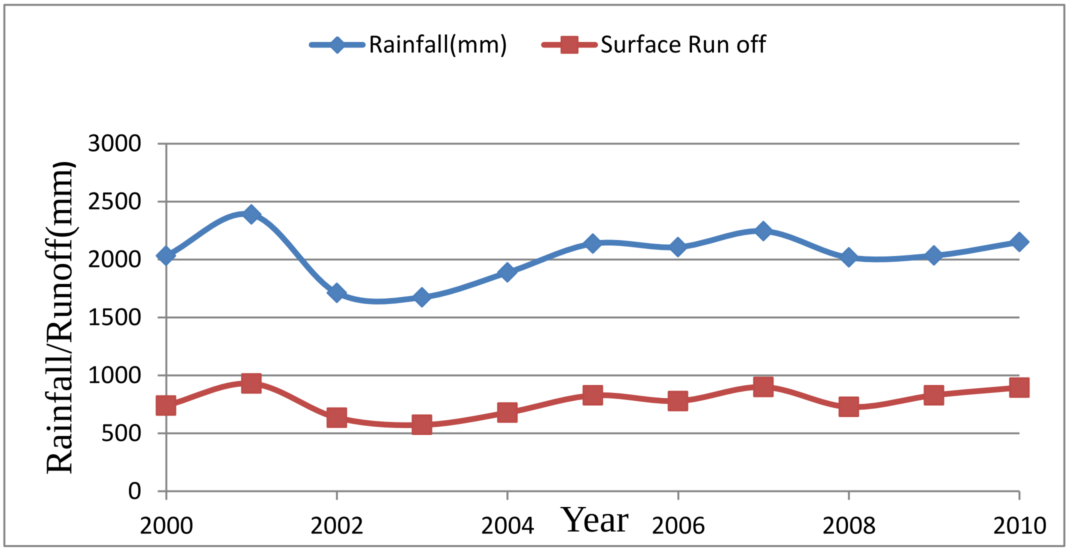


Figure 4.8: Average Annual Rainfall-Run off curve.

4.6. Phosphorus Loading and Transport pathways

Since there is no measured data of phosphorus and nitrogen at national level in Ethiopia catchment, calibration and validation of the model for P and N was not conducted. Instead the model was calibrated and validated by flow as hydrological process has strong impact on nutrient loading and transport pathways.

Calibrating and validating stream flow were used as model performance evaluation, and then simulated P and N was analyzed. The stream flow calibration results showed good agreement between measured and predicted flow at the gaging station Didessa near Arjo of sub-watershed with an R^2 and NSE 0.84 and 0.65 respectively and the scatar plot and hydrograph were shown in figure (4.2 and 4.3) under calibration title. The stream flow validation results showed the model performance during validation was satisfactory with R^2=0.8 and NSE=0.54 and the scatar plot and hydrograph were shown in figure (4.4 and 4.5) of this document under validation title.

Based on the flow calibrated and validated results, the P load and transport pathways, N load and transport pathways and hydrologic impact and their correlation with each other were widely and briefly discussed starting from next title of phosphorus transport pathways.

4.6.1. Phosphorus transport pathways

Phosphorus loss from agricultural lands is commonly controlled by the hydrologic events, such as surface runoff. The runoff can transport P as sediment bound (particulate) or dissolved form. 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. Soil in organic p is divided into solution, active and stable pools.

P solubility is limited in most environments and combines with other ions to form a number of insoluble compounds to that precipitate out of solution. 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). Also the Positive correlation was found between runoff and total P loss (r2= 0.89, p-value = 0.001) on Gilgel Gibe Watershed by (Adela and Behn, 2015). Another investigator was found Total P loss is strongly correlated with total sediment yield with an R2 value of 0.69 on Le Sueur River watershed of Minnesota River Basin (Solomon Muleta, 2010).

Based on scientific facts and consideration, the study was investigated phosphorus was exported from the catchment in the form of Org p attached to sediment and transported in the form of particulate. The particulate Org P form of transport mechanism were accounts an average of (8.48) kg/ha /year that holds 41.46%. Sediment attached P (adsorbed) which accommodates around 11.85 kg/ha/year of transport path that holds 58.45%. The soluble P which was 0.02kg/ha/year the least transport mechanism that accounts only 0.09% as shown in table (4.3). For the all forms of P, surface run off was the dominant means of transport agent.

Table 4.3: Annual different forms of phosphorus loss in the Didessa catchment from (2000-2010).

Year	Org. P(kg/h)	Sol P(kg/h)	Sed.P(kg/h)	Total P(kg/h)
2000	8.43	0.02	11.68	20.13
2001	8.35	0.02	11.89	20.25
2002	9.20	0.02	12.96	22.18
2003	4.44	0.01	6.32	10.77
2004	9.20	0.02	12.91	22.12
2005	9.26	0.025	12.94	22.22
2006	9.03	0.02	12.72	21.77
2007	8.90	0.02	12.58	21.50
2008	8.70	0.02	12.35	21.07
2009	8.92	0.02	12.58	21.53
2010	8.00	0.02	11.37	19.38
Avg.	8.48	0.02	11.85	20.27
sum	92.44	0.19	130.31	222.93
%	41.46	0.09	58.54	

4.6.2 Phosphorus load

4.6.2.1. Org P

The study analysis shown that, the annual average loss of Organic P in the Didessa catchment was 8.48 kg/h/year with 41.46% coverage of the other form of P loss. The maximum organic form of P loaded from the catchment was quantified around 9.26 (kg/ha/years) with 10.02% which was loaded in year 2005.

Minimum org P load observed on the year 20003 was about 4.44 (kg/ha /year) which had coverage of 4.81% of total p loaded during the year 2000-2010 as shown in figure (4:9). The major facts behind the rise of Org p load in the year 2005 was the generation of high amount of surface run off and sediment load resulted from high elevated area around the edge of the catchment boundary.

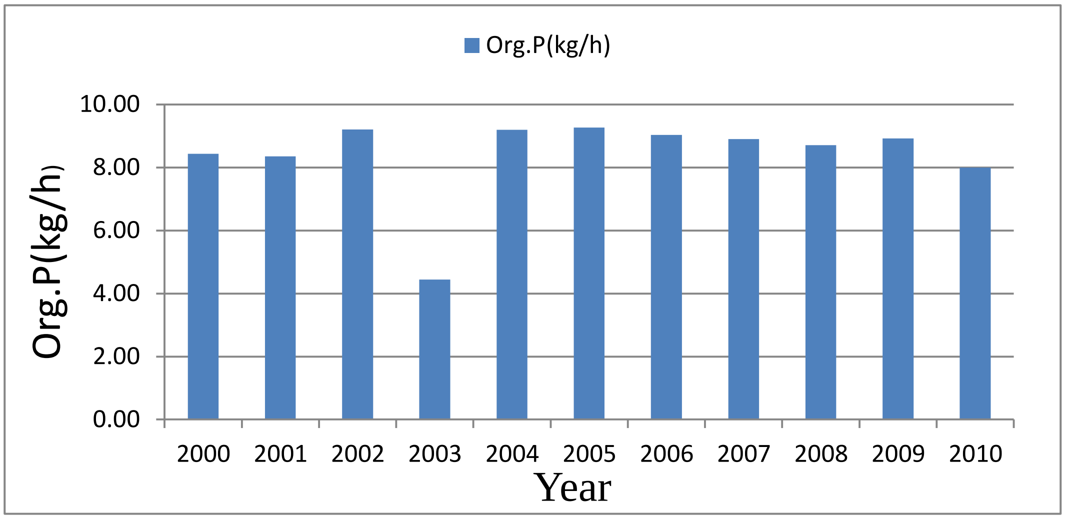


Figure 4.9: Annual Org P load

4.6.2.2 Sol P

As it was investigated, Soluble P was the smallest form of P load in the area when compared to other form of nutrient p load. The average annual Sol P loss in Didessa catchment was identified as 0.02(kg/h/year) during study year of 2000-2010 and has the coverage of 0.09% of the other form of P loss. Maximum amount of sol P was loaded in the year 2009 which was around (0.025kg/h/year) with minimum mount on 2003 which was about 0.01(kg/ha/yea r) as shown in figure (4.10). The main reasons behind the increment of Sol p on this year largely due to high surface run off as figured and the rate of applications of the fertilizers and the usage of additional manures/residues and corresponding miss management might be facilitating the rise of soluble P.

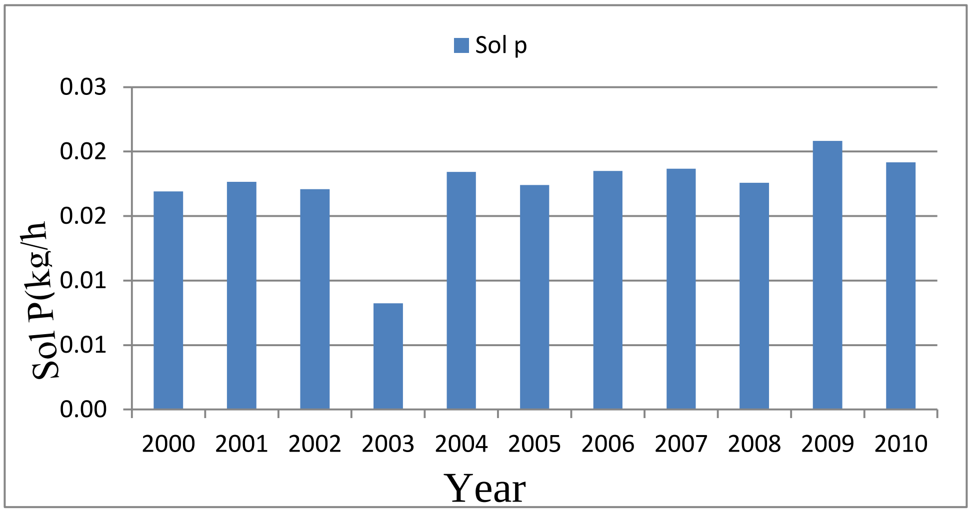


Figure 4.10: Annual Sol P load

4.6.2.3 Sed. P

Sediment P is a mineral form of phosphorus that attached to sediment and transported by surface run off towards the reach. The annual average Sed P loss in the Didessa catchment was identified as 11.85 (kg/h/year) with coverage of 58.54% of the other form of P loss. The high amount of sediment form of P was loaded on the year 2002, which holds around (12.96kg/ha/year) and the minimum amount of Sed P exported was on 2003 year, which was quantified as (6.32kg/h/year) load see figure 4.11 . This was happened that in the same year there was high amount of surface run off and large magnitude of sediment load as shown in previous figure 4.6. In general the surface run off is prevalent mechanism of sediment load and P load.

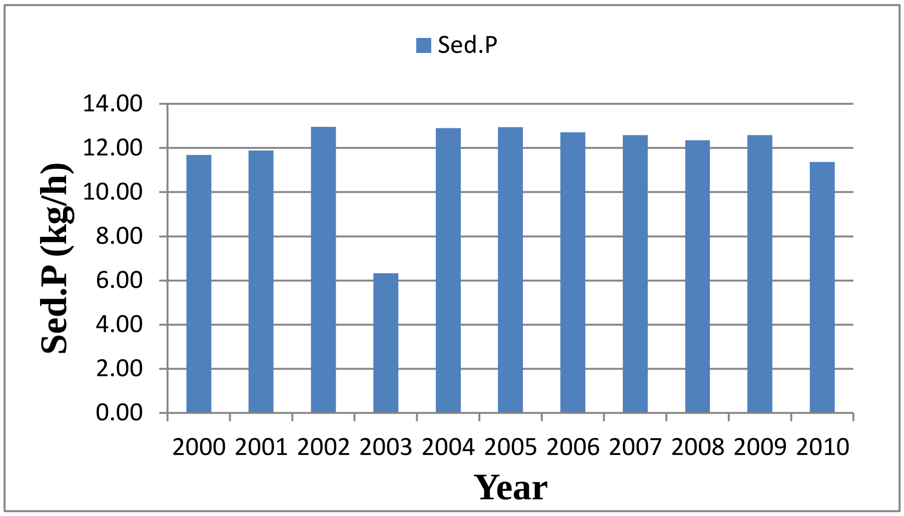
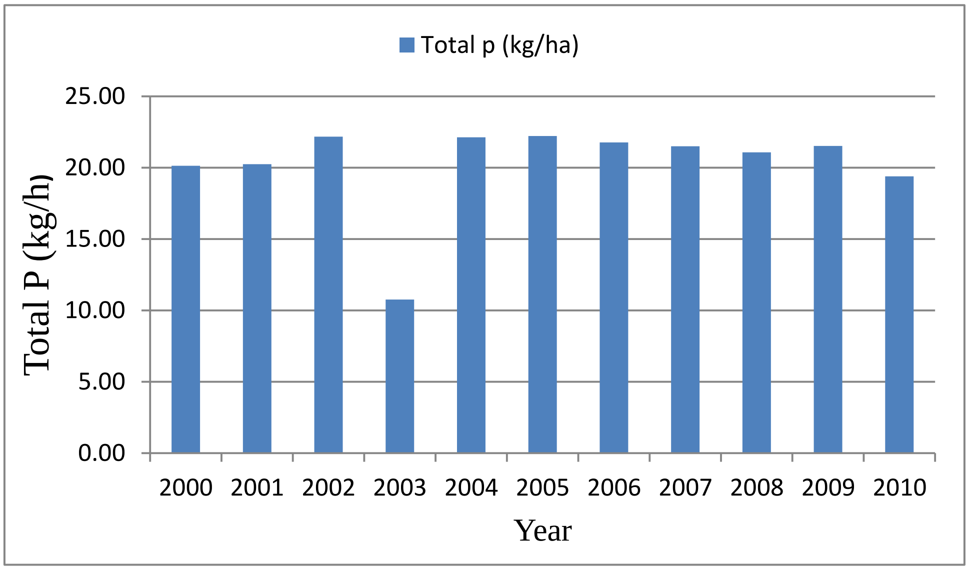


Figure 4.11: Annual Sed P load

4.6.2.4 Total P

Reports were found out, the three main pathways through which mobilized P can reach surface waters are surface run off, subsurface flow and vertical flow to the ground water-surface water interaction zone (Haygarth et al., 2000). According to (Heath Waite et al., 2000) reported that particulate P is the most important fraction during storm run-off events from the agricultural field. The study also confirms Total P transport in Didessa river basin was arises when a significant source of P has good hydrological connectivity to surface water. Based on the literatures reviews and hydrologic correlation of P and sediment yield and physical condition of Didessa basin, the findings of this study was gave directive implication that, the maximum load of total P was discovered on year 2005 which was about

(22.22kg/h/year) and the minimum load was seen on 2003 year with the amount of (10.77kg/h/year) as figured in the figure (4.12). The responsible causes for the rise of total P load in the year 2005 and decrease in the year 2003 was directly associated with increment and decrement of surface run off and sediment load.



4.12: Annual Total P load

4.7. Nitrogen load and Transport Pathways

According to Muleta, (2010), the most sensitive seven parameters for nitrogen simulation were identified. Rate coefficient for mineralization of the residue fresh organic nutrients (RSDCO), Nitrate percolation coefficient (NPERCO), Organic nitrogen enrichment ratio (ERORGN), amount of organic carbon in the soil layer (SOL-CBN), (SOL-NO3), humus mineralization rate (CMN) and Initial NO3 concentration in soil layer (SOL-ORGN) were reported as sensitive parameters on other catchment.

But, for this particular study the sensitivity parameter was not conducted due to lack of measured data. Relationship of simulated output with other hydrological output were discussed to get sound result.

4.7.1. Temporal Distribution of Nitrogen Losses

The average annual total riverine nitrogen load from the Didessa watershed was 22.10 kg/ha/year (Table 4.4). Organic N accounts for 82% of the total loss. The NO_3 SURQ and NO_3 LATQ nitrogen losses accounted for 0.1% and 0.5% of the total loss, respectively. NPERC contributed 16.74% of the predicted total nitrogen loading in the Didessa watershed.

The results of the study showed nitrogen loading in the catchment was majorly in the form of organic nitrogen ,which was transported by surface run off as shown in table 4.5.The findings were identify NO3 was transported through surface run off, lateral flow and percolating to ground water. NO3 was dominantly loaded via Percolation to ground water, this account around 97% of other NO3 loading rout. The least loading rout of NO3 in Didessa catchment was identified as Surface run off which accounts about only 0.26% of other form of NO3 loading and NO3 by lateral flow was found 2.86% during the study.

Table 4.4: Annual nitrogen loss in Didessa catchment (kg/h) (2000-2010)

Year	NO3 SUR Q	NO3LATQ	NO3 PERC	organic N	Total N (kg/h)
2000	0.01	0.11	3.76	19.06	22.94
2001	0.01	0.11	3.75	18.66	22.53
2002	0.01	0.11	3.53	18.18	21.83
2003	0.01	0.11	3.75	18.43	22.3
2004	0.01	0.11	3.87	17.49	21.48
2005	0.02	0.11	3.83	19.31	23.26
2006	0.01	0.11	3.76	18.18	22.06
2007	0.01	0.1	3.5	17.95	21.56
2008	0.01	0.11	3.84	17.91	21.87
2009	0.01	0.11	3.6	18.03	21.75
2010	0.01	0.11	3.51	17.86	21.49
Avg	0.01	0.11	3.70	18.28	22.10
sum	0.11	1.2	40.7	201.06	243.07
%	0.045	0.5	16.74	82.72	100.000

4.7.2. NO_3 SUR Q load

The average annual total nitrogen load by surface water from the Didessa watershed was 0.01 kg/ha/year, which was 0.058% of the total loss. The maximum NO3 load by surface water was found on 2005, which accounts 0.02kg/h/year and the loading was constant through the rest of year figure (4.13). The reason might be nitrate readily percolate to ground water movement rather than precipitate on the surface as phosphorus.

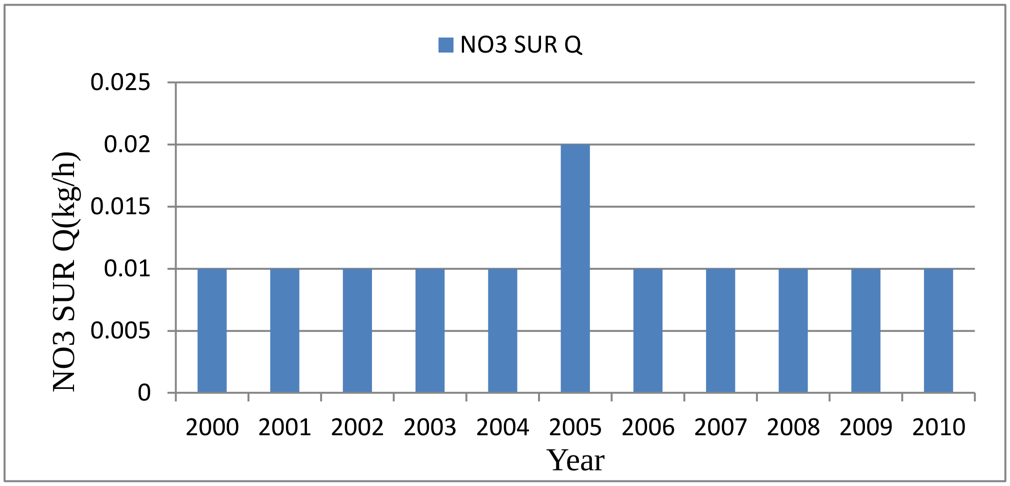


Figure 4.13: Annual NO3 loss by surface water

4.7.3 NO_3 LAT Q Load

The Average annual loss of NO3 by lateral flow was identified as 0.11kg/h/year, which was cover 0.5% of the total nitrogen load in the study year (2000-2010) as shown in table 4.5.

The maximum NO3 load by Lateral water flow was accounted 0.11kg/h and the minimum loading was 0.1 kg/h figure (4.14). The average loading of NO3 LAT Q in the study area was estimated as 0.11kg/h, which was cover 0.5 % of the total nitrogen load.

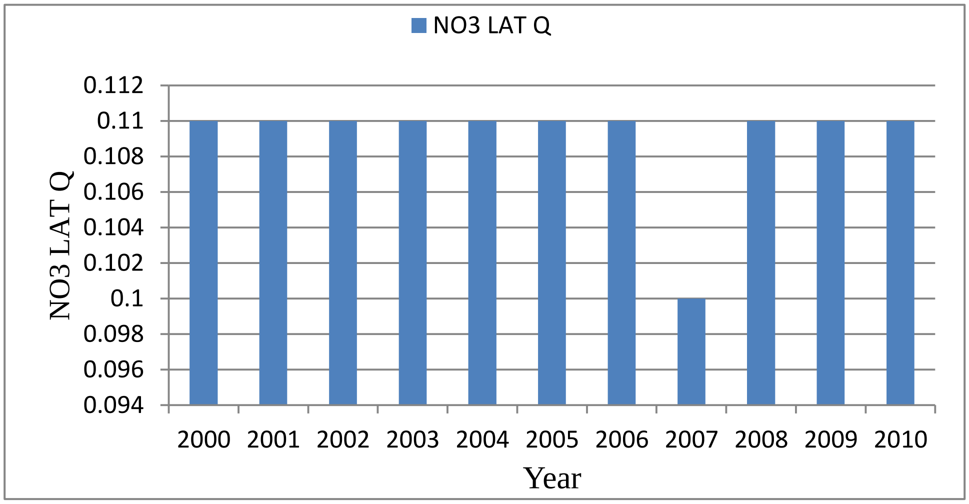


Figure 4.14: Annual NO3 by lateral water flow

4.7.4 NO_3 PERC

The SWAT was simulating Nitrate percolation movement for the study area in the study period. Accordingly, the maximum load of NO3 percolation was identified on the year 2004 with the amount of 3.87kg/h and the minimum NO3 percolation was 3.5 kg/h, which was found in the year 2007 figure (4.15). The average Nitrate percolation was 3.67kg/h, which covers 16.82 % of total nitrogen load in the Didessa watershed.

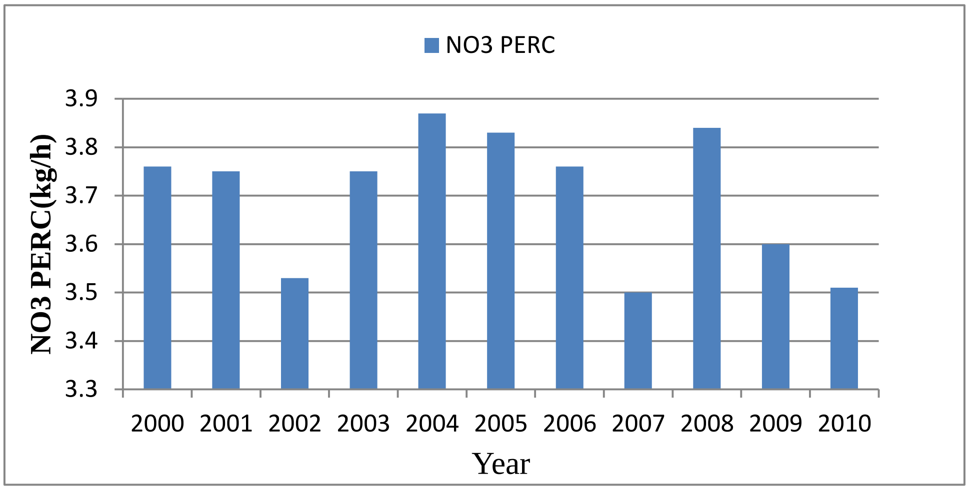
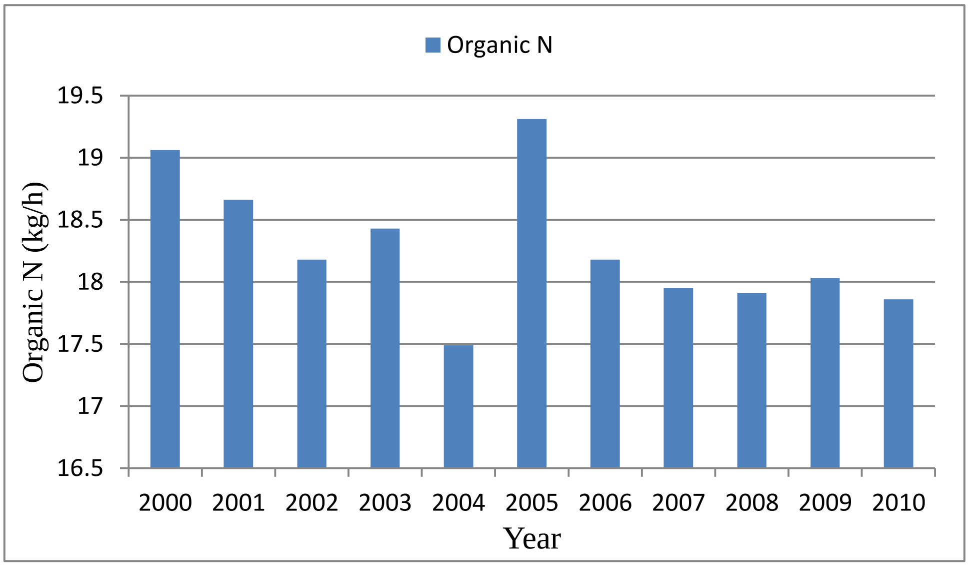


Figure 4.15: Annual NO3 load through percolation

4.7.5 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 2005 which accounts 19.3kg/h and the minimum Organic N load was 17.49kg/h on the year of 2004 figures (4.16). The annual total average of Organic load in the Didessa catchment was investigated 18.28kg/h that accounts 82.72% of total nitrogen load in the catchment.



4.16: Annual Organic N load

4.7.6 Total Nitrogen

Total nitrogen is both organic nitrogen and nitrate-N, in all soil layers needs to be 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 Didessa watershed was 22.01 kg/ha/year as identified during the study period.

The maximum amount of Total nitrogen load was found as 23.34kg/h and the minimum value was 21.49kg/h/year. The values were estimated on the year of 2005 and 2004 respectively. The organic nitrogen was the largest volume of total nitrogen load in Didessa catchment as it contribute 82.72% of the total N loss, which followed by NO3 PERC load (16.74%). Whereas the NO3 SUR Q was the smallest volume of total nitrogen load, as the finding showed only 0.1% of nitrate loaded via surface water.

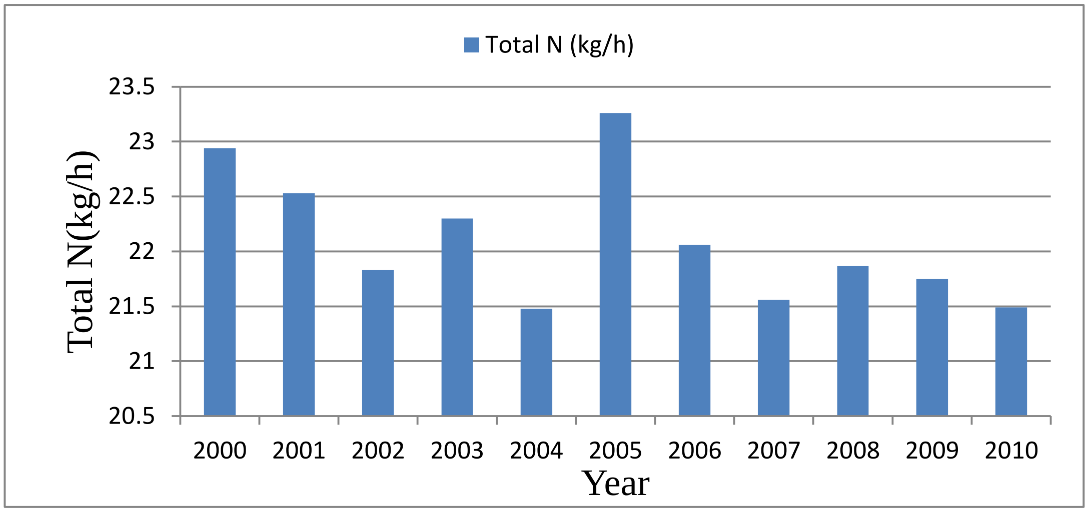


Figure 4.17: Annual Total nitrogen Loss in Didessa basin (2000-2010)

4.8. Prone Sub-Basins

The study area was classified into 253 HRUs and 25 sub-basins as indicated in the figure (4.18). Each sub-basin contributed a load of sediment, run off and nutrient to its outlet and moving distant to water resource.

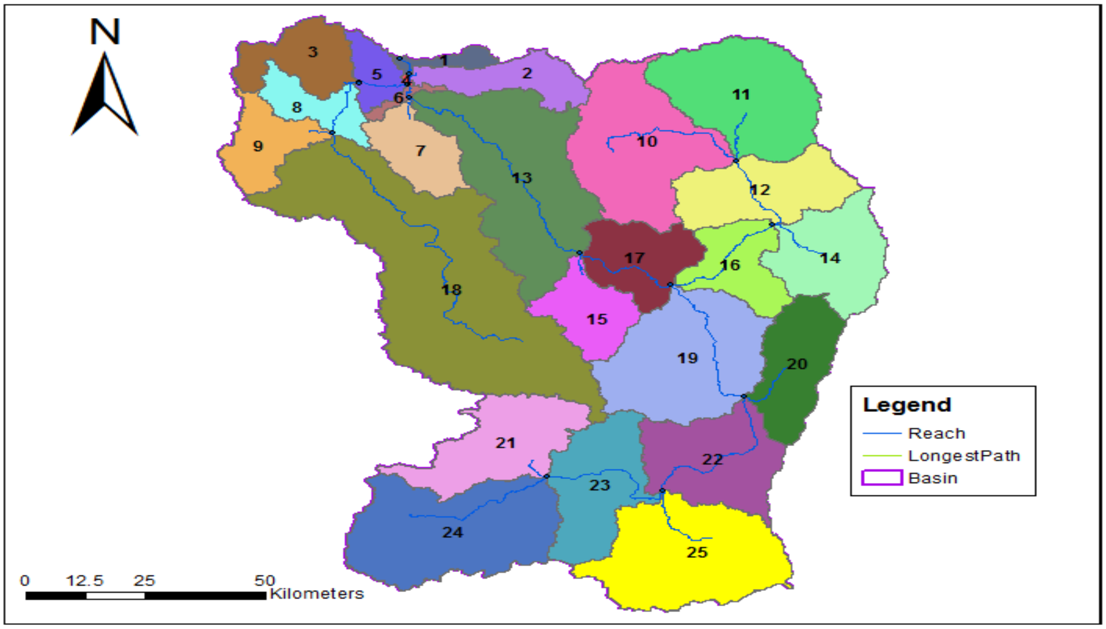


Figure 4.18:sub-basin number location

4.8.1. Spatial Distribution of Run off in Didessa sub-basin

Large volume of surface run off was initiated from sub basins number 11, 23, 5 and 2 which contribute run off volume greater than (800mm). Sub basin number 11, 23 and 5 was accounts 6.33%, 5.33%, and 4.96% of run off load contribution relative to the rest 22 sub basins respectively. The least run off contributing sub basin was sub basin 6 which accounts 2.59% of total area. This might occurred due to change in LULC, overland slope, terrain of land scape, soil types and hydrological condition over the area. The detailed run off distribution on sub basins was showed on figure (4.19).

The maximum run off was initiated from sub basin number 11 followed by sub basin number 23 and 5 with contributing value of 1063.83(mm),896.01(mm) and 834.7(mm) respectively . The average sub basin value of run of production was identified as 519.85 mm in Didessa catchment as annexed at the back. The results were ranged into three classes and spatially shown on the map as shown in table (4.5). The classification was for the sake of easily identifying highest contributing area and to take remedial action for management purposes.

Table 4.5: Summary of run off Yield Vs Contributing subasin

Run off Range (mm)	Sub basin
>800	11, 23, 5, 2
600-800	3 ,4 ,7 ,8 ,9 ,12 ,14 ,16 ,19 ,21 ,22 ,24 ,25
400-600	1, 6, 10, 13, 15, 17, 18, 20

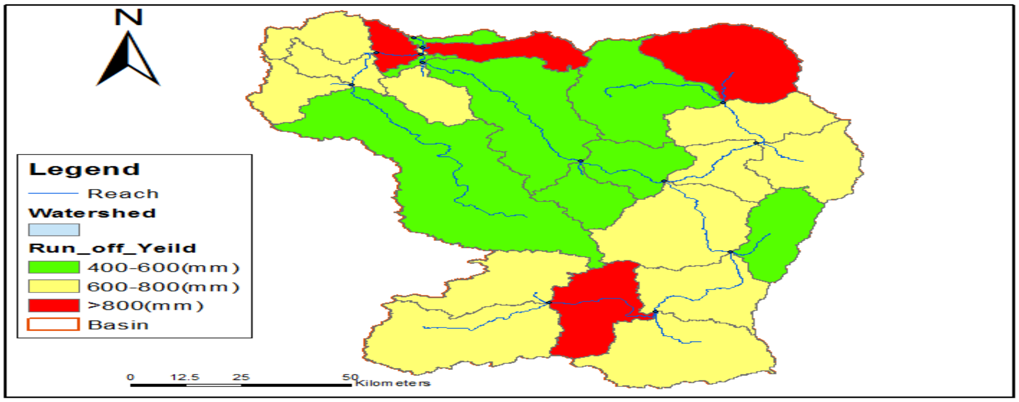


Figure 4.19: Sub-basin Based Spatial Distribution of Run off yield

4.8.2. Spatial Distribution of Sediment

The maximum sediment yield sub basin was observed from sub basins number 11, 3 and 5 with 7.18%, 6.67% and 5.54% of sediment load with respect to the rest sub-basins. Sub basin 6 was the least contributing sediment yield of total area, which covers 2.14% of the total sediment yield. The results were ranged into three classes and spatially shown on the map as shown in figure (4.20). The range of classification was in order to clearly map the loading sub basin from most vulnerable sub basin to least (see table 4.6). The reason for those maximum yielding might be due to steep slope, soil physical and chemical property, farming rate and pattern, LULC change, intensity of rain fall, and neighborhood area conditions and associated hydrological events.

Table 4.6: Summary of sediment Yield Vs Contributing subasin

Sediment yield range (t/h)	Sub basin
>600	2 ,3 , 5 ,7, 8 ,9 ,11
400-600	12 ,13 ,14 ,19 ,21 ,22, 23 ,24 ,25
200-400	1, 4 , 6 ,10 ,16 ,17 ,18

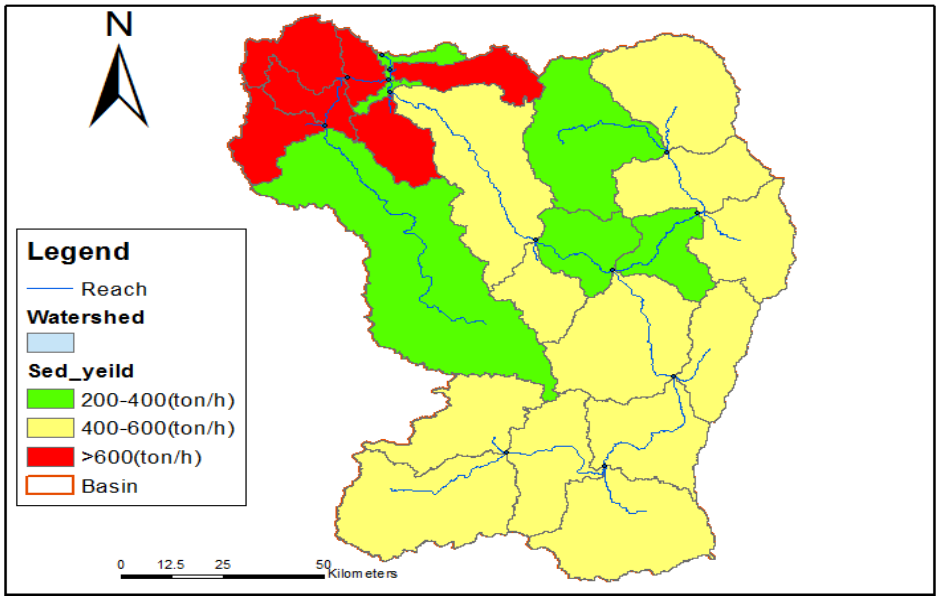


Figure 4.20: Sub-basin Based Spatial Distribution of Sediment yield

4.8.3. Spatial distribution of phosphorus on Didessa sub basin

The average sub basin load on study area of Didessa catchment was identified and annexed at the end of this document.

4.8.3.1. Org P

At sub-basin level, the three high amount of org P was initiated from sub-basin number 17, 23, 24 as indicated in the table (4.7). The values were grouped into three ranges and the spatial distribution was shown in figure (4.21).The possible main cause for high loading org P in the sub basin was rise of slope (>12%) which exposed the area to high run off down to the slope.

Table 4.7: Summary of Org P load Vs Contributing subasin

Org P Range (kg/h)	Sub-basin
>0.35	3,4,8,9,15,16,17,19, 22,23,24
0.3-0.35	2,5,7,10,13,18,20,21,25
0.0-0.3	1,6,11,12,14

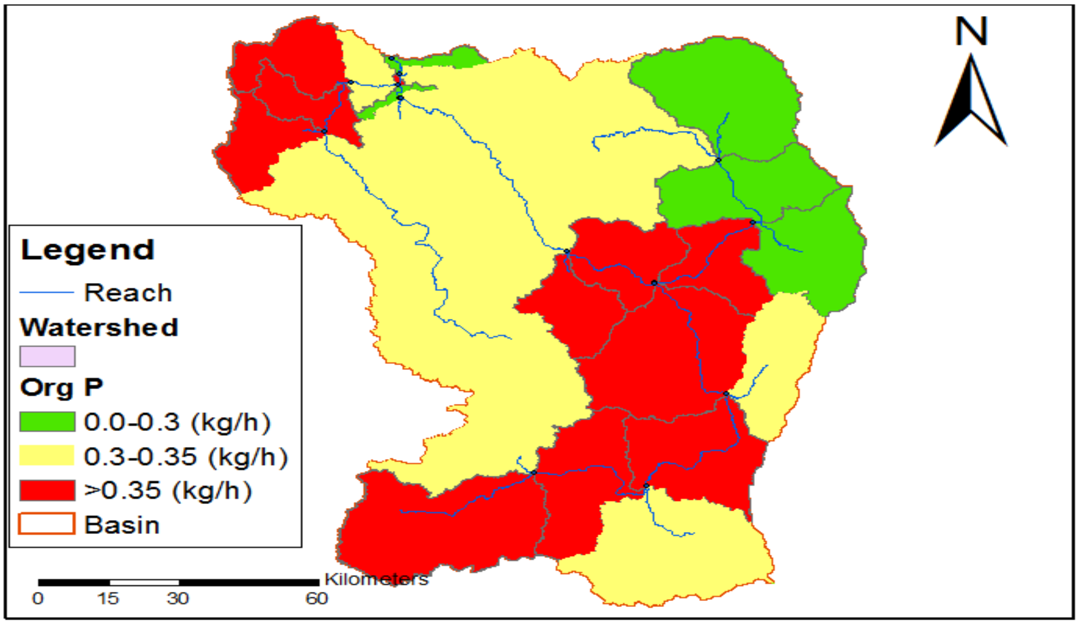


Figure 4.21: Sub-basin Based Spatial Distribution of Org P

4.8.3.2. Sed P

Sub- basin number 17, 23 and 3 were the top three main source of Sed P load as compared with the rest sub-basins respectively. The finding was showed the summarized range of Sed P load and Map of spatial distribution are shown in (table 4.8 and figure 4.22).

Table 4.8: Summary of Sed P load Vs Contributing subasin

Sed P Range (kg/h)	
>0.5	3,4,5,7,8,9,13,15,16,17,19 ,22,23
0.4-0.5	2,10,11,12,14,18,20,21,24,25
0.0-0.4	1,6

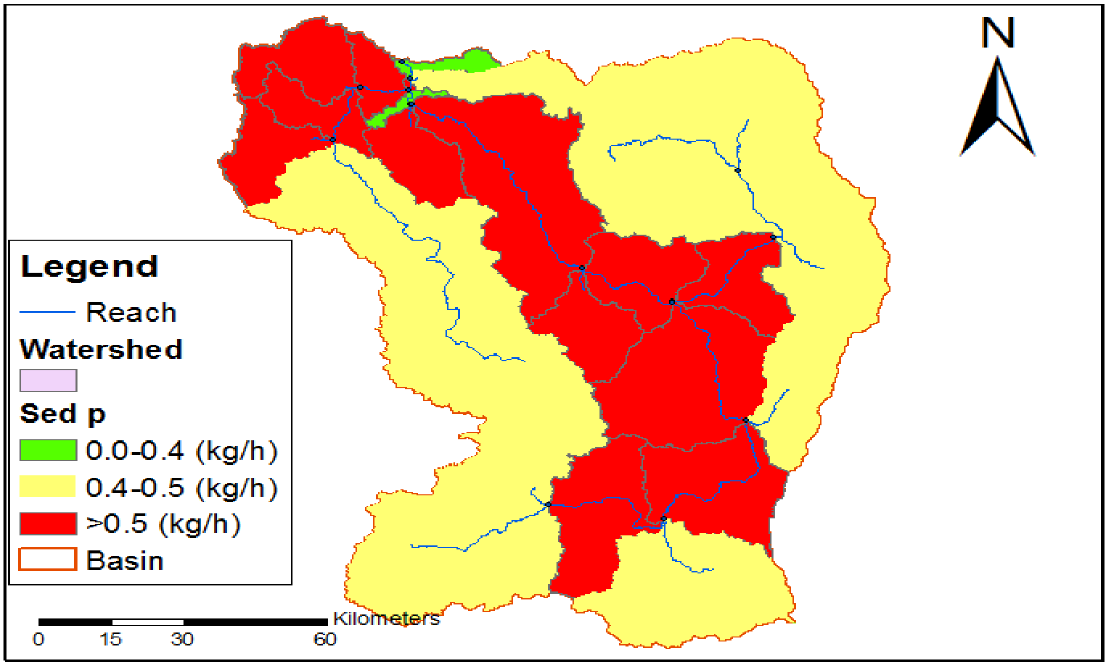


Figure 4.22: Sub-basin Based Spatial Distribution of Sed P

4.8.3.3. Total P

According to the study, the top three sub-basins responsible for high total P load were sub-basin number 17, 23 and 8 respectively relative to the rest sub-basin. Summarized loading range was shown in table (4.9) and map of spatial distribution was shown in figure (4.23).

Table 4.9: Summary of total P load Vs Contributing subasin

Total P range (kg/h)	Sub-basin
>0.9	3,8,9,17,23
0.8-0.9	4,5,7,10,13,15,16,18,19,20,22,24,25
0.7-0.8	2,11,12,14,21
0.0-0.7	1,6

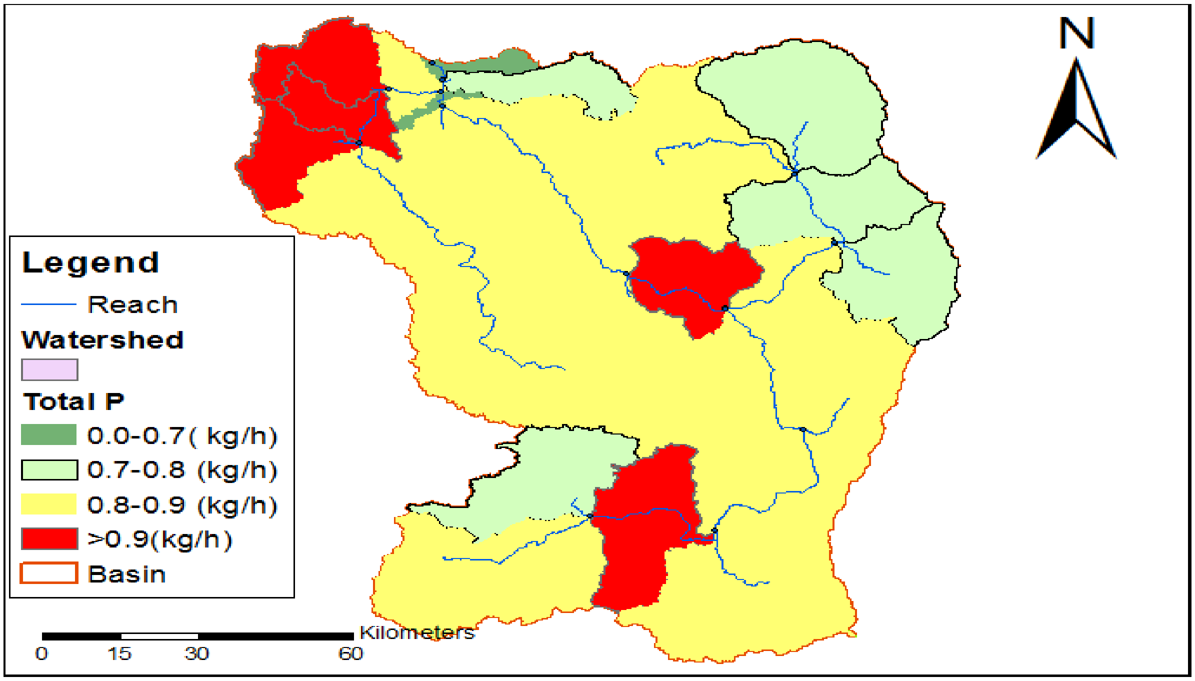


Figure 4.23: Sub-basin Based Spatial Distribution of Total P

4.8.4.1. Spatial Distribution of Organic N

The high amount of Organic N was initiated from sub basins number 17, 22, 16, which accounts 5.79, 5.53 and 5.44%. The least loading basin was sub basin 6 that loads only 1.27% of the total. Based on average sub basin value of organic N, the distribution of N nutrient was ranged as shown in table (4.10) and mapped as showed in figure (4.24).

Table 4.10: Summary of Organic N load Vs Contributing subasin

Org N Range (kg/h)	Sub basin number
5-15	11,14,1,6
15-20	2,12,5,7
20-25	4,25,20,3,9,18,21,24,8
>25	17,22,16,13,19,15,23

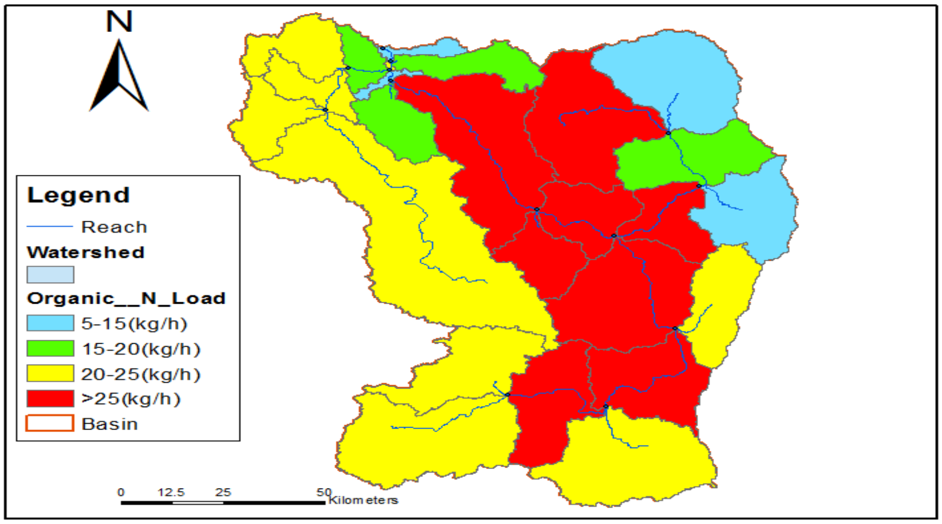


Figure 4.24: Spatial distribution of Organic N load

4.8.4 .2.Spatial distribution of NO_3 load

The study was found, NO3 was transported by Surface flow, lateral flow and ground water percolation. This all agents were transport nitrate from sub basin to water resource outlet. Based on basin values of NO3 load the spatial distribution was seen by classifying the basin into four ranged as in table (4:11) and spatial mapping was done. The three highest loading sub basins were sub basin number 20, 24 and 8 and the least loading sub basin was sub basin number 6. The map classified ranges are shown in figure (4.25).

Table 4.11: Summary of NO3 load Vs Contributing subasin

NO3 Ranges(kg/h)	Sub basin number
0.01-0.05	17,15,16,12,4,14,1,6,
0.05-0.10	13,5,18,7,22,19,11
0.10-0.2	21,25,9,23,10,2
>0.2	20,24,8,3

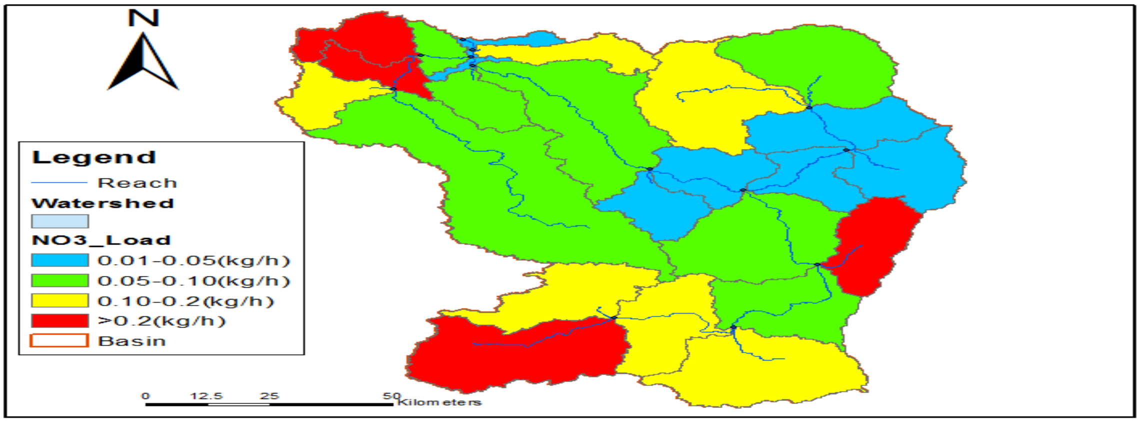


Figure 4.25: Spatial distribution of NO3 load

CHAPTER FIVE

CONCLUSION AND RECOMENDATIONS

5.1. CONCLUSIONS

Pollution of water resource by non-point source pollutant is the recent major global environment. Gaining detailed understanding of the operating process in agricultural field is important to explain how non-point source of pollution affect the water quality of the aquatic environment. For decades there are several research conducted to study the transport and effect of P and N on the water bodies. However, still more remain to develop efficient method that explicitly put the phosphorus and nitrogen fate .Particularly, in this study hydrological modeling is found to be useful tool for investigating loading and transport pathways and hydrologic response analysis at various spatial and temporal scales. As none of the hydrological models can be thought as perfect, models representing a better way are considered as essential criteria on the basis of data availability and the ease and purpose of modeling to evaluate the effects loading and transport pathway of nutrient with hydrological process.

The study has shown that GIS and SWAT 2012 are helpful in evaluating the spatial loading of nitrogen and phosphorus on the catchment. SWAT 2012 has also been shown as it was analyzing of the effect of climate and land use, water quality analysis and sediment yield, for planning of dam construction in the future and flood disaster risk management. 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.

The simulation of hydrological process has quantified the hydrological process in the basin using the reference conditions, defined in this study from 2000-2010. The effect of precipitation, surface runoff, total water yield and sediment yield on phosphorus and nitrogen loading and its transport pathways was evaluated.

According to this study the P and N load, transport pathways and prone area was identified using SWAT model and the average annual total P and total N load were 20.27kg/h/year and 22.01 kg/h/year respectively. The three main pathways through which mobilized P and N reach the water resource were identified as surface run off, subsurface flow and percolation to the ground water which depends on rainfall pattern, duration and intensity. Phosphorus and organic N were dominantly transported via surface run off whereas NO3 was dominantly transported via percolation to ground water.

The highest annual surface runoff was attributed by sub basin 11, 23 and 5 during study period 2000-2010. The e highest annual total P and total N load were contributed by sub basin 17, 23, 3 and 16, 17, 22 respectively.

The results of model calibration and validation have exposed the phenomena of the catchment. Model was calibrated and validated by stream flow and the result of SWAT model performance during calibration and validation was found to be 0.84, 0.8 and 0.65, 0.54 respectively for R2 and NSE. This shows good agreement between the simulated flow and observed stream flow. Nutrient Dynamics and hydrological process are systematically linked. This link provides an opportunity for manipulating the hydrological process if nutrient loads are controlled and managed.

5.2. RECOMMENDATIONS

The study acknowledges that the out looks into future sustainable water resources of Didessa Basin shall depend on the spatial planning of land use and water use with the objective of optimizing the environmental benefit through surface runoff control, erosion protection, nutrient loading control, flood protection and water availability. Hence, the following are the major recommendations of the study:

1. Nutrients, sediments and agricultural chemicals 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.
2. The amount of nutrient load and sediment yield are very high in the study area with the increasing population, increasing agricultural practice and increasing of fertilizer application. Therefore, educating the community the effect of the unwisely use of fertilizers with agricultural practices had on the environment, natural resources and ecosystem is of paramount importance for the catchment management.
3. The main source of P and N is processed fertilizers and conventional manures for agricultural intensive area. Therefore, it is better to undergo detail re-examination over the physical and chemical properties of P in fertilizers and manures to propose the minimizing, neutralizing, replacing strategies to reduce at the source.
4. 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 gaging at catchment level and water resource level by concerning organization.
5. Weather stations should be improved both in quality and quantity for the better performance of hydrological models. Hence, the uses of new and updated data are highly imperative.
6. At sub basin level, there are critical areas responsible for significant nutrient and sediment initiation. To give special attention to aware of the stakeholders and apply

best management practices continuously over those areas is paramount importance for the downstream management.

7. Now a days water quality is major issue of water user, planner and for decision maker. Total suspended solid can affect water quality by reducing aesthetic value of water source. Therefore it is better to undergo physical analysis of water quality for further recommendation and decision making.
8. Lastly, more advanced research should be undergo on pollutant, sediment chemicals loading and flow transport mechanisms and associated impacts to control them efficiently and update the corresponding models prediction efficiency.

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APPENDIX

Appendix A: Annul precipitation of each station

year	Agaro	Arjo	Bedele	Dembi	Nekemte	average
2014	4.566	4.653	4.648	4.124	6.904	4.979
2013	4.795	4.105	5.197	3.479	5.384	4.592
2012	5.134	4.764	5.061	4.491	5.763	5.043
2011	6.712	6.743	4.233	4.102	5.508	5.460
2010	5.669	5.648	5.387	6.058	6.800	5.912
2009	7.090	6.868	4.868	3.846	5.542	5.643
2008	7.146	4.894	5.436	4.866	6.670	5.802
2007	7.579	7.579	5.431	4.421	5.953	6.193
2006	5.543	5.364	6.461	5.841	5.861	5.814
2005	5.871	5.871	5.660	5.766	6.161	5.866
2004	6.450	6.450	5.192	3.170	4.896	5.232
2003	4.879	4.879	3.960	4.251	5.034	4.601
2002	3.708	3.708	3.971	6.814	4.674	4.575
2001	5.132	5.132	5.932	10.046	5.321	6.313
2000	5.344	5.273	4.994	6.209	5.837	5.531
1999	4.461	4.838	6.363	5.498	5.542	5.340
1998	4.968	4.568	5.318	4.387	6.990	5.246
1997	5.446	5.000	5.484	5.535	6.000	5.493
1996	5.188	5.165	4.740	5.039	6.341	5.295
1995	3.638	3.604	5.038	7.056	5.641	4.995
1994	3.944	3.724	4.108	7.070	5.726	4.914
1993	5.397	5.514	4.918	7.255	6.882	5.993
1992	5.468	5.468	5.216	5.787	6.773	5.743
1991	3.943	3.857	4.553	8.103	5.018	5.095
1990	4.351	4.306	4.689	8.329	5.177	5.370

Appendix B: Cumulative PCP of each station

Year	Agaro	Arjo	Bedele	Dembi	Nekemte	average
2014	4.566	4.653	4.648	4.124	6.904	4.979
2013	9.361	8.759	9.845	7.603	12.289	9.571
2012	14.495	13.522	14.906	12.094	18.052	14.614
2011	21.207	20.266	19.139	16.196	23.560	20.073
2010	26.876	25.914	24.526	22.254	30.360	25.986
2009	33.966	32.782	29.394	26.100	35.902	31.629
2008	41.112	37.676	34.829	30.966	42.572	37.431
2007	48.691	45.256	40.260	35.388	48.526	43.624
2006	54.234	50.620	46.721	41.228	54.387	49.438
2005	60.105	56.491	52.382	46.994	60.548	55.304
2004	66.555	62.941	57.573	50.165	65.444	60.536
2003	71.434	67.820	61.534	54.416	70.479	65.136
2002	75.143	71.529	65.505	61.229	75.153	69.712
2001	80.275	76.661	71.436	71.275	80.474	76.024
2000	85.619	81.934	76.430	77.484	86.310	81.556
1999	90.080	86.772	82.793	82.982	91.852	86.896
1998	95.048	91.340	88.111	87.368	98.842	92.142
1997	100.494	96.340	93.595	92.903	104.842	97.635
1996	105.682	101.504	98.336	97.942	111.184	102.929
1995	109.320	105.108	103.373	104.997	116.824	107.925
1994	113.264	108.833	107.482	112.067	122.550	112.839
1993	118.661	114.347	112.399	119.322	129.432	118.832
1992	124.129	119.815	117.616	125.110	136.206	124.575
1991	128.072	123.672	122.169	133.213	141.224	129.670
1990	132.423	127.977	126.858	141.542	146.401	135.040

Appendix C: Weather Generator Parameters used in SWAT

	Weather Generator Parameters used in SWAT for Nekemte									
Month	PCP_MM	PCPSTD	PCPSKW	PR_W1	PR_W2	PCPD	Tmp_max	Tmp_min	Hmd	Dewpt
Jan	8.60	1.49	7.35	0.05	0.30	2.28	26.07	12.30	0.40	10.50
Feb	12.56	1.73	5.34	0.07	0.52	3.84	27.43	13.24	0.35	10.00
Mar	52.64	4.96	4.62	0.16	0.60	9.40	27.60	14.04	0.89	11.10
Apr	101.96	7.65	3.34	0.23	0.66	12.44	26.56	14.37	1.15	12.37
May	247.89	12.50	2.72	0.37	0.78	20.48	24.58	13.83	2.30	14.23
Jun	391.80	14.74	2.62	0.84	0.89	27.32	22.40	12.90	2.86	15.48
Jul	405.87	15.71	1.91	0.87	0.89	28.52	20.99	12.79	2.20	15.41
Aug	406.12	14.60	1.96	0.80	0.91	29.00	21.07	12.85	2.20	15.54
Sep	295.56	11.27	1.73	0.75	0.86	26.48	22.43	12.78	1.55	15.74
Oct	151.96	9.01	2.73	0.34	0.71	17.76	23.84	12.85	1.29	14.58
Nov	47.92	4.97	4.70	0.16	0.45	7.32	24.39	12.62	0.93	13.29
Dec	16.02	2.96	8.58	0.05	0.36	2.68	25.03	12.11	0.75	11.73

		Weather Generator Parameters used in SWAT for Bedele								
Month	PCP_MM	PCPSTD	PCPSKW	PR_W1	PR_W2	PCPD	Tmp_max	Tmp_min	Hmd	Dewpt
Jan	16.46	2.40	7.42	0.09	0.32	3.92	27.03	12.09	0.63	10.79
Feb	20.13	2.90	7.06	0.09	0.45	4.36	28.36	12.82	0.80	8.72
Mar	68.88	5.93	4.12	0.19	0.59	10.16	28.16	13.73	1.14	10.83
Apr	114.16	7.74	2.79	0.25	0.64	12.64	27.62	14.02	1.08	13.65
May	231.47	10.73	1.78	0.38	0.74	19.20	26.05	13.58	1.27	15.50
Jun	321.71	12.62	1.83	0.71	0.78	23.92	24.39	12.89	2.18	17.31
Jul	284.79	11.01	1.59	0.69	0.81	25.20	22.57	12.86	1.31	17.01
Aug	293.68	11.24	1.62	0.81	0.83	26.48	22.78	12.85	1.25	16.98
Sep	295.55	11.94	1.98	0.70	0.79	23.96	24.25	12.65	1.74	17.29
Oct	150.14	9.49	2.77	0.24	0.64	13.16	25.10	12.37	1.49	16.18

Nov	36.36	4.43	5.04	0.13	0.40	5.52	25.67	12.03	0.89	14.68
Dec	20.03	3.14	6.75	0.08	0.31	3.32	26.38	11.85	0.76	12.64

Whereas: 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

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

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

Hmd = average daily humidity in month [%]

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

Appendix D: Run off Yield Sub basin Value

Sub basin number	Run off yield (mm)
1	516.84
2	821.83
3	773.37
4	738.27
5	834.70
6	434.89
7	746.43
8	698.89
9	717.34
10	503.18
11	1063.83
12	667.89
13	594.86
14	729.90
15	586.51
16	625.22
17	591.86
18	509.59
19	697.03
20	452.98
21	645.91
22	671.89
23	896.01
24	684.52
25	646.14
Avg.	673.99
Max	1063.83
Min	434.89

Appendix E: phosphorus loss in sub basin of Didessa catchment

Sub basin	Org P(kg/h)	Sol P (kg/h)	Sed P (kg/h)	Total P(kg/h)
1	0.228	0.001	0.370	0.598
2	0.306	0.001	0.472	0.779
3	0.396	0.001	0.532	0.928
4	0.354	0.001	0.509	0.864
5	0.349	0.001	0.516	0.866
6	0.178	0.001	0.322	0.501
7	0.338	0.001	0.517	0.856
8	0.399	0.001	0.532	0.932
9	0.390	0.001	0.518	0.909
10	0.328	0.001	0.474	0.803
11	0.263	0.001	0.477	0.741
12	0.285	0.001	0.485	0.771
13	0.346	0.001	0.504	0.850
14	0.264	0.001	0.478	0.743
15	0.365	0.001	0.514	0.880
16	0.372	0.001	0.515	0.888
17	0.532	0.001	0.570	1.103
18	0.347	0.001	0.471	0.819
19	0.367	0.001	0.511	0.879
20	0.348	0.000	0.474	0.822
21	0.317	0.000	0.434	0.751
22	0.357	0.001	0.512	0.870
23	0.455	0.001	0.559	1.014
24	0.446	0.000	0.450	0.896
25	0.343	0.001	0.495	0.838
Avg.	0.347	0.001	0.488	0.836

Appendix F: Laboratory results of Didessa water quality

Sample number	Day	Month	Year	NO-3_N (mg/l)	NH4+(mg/l)	T N(mg/l)	PO$_4$3-	(TP(PO43-P)(mg/l)
1	15	August	2017	1.32	0.34	2.76	0.144	0.678
2	16	August	2017	1.6	0.37	2.6	0.321	0.893
3	17	August	2017	1.01	0.43	1.558	0.213	0.782
4	18	August	2017	0.92	0.233	1.94	0.345	0.832
5	19	August	2017	1.395	0.23	2.44	0.135	0.657
6	20	August	2017	1.155	0.29	2.44	0.154	0.578
7	21	August	2017	1.7625	0.17	2.68	0.133	0.879
8	22	August	2017	1.635	0.38	2.43	0.25	0.674
9	23	August	2017	1.89	0.29	2.94	0.155	0.89
10	24	August	2017	1.38	0.17	1.93	0.207	0.901
11	25	August	2017	1.06	0.167	2.05	0.121	0.888
12	26	August	2017	1.25	0.168	2.76	0.146	0.788
13	27	August	2017	1.44	0.203	3.04	0.206	0.954
14	28	August	2017	1.22	0.156	1.87	0.144	0.543
15	29	August	2017	1.34	0.221	2.97	0.133	0.793
16	30	August	2017	1.69	0.273	3.04	0.417	0.901
17	31	August	2017	1.155	0.82	2.92	0.52	1
sum				**23.2225**	**4.911**	**42.368**	**3.744**	**13.631**
Average				**1.366**	**0.289**	**2.492**	**0.220**	**0.802**
18	1	September	2017	1.28	0.23	1.87	0.43	0.89
19	2	September	2017	1.93	0.5	3.05	0.23	0.76
20	3	September	2017	2.1	0.32	3.46	0.45	0.903
21	4	September	2017	1.7	0.31	3.23	0.6	0.98
22	5	September	2017	2.015	0.22	2.89	0.23	0.79
23	6	September	2017	1.815	0.62	2.92	0.123	0.89
24	7	September	2017	1.4225	0.59	2.76	0.18	0.87
25	8	September	2017	1.28	0.19	1.89	0.145	0.84
26	9	September	2017	1.44	0.203	1.78	0.134	0.93
27	10	September	2017	1.83	0.234	2.5	0.345	0.57
28	11	September	2017	2.05	0.34	2.89	0.32	0.67
29	12	September	2017	1.3	0.45	3.09	0.123	0.57
30	13	September	2017	1.04	0.54	2.04	0.234	0.634
31	14	September	2017	1.35	0.223	2.34	0.176	0.84
32	15	September	2017	1.55	0.322	2.97	0.167	0.83
sum				**24.1025**	**5.292**	**39.68**	**3.887**	**11.967**
Average				**1.61**	**0.35**	**2.65**	**0.26**	**0.80**