ADDIS ABABA UNIVERSITY SCHOOL OF GRADUATE STUDIES

ADDIS ABABA INSTITUTE OF TECHNOLOGY (AAiT)

IMPACTS OF LAND USE/COVER ON SURFACE WATER QUANTITY AND QUALITY

(CASE OF AKAKI CATCHMENT, ETHIOPIA)

BY

TESFAKIROS ATSBHA

A Thesis Submitted to the School of Civil and Environmental Engineering

Presented in Fulfillment of the Requirement for the Degree of Master of Science

(Civil and Environmental Engineering, Major Water Supply and Environmental Engineering)

Adviser: Dr. Agizew Nigussie

Addis Ababa University

Addis Ababa, Ethiopia

5/9/2019

Addis Ababa University

Addis Ababa institute of technology

The School of Civil and Environmental Engineering

This is certify that the thesis prepared by **Tesfakiros Atsbha**, entitled **Impacts of land use/cover on surface water quantity and quality (Case of Akaki catchment, Ethiopia),** and submitted in partial fulfillment of the requirement for the degree Master of Science (Civil and Environmental Engineering, Major of Water Supply and Environmental Engineering). It complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

Signed by examining committee

Dr. Agzew Nigusie ____________________

Advisor signature

Dr. Daniel F/selassie ____________________

Internal Examiner signature

Dr. Yniesew Mengistie ____________________

External Examiner signature

__________________ ________________________

Chairman (post graduate committee) signature

CERTIFICATION

The undersigned certify that he has read the thesis entitled Impacts of Land Use/Cover on Surface Water Quantity and Quality (Case of Akaki catchment, Ethiopia) and hereby recommend for acceptance by the Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science.

..………………………………………...

Dr. Agizew Nigussie

(Advisor)

……………………………………………………………….

Date

DECLARATION AND COPY RIGHT

I, Tesfakiros, declare that this is my own original work and that it has not been presented and will not be presented to any other University for similar or any degree award.

Signature________________________

Date_________________________

Tesfakiros Atsbha

tesfak129@gmail.com

+251914399843

March 2019

ACKNOWLEDGMENT

I would like to express my special thanks and deep-hearted appreciation to my advisor Dr.Agizew Nigussie for his genuine and constructive advice, supervision and sacrifice his golden time from the very beginning up to what is now.

I am also very grateful to Addis Ababa Institute of Technology, School of Civil and Environmental Engineering for allowing me to take part in the Master Program and full MSc thesis financial support.

Moreover, my gratitude goes to the Ethiopian Ministry of Water Resources, Ethiopian National Metrological Agency and Addis Ababa Environmental Protection Agency for providing me materials and data required for the research.

Finally yet importantly, I am very thankful to my friends Gidena H, Hagos A, Tewlde G. and Ashenafi G. for their professional help.

ABBREVIATIONS

CSA…...critical source area

DEM….Digital Elevation Model

EPA………… Environmental Protection Agency

HU… Hydraulic Response Unit

LET………….. Latitude

LONG…...longitude

LULL…………….land use land cover

NPS… Non-Point Source

NOSE………….. Nash Sutcliffe efficiency

PS…………point source

R^2…………….Coefficient of determination

SRTM …………Shuttle Radar Topographic Mission

SUFI2… Sequential Uncertainty Fitting Version 2

SWAT… Soil and Water Assessment Tool

TN…...Total Nitrogen Load

TP………….. Total Phosphorus Load

UTM…Unified Threat Management

WASP….Water Quality Analysis Simulation Program

WXGEN….Weather Generator Data Base

XLSTAT…Excel Statistical Analyst Software

CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF APPENDIX TABLES

LIST OF APPENDIX FIGURES

ABSTRACT

Evaluating the impacts of land use on surface water quality and quantity based on temporal and spatial variation using the integrated watershed (SWAT) and water quality models (WASP) were the aims of this study. SWAT model's performance was assessed using Nash–Sutcliffe coefficient (NSE) and coefficient of determination (R^2) with the help of SWAT CUP software. The model was calibrated from 1989 to 1994 and validated from 1995 to 1997 for stream flow using the 1989 land use/land cover map. The monthly calibration and validation results showed (NSE = 0.74, R^2 = 0.76) and (NSE = 0.53, R^2= 0.55) respectively. Annual stream flow was evaluated on the years 1989, 2003 and 2016 and the result shows that it increases by 10.1% from (1989-2003) and by 30.3% from (1989-2016) on the downstream of Little Akaki river (reach 51). This is because urbanization increases by 63.7% and forestland decreases by 61.6% from the upstream to the downstream of the river. Sediment load decreased by 98.2% when urbanization is increased by 35.2% and barren lands decreased by 37.3% from (1989-2016). It also increased by 82.6% when urbanization increased by 53.5% and barren land decreased by 32.4% from (1989-2016). pH, Temperature, TSS, NH4-N, NO2-N, TN and TP decreases its quality by 5.9%, 0.8%, 7.0%, 59.2%, 67.0%, 34.5% and 45.9% from upstream to downstream of Great Akaki river. This is because of built up area increases by 45.7% and forestland decreases by 28.5% from upstream to downstream of Great Akaki River. Water quality of the rivers was evaluated temporally and the results showed that pH, Temperature, TSS, NH4-N, NO2-N, TN and TP decreases its quality by 5.29%, 9.11%, 48.47%, 45.88%, 43.28%, 47.1% and 17.69% respectively from (1989-2016) on little Akaki river. When the simulated result are compared to water quality guide lines pH, TSS, NH4-N, TN and TP exceeds the guideline by 2.9%, 85.8%, 5.2%, 2.3%, & 0.2% on downstream of little Akaki and by 11.1%, 87.3%, 10.7%, 31.6% & 7.35 Great Akaki rivers respectively.

Key words: land use, surface water quality and quantity, SWAT, WASP, Akaki catchment

1. INTRODUCTION

Surface water is the most important economic resource for humans, for it provides water for agricultural, industrial and anthropogenic activities. Surface water quality plays vital role in protecting aquatic ecosystems (Ullah & , J. Jiang, 2018). Surface water quality is crucial for human beings by means of sustainability; nevertheless, human activities adversely affect the water resources. (Gülbaz, 2014)

Mobilization and delivery of pollutants added to water and its concentration at catchment scale source are mainly influenced by LULC, land management practices, topographic conditions, surficial geology, climatic conditions and watershed hydrology (Ullah & , J. Jiang, 2018).

The land use within the watershed has great impacts on the water quality of rivers. The water quality of rivers may degrade due to the changes in the land cover patterns within the watershed as human activities increase (Yong & Chen, 2002). Changes in the land cover and land management practices have been regarded as the key influencing factors behind the alteration of the hydrological system, which leads to the change in runoff as well as the water quality (Ding et al., 2015).

The contribution of non-point source pollutants from urban surfaces and agricultural land can greatly degrade the chemical water quality of urban streams and other receiving water. The increase in impervious surfaces expedites the mobilization of contaminants increase surface runoff. In addition, the connectivity of surface and subsurface flow paths increases the rate and magnitude of transference into receiving waters (McGrane, 2016).

Forestland and grassland have negative correlation with water pollution, and the built-up area had negative impacts on the water quality. Besides, there is significant negative relationship between the landscape diversity and indicators of water quality within a watershed (Huang, Zhan, Yan, Wu, & Deng, 2013).

The generation of runoff from urban surfaces can carry a suite of contaminants including heavy metals and major nutrients (McGrane, 2016). Storm water or urban runoff added to the urban water hydrology causes heavy water pollution with contaminants in the city roads. Another problem is associated with the construction of roadways and house, which may expose the soil contaminants and this, may accelerate the erosion, which chokes the drainage system of the city due to sediments and fills. The urban drainage system is highly uneven in terms of various characteristics such as slope, size, shape, roughness and degree of imperviousness which leads to change in surface water quality and quantity (Shrivastava, 2016). Therefore, an understanding of the influence of land use and management within a catchment is required to assess the impact of non-point source pollution on water quality (Sliva & Williams, 2001).

Pollutants in runoff and seepage from urban, agricultural and forest areas contribute to water pollution in areas of Addis Ababa city. The state of the metropolitan environment of Addis Ababa and the environmental pollution of the Akaki catchment have been a subject of concern for many scholars, institutions, the affected community, many environmental groups and MSc thesis's (Alemayehu, 2001).

(Agaje, 2007) studied about the suitability assessment of the little Akaki river for irrigation. He takes two sample points and conduct the lab only for the dry months of 2007. Also (Solomun, 2011) was assessed the impacts of human activities on the Greater Akaki River. Physicochemical samples and macro invertebrates were collected bimonthly from eight sites established on the Greater Akaki River from February 2006 to April 2006. In addition to these studies (Tafere, 2008) also done his thesis on the assessment of River Water Quality in Addis Ababa May 20, 2007 to June 8, 2007 for some parameters on the upstream and downstream of both Great and Little Akaki rivers. (Ferezer Eshetu, 2009) who was a student of Stockholm university department of physical geography and quaternary geology also done his Msc thesis on Physico-chemical pollution pattern in Akaki River basin, Addis Ababa, Ethiopia. Moreover, his outcome of the study was observed absence of spatial and temporal pattern on both surface and groundwater but displayed a huge variation.

However almost all these studies and other studies were focused on analyzing the water quality using physical model (laboratory). Due to lack of time to conduct lab analysis, lack of budget and well-prepared materials these studies were limited to analyze for a short temporal variation, very small number of spatial variations and very small number of water quality parameters. The remaining few researchers who have analyzed using models also limited on specific time and water quality parameters.

Understanding the spatial and temporal variation in urban water quality is an area that continues to fuel research, as the quest for sustainable ways to manage flow and to search for water quality (McGrane, 2016).

Surface water quality models can be useful tools to simulate and predict the levels, distributions, and risks of chemical pollutants in a given water body. The modeling results from these models under different pollution scenarios are very important components of environmental impact assessment and can provide a basis and technique support for environmental management agencies to make right decisions (Wang, Li, Jia, Qi, & Ding, 2013). Therefore, evaluating the impacts of land use on surface water quantity and quality of Akaki catchment using watershed and water quality models was the aim of this work.

1.1 Statement of the problem

Addis Ababa city has steep slopes from North end to the Akaki plateau. This elevation ranges between 3300 m (at the northern part) and 2035 m (at the southern). This high elevation difference could favor run off with higher speed and quantity of flow.

The degradation of Akaki river water quality becomes one of the major environmental problems that we are facing today. Because Akaki Rivers are used as receivers of all kinds of wastes disposed from Addis Ababa and nearby without any treatments, and there is no law that prohibit them not to do so.

In the study area streams and rivers, receive the major part of the waste produced by the residents. In the southern part of the city, the same rivers serve for various purposes such as horticulture, drinking water for cattle, washing and for other domestic purposes (Fafuguta, 2015).

Water pollution is also the major issue in the case of Aba Samuel Lake, which collects the effluent from Great and Little Akaki Rivers. As many people live around the lake, they use the lake for their daily activity (domestic purposes). Of the total households of the dam area, 40% use the lake and river water for drinking and cooking, while 70% of them use it for bathing/washing and about 93% of their animals depend on the lake and river water (Nigusie, 2005).

Therefore, as almost all surface water sources of Akaki catchment are used for different purposes, the degree of water pollution due to land use/cover change and the level of water quality in spatial and temporal variation should be clearly identified. Therefore, this research was conducted to evaluate the impact of land use on stream water quantity and quality, and their changes with temporal and special variation due to land use change.

1.2 Objective

1.2.1 General objective

The main objective of this thesis was to evaluate the impact of land use on surface water quantity and quality on Akaki catchment.

1.2.2 Specific objective

1) To explore the temporal variation of stream water flow
2) To investigate the temporal and spatial variations of pollutant loads (sediment and nutrient) and identify the more polluted areas
3) To evaluate the temporal and spatial variation of river water quality
4) To assess the degree of water pollution in the Little and Great Akaki Rivers

1.4 Significance of the study

Scientifically, the result will provide sub-base line information on the change of water quality and its degree of pollution for the study area. Through trend analysis, it will indicate to what extent land use is comparable to the natural background. Knowing the relative contributions of land use and natural sources will help to advise appropriate mechanisms for future intervention and uses as feasibility study to study the pollution prevention mechanisms or mitigation measures for the future.

1.5 Limitation of the study

Point source pollution, such as industrial outflows and outflows from wastewater treatment plant are factors to change the quality and quantity of surface water on Akaki catchment. However as the industrial out flows are difficult to gate due to the security and there is no time series data of outflows from waste water treatment plant this research is limited only on non-point source of pollution.

WASP model has the capability of calibration and validation of simulated water quality parameters. However, due to lack of water quality data, it was calibrate manually using the yearly data of specific sites and years.

2. LITERATURE REVIEW

2.1 Land use

It is widely known that watershed hydrology is dependent on many factors: land use, climate, and soil conditions. But the relative impacts of different types of land use on the surface water are yet to be ascertained and quantified.(Yong & Chen, 2002)

Land use is changed due to unplanned urbanization, intense agricultural activities and deforestation which are positively associated with carbon, nitrogen and phosphorous related water quality parameters (Ullah & , J. Jiang, 2018). As land use/cover and rivers are intimately linked, the opportunity is provided to assess how changes to this can impact rivers and their water quality, though quality is determined by factors such as climate, landscape and geology (Santikari, 2017). Changes in land management could have a substantial impact in water quality improvement, especially relevant where cost-efficient solutions to water quality impairment are a requirement. This could include efficient use of fertilizers in agricultural land management by reducing quantities of fertilizer applied or maintaining and/or establishing riparian buffer areas to mitigate the impacts to streams from the land-based activities. Vegetation (indigenous or exotic) as riparian buffers can also influence water quality and a proper understanding of that role is necessary for effective land and water management (Santikari, 2017).

The management of land use activities can play a role, e.g., altering river channels or changing the imperviousness of a surface. So surface water discharge increases or decreases altering the flow in rivers and groundwater and affecting the physical, chemical and biological processes in the receiving water bodies(Yong & Chen, 2002). Furthermore, the role of land use types on water sustainability should be investigated to avoid present and future problems like flood, drought and water contamination (Gülbaz, 2014).

2.2 Water quality

Water is most indispensable requirement for all living organisms and any alterations in water may lead to the issue of survival for these organisms. Good quality of water is essential for living organisms. The quality of water can be assessed by studying its physical and chemical characteristics. Because of vast population and negligence of human being, the quality of water is being deteriorated day by day. (Virendra, Salahuddin, & Manish, 2013)

People on globe are under tremendous threat due to undesired changes in the physical, chemical and biological characteristics of air, water and soil. Due to increased human population, industrialization, use of fertilizers and human-made activity water is highly polluted with different harmful contaminants. The availability of good quality water is an indispensable feature for preventing diseases and improving quality of life (Patil, Sawant, & Rn, 2012)

Consideration of water quality is important in wetland habitat evaluation because a host of interacting physical and chemical factors can influence the levels of the primary productivity and thus influence trophic structure and total biomass throughout the aquatic food web(Tiwari, 2015).

It is very essential and important to test the water before used for drinking, domestic, agricultural or industrial purpose. Water must be tested with different physic-chemical parameters. Selection of parameters for testing of water is solely depends upon for what purpose we going to use that water and what extent we need its quality and purity (Tiwari, 2015).

It is necessary to know details about different physic-chemical parameters such as color, odor, turbidity, TDS, TSS, temperature, acidity, hardness, pH, sulphate, chloride, DO, BOD, COD, alkalinity, hardness, nitrate, nitrite, phosphate etc. for testing of water quality for different purposes (Patil et al., 2012).

As water quality, is very essential for wet land habitat, animals and human life, this research was modeling some of physic-chemical parameters like TSS, temperature, pH, Nitrate-N, NH4-N, TN and TP.

Temperature

In an established system, the water temperature controls the rate of all chemical reactions, and affects fish growth, reproduction and immunity. Drastic temperature changes can be fatal to fish (Patil et al., 2012).

Temperature can exert great control over aquatic communities. If the overall water body temperature of a system is altered, an aquatic community shift can be expected. In water above 30 c^o, a suppression of all benthic organisms can be expected. In addition, different plankton groups will flourish under different temperatures. For example, diatoms dominate at 20-25 c^o, green algae dominate at 30–35 c^o, and cyano-bacteria dominate above 35 c^o (Tiwari, 2015). Fish species like Salmo trutta needs water quality range of 12-13 c^o for growth and Clarias gariepinus needs temperature of 28-30 c^o for growth (Department of Water Affairs and Forestry, 1996).

PH

PH is an indicator of the existence of biological life as most of them thrive in a quite narrow and critical pH range (Tiwari, 2015).

PH is most important in determining the corrosive nature of water. Lower the PH value higher is the corrosive nature of water. The reduced rate of photosynthetic activity, the assimilation of carbon dioxide and bicarbonates, which are ultimately responsible for increase in pH, the low oxygen values coincided with high temperature during the summer month. Various factors bring about changes on the PH of water. The higher PH values observed suggests that carbon dioxide, carbonate-bicarbonate equilibrium is affected more due to change in physic-chemical condition (Patil et al., 2012).

According to (UNEP/UNU-EHS, 2016) the PH guidelines for fresh water ecosystems of rivers and streams is 5-9.

Total Suspended Solids (TSS)

Total Suspended solids are an indication of the amount of erosion that took place nearby or upstream. This parameter would be the most significant measurement, as it would depict the effective and compliance of control measures e.g. riparian reserve along the waterways. The series of sediment-induced changes that can occur in a water body may change the composition of an aquatic community. The settling of suspended solids from turbid waters threatens benthic aquatic communities. Deposited particles may obscure sources of food, habitat, hiding places, and nesting sites. Most aquatic insects will simply drift with the current out of the affected area.

Finally, sediment deposition may encourage species shifts because of a change of substrate. Sediment deposition may also affect the physical characteristics of the streambed. Sediment accumulation causes streambed elevation and a decrease in channel capacity. Flooding is more likely after sediment accumulation. Because the stream cannot accommodate the same volume of water. In addition, a substrate that is closer to the surface receives more light and supports increased numbers of photosynthetic organisms, such as rooted algae. As a result, recreational use may be threatened because moving parts of boats may become tangled in aquatic plants. Sediment, which is generally negatively charged, attracts positively charged molecules. Some of these molecules (phosphorus, heavy metals, and pesticides) are pollutants. These positively charged pollutants are in equilibrium with the water column and are often released slowly into the water resource (Tiwari, 2015).

Greater than 100 mg/l of total suspended solids increasingly severe problems with the clogging of drip irrigation emitters whereas for agriculture it may range up to 1000 mg/l (DWAF, 1996).

Ammonia as Nitrogen (NH_4-N)

Ammonia levels in excess of the recommended limits may harm aquatic life. Although the ammonia molecule is a nutrient required for life, excess ammonia may accumulate in the organism and cause alteration of metabolism or increases in body PH. It is an indicator of pollution from the excessive usage of ammonia rich fertilizers (Tiwari, 2015).

Taste and odour complaints are likely to occur if the ammonia concentration exceeds 1.5 mg/l. High concentrations of ammonia can also give rise to nitrite, which is potentially toxic, especially to infants (DWAF, 1993). Therefore, according to this study 0-1 mg/l of ammonia is recommended for domestic use.

Nitrite as Nitrogen (NO_2-N)

The growth of macrophytes and phytoplankton is stimulated principally by nutrients such as nitrites. Many bodies of freshwater are currently experiencing influxes of nitrogen and phosphorus from outside sources. The increasing concentration of available phosphorus allows plants to assimilate more nitrogen before the phosphorus is depleted. Thus, if sufficient phosphorus is available, high concentrations of nitrates will lead to phytoplankton (algae) and macrophyte (aquatic plant) production. This is mostly due to the usage of fertilizers (Tiwari, 2015).

Natural sources of nitrite to surface waters include wet and dry deposition of HNO^-3 or NO^-_3, which are formed through nitrogen cycling in the atmosphere. Other natural sources of nitrate include igneous rocks and volcanic activity, mineralization of native soil organic nitrogen and the complete oxidation of vegetable and animal debris (Chambers et al., 2001).
Nitrite levels in drinking-water are usually below 0.1 mg/l (World Health Organization, 2011).

Total nitrogen (TN)

There are three forms of nitrogen that are commonly measured in water bodies: ammonia, nitrates and nitrites. Total nitrogen is the sum of total kjeldahl nitrogen (ammonia, organic and reduced nitrogen) and nitrate-nitrite. It can be derived by monitoring for organic nitrogen compounds, free-ammonia, and nitrate-nitrite individually and adding the components together.

Total Nitrogen is an essential nutrient for plants and animals. However, an excess amount of nitrogen in a waterway may lead to low levels of dissolved oxygen and negatively alter various plant life and organisms (Tiwari, 2015).

According to the study of United Nations University on international water quality guide lines for healthy fresh water ecosystem the total nitrogen guide line range is 0.7-2.5 (UNEP/UNU-EHS, 2016).

Total phosphors (TP)

It is an essential element for plant life, but when there is too much of it in water, it can speed up eutrophication (a reduction in dissolved oxygen in water bodies caused by an increase of mineral and organic nutrients) of rivers and lakes. Soil erosion is a major contributor of phosphorus to streams. Phosphorus is an essential nutrient for plants and is a natural component of healthy rivers. Agricultural and urban land use can add more phosphorus to waterways, mainly as attached to sediment, which can cause excessive growth of algae and deteriorate river habitats (Patil et al., 2012).

Also the study of United Nations University on international water quality guide lines for healthy fresh water ecosystem on rivers and streams put the guidelines for total phosphorus as 0.02-0.19 (UNEP/UNU-EHS, 2016).

Surface water pollution

Water is one of the most important compounds that profoundly influence life. In spite of its enormousness, increasing the population of any country increases the demand for water supply and everything needed by man for survival. Satisfying these, anthropogenic needs tend to change the originality of some of the existing natural resources of which water is of no exception. Once these water resources are polluted, its quality cannot be restored by minimizing the factors that contribute to the pollution. The most common source of pollution of water is from substances used in forestry, waste and agriculture such as insecticides, herbicides, fungicides etc, and urban runoff, aerosols from pharmaceuticals and personal care products (Collins & Tiimub, 2014).

Human activities such as agriculture, housing and recreation also contribute to the degradation of water quality of surface water quality. Excessive loadings of pollution into river, lakes, reservoir and estuaries have become contribution to major cause of water pollution. Source of pollution can be categorized in two types, point source pollution and non-point source pollution (Ain Nihla Kamarudzaman, Voon Kim Feng, Roslaili Abdul Aziz, & Mohd Faizal Ab Jalil, 2011).

As defined by EPA, point sources are any discernible, confined, and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, or vessel or other floating craft from which pollutants are or may be discharged. Point source pollution is a single identify localized source (Valcu, 2013).

Point sources are relatively easy to identify, quantify and control. Thus, point sources can be identified and their emissions can be properly measured at a relatively low cost. It is assumed that there are no stochastic elements or errors in emissions measurement. This makes the polluters easily to be identified and thus made accountable for their emissions (Valcu, 2013).

Nonpoint source of pollution is result from precipitation, land runoff, infiltration, drainage, seepage, hydrologic modification, or atmospheric depositions. As runoff from rainfall or snowmelt moves, it picks up and transports natural pollutants and pollutants resulting from human activity, ultimately depositing them into rivers, lakes, wetlands, coastal waters, and groundwater (Valcu, 2013).

Thus, nonpoint source emissions' diffuse nature makes the loadings more difficult and more costly to measure. Nonpoint sources can be identified as emissions coming from mobile sources, leaching, and runoff from farm fields. There is uncertainty about the contribution of each polluter to the total amount of pollution (Valcu, 2013).

Loadings from point sources can be measured directly, whereas nonpoint sources loadings can be estimated. Therefore, this research was more interested on the estimated loadings. Because knowing of those pollutants is used to control and monitor them.

2.3 Impact of land use on surface water sources

Within the last few decades, the water demand has increased in parallel to the increase in the world's population, industrialization, agriculture and urbanization. Thus, more water resources have been utilized to supply this demand, which led to generation of high amounts of raw wastewater and in turn, discharge of more wastewater either treated, partially treated and/or untreated into the water bodies. As a result, water resources have been deteriorated, and water has become a more vulnerable natural resource with its quality and quantity (Alpaslan Ekdal, Melike Gurel, Cigdem Guzel, 2011).

Natural processes and human activities in urban areas, which can either, be point or non-point sources such as urbanization, industrial as well as agricultural activities govern the physic-chemical and biological composition of surface water and its properties in a particular region. Human activities are a major factor determining the quality and quantity of surface water through atmospheric pollution, effluent discharges, use of agricultural chemicals and eroded soils. In addition, urban land uses create impervious surfaces resulting in storm runoff events that negatively affect stream ecosystems and water quality and quality (E, 2014).

Urbanization affects microclimate, surface water dynamics, groundwater recharge, stream geomorphology, biogeochemistry, and stream ecology (Driscoll, Clinton, Jefferson, Manda, &

Mcmillan, 2010). Consequently, water quantity, quality (i.e., sediment, nutrient dynamics, and other pollutants), and watershed functions are impacted (Sun & Caldwell, 2012).

Impact of land use on water quantity

Forest clearing or converting forestlands to urban uses increases surface albedo (reflection of solar radiation), decreases net radiation, reduces latent heat, enhances summer storm intensity, and causes heat island effects (Driscoll et al., 2010). Removing forest vegetation cover reduces plant transpiration and canopy interception and alters soil infiltration capacity. These factors result in a dramatic increase in overland flow due to decreases of total water loss and infiltration. The magnitude of stream flow change due to land use/land cover change depends on the severity of disturbances (e.g., percentage of forest removal, soil compaction, extent of impervious area, road density), local climate (radiation inputs, rainfall patterns), soil and geology (Sun & Caldwell, 2012).

The transformation from undeveloped spaces into urban environments results in marked alterations to the landscape, with spatial and temporal dynamics of change varying between developed and developing countries. Those impacts are through the alteration of the topography and surfaces because of new construction, demolition and redevelopment and occur at a range of scales (McGrane, 2016).

As building density increases and larger neighborhood areas emerge, greater impervious surface area modifies the way rainfall is translated into runoff at the surface and near surface levels. A small increase in watertight surface area results in considerably higher peak discharges (McGrane, 2016).

Impact of land use on water quality

Impacts of land use on water quality are primarily caused by significant production of pollutants and reduction of retention capacity of watersheds because of increased impervious surfaces. Conversion of portions of watersheds from forest to urban cover often elevates sediment and nutrient concentrations by tens to hundreds of times in surface waters (Sun & Caldwell, 2012).

The contributions from both point-source and non-point source pollutants from urban surfaces can greatly degrade the chemical water quality of urban streams and other receiving waters, often transporting dirty water over vast areas into downstream, estuarine and coastal environments. The increase in impervious surfaces expedites the mobilization of contaminants through increased surface runoff and hydraulic efficiency. Additionally, the connectivity of surface and subsurface flow paths increases the rate and magnitude of transference into receiving waters (McGrane, 2016).

Storm water or urban runoff plays an important role added to the urban water hydrology, which deals with the problem of tremendous amount of water causing heavy water pollution with contaminants flushes in the city roads. Another problem is associated with the construction of roadways and house, which may expose the soil contaminants and this, may accelerate the erosion, which chokes the drainage system of the city due to sediments and fills. The urban drainage system is highly uneven in terms of various characteristics such as slope, size, shape, roughness and degree of imperviousness (Shrivastava, 2016).

The generation of runoff from urban surfaces can carry a suite of contaminants including heavy metals, major nutrients (e.g. sodium, nitrate and phosphorus) and rubber residue from roads (McGrane, 2016).

According to the study of (A.J. Robson*, 1997) who studies on a summary of regional water quality for Eastern UK Rivers, there are Variations in water quality and chemical loads. These variations are related to regional differences in geology, climate, and land use and population distribution. For all the examined determinants, industrial and domestic inputs cause significant increases in river concentrations.

The study of (Survey, 1980) which studied on effects of urbanization on the water quality of lakes in Eagan, Minnesota Water-quality characteristics of lakes and ponds in the city of Eagan were showed that differences in water quality between lakes were related to differences in the percentage of urbanization. However, water-quality variations within each lake during the study were affected more by climatic variations than by land-use changes during that period.

Ferezer Eshetu who was a student of Stockholm university department of physical geography and quaternary geology have done his Msc thesis on Physico-chemical pollution pattern in Akaki River basin, Addis Ababa, Ethiopia. Moreover, his outcome of the study was observed absence of spatial and temporal pattern on both surface and groundwater but displayed a huge variation. The result also showed increasing concentration and variation of all parameters inside and outside the city of Addis Ababa with increasing industrialization and urbanization. Comparison also showed that the little Akaki is highly polluted as compared to Great Akaki River. High concentration and variation of pollutants along the river course was found mostly inside and outside (downstream) the city of Addis Ababa. Water quality parameters like nitrate and phosphate also showed high temporal and spatial variation and concentration on surface water. This variation likely arises due to the rapid urbanization and industrialization of the city.

Efrem Benito Salami who is a student of Addis Ababa university collage of natural and computational science has done his thesis on 2016 entitled as Physicochemical and Bacteriological Analysis of Some Selected Sites from Kebena River and Its Pollution Status in Addis Ababa. Bacteriological and physicochemical analyses had been carrying out to study the quality of Kebena River based on spatial variations. Results were indicated a higher bacteriological contamination in the Downstream as compared to that of Upstream and Midstream due to rapid urbanization of Addis Ababa city.

2.4 Surface water quality models

Introduction

Now a days a rapid growth of industrialization, urbanization and agricultural practices results in the pollution of water bodies with high rate. These practices not only pollute the water resources with high pollutant concentration but also increase number of pollutants. The discharging of degradable wastewater in water bodies result in decrease in water quality. This has caused a serious concern over the deterioration of river water quality. Because of which the need of satisfying water quality is growing, establishing strategies for management of future water quality, analysis of past trend and study of present status of river water quality is imperative. To understand the present pollutant load, pollutant transfer and future cause-effect relation between pollutant source and water quality, Mathematical Modeling is considered as one of the best tools for estimation (Nair Sumita, Bhatia Sukhpreet Kaur, January, 2017).

Urban water hydrology is a science part of hydrology investigating the hydrological cycle and its change water regime and quality within urban areas and its impact on various sectors. It includes urban water infrastructure system that is complex and dynamic. The problems in urban water addressed towards the complex water related interactions, which requires adoptable, sustainable and management strategies to maintain existing services and provide new ones. In this multifaceted urban environment, modeling tools are needed to support system's performance under different future scenarios (Shrivastava, 2016).

Surface, water quality models have made a big progress from single factor of water quality to multi factors of water quality, from steady-state model to dynamic model, from point source model to the coupling model of point and nonpoint sources, and from zero-dimensional mode to one-dimensional, two-dimensional, and three-dimensional models (Wang et al., 2013).

More than 100 models of surface water quality have been developed. Some of these models are discussed below.

2.4.1 Streeter-Phelps models (s-p models)

Streeter and Phelps established the first S-P model in 1925. S-P models focus on oxygen balance and one-order decay of BOD and they are one-dimensional steady-state models (Wang et al., 2013).

2.4.2 QUAL models

QUAL I, QUAL II, QUAL2E, QUAL2E UNCAS and QUAL 2K are all the QUAL models and its modified version. QUAL models are suitable for dendritic river and non-point source pollution, including one-dimensional steady state or dynamic models (Wang et al., 2013).
The early QUAL models were used for steady-state dissolved oxygen studies in streams (Mohamoud, 2009)

QUAL was and remains a highly versatile one-dimensional, steady-state model with the capability to model major nutrient reactions, planktonic algae production, sediment and carbonaceous oxygen demand, re aeration, and resulting impacts on dissolved oxygen. Options within the model include heat and mass-balance modeling for conservative constituents, coliform bacteria, and non-conservative substances such as radionuclides QUAL examines only steady-state conditions for stream flow and discharge as specified in regulatory requirements (Heathcote, 2009).

2.4.3 MIKE models

MIKE11, MIKE 21 and MIKE 31 models developed by Denmark Hydrology Institute are suitable for water quality simulation in rivers, estuaries, and tidal wetlands, including one-, two-, or three dimensional models (Wang et al., 2013)

It is best for sediment-water interactions and several incorporate much shorter reach lengths than does other models. However, it can become unstable in simulation of water quality constituents, especially at low concentrations. Cost is also an important consideration. MIKE11 is a very well supported and easy to use tool, has the disadvantage of very high cost, typically in the $25,000 range even for a very basic configuration. A MIKE11 configuration appropriate for the Grand, especially if coupled with the GIS interface (MIKE-BASIN) would more likely cost much more; cost alone may therefore preclude use of this proprietary tool (Heathcote, 2009).

2.4.4 QUASAR model

Whitehead established this model in 1997. QUASAR model is suitable for dissolved oxygen simulation in larger rivers, and it is a one-dimensional dynamic model including PC QUA SAR, HERMES, and QUESTOR modes (Wang et al., 2013).

2.4.5 PLOAD

PLOAD is a simple watershed model that is based on annual precipitation, land use and Best Management Practices (BMP). PLOAD can be used when you want estimates of annual and seasonal loading to drive simple eutrophication models (Heathcote, 2009).

2.4.6 EFDC (Environmental fluid dynamics code) model

Virginia Institute of Marine Science developed this model. The USEPA has listed the EFDC model as a tool for water quality management in 1997. EFDC model is suitable for water quality simulation in rivers, lakes, reservoirs, estuaries, and wetlands, including one-, two-, or three-dimensional models (Wang et al., 2013).

EFDC model is an enhancement of the Princeton ocean model (POM). EFDC is an orthogonal, curvilinear grid hydrodynamic model that can be used to simulate aquatic systems in one, two, and three dimensions. EFDC simulates the circulation and transport of material in complex surface water environments including estuaries, coastal embayment's, lakes, and offshore. EFDC is an example of the impact of faster computers, which uses dynamic, spatially detailed simulations driven by better transport models (Mohamoud, 2009).

2.4.7 Water quality analysis simulation program (WASP) models

WASP1-7 models which are developed for the first time by USEPA in 1983, are suitable for water quality simulation in rivers, lakes, estuaries, coastal wetlands, and reservoirs, including one-, two-, or three-dimensional models (Wang et al., 2013).

U.S. EPA Region 4 developed efficient hydrodynamic linkage routines for the WASP model. This allowed the linkage of three- dimensional hydrodynamic models like EFDC to WASP in both time and space. This greatly improved the use of large-scale hydrodynamic models in applications of water quality model (Mohamoud, 2009).

WASP essentially represents a body of water as a series of boxes (control volumes), with environmental properties and chemical concentrations considered uniform within each box or element. A Windows-based user interface simplifies the significant challenge of parameter estimation and data input (Heathcote, 2009).

Numerous studies point to the limitation of the model for various kinds of problems and settings. However, the overwhelming message in the literature is that the model is simply so complex that it is inaccessible to all but the most experienced users. Even analysis of uncertainty is limited because of the model's complexity. While unquestionably a powerful tool for the three-dimensional simulation of lakes, rivers and reservoirs (Heathcote, 2009).

In fact, a highly complex model like WASP7 may be much less accurate because of the need to calibrate a very large number of state variables, and accurately reflect hundreds of thousands of state variable interactions across many model components (Heathcote, 2009).

However, for experienced users it is a powerful tool. Because it has the ability to run under Windows operating system and includes a graphical user interface for generating input files and visualizing the output files for easy evaluation of simulation results. The outputs of WASP can be transferred to programs used for Geographical Information System (GIS) and water quality statistics (Alpaslan Ekdal, Melike Gurel, Cigdem Guzel, 2011).

The model is used for the interpretation and prediction of water quality responses to natural events and anthropogenic pollution as well as for different pollution management scenarios and decisions. It is a dynamic compartment – modeling program for aquatic systems, including the water column and the underlying benthos. The WASP7 package includes models to simulate toxicant fate, including general toxicants, organic chemicals, and mercury; a heat balance model to simulate water temperature; and two models to simulate conventional water quality, including a basic eutrophication model and an advanced eutrophication model. The general WASP7 mass balance equations, the specific chemical kinetics equations and the input dataset uniquely define a special set of water quality equations. It integrates these numerically, using an adaptive time step Euler scheme as the simulation proceeds in time. Following a simulation, the WASP postprocessor allows the user to produce graphs and tables of all display variables (Alpaslan Ekdal, Melike Gurel, Cigdem Guzel, 2011).

2.5 Watershed models

2.5.1 RUNQUAL Model

It is a continuous daily simulation model used to estimate runoff volumes and quality and contaminant loads from the previous and impervious surface and quality from sites. In this model, more than two contaminants are needed at the catchment sites and have no drainage network in the lumped fashion. These resulting contaminants are routed through the best management practices, which modify its characteristics before discharge from the site (Shrivastava, 2016).

2.5.2 SWMM (Storm Water Management Model)

SWMM is a dynamic rainfall-routing simulation model used for single event or long-term event to estimating the runoff quantity and quality, flow rate, flow depth and quantity of water in the each pipe of the urban areas and sub catchment. It is specially used for the long-term simulation and dynamic flood routing. SWMM accounts for various hydrologic processes that produce runoff from urban areas. In routing portion includes the routing of runoff overland along with the pumps, regulators, pipes and channels (Shrivastava, 2016).

SWMM continues to be widely used throughout the world for planning, analysis and design related to storm water runoff, combined sewers, sanitary sewers, and other drainage systems in urban areas, with many applications in non-urban areas as well (Mohamoud, 2009).

2.5.3 L-THIA

L-THIA has been used in various studies and long-term watershed management plans because only daily rainfall data, in conjunction with a land use or soil dataset, are needed for daily direct runoff simulation and pollutant loads using the Natural Resources Conservation Services curve number (NRCS-CN) method and event mean concentration (EMC) databases for representative land uses. The Arc GIS interface to the L-THIA model has been developed and used for almost two decades. The Low Impact Development (LID) module was developed and integrated into L-THIA for environmentally friendly urban land use planning (Ryu et al., 2016).

The Long Term Hydrologic Impact Assessment (L-THIA) model was previously improved by incorporating direct runoff lag time and base flow. However, the improved model, called the L-THIA asymptotic curve number (ACN) model cannot simulate pollutant loads from a watershed or in stream water quality (Ryu et al., 2016).

2.5.4 Hydraulic simulation program – FORTRAN (HSPF)

HSPF was developed using structured programming techniques. Although the code was completely new, its algorithms were derived from the hydrologic simulation program, which was based on the Stanford watershed model, along with the agricultural runoff model and nonpoint source model. HSPF is a comprehensive watershed model that simulates nutrient and pesticide transport and fate in land and water segments (Mohamoud, 2009).

Hydrological Simulation Program - Fortran (HSPF) is the key to the BASINS suite of models, which calculates daily stream flow rates and the corresponding pollutant concentrations at the watershed outlet.

HSPF simulates the hydrology and associated water quality processes on pervious, impervious land surfaces, in streams and well-mixed impoundments. HSPF is a lumped parameter, continuous stream flow simulation model based on the Stanford Watershed Model (SWM), the first real watershed model performed on a digital computer. The model requires land use, channel reach, and meteorological data and information on expected pollutants. HSPF is designed to interact with BASINS utilities and data sets to facilitate the extraction of appropriate information and the preparation of model input files. HSPF runs on a single watershed or a system of multiply connected sub-watersheds that have been delineated using the BASINS Watershed Delineation tool and GIS elevation datasets such as the Digital Elevation Model (DEM) provided by USGS. Generally, spatial variability within a large watershed is estimate by subdividing the watershed into sub-watersheds. In doing this, one then must select parameters for each sub-watershed to reflect the spatial heterogeneity (Heathcote, 2009).

It has much more detailed heat budget calculations. In fact, a highly complex model like HSPF may be much less accurate because of the need to calibrate a very large number of state variables, and accurately reflect hundreds of thousands of state variable interactions across many model components (Heathcote, 2009).

2.5.5 SWAT Model

The SWAT model is the result of non-point modeling efforts carried out by Agricultural Research Service, Texas University, and by several federal agencies. SWAT model was developed to simulate the impact of land management activities on water sediment, and agricultural chemical yields in the watersheds, which have varying soils and land use conditions. Besides, the model has the capacity to simulate small watersheds as well as large complex watersheds. SWAT is a physically based basin scale model that is known as computationally efficient and capable of continuous simulations. Some specific input data such as weather, soil properties, topography, vegetation, and land management practices, are required by SWAT. SWAT is a computationally efficient model as it manages to simulate large basins without time and money consumption.

The model (up to 100 years) performs continuous long-term simulation on a daily time-step to predict discharge, sediment, nutrient, and pesticide yields from agricultural watersheds (Alpaslan Ekdal, Melike Gurel, Cigdem Guzel, 2011).

The Soil and Water Assessment Tool (SWAT***)*** is a physically based continuous-event hydrologic model developed 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. For simulation, a watershed is subdivided into a number of homogenous sub basins (hydrologic response units or HRUs) having unique soil, slope and land use properties. The input information for each sub basin is grouped into categories of weather, unique areas of land cover, soil, and management within the sub basin, ponds/reservoirs, groundwater, and the main channel or reach, draining the sub basin. The loading and movement of runoff, sediment, nutrient and pesticide loadings to the main channel in each sub basin is simulated considering the effect of several physical processes that influence the hydrology (Neitsch, Arnold, Kiniry, & Williams., 2005).

Watershed models such as SWAT are quite effective at capturing the spatial variability of a watershed in terms of topography, land use, soil, and management practices. This is because overland hydrologic processes (runoff, infiltration, and evapotranspiration), soil erosion, and nutrient/ pesticide wash-off and leaching processes are represented in sufficient detail in these watershed models (Narasimhan, Srinivasan, Bednarz, Ernst, & Allen, 2010).

SWAT is developed to examine the influence of topographic, land use, soil and climatic conditions on stream flow and pollution load magnitudes. It is physically-based semi distributed watershed hydrological model, requires continuous time step, readily available data for simulating stream flow, sediment load and nutrient concentration of watershed process as a result of land use land cover change and management practice, through calibration and validation of the model parameters (Rao, Pradesh, Pradesh, & Pradesh, 2015).

Simulation of the hydrology of a watershed can be separate into two major divisions. The first division is the land phase of the hydrologic cycle, which controls the amount of water, sediment, nutrient and pesticide loadings to the main channel in each sub basin. The second division is the water or routing phase of the hydrologic cycle that can be defined as the movement of water, sediments, etc. through the channel network of the watershed to the outlet (Rao et al., 2015).

SWAT is a daily time step model that can predict the effects of land use management and can be used where there are no nearby meteorological stations with hourly data and where there is no nearby gauged watershed (Wang et al., 2013).

(Cervantes, 2004) Have studied the impact of CSO (combined sewer overflows) on the lower Hudson River using SWAT 6.1 model. However, due to limited field data, the calibration and validation phases were not performed with the Mercury model, and only calibration was performed in the Heat Model. Generally, simulation results agree with observations for the DO/BOD/ammonia simulation and the FC model after calibration and validation.

2.6 Integrating watershed and water quality modeling

The ever increase stress of urbanization demands the sustainable water management strategies and utility provision for government and organizations. As a result, there is an increasing in demand for better use, productivity, flexibility, robustness and quality of urban water modeling system. Modeling the urban water hydrological system has progressed along with the same path as management. Therefore, there is urgent need for better order in modeling techniques and an assessment with the objective of integrated modeling in urban system. This integrated modeling of the urban water is aim to evaluate the different strategies and scenarios for management and framework at the planning level (Shrivastava, 2016).

There are many urban water hydrological models have been developed but the idea model must control variations of demands at spatial scale and temporal scale. At present, there is no single urban water model, which acceptably meets the current and future needs of the urban cities. Therefore, it is better to use coupled model than single model at temporal and spatial resolution (Shrivastava, 2016).

The study by (Alpaslan Ekdal, Melike Gurel, Cigdem Guzel, 2011) was studied to initializing the components of an integrated modeling system intended to be used for coastal ecological analysis of a lagoon. For attaining this purpose, a general water quality model and a watershed model, which will calculate the nutrient inputs and force the water quality model, are used. The Soil and Water Assessment Tool (SWAT) was used as the watershed model to estimate the non-point pollutant loads arising from the study area, and Water Quality Analysis Simulation Program (WASP) was selected for the water quality modeling studies. The flow and the pollutant loads discharging into the Lagoon system from its sub-watersheds were estimated by SWAT. The estimated flow and pollutant load outputs obtained from this model were used as the input to WASP. Different water quality parameters were simulated. The simulation results indicated that WASP was able to catch the general trend of the monitoring data. However, in most cases, the simulation results for the boundaries fitted at a higher level than the other regions of the system.

(Seo & Bae, 2013) Was studied aims to compare two different water quality models, ADVANCED EUTRO water quality module in WASP7(Water Quality Analysis and Simulation Program) and HEM3D (Hydrodynamic and Eutrophication Model-3D) water quality module in EFDC (Environmental Fluid Dynamics Code) in the prediction of water quality in surface waters.

It was found that application of EFDC-WASP7 that employs USEPA's approach and the application of EFDC-HEM3D may results in different results. Due to limited data availability, it is difficult to conclude which model shows better accuracy over the other model at this stage. However, this result indicates that it is necessary to check either or both models very closely with sufficient amount of observed data in the fields (Seo & Bae, 2013).

2.7 Model selection criteria

Worldwide, hundreds models of surface water quality have been developed. Classified these models based on water body types, model-establishing methods, water quality coefficient, water quality components, model property, spatial dimension, and reaction kinetics to select applicable model is necessary.

Controlling nonpoint source pollution requires the use of integrative modeling approaches that simulate the interactions among integrated stressors. However, current models and modeling approaches cannot represent integrated stressors and many available models do not match the complexities of the modeled system. Only a very few watershed models can represent the various hydro modification types and scenarios and can simulate scenario-specific flow alterations and water quality degradation. (Mohamoud, 2009) (Heathcote, 2009). In addition to this, a model must control variations of demands at spatial scale and temporal scale (Shrivastava, 2016).

Modeling integrated stressors like Hydro modification due to land use change requires the development and application of predictive models and innovative modeling approaches. While there is no single model that meets all user needs throughout a watershed (Mohamoud, 2009) (Heathcote, 2009).

For the sustainable management of receiving waters, a unified holistic approach is required. This is why watershed based management is becoming an increasingly popular instrument for the improvement of water quality since the late 1980s.

For attaining this purpose, a general water quality model and a watershed model, which will calculate the nutrient inputs and force the water quality model, were selected to conduct this research. The Soil and Water Assessment Tool (SWAT) was used as the watershed model to estimate the non-point pollutant loads arising from the study area, and Water Quality Analysis Simulation Program (WASP) was selected for the water quality modeling studies. The flow and the pollutant loads discharging into the stream from its sub-watersheds were estimated by SWAT. The estimated flow and pollutant load outputs obtained from this model were used as the input to WASP. NH_4–N, NO_2–N, TN, TP, TSS, pH and temperature were simulated using WASP.

3. METHODS AND METHODOLOGY

3.1 Description of the study area

3.1.1 Location

Akaki catchment is located in central Ethiopia along the western margin of the main Ethiopian rift valley. The catchment is situated at the north western Awash River between 8^{o}46'–9 ^{o} 14' N and 38 ^{o} 34'–39 ^{o} 04'E (Berga, 2011). The capital city, Addis Ababa and other small towns such as Akaki, Sendafa, Burayu and smaller peasant association villages are found in this catchment (Oljira, 2006). The Intoto Mountain forms the northern drainage boundary of the Akaki River Catchment and other volcanic mountains- Yerer, Wechecha and Furi - bound it from the eastern, western and southwestern boundaries respectively (Berga, 2011).

The Great Akaki River that drains the eastern part of Addis Ababa and Little Akaki River that drains the western part of the Addis Ababa are the main tributaries of the catchment. Addis Ababa and those two rivers are located at the center of the catchment and Akaki catchment has an area of about 1445.40 km^2. Both Great and little Akaki rivers flows across the residential and commercial centers of Addis Ababa towards Lake Aba Samuel, which is an artificial reservoir 30 km south of the city.

To show the temporal and spatial variation of River water quality reach 51, 55, 65 & 74 from little Akaki River and reach 37, 45, 48, 67 & 98 from great Akaki River were taken from upper area to lower area respectively. In addition, the sub basins corresponding to these reaches were taken to show the variation of pollutant loads on the watershed. The study area is shown in the figure below in Awash DEM and the reaches are shown on **Appendix – N.**

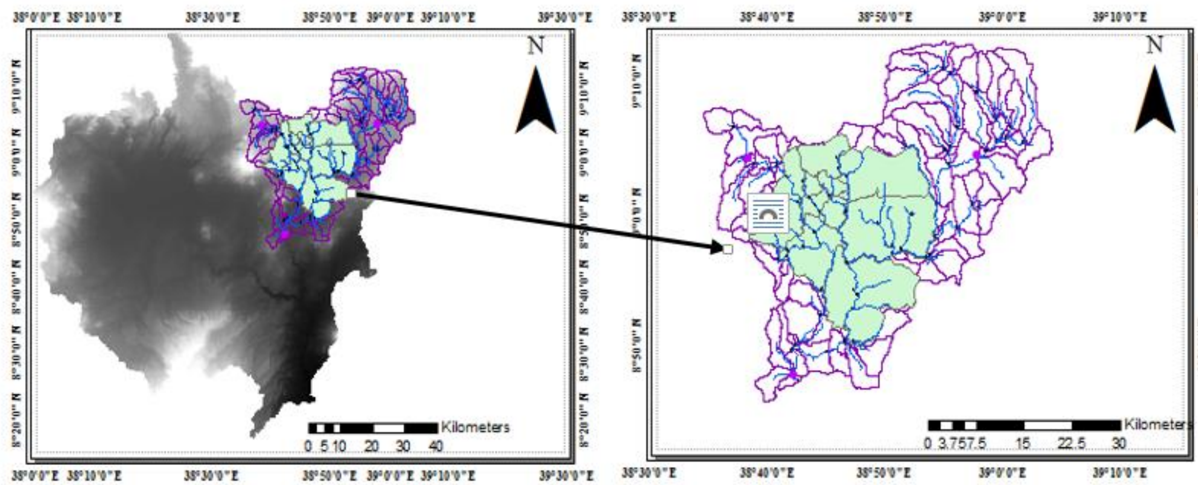


Figure 1 Study area location map of Akaki catchment

3.1.2 Climatic condition

Rainfall

The catchment is located in the region where rainy months are nearby distributed. In the region, there are seven main rainy months from March to September, and the rest of the months have small rains. The highest rain occurs from June to September according to the data collected from metrological agency. The mean monthly rainfall of four stations is shown on the figure below and yearly rainfall of the stations is showed on **Appendix-A.**

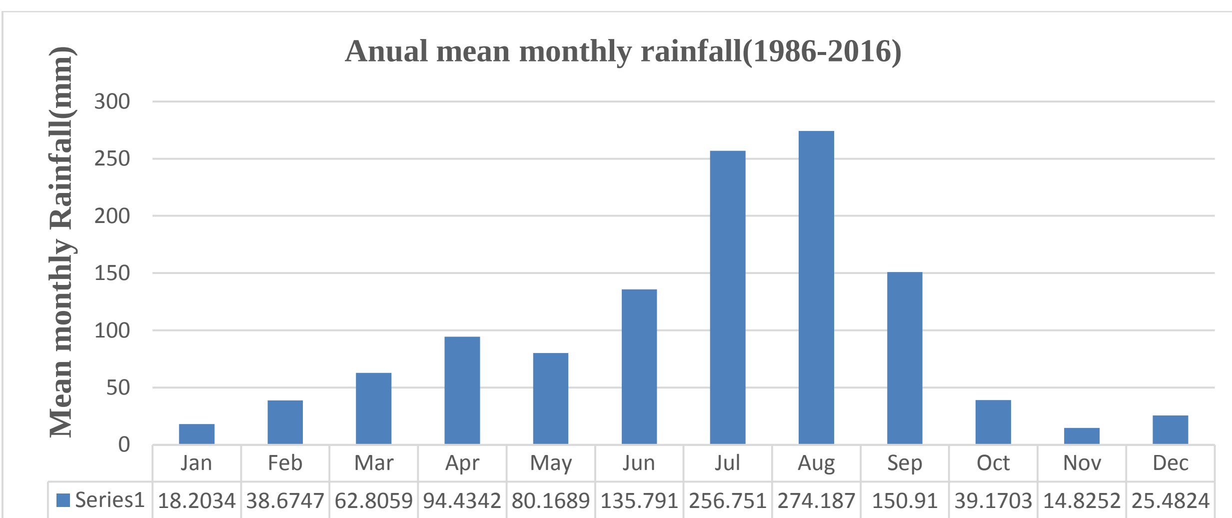


Figure 2 Mean monthly rainfall intensity of four stations in & around Addis Ababa

Tempreture

The study area lies in Weina Dega and Dega climatic zones between mean monthly temperature of 7 c^{o} and 27 c^{o}. The highest maximum mean monthly temperature were recorded on February, March, April and May whereas the lowest maximum mean monthly temperature were recorded on July, August and September. The highest minimum mean monthly temperature were recorded from February to September whereas on the other months the minimum temperature was low. The annual average maximum and minimum temperature (c^{o}) for the four station is showed on **Appendix – B**.

Wind speed

Wind directions during dry season in most parts of Ethiopia is generally from the east direction (easterly or southeasterly), changing to westerly or northwesterly during the rainy season. According to the 32 years, metrological data of AA OBS station the minimum average monthly wind speed was occurred during August.

Table 1 Annual mean monthly wind speed for AA OBS station

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind speed(m/s)	0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.4	0.5	0.7	0.7	0.7

Relative humidity

The mean monthly relative humidity of AA OBS station was highest in August (74%), and least on February, Nov and December (50%).

Table 2 Annual mean monthly relative humidity of AA OBS station

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Relative humidity (%)	52	50	52	56	54	64	72	74	68	53	50	50

3.1.3 Land use/land cover type

Most of the northern part of the study area is occupied by settlement, mixed land use practices and planted trees (Eucalyptus) in the up hills of the Entoto ridge whereas the southern part is dominated by non-irrigated agriculture. Most industries are concentrated along little and Great

Akaki Rivers, which offer prospect for their effluents to get easily in to the rivers and end up into the Aba Samuel reservoir.

There are different types of land use/land cover classifications. However according to different literatures the land use/land cover types are mainly classified as agricultural, barren land, mixed forest, forest evergreen, water body and residential areas (commercial, institutional, industrial, asphalt etc.).

3.1.4 Soil characteristics

The climatic condition and topography of the area favor the development of thick soil profiles mostly due to the physical disintegration and chemical decomposition of volcanic rocks on which it lies (Alemayehu, 2001).The weathering products either remain in place and form residual soils are transported and deposited to form alluvial deposits in low-lying areas. In the localities where the topography is plain to gently sloping (central and southern parts), the area is covered by thick soils. In general, the types of soils that are found in the study area are vertic cambisols, chromic cambisols, chromic luvisols, chromic vertisols, eutric nitisols, Leptosols, orthic solonchaks, calcic xerosols and pellic vertisols. Among these types of soils, the highest area is covered by pellic vertisols.

3.2 Data collection

The purpose of this chapter was to bring all the available data and select relevant information for the analysis. The data collection system in this research was mostly from secondary data. Secondary data was collected through recorded data, historical data, literature studies, and document analysis.

The required data sets to conduct this study were;

1. Spatial data like (DEM, satellite image & Soil map)
2. Hydrological data like river flow, sediment load and nutrient loads
3. Metrological data such as rain fall, Air Temperature, Wind Speed, Solar Radiation and relative humidity
4. Water quality data

3.2.1 Spatial data

a) DEM (Digital Elevation Model)

Digital Elevation model (DEM) is one of the main inputs of the SWAT (Soil and Water Assessment Tool) model. It is used in the SWAT model along with soil and land use/cover data to delineate the watershed and to further divide the watershed into sub-watersheds and hydrologic response units (HRUs).

For this project, a digital elevation model (DEM) of upper awash was obtained from Ministry of Water, Irrigation and Electricity, GIS department in the format of SRTM (Shuttle Radar Topography Mission) with a spatial resolution of 30 m x 30 m.

b) Satellite image

Cloud free satellite image of Akaki catchment was acquired for the years 1989, 2003 and 2016 from the website of Landsat satellite image product (https://glovis.usgs.gov/). To avoid a seasonal variation in vegetation pattern and distribution throughout a year, the selection dates of the acquired data were made in the same annual season of the acquired years. The date of acquisition, cloud cover and number of band for satellite image downloaded from Landsat image product are summarized below;

Table 3 Percentage of cloud cover & No of bands for downloaded Landsat images

Acquisition date	Cloud cover (%)	No of band	Image product
Jan 21, 1989	0.00	7	Landsat 5-TM
Feb 05, 2003	0.00	9	Landsat 7-ETM
Dec 03, 2016	0.03	11	Landsat 8

c) **Soil characteristics**

Soil data resolution has also a significant impact on the modelling of stream flow, sediment load and nutrient content. According to the soil data obtained from Ministry of Water, Irrigation and Electricity, nine types of soils in a shape file format were found on the study area. These soils are classified according to their Swat code and global name for HRUs definition and soil reclassification.

Table 4 Global soil type classification and their swat code representation naming

Global soil name	Swat code	Total area cover (km^2)	%age area cover
chromic cambisols	Bc9-2b-8	478	0.331
chromic luvisols	Lc13-1a-127	13020	9.008
eutric nitisols	Ne10-3b-154	15366	10.631
chromic vertisols	Vc13-3a-260	7028	4.862
pellic vertisols	Vp10-3a-285	84713	58.609
calcic xerosols	Xk1-2-3a-318	9362	6.477
orthic solonchaks	Zo12-2a-387	10527	7.283
vertic cambisols	Bv13-3a-474	2819	1.95
Leptosols	R1-1639	1227	0.849

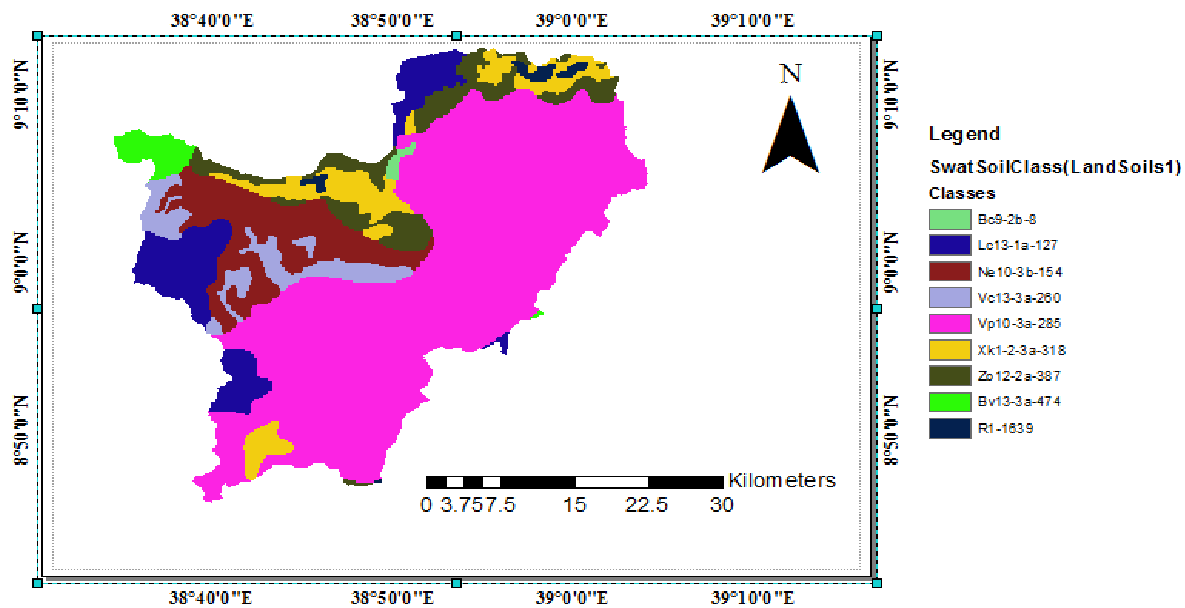


Figure 3 Soil map of the study area

3.2.2 Hydrological data

The daily observed stream flow data of one gauge named Akaki (located around Akaki sub city) was collected from Ministry of Water, Irrigation and Electricity, Hydrology Department from 1986 to 2004. This data was required to calibrate and validate SWAT model with the simulation result of river water flow. This flow data was formatted as to the requirement of the SWAT model.

There is no any observed data for the sediment load and nutrient load on the catchment except some daily sediment concentrations for some years. These specific sediment concentrations ware listed on table 10.

3.2.3 Metrological/ Weather Data

Climatic data is among the most important variables required by SWAT to model the land phase of the hydrologic cycle. The climatic variables required by SWAT consist of daily rainfall, maximum/minimum daily air temperature, solar radiation, wind speed and relative humidity.

All the weather data was obtained from the Ethiopian National Metrological Agency. There were different meteorological stations located inside and outside of Akaki catchment. However, only four of them named AA OBS, AA BOLE, INTOTO and AKAKI were considered for further analysis. The other stations were not considered since there were no enough data. The daily rainfall and temperature data of the four station was recorded from 1986 to 2016. However, the other parameter of weather data like wind speed, sunshine and relative humidity were fully available only in the AA OBS station from 1986-2016. In line with this, there were missing data in all stations. Due to this reason, checking consistency, data quality, fill the missing data and select the weather generator station were required.

Table 5 Meteorological stations in Akaki watershed

ID	NAME	LATITUDE	LONGITUDE	ELEVATION
1	AA BOLE	38.799	8.981	2354
2	AA OBS	38.748	9.019	2386
3	AKAKI	38.786	8.870	2057
4	INTOTO	38.721	9.084	2903

3.2.4 Water quality

Daily observed water quality data was required for the WASP calibration and validation. Normally, water quality samples measurement are costly and time consuming to collect and analyze. As a result, there was no well-organized data for each station for long time. Only yearly water quality data of TSS (mg/l), Temperature (c^o), pH, TN (mg/l) and TP (mg/l) on 2003 were available and collected from Addis Ababa city Environmental Protection Authority.

3.3 Methodology

The methodology adopted to achieve the stated objectives were SWAT model to simulate the stream flow, pollutant load at different locations of the river segment from upper to lower in different interval of time, and water quality status at these point of location and time interval within the hydrological process were assessed using WASP. However, before proceeding to those models filling of missing meteorological and hydrological data, checking of data quality, consistency and generation of weather data were done.

3.3.1 Data analysis

A. Filling of missing data

Some rain gage stations may have short breaks in the records because of absence of the observer or because of instrumental failures. It is often necessary to estimate or fill on the missing record. The missing rainfall data of a station was estimated from the observations of precipitation at some other stations as close to around the station with the missing record as possible. The XLSTAT 2014 model was used to fill the missing data. In Akaki catchment, the missing data were filled only when the data missed in each station was less than thirty percent using mean simulation from all the neighborhood stations.

B. Consistency checking

After all the missing data were filled, it was important to check if the estimate was done with correct scaling. Correct scaling implies same gradient of accumulated plot of stations for long period using double mass curve analysis.

The double-mass curve analysis revealed that there was good direct correlation between the cumulative rainfall records at AA OBS, AA BOLE, AKAKI and INTOTO gaging stations with the cumulative average rainfall at the other stations R^2 =0.9994, 0.9994, 0.9985 and 0.9998 respectively. This indicates that the rainfall data at all gaging station was consistent. The consistencies of their rainfall records were checked using similar procedure and it was found that no significant shift of slope was observe on their respective plots. As presented in **appendix – C**, the correlation coefficients of the four stations indicated that there was good direct correlation between the stations' records and their corresponding base stations. Therefore, it was concluded that the rainfall data from all stations will be used for further application.

C. Checking of stream flow data quality

The stream flow data must be checked for continuity and consistency before used for further analysis. The quality control can be done by visual inspection, filling of missing data if there is any, accumulated plot and double mass curve. This will help identify if there are any gaps or unphysical peaks in data series and correct them before the data is used. Otherwise, using the erroneous data as input to the model will give erroneous output.

The data quality check was made by XLSTAT 2014.5.03 - Dixon test after filling the missed data. Accordingly, no value that is outside of Z-score was considered for the observed annual river flow data.

Weather Generator station selection and data preparation

The SWAT Model contains weather generator model called WXGEN. It is used in SWAT model to generate climatic data or to fill missing data using monthly statistics which is calculated from existing daily data. The meteorological data were analyzed to determine the various statistical parameters like mean monthly maximum and minimum temperature, average monthly wind speed, number of rainy days, average daily solar radiation, standard deviation for air temperature, precipitation, and maximum half hour time probabilities required as input by the weather generator file in SWAT. The analyzed data was presented as mean monthly series.

For this study the AA OBS station daily measured rainfall, air temperature, relative humidity and wind speed data from 1986-2016 was use as input to generate those parameters for the other stations by standing from this station by SWAT model.

The PCPSTAT was used for rainfall to calculate mean, total and standard deviation of rain fall and DEW02.exe was used to calculate the temperature and mean relative humidity.

Also preparing the maximum half hour rain from the rainfall data were required by the swat weather generator data base which is the probability distribution of maximum rainfall depth in variant of time scale. Therfore, half hour rainfall was prepared from the one third of the rainfall data.

The average monthly solar radiation for weather generator data base prepared from the sunshine hour data or temperature using different forms. So, in the present study, data of daily temperature are available in AA OBS station from 1986-2016. Therefore solar radiation result was driven from the temperature data using the formulas below.

$$Rs = KRS\sqrt{(Tmax - Tmin)Ra}$$

$$\mathrm{Ra} = 37.6\mathrm{d}(\omega\sin\varphi\sin\delta - \cos\varphi\cos\delta\sin\omega)$$

$$d = 1 + 0.033\cos\left(\frac{2\pi}{365}\right)n$$

$$\delta = 0.0493\sin(\frac{2\pi}{365}n - 1.39)$$

$$\omega = \arccos(-\tan\varphi tan\delta)$$

Where

- Ra is extraterrestrial radiation MJM^{-2} $DAY^{-1,}$
- d is relative distance between the sun and the earth,
- ω the sun set hour angle (rad),
- φ the latitude (rad),
- δ is solar declination angle (rad),
- n is the number of the day of the year starting from the first of January,
- Tmax is maximum temperature (c^o),
- Tmin is minimum temperature (c^o) and KRS adjustment coefficient (0.16 ... 0.09).(Chen & Li, 2012)

For interior locations, where land mass dominates and air masses are not strongly influenced by a large water body, kRs ≅ 0.16. Therefore, KRs was take as 0.16. (Chen & Li, 2012)

Those all data were prepared as requirement of WXGEN for swat model and used to generate the relative humidity, wind speed and solar radiation of the other three gage stations.

D. Image processing and land use classification

Land use/cover data has a significant effect on the hydrological modeling; it affects the runoff, nutrient and sediment transport in the watershed. Therefore, a detail analysis and mapping of the land use/cover is crucial for proper hydrological modeling.

On this study, there was no available land use/land cover map for the required years. However, it was processed using ERDASE IMAGINE 2015 by connecting with Google earth automatically. Procedures while processing ERDASE IMAGINE 2015 in order to prepare land use/land cover are presented below.

Image Pre-processing

This study was done using Landsat images of seven bands to identify changes in land use/cover distribution in Akaki catchment. Landsat TM, ETM+ and Ls8 were selected for the period of 1989, 2003 and 2016. To avoid a seasonal variation in vegetation pattern and distribution throughout a year; the selection of dates of the acquired data were made in the same annual season of the acquired years.

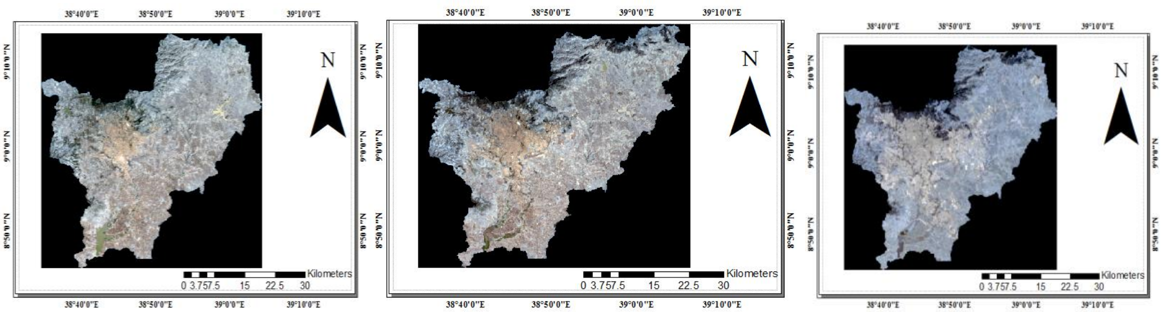
The image data files were downloaded in zipped files from the https://www.usgs.gov United State Geological Survey (USGS) website and extracted to Tiff format files.

Layer stacking images

The reflectance bands acquired from the Landsat image product was layer stacked using ERDAS IMAGINE software (raster→ spectral→ stack layer) to make meaningful image for interpretation. This allows different combinations of RGB to display in the view. A layer stack was used to combine separate image bands into a single multispectral image format. Layer staking of the different bands of downloaded satellite images of the three years have been done for all the data on ERDAS Imagine.

Sub setting an image

Sub setting an image can be useful when working with large images. Sub setting is the process of cropping a portion of an image for further processing. Sub setting of Akaki watershed satellite image was performed using the layer stacked images by the delineated watershed shape file. The stack layer after sub setting the image of the study area is presented in figure 4 below.



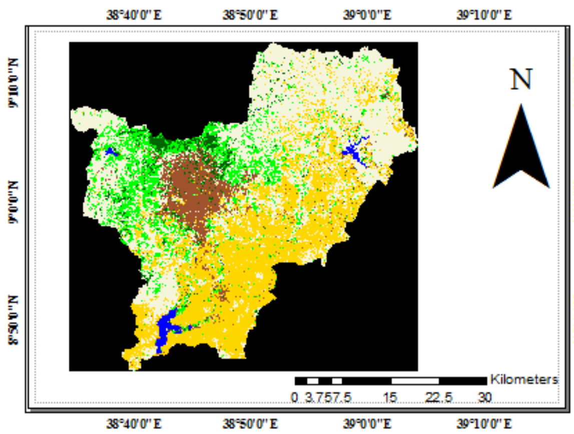
a) Subset image of 1989 b) subset image of 2003 c) subset image of 2016

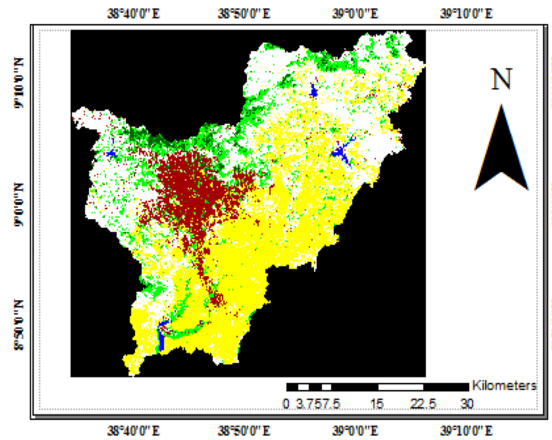
Figure 4 Subset image of 1989, 2003 and 2016

Image Classification

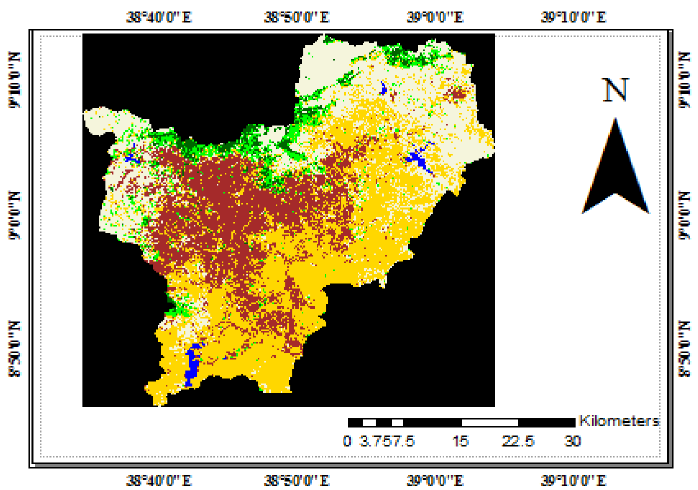
Image classification is the process of assigning pixels of continuous raster images to the predefined land cover classes**.** Digitization, image rectification, terrain analysis and exporting of an image were performed during land cover classification. The image rectification process supports the manual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

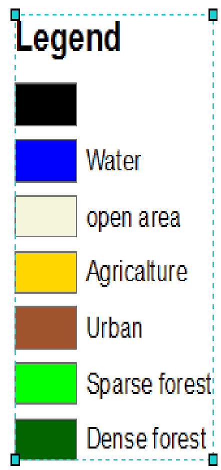
Image classification and enhancement for this study were made using ERDAS Imagine. The main objective of classifying satellite images is to categorize pixel values automatically and transform them directly in to the classes of land use. The previous documents, the different band combination and integrating with Google Earth were taken as a signature defining for supervised classification. Then, the land use/cover map of the study area for this reach was done categorizing each pixel values by integrating with Google Earth and classified the signature using supervised classification on ERDAS IMAGINE 15. The supervised classified map of land use/cover for the years 1989, 2003 and 2016 is shown in figure 5 below.





a) Classified map of land use/land cover 1989 b) Classified map of land use/land cover 2003





d) Classified map of land use/land cover 2016 d) legend of all mapes

Figure 5 Land use/cover maps

According to the classification of the land use/cover map of the study area, the change of land use/cover through time is shown in table 5 below.

Table 6 land use/land cover change from 1989 to 2003 and from 2003 to 2016

		1989		2003		2016	
Land use global name	land use	%age cover area	Area (Km^2)	%age cover area	Area (Km^2)	%age cover area	Area (km^2)
Water body	WATR	1.16	17	0.64	9	0.8	12
Barren land	BARR	43.16	624	38.47	556	27.89	403
Forest mixed	FRST	12.19	176	11.29	163	5.61	81
Agricultural land	AGRL	32.57	471	36.59	529	39.16	566
Forest ever green	FRSE	3.47	50	1.96	28	3.13	45
Residential	URBN	7.28	105	10.3	149	23.2	335

Land use change rate of Akaki catchment

Over the study period, residential/built-up area increased from 1989 to 2016 whereas barren land decreased with in the investigation period. In addition, the coverage of forest area showed high decrement. The agricultural/cropland reduced significantly from 1989 to 2003, but it increased from 2003 to 2016. Therefore, this significant change of land use can influence the process of hydrology and surface water quality. The rate of change on percentage of the land use change is shown in the table below.

Table 7 Rate of percentage change of land use in Akaki catchment (1986 to 2016)

Land use type	years		
	1989-2003	2003-2016	1989-2016
Water body	-30.7	14.28	-17.24
Barren land	-5.7	-15.95	-21.5
Forest mixed	-3.83	-33.6	-36.96
Agricultural land row crops	5.8	3.37	9.16
Forest ever green	-28.2	23.28	-5.26
Residential/built up area	17.3	38.4	52.2

3.3.2 SWAT Model Simulation Procedure

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

- Create new SWAT project
- Delineate the designated watershed for modeling
- Define land use/soil/slope data grids
- Determine the distribution of HRUs based on the land use and soil data
- Define rainfall, temperature and other weather data
- Write the SWAT input files- requires access to data on soil, weather, land cover, plant growth, fertilizer and pesticide use, tillage, and urban activities
- Edit the input files – if necessary
- Setup and run SWAT
- Sensitivity analysis
- Calibration and validation

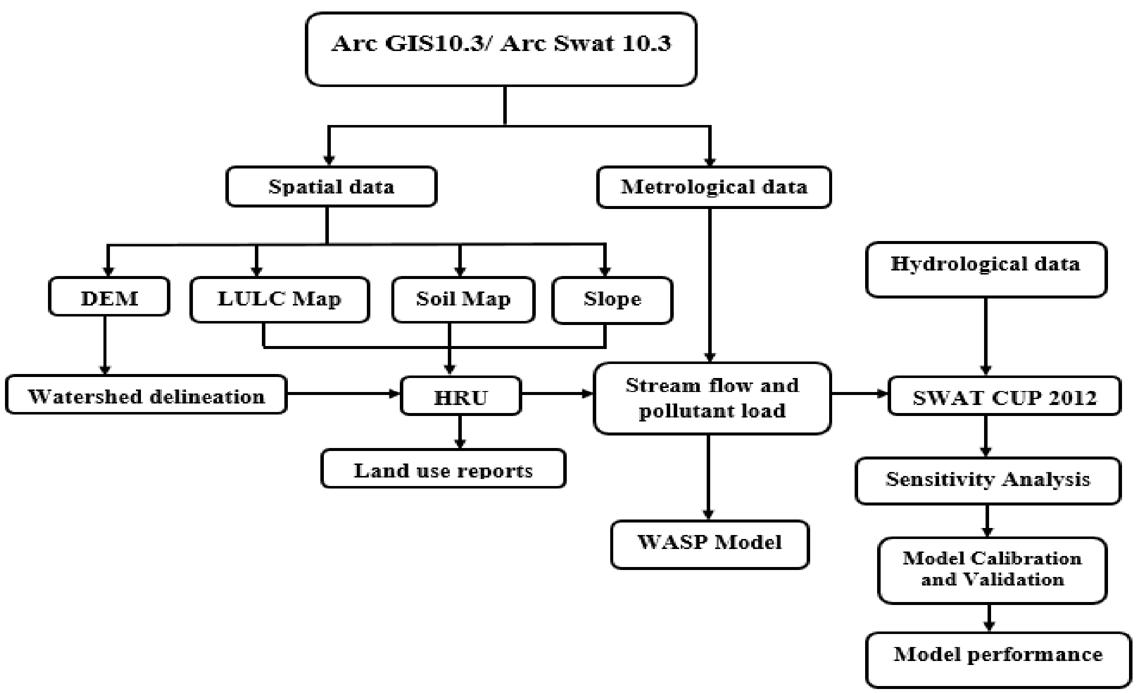


Figure 6 SWAT Model Simulation Procedures

1. **Watershed Delineation**

The delineation process requires a Digital Elevation Model (DEM) in ESRI grid format. Drainage boundaries on the DEM, masking the Digital Elevation Model (DEM) with coverage of the study area to delineate watershed using Arc SWAT steps were used. The DEM of watershed was project to UTM Coordinate system using Arc map in Arc GIS and imported to Arc SWAT to start automatic watershed delineation.

Flow directions for individual DEM cells were created using flow direction and accumulation tool in Arc SWAT. SWAT computes flow direction for individual DEM cells and uses stream threshold area in hectares to create streams based on these directions.

An outlet, or pour point, is the point at which water flows out of an area. This is the lowest point along the boundary of the watershed. The cells in the source raster were used as pour points above which the contributing area is determined. In order to create sub-watersheds, additional drainage outlets need to be defined. After several nodes or vertices were defined into drainage outlets along the stream arcs reservoir locations were create.

The Akaki watershed was delineated with an outlet point at Aba-Samuel reservoir. The overall watershed was further classified into sub-basins based on the algorithms provided by the SWAT model. Consequently, the delineated map of the study area is shown below.

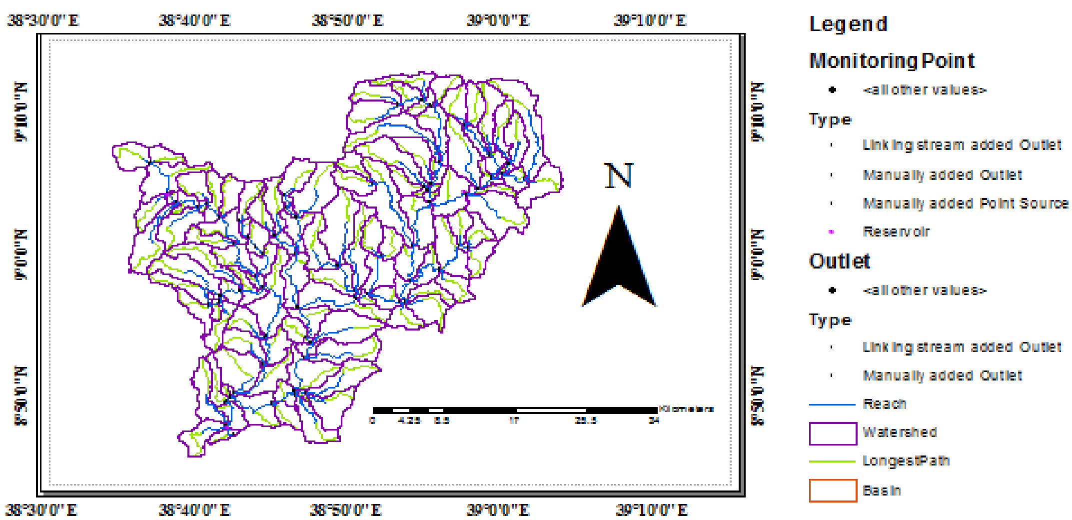


Figure 7 Delineated map of the study area

2. **Hydrological Response Units (HRUs)**

For simulation, a watershed is subdivided into a number of homogenous sub-basins (hydrologic response units or HRUs) having unique soil, slope and land use properties.
The HRU analysis tool in Arc SWAT helps to load land use, soil and slope map to the project. The land use and the soil data in a projected shape file format were loaded into the Arc SWAT interface to determine the area and hydrologic parameters of each land-soil category simulated within each sub-watershed. The land cover classes were defined using the look up table. A look-up table that identifies the 4-letter SWAT code for the different categories of land cover/use was prepared, to relate the grid values to SWAT land cover/land use classes. After the land use SWAT code assigned to all map categories, calculation of the area covered by each land use and reclassification were done. As of the land use, the soil layer in the map was linked to the user soil database information by loading the soil look-up table and reclassification applied the land slope classes were also integrated in defining the hydrologic response units. The DEM data used during the watershed delineation was also used for slope classification. Based on the suggested min, max, mean and median slope statistics of the watershed, five slope classes (0- 5, 5-10, 10-15, 15-20 and >20) were applied on slope grids reclassification. The generated classification of the slope in the watershed are shown in table 8 and figure 8 below.

Table 8 multiple slope distribution and grid classification of HRU in Akaki watershed

Slope (%)	Area cover (km^2)	% age of area cover
0 - 5	673	47
5-10	372	26
10-15	166	11
15-20	91	6
>20	145	10

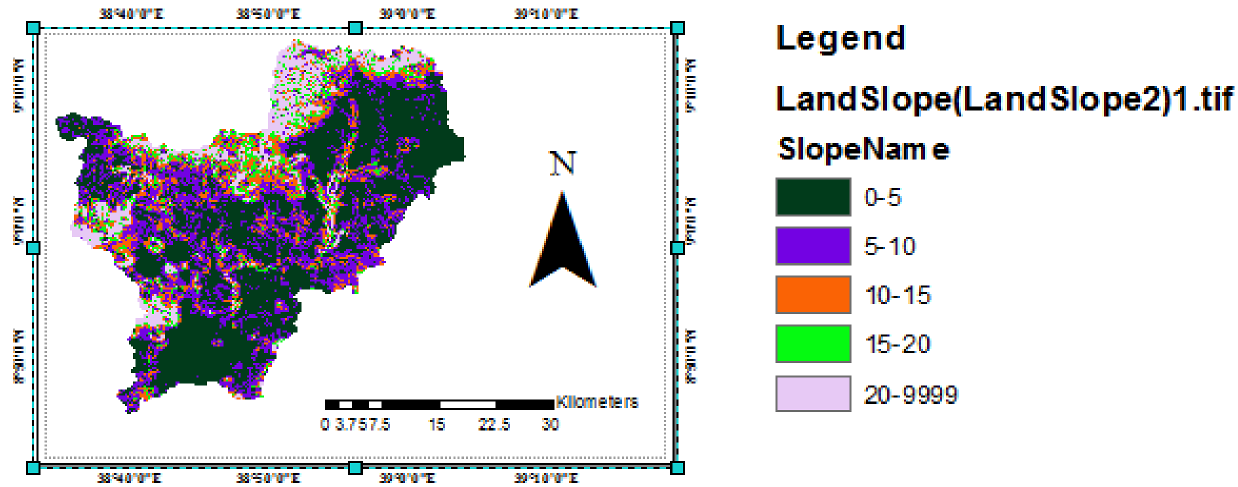


Figure 8 multiple slope distribution and grid classification of HRU in Akaki watershed

After the reclassification of the land use, soil and slope grids overlay operation was performed. The last step in the HRU analysis was the HRU definition. The HRU definition in this study was determined by assigning multiple HRU to each sub-watershed. In multiple HRU definition, a threshold level was used to eliminate minor land uses, soils or slope classes in each sub-basin. Land uses, soils or slope classes which cover less than the threshold level were eliminated. In the SWAT user manual, it is suggested that it is better to use a larger number of sub-basins than larger number of HRUs in a sub-basin; a maximum of 10 HRUs in a sub-basin is recommended. Hence, taking the recommendations in to consideration, 10%, 10%, and 10% threshold levels for the land use, soil and slope classes were applied, respectively to encompass most of spatial details.

3. **Importing Climate Data /write impute tables**

The flow, sediment and water quality of a watershed provides the climate input to determine the magnitude of pollution and water quality examination. The climatic variables required by SWAT consist of daily precipitation, maximum/minimum temperature and the weather generator data prepared form AA OBS station in the SWAT 2012 database in WXGN users. Therefore, on the Arc GIS/Arc SWAT interface on write impute tables the WXGN user prepared, precipitation file and max/min temperature file in text formats were imported in to the model.

4. Edit swat input

Edit swat input is used to add point source discharge and inlet discharge, to edit reservoir, sub basin data and watershed data. In addition, write input file are rewrite on it. However as there is no point source discharge and inlet discharge on this project only rewrite input files was done.

5. **Run Swat Model**

The Run SWAT icon, which is located under the SWAT simulation menu, was set from 01/01/1986 to 12/31/1997, from 01/01/1996 to 12/31/2007 as well as from 01/01/2006 to 12/31/2016 with a monthly printout option for the entire three scenario's respectively. NYSKIP was set to 3 years as a warm up period for the model for all simulations. Then the rest of the parameters were left as default values, the Setup SWAT Run icon was activated and the simulation was run.

SWAT Simulation

Based on the HRU definition, 130 sub-watersheds were created on the study area. The total area of Akaki watershed is then determined to be 144540 hectares. In addition, based on the model set up, the minimum area threshold values are set as 10% for land use, soil and slope. Hydrological Response Units (HRU) of 600, 608 and 565 for land use maps of 1989, 2003 and 2016 respectively were identified.

Three simulations based on land use/cover map of 1989, 2003 and 2016 were run with three years warm up period. The simulations were from (1986-1997) with warm up period (1986-1988) for land use/cover map of 1989, (1996-2007) with warm up period of (1996-1998) for land use/cover map of 2003 and (2006-2016) with warm up period of (2006-2008) for land use/cover map of 2016.

The simulation was limited by a model boundary based on HRU, sub basin, reach, reservoir and water quality index output data. The data on watershed statistics for flow, sediment load, nutrient and water quality parameters were obtained in "output.std" text file and Microsoft Access format.

Model sensitivity analysis

Sensitivity analysis helps to identify parameters that affect stream flow, sediment load and nutrient concentration. Those parameters include management parameters, soil parameters and ground water parameters etc.

For Akaki catchment sensitivity analysis was carried out at Akaki station on reach 112. The simulation period was from January 1986 to December 2016. The simulation result from January 1986 to 1988 was used as model warm up period; from 1989 to 1994 was used as calibration period, and the period from January 1995 to December 1997 was used as model validation time for the first scenario. The second scenario, the land use/cover map of 2003, was also calibrated from 1998-2002 and validated from 2003-2004.

Twenty parameters were taken to analyze sensitivity though the result indicated that ten parameters were more sensitive for stream flow. The P-values and T-values as well as the rank of the sensitive parameters are present in the figure below.

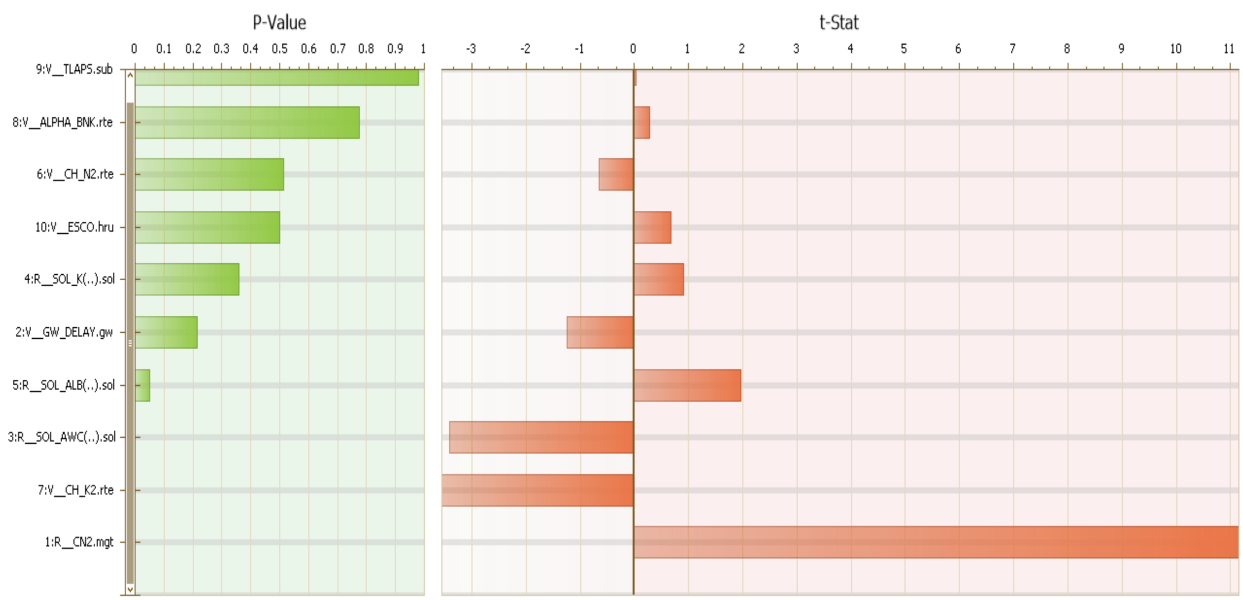


Figure 9 P-value and T- test of sensitive parameters for land use/land cover map 1989

As shown in figure 9, T- stat provides a measure of sensitivity (large in absolute value area more sensitive) and P-value determine significance of sensitivity of the parameters (P-Value close to zero are more significant). Therefore according to the sensitivity analysis result of the simulation shown in the figure, R__CN2.mgt, V_CH_K2.rte, R_SOL_AWC.sol, R_SOL_ALB.sol, GW _ DELAY,gw, R_SOL_K.sol, V_ESCO.hru, V_CH_N2.rte, V_ALPHA_BNK.rte and V_TLAPS.sub respectively were the more significant sensitive parameters for the land use/land cover map of 1989.

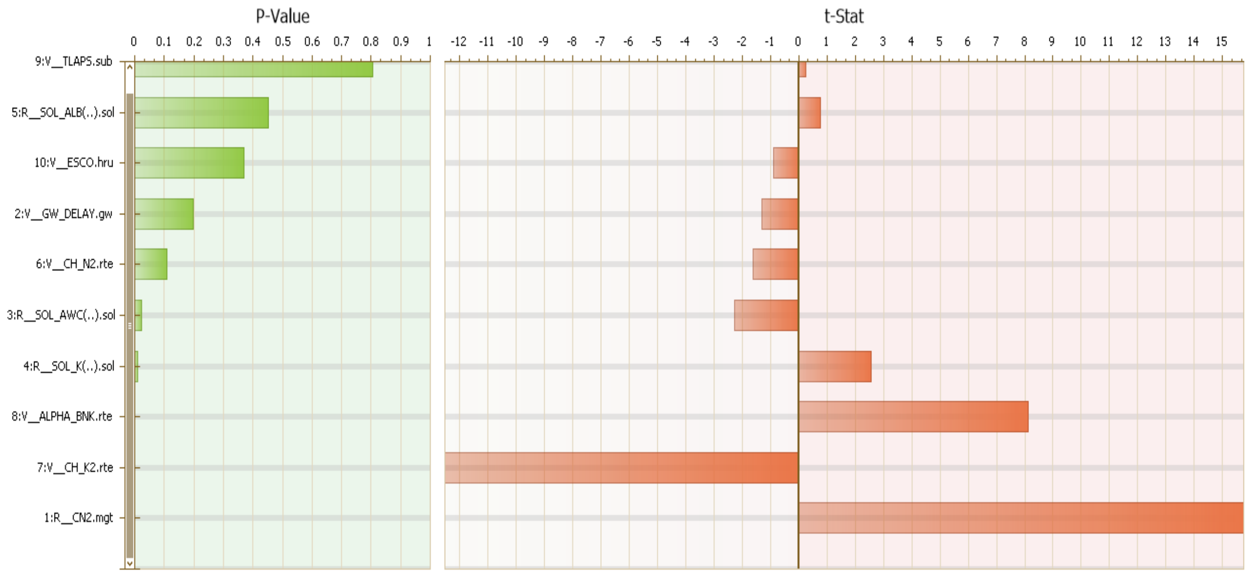


Figure 10 The most sensitive parameters for 2003 land use/cover

As indicated in figure 10, the most sensitive parameters of the second scenario were similar with the first one, but the extent of their influence were different. Both figures show that R__CN2.mgt and V_CH_K2.rte were the most sensitive parameters for both scenarios.

Stream flow calibration and validation

The calibration was carried out for six years from January 1989 to December 1994 and flow validation was done for three years from 1995-1997 for monthly stream flow using the sensitive parameters identified for the land use/cover map of 1989. The second scenario for the land use/cover map of 2003 was also calibrated from 1998-2002 and validated from 2003-2004. Akaki station was selected for calibration and validation as it covers a larger catchment area and has a better data availability.

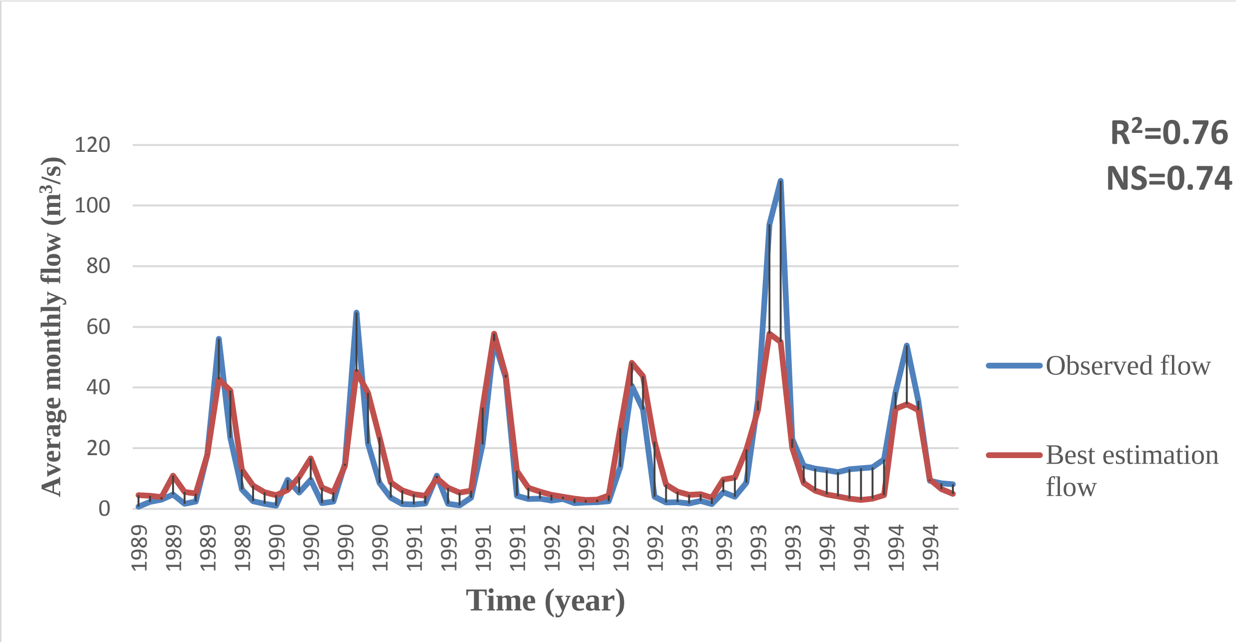


Figure 11 Calibration result (1989- 1994) for land use/land cover map 1989

As shown in Figure 11, the model was calibrated using monthly stream flow of observed data from the Akaki hydrological Station. The calibration results show that the coefficient of determination and Nash-Sutcliff Efficient (NSE) were 0.76 and 0.74, respectively. This indicates that there is a good correlation and agreement between the monthly measured data and simulated flow.

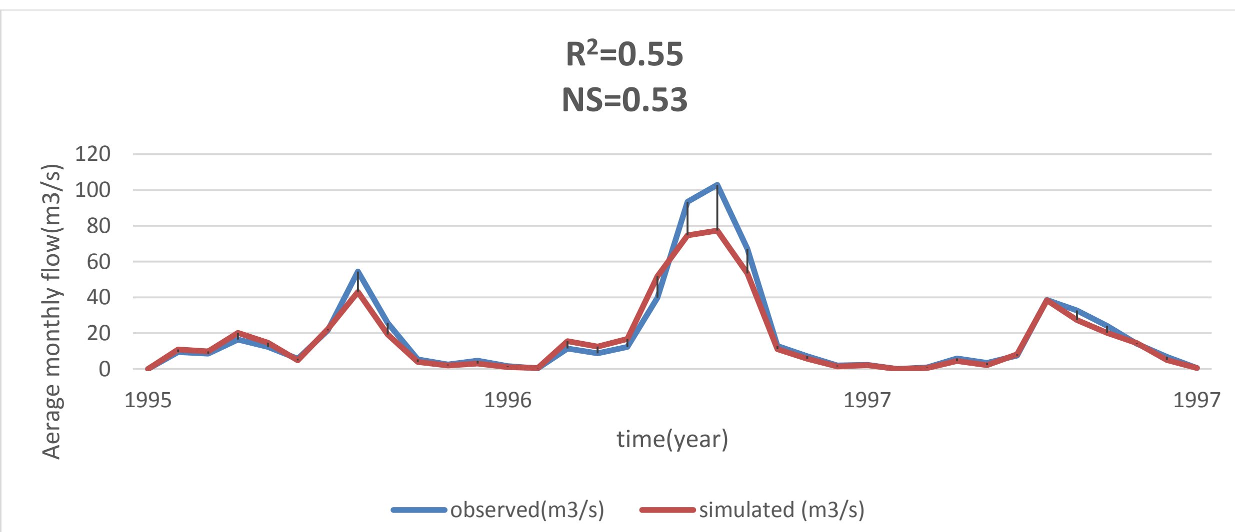


Figure 12 Validation result (1995- 1997) for land use/land cover map of 1989

As presented in Figure 12, the model was validated using monthly stream flow of observed data from the Akaki hydrological Station. The validation results show that the coefficient of determination and Nash-Sutcliff Efficient (NSE) were 0.55 and 0.53, respectively. This shows that the model performance was good during the validation period.

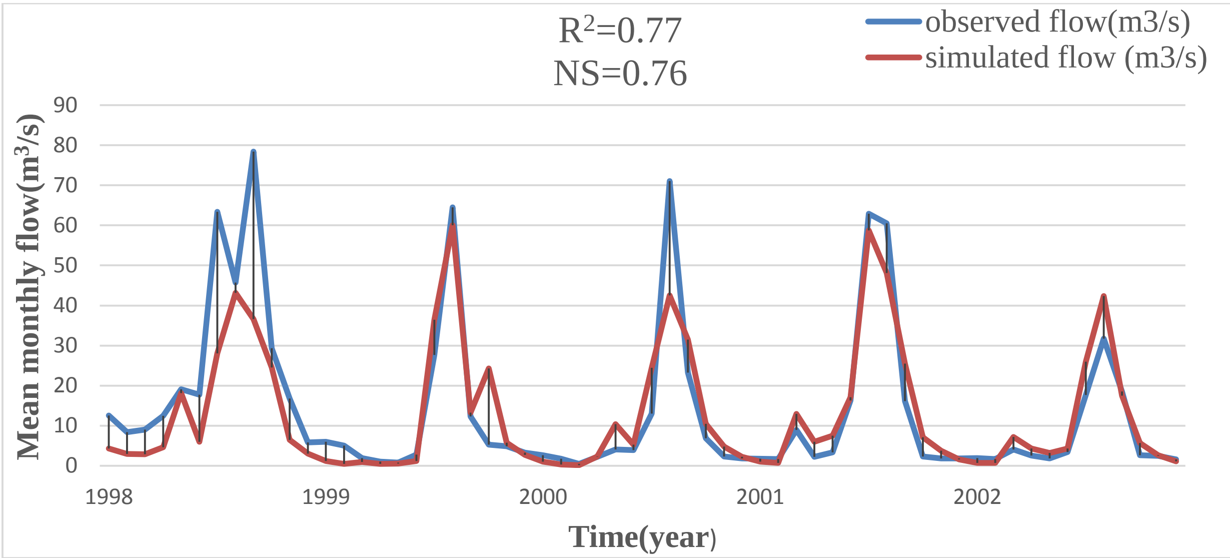


Figure 13 Calibration result (1998-2002) for land use/land cover map 2003

Figure 13 indicates that there is a good correlation between the observed data and simulated result. Consequently, this result may use for further analysis.

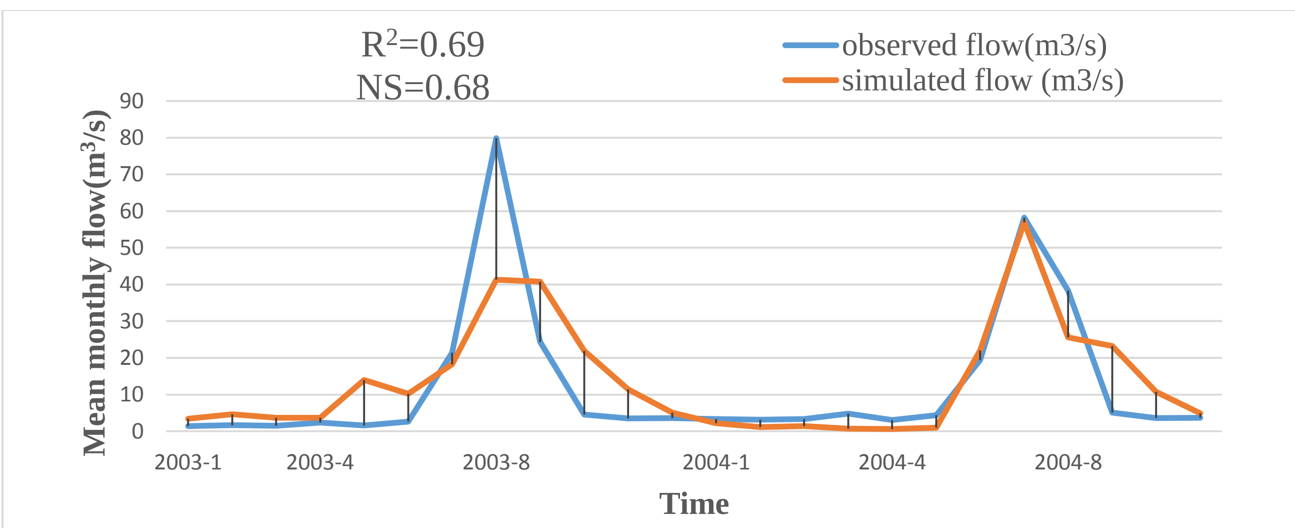


Figure 14 Validation result (2003-2004) for land use/land cover map 2003

Figure 14 shows that there is a best correlation between the measured and simulated result of monthly stream flow. Therefore, the simulated results of SWAT model may use for other water resource management strategies.

Table 9 Model performance of stream flow for calibration and validation period

Period	Mean Monthly Flow (m^3/s)		Model Efficiency	
	observed	Simulated	R^2	NS
Calibration(1989-1994)	14.92	15.22	0.76	0.74
Validation(1995-1997)	17.95	19.71	0.55	0.53
Calibration(1998-2002)	14.29	12.83	0.77	0.76
Validation(2003-2004)	12.46	13.7	0.69	0.68

As observed from table 9 above, the model performance values for calibration and validation of the flow simulations for both scenarios are satisfactory. This indicates that the model adequately captured the physical processes involved in the generation of stream flow. Hence, the model simulations can be used for various water resource management and development aspects. On this study, those results were used as an input to analyze water quality using WASP model.

Calibration of sediment concentration

SWAT has the capacity to calibrating sediment load, sediment concentration and nutrient loads. However, there is no observed data of these parameters, except the specific days, which had the observed data of sediment concentration. Therefore this study was conducted only the calibration of these daily sediment concentrations with that of simulated ones using percentage error method manually. The percentage error was estimated using the formula

$$\%\text{age error} = \left(\frac{\text{observed} - \text{simulated}}{\text{observed} + \text{simulated}}\right) * 100$$

Comparison of their difference is categorized as <15 vary good, 15-25 good, 25-35 fair and >35 poor according to USGS water quality regulations.

Table 10 Sediment concentration calibration

Date & Time of sampling	Observed sediment concentration (mg/l)	simulated sediment concentration (mg/l)	%age error	model performance
6-Dec-1989	139.12	97.46	17.6	Good
15-Feb-1990	420.59	247.7	25.9	Fair
7-Apr-1990	2020.00	238.2	78.9	poor
10-Aug-1990	2141.43	334.9	73.0	poor
8-Oct-1990	310.00	158.90	32.2	fair
17-Nov-1992	320.00	216.20	19.4	Good
28-Sep-1992	252.50	165.80	20.7	Good
2-Feb-1995	156.67	112.89	16.2	Good
6-May-1995	339.05	167.01	34.0	Fair
8-Jun-1995	638.38	442.65	18.1	Good
5-Aug-1996	233.20	368.20	-22.4	Good
11-Aug-1997	874.30	524.90	25.0	Good
7-Sep-1998	775.30	233.9	53.6	Poor
23-Aug-1998	655.00	362.5	28.7	Fair
13-May-1999	233.33	238.32	-1.1	Very good
17-Sep-2002	481.46	330.8	18.5	Good
24-Mar-2003	307.59	235.5	13.3	Very good
17-Jun-2005	172.13	163.20	2.7	Very good
15-Dec-2005	205.33	113	29.0	Fair
8-Apr-2009	335.65	294.5	6.5	Very good

According to table 10 above, the model performance is satisfactory except the three days which shows poor. This indicates that the model adequately captured the physical processes involved in the generation of sediment concentration in the watershed. Hence, the model simulations can be used as an input for various water resource management and for other water quality model.

3.3.3 WASP Model Simulation Procedure

Water quality modeling using wasp model requires different procedures. The key procedures followed on WASP 7.3 model are listed below step by step.

1) **Simulation Control**

On this study, three daily stimulations on the years 1989, 2003 and 2016 were carried out. The WASP 7.3 version model has 8 model types. Although this project considered only advanced eutrophication model to simulate (TSS, pH, NH_4-N, NO_3-N, TN and TP) and heat model to simulate temperature of water. The model simulates the hydrodynamics as gross flows using EULER solution.

2) **Time Step**

Time step sets duration of simulation. Consequently, on this project the duration of simulation was sets from 1/1/1989-12/31/1989, 1/1/2003-12/31/2003 and 1/1/2016-12/31/2016.

3) **Segment Properties**

The catchment was divided in to 130 segments or reaches to represent real-actively homogeneous sections. However much of the discussion in this paper was focused on segment 51, 55, 65 and 74 on the little Akaki River and 37, 45, 48, 49, 53, 54, 66, 67 & 98 on Great Akaki River from upstream to low stream respectively to show the spatial variations. These segments were selected because of some observed data were available for calibration. Therefore, these segments were added to WASP model and these segment properties were fill as in put to WASP model from Arc GIS of the delineated section. The initial concentrations of the segment parameters were set to zero except pH, which is 7.

4) **System Properties**

All parameters required on WASP were ticked by the simulated option, their maximum concentration, scale factor and the user-filled conversion factors.

5) **Loadings**

On this step all, the nutrient loadings for the main segments were imported from SWAT model to WASP model.

6) **Flows**

The surface water flow of each segment of SWAT model was taken as input for WASP model and the values were filled as the requirement of WASP model.

7) **Boundary Concentrations**

The boundary segment concentrations from SWAT model were filled for all scenarios just like the loads and flows.

8) **Post processor**

After all processes were carried out, the model was executed to run and the results were shown using visual graphic post-processor. The Post-Processor was developed as an efficient means of processing the vast amount of data produced by the execution of the WASP model. It has the ability to display results from all the models (EUTRO and TOXI) included in the WASP modeling package. Although there were two graphical post processor models on WASP, x/y plot was used on this project to show the results in graph and tabular form.

9) **WASP calibration**

WASP calibration of the simulated water quality parameters with observed data was done manually using percentage error difference.

3.4 WASP simulation

On this study, the water quality parameters pH, TSS, Temperature, NH_4-N, NO_2-N, TN and TP were simulated. The simulation were conducted for three years, Jan 1989 to Dec 1989, from Jan 2003 to Dec 2003 and from Jan 2016 to Dec 2016 to show the temporal variation of water quality due to land use impacts. Those water quality parameters were simulated on Little Akaki and Great Akaki Rivers from upper stream to downstream to show the spatial variation. Reach 51, 55, 65 and 74 from Little Akaki River and reach 37, 45, 48, 67 and 98 from Great Akaki River from upper to downstream respectively were taken as a sample.

WASP calibration

Although WASP model has the ability to calibrate and validate water quality parameters, manual calibration was conducted, due to lack of observed water quality parameters. Water quality monitoring data were available for surface water at ten monitoring stations of Great and Little Akaki Rivers. However, those data were yearly water quality data and limited to some parameters. Therefore, the simulated water quality parameters were calibrated only for the available water quality data using percentage error difference. Comparison of their difference percentage between the observed and the simulated value is categorized as <15 vary good, 15-25 good, 25-35 fair and >35 poor according to USGS water quality regulations.

Table 11 WASP model calibration on reach 65

Water quality parameter	2003 simulated	2003 observed	% age error	Model performance
TSS(mg/l)	410.23	159.25	-44	Poor
Temperature(c^o)	20.68	18.5	-6	Very Good
PH	5.75	6.57	7	Very Good
TN(mg/l)	0.778	28.41	94.7	poor
TP(mg/l)	0.157	1.96	85.2	poor

Table 12 WASP model calibration on reach 67

Water quality parameter	2003 simulated	2003 observed	% age error	Model performance
TSS(mg/l)	363.46	285.5	-12.0	Very Good
Temperature(c^o)	24.66	20.925	-8.2	Very Good
PH	5.55	6.25	5.9	Very Good
TN(mg/l)	0.777	9.3	84.6	Poor
TP(mg/l)	0.2163	2.985	86.5	Poor

The performance efficiency values of one-year calibration period for both reaches (table 11 & 12) proved that WASP model simulation result was good against the experimental result of the water quality parameters. Therefore, the water quality result obtain from WASP model may use for other purposes, such as protection of polluted area.

In addition, water quality parameters were compared with monitored out puts of (Tafere, 2008) who asses the water quality of both Great and Litlle Akaki rivers as shown on the tables below. Both the simulated and monitored data was taken at (9^o04’50”N & 38^0 46’28” E) and (90 01’45”N & $38^0$46’50”) on the upstream and downstream Great Akaki river. Also for Little Akaki the sampling points are located at (9^0 03’45” N & 38^0 43’02” E) and (8^0 58’ 38”N & 38^0 4’ 11”E) on its upstream and downstream respectively.

Table 13 Comparison of water quality simulation and monitored results

Water quality parameter	Simulated result of this thesis on 2003	Monitored data by (Tafere on 2007)	Percentage error	Model performance
TSS(mg/l) upstream	227	315	-16.2	Good
TSS (mg/l) downstream	365	382	-2.3	Very good
T (^{o}c) upstream	15	18.25	-9.8	Very good
T (^{o}c) down stream	21	22	-2.3	Very good
pH upstream	5.5	5.78	-2.5	Very good
pH down stream	5.48	5.76	-2.5	Very good
NH4-N(mg/l) upstream	1.328	1.75	-13.7	Very good
NH4-N(mg/l) down stream	1.78	3.3	-29.9	Fair
TP(mg/l) upstream	0.21	0.213	-0.7	Very good
TP(mg/l) upstream	0.2163	0.41	-30.9	Fair

Table 14 Comparison of water quality simulation and monitored results

Water quality parameter	Simulated result of this thesis on 2003	Monitored data by (Tafere on 2007)	Percentage error	Model performance
TSS(mg/l) upstream	256	333	-13.1	Very good
TSS (mg/l) downstream	410	561	-15.6	Good
T (^{o}c) upstream	17.4	18.6	-3.3	Very good
T (^{o}c) down stream	20.6	21.3	-1.7	Very good
pH upstream	5.745	6	-2.2	Very good
pH down stream	5.75	5.9	-1.3	Very good
NH4-N(mg/l) upstream	0.46	1.25	-46.2	Poor
NH4-N(mg/l) down stream	0.73	1.75	-41.1	Poor
TP(mg/l) upstream	0.157	0.22	-16.7	Good
TP(mg/l) upstream	0.157	1.13	-75.6	Poor

Water Quality Laboratory Process Team (Daniel weyessa, 2004) monitors the Awash River and Tributaries Pollution and the simulated results of this thesis were compared with the monitored data as shown on the tables below.

Table 15 Comparison of monitored and simulated results on little Akaki river

Water quality parameter	Simulated result 2003	Monitored data by (Daniel weyessa, 2004)	Percentage error	Model performance
TSS (mg/l) downstream	410	240	26.2	Good
T (oc) down stream	20.61	20.1	1.3	Very good
pH down stream	5.75	7.75	-14.8	Very good
TP(mg/l) upstream	0.157	0.89	-70.0	Fair

Table 16 Comparison of monitored and simulated results on Great Akaki River

Water quality parameter	Simulated result 2003	Monitored data by (Daniel weyessa, 2004)	Percentage error	Model performance
TSS (mg/l) downstream	363	480	-13.9	Very good
T (oc) down stream	24.6	20.4	9.3	Very good
pH down stream	5.5	7.3	-14.1	Very good
TP(mg/l) upstream	0.21	1.51	-75.6	Fair

4. RESULTS AND DISCUSSION

4.1 Evaluation of surface water quantity due to land use change

4.1.1 Evaluation of stream flow based on temporal variation

Temporal variation of stream water flow was evaluated by selecting the reaches of little Akaki and Great Akaki Rivers. These reaches were selected to show the effect of land use change on stream flow through time. The land use/cover change through time is shown on the figure below for the catchment area of upstream and downstream of Great and Little Akaki rivers.

Table 17 Simulated stream flow and land use/cover change

		Percentage land use coverage			
Segment type	Year	Agricultural land	Barren land	Forestland	Urban area
Reach 98	1989	3.03	21.8	38.47	36.7
	2003	7.63	22.82	26.76	42.79
	2016	14.2	15.23	24.8	45.77
Reach 74	1989	9.09	3.68	20.83	65.09
	2003	10.7	2.85	15.36	71.03
	2016	11.23	2.88	10.6	76.72
Reach 51	1989	0.41	19.63	58.48	21.4
	2003	0.31	19.94	46.25	33.4
	2016	9.99	9.47	35.66	44.91
Reach 37	1989	0.84	33.26	54	11.17
	2003	1.4	35.63	47.86	14.84
	2016	11.08	27.21	44.67	17.03

Forestland decreases by 18% and 21.6% from (1989 to 2003) and from (1989 to 2016) respectively. However, urbanization increases by 7.7% and 11% from (1989 to 2003) and from 1989 to 2016 respectively on, the downstream of Great Akaki River (reach 51).

On the downstream of Little Akaki River (reach 51) Forestland decreases by 18% and 21.6% from (1989 to 2003) and from (1989 to 2016) respectively. However, urbanization increases by 7.7% and 11% from 1989 to 2003 and from (1989 to 2016) respectively.

This significant change of land use/cover causes a significant change on the annual stream water flow as shown on figure 15 below.

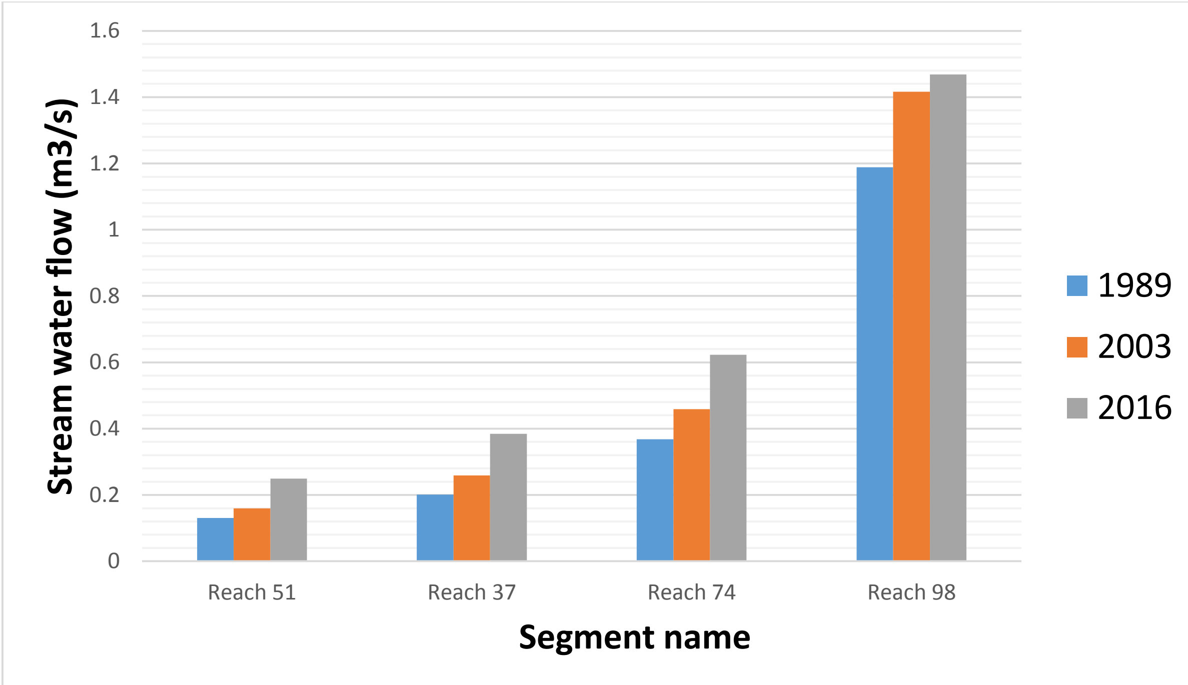


Figure 15 Temporal variation of annual stream flow on Akaki River

The significant change of the land use/cover on down stream of Little Akaki River (reach 51) favor to change the annual stream water flow by 10.1% from (1989-2003) and by 30.3% from (1989-2016). The stream flow also increases by 12.5% from (1989-2003) and by 31.2% from (1989-2016).

4.2 Evaluation of surface water quality

4.2.1 Spatial and temporal evolution of pollutant loads and more polluted areas

Identifying the area contributing most of the pollutants in a watershed is important for cost-effective implementation of best management practices. Identification of such areas is often done through watershed modeling. The Soil and Water Assessment Tool (SWAT) were used to identify the more polluted area of sediment and nutrients. The total sediment load, nitrogen (TN) and phosphorus (TP) were identified based on the average annually time scale of sub basin, total load from their contributing sub watershed and using spatial analyst tool by exporting the sub basin shape file in to the ARC GIS 10.3 interface. Pollutant loads were also evaluate for spatial and temporal variations due to land use/cover change.

A. Evaluation on spatial variation of sediment load and identifay of more polluted area

After SWAT model was simulated, the sub basins, which have high and low sediment load, were taken to evaluate the impact of land use spatially.

Table 18 Spatial variation of sediment load and identification of more polluted area

Sub basin	Barren land (%)	Forest mixed (%)	Agricultural land (%)	Forest ever green (%)	Residential/built up area (%)	Sediment load (Metric ton/ha)
3	73.8	9.52	9.52	8.77	0	1271
2	93.58	0.78	0.07	0.39	0	1249
6	79.56	6.58	2.18	5.98	0	1200
1	74.4	5.06	3.63	5.18	0.06	719
11	92.16	2.38	4.22	0	0.07	140
121	2.07	0.44	82.42	0	15.94	15
51	9.17	22.14	10.27	6.78	48.07	1.26
74	0.85	0.85	9.03	0	90.89	0.48
66	3.67	0.8	14.68	1.28	81.2	0.43
88	0	0	1.49	0	98.41	0.25

Table 16 above shows that sub basins 2, 3 and 6 are more polluted areas, whereas sub basins 88, 66 and 74 are the least polluted areas. the sub basins, which have high sediment load have high percentage coverage of barren lands, but the sub basins, which have low sediment load have high percentage coverage of residential/built up areas. Therefore, barren lands are the more polluted area for sediment load. In addition, the spatial variation of sediment load was explored on the above table, and it was observed that agricultural land and barren land have positive correlation, but residential/built up area has negative correlation with sediment yield.

B. Evaluation on temporal variation of sediment load

Temporal variation of sediment load was evaluated from 1989 to 2003 and from 2003 to 2016 by selecting sub basins 51, 108 and 3 to show the impact of land use change. The change on the percentage coverage area of land use for those sub basins is shown on the table 14 below.

Table 19 Temporal variation of sediment load

Sub basin	Sub basin 51 area of coverage (%)			Sub basin 108 area of coverage (%)			Sub basin 3 area of coverage (%)		
land use classification	1989	2003	2016	1989	2003	2016	1989	2003	2016
Barren land	20.14	19.74	9.17	20.24	10.33	0	88.85	77.9	73.8
Forest mixed	33.91	24.73	22.14	4.34	17.56	4.75	3.14	10.6	9.52
Agricultural land	0.4	0.3	10.27	64.65	57	39.24	7.68	5.3	9.52
Forest ever green	18.75	15.96	6.78	1.86	0	2.48	1.73	7.79	8.77
Residential	23.23	35.7	48.07	10.53	16.73	55.15	0	0	0
Sediment load (Metric ton/ha)	140	115	1.3	95.4	28.9	9.1	2602	1640.	1271

Sediment load decreased by 98.2% when urbanization is increased by 35.2% and barren lands decreased by 37.3% from (1989-2016) on sub basin 51. It also increased by 82.6% when urbanization increased by 53.5% and barren land decreased by 32.4% from (1989-2016) on sub basin 3. Therefore increasing residential/built up area has a positive impact on but increasing agricultural, forest and barren lands has a negative impact on sediment load.

C. Evaluation on spatial variation of TN & TP and identification of more polluted area

To evaluate spatial variation of TP and TN the sub basins listed on table 15 below were taken as a sample.

Table 20 Spatial variation of TN, TP, and identification of more polluted area

Sub basin	Land use land cover area coverage (%)age					Magnitude of TP & TN in Kg/ha	
	Barren land	Forest mixed	Agricultural land	Forest ever green	Residential/built up area	TN	TP
45	1.31	5.24	25.57	7.21	62.28	24.9	4.4
90	2.24	0.2	96.72	0	2.45	21.6	3.101
129	6.84	0.07	85.49	0	1.18	21.2	3.7
111	1.89	1.79	58.43	0.07	39.45	12.2	2.1
6	79.56	6.58	2.18	5.98	0	7.3	0.9
37	16.26	33.42	4.58	0	0	3.2	0.4
51	9.17	22.14	10.27	6.78	48.07	3.1	0.6
47	4.35	23.27	8.29	25.36	28.71	2.25	0.4

As shown on the table above sub basins 45, 90 and 129 are more polluted whereas it was observed that sub basins 46, 51 and 37 are less polluted. Spatial variation of TN and TP was also evaluated on those sub basins, and the result indicates that TN and TP were high on agriculture and residential/built up areas but low on forestlands. This observation was similar with the idea of (Journals, Science, & Pierce, 2017) and (Madjid Delkash, Furat A. M. Al-Faraj, n.d.) There is a positive correlation between urban and agricultural land uses with nitrogen and phosphorus concentrations and loads. Nevertheless, there is a negative correlation between riparian vegetation, grassed swales and artificial wetlands with nutrient load concentration. Therefore, urbanization and agricultural lands have a negative impact on TP & TN loads though forestlands have positive impact.

D. Evaluation o temporal variation of TN and TP

Temporal variation of TN & TP loads were evaluated by taking sub basins 66, 74 and 121 as a sample. Those sub basins were evaluated on 1989, 2003 and 2016 to assess the impact of land use on TN & TP temporally.

Table 21 Temporal variation of TN & TP

Sub basin	Sub basin 66 area of coverage (%)			Sub basin 74 area of coverage (%)74			Sub basin 121 area of coverage (%)		
land use	1989	2003	2016	1989	2003	2016	1989	2003	2016
Barren land	2.71	2.55	3.67	5.31	3.29	0.85	7.16	6.17	2.07
Forest mixed	3.35	9.41	0.8	2.76	5.52	0.85	0.44	2.22	0.44
Agricultural land	2.39	2.87	14.68	4.57	4.46	9.03	91.8	91.5	82.42
Forest ever green	11.8	1.28	1.28	2.76	0	0	0.44	0.2	0
Residential	81.36	85.5	81.2	86.22	88.34	90.9	1.09	0.54	15.94
Magnitude of TN in Kg/ha	2.914	3.475	5.391	3.156	3.827	5.82	17.792	17.5	48.83
Magnitude of TP in Kg/ha	1.113	1.128	1.62	1.237	1.255	1.78	3.947	3.01	6.072

Table 19 above, shows that TN & TP were increased slightly from time to time. This is due to increase in built up area and agricultural land as well as decrease in forestlands. Therefore built up areas and agricultural lands have a positive correlation, but forestlands has a negative correlation with TN & TP loads. Barren lands indicated neither a strong nor a significant correlation to TN & TP loads. In addition, it is observed that built up areas and agricultural lands are very sensitive to TN & TP. Therefore, it was concluded that there was a significant temporal variation of TN & TP due to land use/cover changes.

4.3 Evaluation on spatial variation of river water quality

Water quality parameters were evaluated spatially from upstream to downstream to know the land use/cover changes on both rivers. Reach 51, 55, 65 and 74 were taken to evaluate land use impacts on little Akaki and reach 37, 45, 48, 67 and 98 were taken for Great Akaki from upstream to downstream respectively. The catchment area for those reaches is starting from Intoto Mountains to the downstream of Addis Ababa town. land use distribution of the catchment shows that the maximum area was cover by residential/built up, forest area, barren land and agricultural land respectively. The upstream of the catchment area was dominated by forestland and the downstream was dominated by urbanization. Urbanization increased from upstream to downstream, but forestland decreases from upstream to downstream.

Water quality parameters (pH, temperature, TSS, NH_4-N, NO_2-N, TN and TP) were simulated using WASP model and the result is listed on the tables below.

Table 22 Water quality of little Akaki river on 1989

Water quality parameters	Reach 51	Reach 55	Reach 65	Reach 74
PH	6.744	5.920	5.747	5.746
Temperature(c^o)	22.31	20.68	17.42	16.46
TSS(mg/l)	255.6	257.23	256.25	192.86
NH4-N(mg/l)	0.45	0.46	0.46	2.15
NO2-N(mg/l)	0.0953	0.0955	0.0954	0.1234
TN(mg/l)	0.466	0.47	0.469	0.44
TP(mg/l)	0.156	0.158	0.157	0.162

Table 23 Water quality of Great Akaki River on 1989

Water quality parameters	Reach 37	Reach 45	Reach 48	Reach 67	Reach 98
PH	6.25	6.12	6.03	5.55	5.58
Temperature(c^o)	14.30	16.12	18.48	14.54	14.43
TSS(mg/l)	198.05	208.02	226.3	227.9	156.99
NH_4-N(mg/l)	0.34	0.38	0.46	1.328	3.41
NO_2-N(mg/l)	0.0052	0.0054	0.0060	0.0263	0.1051
TN(mg/l)	0.18	0.21	0.27	0.37	0.4
TP(mg/l)	0.079	0.092	0.118	0.213	0.171

Evaluation on spatial variation of pH

pH decreased from upstream to downstream of the river on both rivers, except slight increase on reach 98. This observation shows that pH decreases when urbanization increases and forestland decreases. Therefore, increase in built up area has a negative impact on pH, but increase on forestland has positive impact on pH. pH value of the water indicates that its quality is deteriorated from upstream to downstream of the river. More over the correlation of agricultural land and barren land with pH is complex.

Evaluation on spatial variation of temperature

Temperature is increasing on Great Akaki River but it decreases on Little Akaki River from upstream to downstream. The reason for decreasing temperature is very complex and the reason for increasing of temperature is due to increase in urbanization and decrease in forestland. Thus, urbanization has a strong positive relationship, but forests have a negative relationship with temperature. However, agriculture and barren land does not show any significant change on temperature. This observation is the same with (Ibrahim, Abu Samah, Fauzi, & Noor, 2016) built up area, forest and water bodies have caused significant difference in the temperature variation. However, bare land did not show significant impact. Therefore, it can be concluded that green areas have lower temperature, and built up areas have high temperature.

Evaluation on spatial variation of TSS

As shown on tables 20 & 21 above, the total suspended solids (TSS) increased from upper to low stream except slightly decrease on reach 74 and 98. This observation shows that there is a special variation of TSS due to land use changes. TSS is high on urban areas but low on forest areas. It has similar analysis with (Hart, 2006) forested drainage areas had lower TSS than agriculture and urban area. In addition, the result shows that Little Akaki River has high TSS than Great Akaki River because the catchment area of little Akaki River is dominated by urban area than that of Great Akaki River.

Evaluation on spatial variation of NH_4-N, NO_2-N, TN and TP

All NH_4-N, NO_2-N, TN and TP have high value on the upper part of both rivers than the lower part as shown on tables 20 & 21 above. This is because the upper part of the catchment area has high forest coverage whereas the lower part has high urbanization coverage. Therefore, the result shows NH_4-N, NO_2-N, TN and TP decreases due to increase in forest area, and they increases due to increase in urbanization. This observation gives similar idea with (Huang et al., 2013) and (Ding et al., 2015) the proportion of forested land was negatively associated with total phosphorus, nitrogen, ammonia as nitrogen and nitrite as nitrogen. The proportion of urban land was strongly positively associated with total nitrogen and ammonia nitrogen concentrations.

Generally, all the seven water quality parameters show a significant spatial variation due to land use changes. All parameters deteriorates from upper to lower stream. This shows that urban lands and forest areas are very sensitive for spatial variation water quality. As a result, built up areas has negative influence in water quality. However, forestlands has a positive influence on water quality. Besides, the impact of barren land and agricultural land is complicated. This is the same observation with (Ding et al., 2015) and (Huang et al., 2013) the increase of the built up area and decrease of forests tends to degrade the water quality. However, agricultural land use did not have a significant impact on water quality.

4.2.2 Evaluation on temporal variation of river water quality

Water quality parameters were evaluated temporally for 1989, 2003 and 2016 to see the change of their value due to land use impacts. To show land use impact on temporal variation of water quality, reach 65 and reach 67 from Little and Great Akaki Rivers respectively were taken as a sample. The temporal change on water quality parameters on both reaches are shown on table 19 and 20 below.

Table 24 Temporal variation of water quality on reach 65

water quality parameter	1989	2003	2016	Change (%) (1989-2003)	Change (%) (2003-2016)	Change (%) (1989-2016)
PH	5.747	5.75	5.17	0.03	-5.31	-5.29
Temperature(c^o)	17.42	20.61	14.51	8.39	-17.37	-9.11
TSS(mg/l)	256.25	410.23	738.37	23.10	28.57	48.47
NH_4-N(mg/l)	0.46	0.73	1.24	22.69	25.89	45.88
NO_2-N(mg/l)	0.0954	0.145	0.241	20.63	24.87	43.28
TN(mg/l)	0.469	0.778	1.3041	24.78	25.27	47.10
TP(mg/l)	0.157	0.157	0.2245	0.00	17.69	17.69

Table 25 Temporal variation of water quality on reach 67

water quality parameter	1989	2003	2016	Change (%) (1989-2003)	Change (%) (2003-2016)	Change (%) (1989-2016)
PH	5.55	5.548	4.938	-0.02	-5.82	-5.84
Temperature(c^o)	14.54	24.66	17.42	25.82	-17.21	9.01
TSS(mg/l)	227.9	363.46	654.67	22.92	28.60	48.36
NH_4-N(mg/l)	1.328	1.776	3.8	14.43	36.30	48.21
NO_2-N(mg/l)	0.0263	0.04	0.07	20.66	27.27	45.38
TN(mg/l)	0.37	0.777	1.29	35.48	24.82	55.42
TP(mg/l)	0.213	0.2163	0.2985	0.77	15.97	16.72

According to tables 19 and 20 above, except temperature from (2003-2016), all the parameters on all years increased through time. This result shows the river water quality has a significant temporal variation due to land use change. This significant change on the deterioration of water quality is due to increase on residential/built up area and decrease on forestlands. Both forestland and grassland have significant positive influence on the water quality. This observation also gives the same suggestion with (Huang et al., 2013) the areas of the forest and grassland negatively related to TP, TN, NH_3-N. The built-up area positively related to TP, TN, NH_3-N, and NO_2-N.

4.3 Assessment of the degree of water pollution on little and Great Akaki Rivers

To know whether the rivers are polluted, river water quality status was evaluated at the downstream of both Little and great Akaki Rivers on reach 65 and reach 67 respectively on the year of 2016. The mean monthly and average yearly water quality result for a specific water quality parameters is shown on the table below.

Table 26 Mean monthly water quality status of Little Akaki River

Month	Temperature(c^o)	TSS(mg/l)	pH	NO_2-N(mg/l)	NH_4-N(mg/l)	TP(mg/l)	TN(mg/l)
Jan	32.563	923.792	5.185	0.563	2.275	0.413	2.714
Feb	32.932	952.505	5.181	0.602	2.786	0.523	3.244
Mar	31.542	946.362	5.181	0.543	2.165	0.442	2.566
Apr	27.259	809.250	5.179	0.664	1.651	0.330	2.093
May	23.000	780.778	5.174	0.169	1.245	0.219	1.201
Jun	23.728	682.022	5.170	0.092	0.960	0.167	0.854
Jul	17.431	549.747	5.166	0.061	0.777	0.131	0.642
Aug	18.185	578.59	5.161	0.047	0.668	0.112	0.536
Sep	21.521	628.268	5.161	0.042	0.663	0.111	0.532
Oct	21.642	596.942	5.165	0.041	0.638	0.097	0.484
Nov	23.106	683.129	5.170	0.041	0.505	0.069	0.378
Dec	23.593	742.325	5.177	0.054	0.662	0.100	0.550
yearly	24.661	738.365	5.173	0.241	1.240	0.224	1.304

Table 27 Mean monthly water quality status of Great Akaki River

Month	Temperature(c^o)	TSS(mg/l)	pH	NO_2-N (mg/l)	NH_4-N (mg/l)	TP(mg/l)	TN(mg/l)
Jan	42.44	935.87	4.99	0.03	0.36	0.53	2.83
Feb	47.90	1228.26	4.72	0.35	18.38	1.62	6.81
Mar	26.32	632.32	4.67	0.13	14.66	0.93	2.95
Apr	16.80	553.99	4.97	0.06	1.33	0.10	0.48
May	17.44	698.84	4.95	0.08	1.27	0.11	0.44
Jun	15.32	542.58	5.00	0.06	0.89	0.03	0.19
Jul	11.35	558.09	4.98	0.08	0.91	0.04	0.22
Aug	12.40	487.39	4.95	0.06	1.18	0.08	0.34
Sep	13.64	531.49	4.99	0.05	1.02	0.05	0.31
Oct	16.71	622.81	5.01	0.02	1.20	0.05	0.37
Nov	16.06	548.79	5.01	0.01	1.04	0.05	0.34
Dec	12.82	556.86	5.01	0.01	1.37	0.09	0.69
yearly	20.61	654.67	4.94	0.08	3.82	0.30	1.30

The mean monthly and yearly water quality condition of Little and Great Akaki Rivers on 2016 were presented on the tables 24 & 25. To know its degree of pollution, the water quality status of each parameters compared with different guidelines are discussed below.

Temperature (c^o)

As described the tables 21 & 22 above, the mean monthly water temperature was observed from 11.35-47.9 c^o on Great Akaki River and from 17.4-32.9 c^o on Little Akaki River, and the annual average temperature was 24.6 c^o on Little Akaki River and 20.61 c^o on Great Akaki River. The maximum temperatures were observed on January, February and March.

According to (Tiwari, 2015) different plankton groups will flourish under different temperatures. For example, diatoms dominate at 20-25 c^o, green algae dominate at 30–35 c^o, and cyano-bacteria dominate above 35 c^o. Therefore, Great Akaki River can be dominated by green algae on march and by cyano bacteria on January and February. In addition, Little Akaki River can be dominated at all the months, except July and August, by diatoms, green algae and cyano-bacteria because the temperature was greater than 20 c^o.

The study by (Department of Water Affairs and Forestry, 1996) states that fish species like Salmo trutta needs water quality range of 12-13 c^o for growth and Clarias gariepinus needs temperature of 28-30 c^o for growth. Therefore, Fish species like Salmo trutta can be destroyed from both Rivers all most in all months and Clarias gariepinus can be destroyed on January, February and March.

pH

The yearly average pH value was 5.173 and 4.94 on Great and Little Akaki Rivers respectively, on the year of 2016. According to the study conducted by (Magara, n.d.) pH standard for agricultural use was set as 6.5 to 7.5. The standard of pH is also 6-9 according to Addis Ababa environmental protection agency. Similarly, the range of pH suitable for fisheries was to be 5.0-9.0 (Environmental & Agency, 2001). Therefore, as the pH value was less than 6.5 on both rivers, using of this water source for agriculture can cause an effect on the vegetation, and as the pH value was observed below 5.0, the river water quality may not be suitable for fishery.

Total suspendered solids

The average yearly total suspended solids was 738.365 mg/l and 654.67 mg/l on the downstream of little and Great Akaki Rivers respectively. The minimum TSS observed was 549.747 mg/l on Little Akaki on July and 487.39 mg/l on Great Akaki on August.

TSS concentration of more than 50 mg/l affects the proper functioning of fish gills. Above 30 mg/l of TSS, adversely affects slow sand filtration systems. Therefore TSS standards of 50 mg/l and 25 mg/l were adopted for fishery and water supply use respectively (Magara, n.d.). another study by (Environmental & Agency, 2001) states that greater than 30 mg/l of TSS on sewage effluent indicates that performance efficiency of treatment plant is not good. In addition to this, the maximum limit of TSS for fresh surface water is 25mg/l. Greater than 100 mg/l of total suspended solids are increasingly severe problems with the clogging of drip irrigation emitters according to the study of (DWAF, 1996).

Depending on those ideas and the simulated results of TSS, it can be concluded that the source of water from both rivers cannot be used for water supply and fishery without treatment, because the concentration of TSS was very high, when it is compared to the standard in all months of the year.

Nitrite as nitrogen (NO_2-N)

The yearly average concentration of (NO_2-N) was simulated as 0.241 mg/l and 0.08 mg/l on Little and Great Akaki Rivers respectively. Nitrite levels in drinking-water are usually below 0.1 mg/l (World Health Organization, 2011) and it is limited for surface water sources less than 0.05 mg/l (Environmental & Agency, 2001). Therefore using this water source may cause adverse effect on humans as well as animals because the mean monthly Nitrite concentration was greater than the standard except the rainy months.

Ammonia as nitrogen NH_4-N

Taste and odour complaints are likely to occur if the ammonia concentration exceeds 1.5 mg/l. High concentrations of ammonia can also give rise to nitrite, which is potentially toxic, especially to infants (DWAF, 1993). Therefore, according to this study 0-1 mg/l of ammonia is recommended for domestic use. Another study by (Environmental & Agency, 2001) recommends ammonia on fresh surface water sources should be between 0.4-1 mg/l. However as indicated on tables 21 & 22, less than 1 mg/l of mean monthly ammonia concentration is observed only on Jun and July on little Akaki river, and from Jun to December on Great Akaki river. Therefore, those sources may exceeds taste & odour, and using the sources for domestic use without treatment may have an effect.

Total phosphorus concentration (TP)

According to tables 21 and 22 above, yearly average total phosphors concentration was observed as 0.224 mg/l on little Akaki River and 0.3 mg/l on Great Akaki River. In addition, the mean monthly concentration of total phosphorus shows high result on the dry months of the year on both rivers. water quality guide lines for healthy fresh water ecosystem on rivers and streams for total phosphorus as 0.02-0.19 (UNEP/UNU-EHS, 2016). Thus, it is conculded that the river is not healthy fresh water ecosystem.

Total nitrogen concentration (TN)

Total nitrogen water quality guide lines for healthy fresh water ecosystem is range as 0.7-2.5 mg/l (UNEP/UNU-EHS, 2016) and from 1-3 mg/l (Environmental & Agency, 2001). However, the simulated result of total nitrogen concentration was observed greater than 2.5 mg/l on January, February and March as shown on tables 21 & 22. Therefore, the concentration of total nitrogen exceeds the guideline on the dry months of the year. Consequently, this water is not healthy fresh water and using it for domestic use may cause adverse effects on humans and animals.

5. CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

In this study, a watershed model (SWAT) and a water quality model (WASP) was used together for evaluating impact of land use on surface water quantity and quality. Although there were manual calibration for some parameters due to the absence of observed data, the simulation results indicated that both models were able to catch the general trend of the monitoring data. Therefore, the results simulated from these models can be used for further study.

The significant change of the land use/cover on downstream of Little Akaki River (reach 51) favor to change the annual stream water flow by 10.1% from (1989-2003) and by 30.3% from (1989-2016). The stream flow also increases by 12.5% from (1989-2003) and by 31.2% from (1989-2016) on the downstream of Great Akaki river (reach 98). This is due to increasing of built up area by 45.7% and decreasing of forestland by 28.5% from upstream to downstream of Great Akaki River. In addition to this urbanization increases by 63.7% and forestland decreases by 61.6% from the upstream to the downstream of little Akaki river. Therefore annual stream flow has a positive correlation with built up areas and negative correlation with forestlands.

Sediment load decreased by 98.2% when urbanization is increased by 35.2% and barren lands decreased by 37.3% from (1989-2016). It also increased by 82.6% when urbanization increased by 53.5% and barren land decreased by 32.4% from (1989-2016). The results show that there was an increase on sediment load when agriculture and barren lands increased.

According to the WASP result, the spatial variation of the water quality parameters from the upstream to downstream of Great and little Akaki Rivers were evaluated. The result show that pH, Temperature, TSS, NH4-N, NO2-N, TN and TP decreases its quality by 8.0%, 12.3%, 0.1%, 1.1%, 0.1%, 0.3% and 0.3% respectively from upstream to downstream of little Akaki river and by 5.9%, 0.8%, 7.0%, 59.2%, 67.0%, 34.5% and 45.9% from upstream to downstream of Great Akaki river. This is because of built up area increases by 45.7% and forestland decreases by 28.5% from upstream to downstream of Great Akaki River. In addition to this urbanization increases by 63.7% and forestland decreases by 61.6% from the upstream to the downstream of little Akaki river.

Water quality of both rivers was evaluated temporally and the results showed that pH, Temperature, TSS, NH4-N, NO2-N, TN and TP decreases its quality by 5.29%, 9.11%, 48.47%, 45.88%, 43.28%, 47.1% and 17.69% respectively from (1989-20160 on little Akaki river and by 5.84%, 9.01%, 48.36%, 48.21%, 45.38%, 55.42% and 16.72% respectively from (1989-2016) Great Akaki river. This is due to increasing of built up area by 45.7% and decreasing of forestland by 28.5% from upstream to downstream of Great Akaki River. In addition to this urbanization increases by 63.7% and forestland decreases by 61.6% from the upstream to the downstream of little Akaki river.

The concentration of the selected water quality parameters on the downstream of both rivers were evaluated on 2016 to know the status of water quality. When the simulated result are compared to water quality guide lines pH, TSS, NH4-N, TN and TP exceeds the guideline by 2.9%, 85.8%, 5.2%, 2.3%, & 0.2% on downstream of little Akaki and by 11.1%, 87.3%, 10.7%, 31.6% & 7.35 Great Akaki rivers respectively.

5.2 RECOMMENDATION

Except the concentration of sediment load for a few days, there was no any observed data of sediment load, nitrogen load and phosphorus load. Therefore, it is recommended to collect those data by the responsible office, in order to well conduct the calibration and validation process of SWAT model.

Few period of water quality data was used in this study due to high cost and requires long time to survey. However, daily, weekly, and annually water quality recorded data were required by WASP model for calibration and validation. So, it will be recommended to record the daily, weekly, monthly and annually water quality data of Addis Ababa Rivers to get a better simulation result.

The critical source areas of pollution and the magnitude of the pollutant loads was estimated. Therefore studying the mitigation and control mechanisms for those areas of pollution is recommended for further study.

This study was interested only on the non-point source of pollution. Therefore studying the point source of pollutants is recommended for the future.

The surface water sources of Akaki catchment should be treated before the people used it.

REFERENCES

Ain Nihla Kamarudzaman, Voon Kim Feng, Roslaili Abdul Aziz, & Mohd Faizal Ab Jalil. (2011). Study of Point and Non Point Sources Pollution – A Case Study of Timah Tasoh Lake in Perlis, Malaysia. *International Proceedings of Chemical, Biological and Environmental Engineering (IPCBEE)*, *19*, 84–88.

Alemayehu, T. (2001). The impact of uncontrolled waste disposal on surface watwer quality in addis ababa, Ethiopia. *SINET: Ethiopian Journal Science*. https://doi.org/10.4314/sinet.v24i1.18177

Alpaslan Ekdal, Melike Gurel, Cigdem Guzel, A. E. (2011). Application of WASP and SWAT Models for a Mediterranean Coastal Lagoon with Limited Seawater Exchange Application of WASP and SWAT models for a Mediterranean Coastal, (December 2014).

Berga, A. (2011). Institute of Technology School of Graduate Studies Department of Civil Engineering Addis Ababa University the Effect of Land Use Change on Hydrology of Akaki Catchment the Effect of Land Use Change on Hydrology of Akaki Catchment.

Cervantes, W. D. M. (2004). Modeling Water Quantity and Water Quality with the SWMM ContinuousStreamflow Model under Non-Stationery Land-Use Condition Using GIS, 161.

Chambers, P. A., Guy, M., Roberts, E. S., Charlton, M. N., Kent, R., & Gagnon, C. (2001). *N u t r i e n t s a n d T h e i r I m p a c t o n t h e C a n a d i a n E n v i r o n m e n t.*

Chen, J., & Li, G. (2012). Estimation of monthly mean solar radiation from air temperature in combination with other routinely observed meteorological data in Yangtze River Basin in China. https://doi.org/10.1002/met.1306

Collins, K., & Tiimub, B. M. (2014). Determination Of Sources Of Water Pollution. *International Journal of Technology Enhancements and Emerging Egineering Research*, *2*(12), 17–22.

Daniel weyessa, P. (2004). *Awash River & Tributaries pollution monitoring study annual*

Report. Oromia Water Resources Bureau Water.

Department of Water Affairs and Forestry. (1996). *South African Water Quality Guidelines VOLUME 6 AGRICULTURAL USE: AQUACULTURE*. *Agricultural Water Use: Aquaculture.* (Vol. 6). https://doi.org/10.1007/978-3-642-39088-3_14

Ding, J., Jiang, Y., Fu, L., Liu, Q., Peng, Q., & Kang, M. (2015). Impacts of land use on surface water quality in a subtropical river basin: A case study of the dongjiang river basin, Southeastern China. *Water (Switzerland)*, *7*(8), 4427–4445. https://doi.org/10.3390/w7084427

Driscoll, M. O., Clinton, S., Jefferson, A., Manda, A., & Mcmillan, S. (2010). Urbanization Effects on Watershed Hydrology and In-Stream Processes in the Southern United States, 605–648. https://doi.org/10.3390/w2030605

DWAF. (1993). *South African Water Quality Guidelines: Domestic Water Use*. *Department of Water Affairs and Forestry* (Vol. 1).

DWAF, D. of water and forestry. (1996). *WATER QUALITY GUIDELINES AGRICULTURAL USE : IRRIGATION Volume 4* (Vol. 4).

E, E. (2014). Pollution of Ekulu River in Enugu: A Case of Negative Human Impact on the Environment. *IOSR Journal of Environmental Science Ver. I*, *8*(10), 2319–2399. Retrieved from www.iosrjournals.org

Environmental, T., & Agency, P. (2001). Parameters of Water Quality: Interpretation of Water Quality, 133. https://doi.org/10.1017/CBO9781107415324.004

Fafuguta, E. (2015). Socio-Economic Problems of Water Pollution : The Case of Akaki River, 0–73.

Gülbaz, S. (2014). Impact of Land Use / Cover Changes on Water Quality and Quantity in a Calibrated Hydrodynamic Model Impact of Land Use / Cover Changes on Water Quality and, (June).

Hart, H. M. (2006). Effect of Land Use on Total Suspended Solids and Turbidity in the Little River Watershed, Blount County, Tennessee, 144.

Heathcote, I. W. (2009). A Review and Comparison of Dissolved Oxygen Models Appropriate for the Grand River Watershed, (January).

Huang, J., Zhan, J., Yan, H., Wu, F., & Deng, X. (2013). Evaluation of the impacts of land use on water quality: A case study in the Chaohu lake basin. *The Scientific World*

Journal, *2013*. https://doi.org/10.1155/2013/329187

Ibrahim, I., Abu Samah, A., Fauzi, R., & Noor, N. M. (2016). The land surface temperature impact to land cover types. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, *41*(June), 871–876. https://doi.org/10.5194/isprsarchives-XLI-B3-871-2016

Journals, E., Science, A., & Pierce, F. (2017). *LAND USE EFFECT ON NITROGEN AND PHOSPHORUS FLUXES INTO AND FROM SOIL* (Vol. 5).

Madjid Delkash, Furat A. M. Al-Faraj, and M. S. (n.d.). Impacts of Anthropogenic Land Use Changes on Nutrient Concentrations in Surface Waterbodies: A Review, (January 2018).

Magara, Y. (n.d.). *CLASSIFICATION OF WATER QUALITY STANDARDS* (Vol. I).

McGrane, S. J. (2016). Impacts of urbanisation on hydrological and water quality dynamics, and urban water management: a review. *Hydrological Sciences Journal*, *61*(13), 2295–2311. https://doi.org/10.1080/02626667.2015.1128084

Mohamoud, Y. M. (2009). Modeling the Impacts of Hydromodification on Water Modeling the Impacts of Hydromodification on Water Quantity and Quality, (September).

Narasimhan, B., Srinivasan, R., Bednarz, S. T., Ernst, M. R., & Allen, P. M. (2010). A comprehensive modeling approach for reservoir water quality assessment and management due to point and nonpoint source pollution. *Transactions of the ASABE*, *53*(5), 1605–1617. https://doi.org/10.13031/2013.34908

Neitsch, S. L., Arnold, J. G., Kiniry, J. R., & Williams., J. R. (2005). Soil and Water Assessment Tool User’s Manual Version 2005. *Diffuse Pollution Conference Dublin*, 494.

Oljira, E. (2006). SCHOOL OF GRADUATE STUDIES DEPARTMENT OF EARTH SCIENCES NUMERICAL GROUNDWATER FLOW MODELING OF THE AKAKI RIVER CATCHMENT A thesis submitted to the School of Graduate Studies, (June).

Patil, P., Sawant, D., & Rn, D. (2012). Physico-Chemical Parameters for Testing of Water–a Review. *International Journal of Environmental Sciences*, *3*(3), 1194–1207. https://doi.org/10.1080/0960878021012339

Rao, G. V. R. S., Pradesh, A., Pradesh, A., & Pradesh, A. (2015). SWAT BASED HYDROLOGICAL MODELLING OF KETAR WATERSHED , LAKE ZIWAY

CATCHMENT , ETHIOPIA, *5*(3), 33–44.

Ryu, J., Jang, W. S., Kim, J., Jung, Y., Engel, B. A., & Lim, K. J. (2016). Development of field pollutant load estimation module and linkage of QUAL2E with watershed-scale L-THIA ACN model. *Water (Switzerland)*, *8*(7). https://doi.org/10.3390/w8070292

Santikari, V. P. (2017). Evaluating Effects of Construction-Related Land Use Change on Streamflow and Water Quality, *43*(1), 139–152.

Seo, D., & Bae, S. (2013). *Comparative Analysis of WASP7 and HEM3D Water Quality Models- Application to the Nakdong River , Korea*.

Shrivastava, P. (2016). Urban Water Hydrological Modelling. *International Journal of Latest Trends in Engineering and Technology (IJLTET)*, *7*(2), 489–493.

Sliva, L., & Williams, D. D. (2001). Buffer zone versus whole catchment approaches to studying land use impact on river water quality. *Water Research*, *35*(14), 3462–3472. https://doi.org/10.1016/S0043-1354(01)00062-8

Sun, G., & Caldwell, P. (2012). Impacts of Urbanization on Stream Water Quantity and Quality in the United States. *Water Resources Impact*, *17*(1), 17–20.

Survey, U. S. G. (1980). Effects of Urbanization on the Water Quality of Lakes in Eagan , Minnesota.

Tiwari, S. (2015). Water Quality Parameters – A Review. *International Journal of Engineering Science Invention Research & Development*, *1*(9), 319–324.

Ullah, K. A., & , J. Jiang, P. W. (2018). Land use impacts on surface water quality by statistical approaches, *4*(2), 231–250. https://doi.org/10.22034/gjesm.2018.04.02.010

UNEP/UNU-EHS. (2016). How to develop guidelines for healthy freshwater. INTERNATIONAL WATER QUALITY GUIDELINES FOR ECOSYSTEMS (IWQGES. DRAFT FOR REGIONAL CONSULTATIONS, 30. Retrieved from http://web.unep.org/sites/default/files/Documents/20160315_iwqges_pd_final.pdf

Valcu, A. M. (2013). Agricultural nonpoint source pollution and water quality trading : empirical analysis under imperfect cost information and measurement error.

Virendra, S., Salahuddin, K., & Manish, V. (2013). Preimpoundmental studies on Water Quality of Narmada River of India, *2*(6), 31–38.

Wang, Q., Li, S., Jia, P., Qi, C., & Ding, F. (2013). A Review of Surface Water Quality Models, *2013*.

World Health Organization. (2011). Nitrate and nitrite in drinking water. *WHO Guidelines for Drinking-Water Quality*, *37*(4), 227–231. https://doi.org/10.1159/000225441

Yong, S. T. Y., & Chen, W. (2002). Modeling the relationship between land use and surface water quality. *Journal of Environmental Management*, *66*(4), 377–393. https://doi.org/10.1006/jema.2002.0593

Appendix-A

Table 0 - 1 Total annual precipitation (mm) for the four stations used on the analysis

YEAR	INTOTO	AKAKI	AA OBS	AA BOLE
1986	2385.7124	1039.8	1248.629	1055
1987	2389.4986	1121.5	1317.9	869.4
1988	1837.008	1111.8	1202.6	1021.9
1989	1560.5302	1185.7	1321.3	1058.3
1990	1647.2974	1069.9	1124.6	1121.7
1991	1327.6	994	1201.657	991
1992	1232.1	854.3	1101.4	975.4
1993	1271	958.5	1567.9	1207.8
1994	1174.7	792.1	1042.5	816.8
1995	1174.5	912.4	1156.426	1009.7
1996	1648.7	1112.2	1552.444	1552.5
1997	986.6	861.8894	952.4	877.1
1998	1436.1	1071.8	1337.7	1379.8
1999	973.7	955.2	955.5072	946.7
2000	1163.4	854.5	1191.1	902.1
2001	1263.1	895.7	1452	1102.7
2002	1099.2	771.3	1016.1	891
2003	1221.9	1095.8	1173.3	953.3427
2004	1195	787.1	1158.5	1011.869
2005	1154.7	1103.9	1600.441	1084.1
2006	1255.4	1017.4	1355.289	1205.9
2007	1194.5	1018.7	1318.184	1317.972
2008	1368.5	1013.8493	1330.7	1004.6
2009	1606.2621	982.7	1240.6	947
2010	1440.9	1306.1	1381.2	1146.1
2011	1206.255	972.2959	1052.4	1091.398

2012	1470.8627	921.3556	1060.768	1111.026
2013	1607.1	936.3	1267.145	976.2506
2014	1056.3	980.3913	1080.8	772.2
2015	1310.7116	973.2458	1070.507	1037.493
2016	1473.5191	1357.3226	1827.611	1454.06
2017	1232.2942	1181.9708	1848.444	1196.82

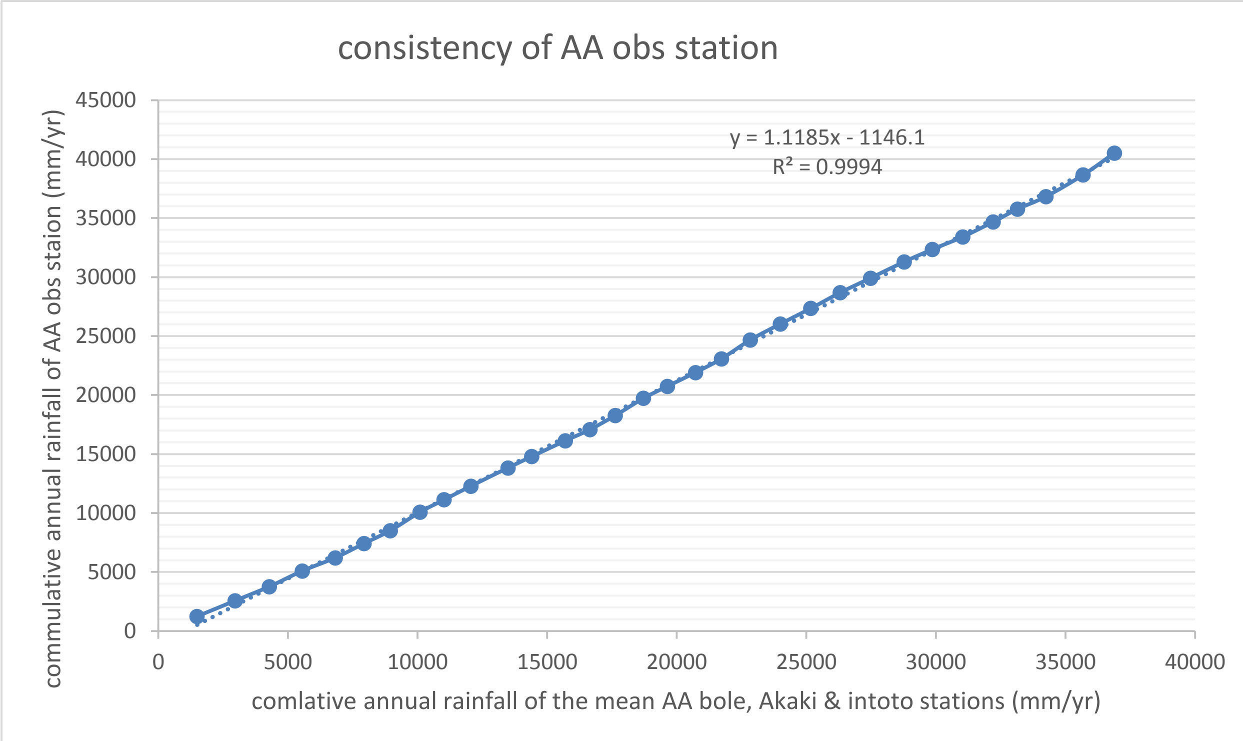
Appendix-B

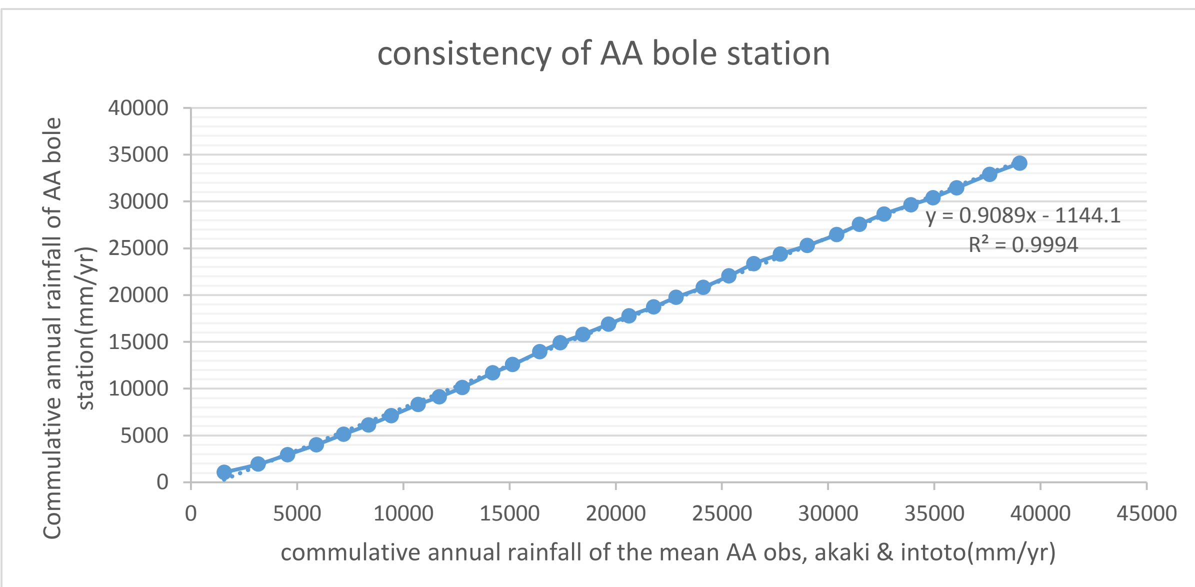
Table 0 - 2 Annual average maximum and minimum temperature (c^o) for the four station

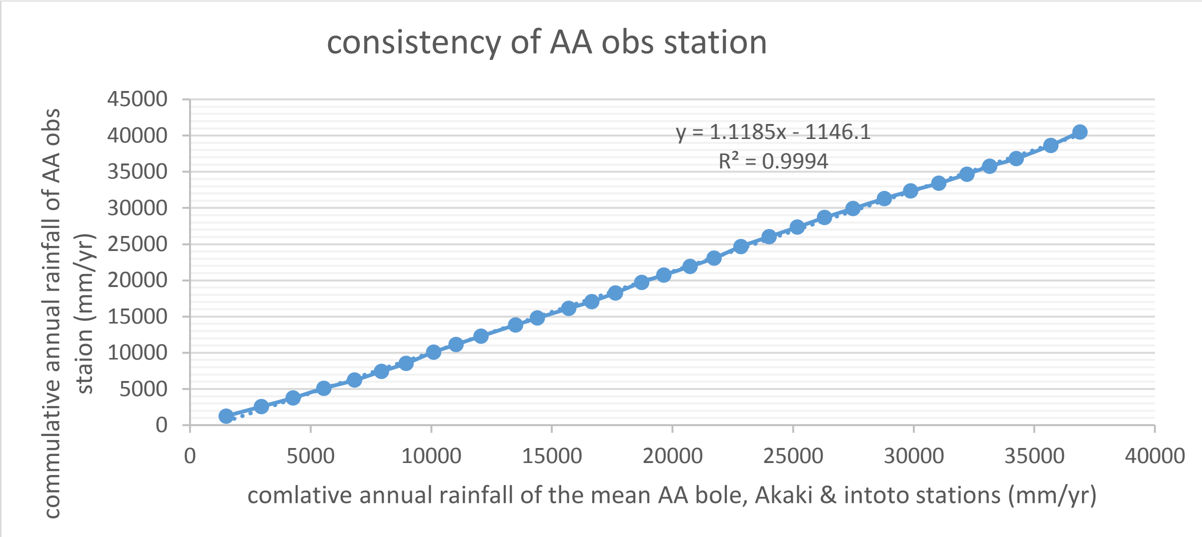
year	AA BOLE		AA OBSE		AKAKI		INTOTO	
	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin
1986	22.79	7.67	22.94	9.84	22.00	9.84	22.94	9.84
1987	23.27	9.20	23.36	11.01	23.33	11.01	23.36	11.01
1988	23.45	9.14	23.22	11.08	23.50	10.69	23.22	11.08
1989	22.82	8.92	22.61	10.64	22.86	8.30	22.61	10.64
1990	23.19	9.00	22.82	10.63	23.19	8.83	22.82	10.63
1991	23.66	9.42	23.22	11.26	23.72	9.54	23.22	11.26
1992	23.02	9.51	22.82	10.97	23.04	11.90	22.82	10.97
1993	23.02	9.11	22.63	10.58	23.02	9.35	22.63	10.58
1994	23.83	8.89	23.43	10.19	23.85	8.87	23.43	10.19
1995	23.73	9.49	23.71	10.61	23.73	9.10	23.71	10.61
1996	23.27	9.30	23.43	10.45	23.48	9.17	23.43	10.45
1997	24.01	9.97	24.09	10.65	26.01	11.84	24.09	10.65
1998	23.78	10.12	23.77	11.11	25.85	14.18	23.77	11.11
1999	23.84	8.89	23.97	10.11	25.76	12.81	23.97	10.11
2000	23.53	9.70	23.73	10.57	26.00	12.90	23.73	10.57
2001	23.61	9.31	23.66	10.29	26.24	13.72	23.66	10.29
2002	24.50	9.90	24.12	11.50	26.71	14.50	24.12	11.50
2003	23.93	9.92	23.70	10.79	26.41	14.20	23.70	10.79

2004	23.68	10.01	23.51	10.26	26.49	14.89	23.51	10.26
2005	23.78	10.00	23.67	10.37	26.36	15.34	23.67	10.37
2006	23.23	10.79	23.63	10.42	26.24	15.42	23.63	10.42
2007	22.97	10.46	23.77	10.23	26.09	16.28	23.77	10.23
2008	23.44	10.00	23.43	10.41	26.44	15.34	23.43	10.41
2009	23.76	10.80	23.79	11.09	26.43	15.61	23.79	11.09
2010	22.97	11.03	22.78	11.47	26.11	12.84	22.78	11.47
2011	23.32	10.63	23.43	11.17	26.58	11.89	23.43	11.17
2012	23.95	10.77	24.02	11.03	26.37	10.63	24.02	11.03
2013	23.89	11.20	23.74	11.20	26.64	7.53	23.74	11.20
2014	23.96	11.38	24.08	11.53	25.72	10.95	24.08	11.53
2015	24.18	10.78	24.36	11.26	26.93	11.09	24.36	11.26
2016	23.19	11.10	24.02	11.44	26.13	11.74	24.02	11.44
2017	24.01	11.48	24.55	11.44	26.14	12.14	24.55	11.4

Appendix-C


consistency of AA obs station
y = 1.1185x - 1146.1
R² = 0.9994
commulative annual rainfall of AA obs staion (mm/yr)
comlative annual rainfall of the mean AA bole, Akaki & intoto stations (mm/yr)
0
5000
10000
15000
20000
25000
30000
35000
40000
45000


consistency of AA bole station
y = 0.9089x - 1144.1
R² = 0.9994
Commulative annual rainfall of AA bole station(mm/yr)
commulative annual rainfall of the mean AA obs, akaki & intoto(mm/yr)
0
5000
10000
15000
20000
25000
30000
35000
40000
45000



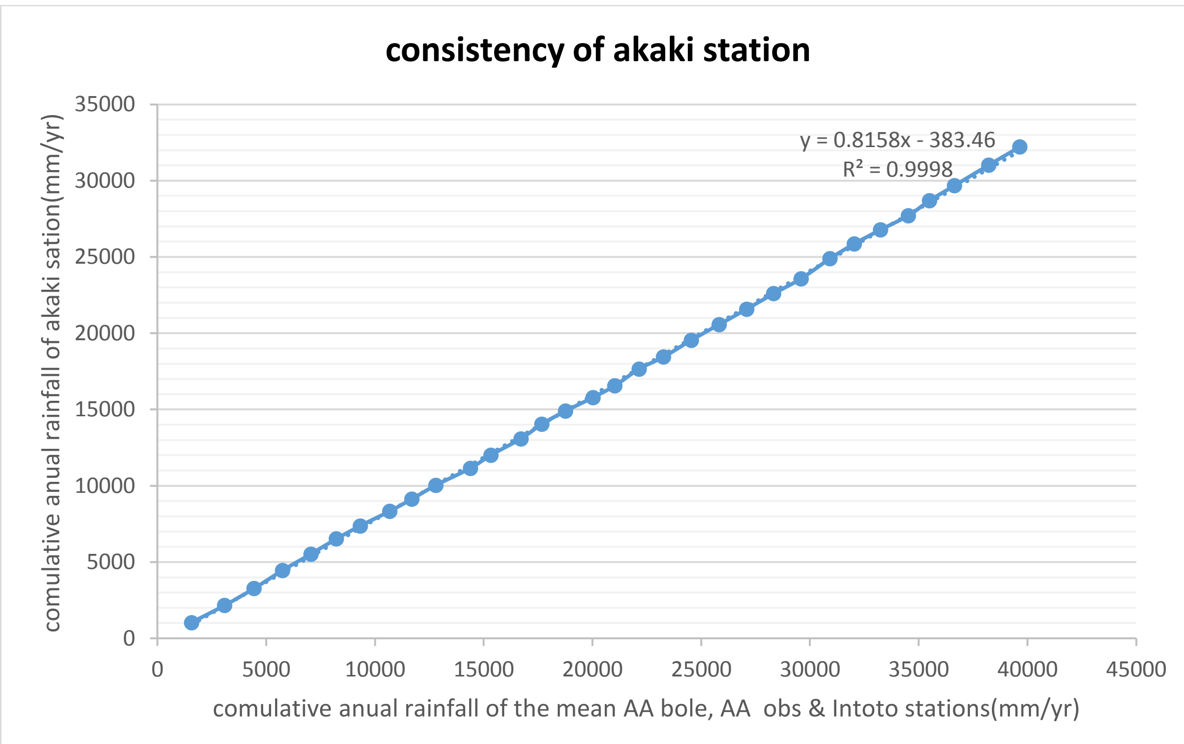


Figure 0 - 1 Consistency of each stations using double mass curve

Appendix - D

Table 0 - 3 Average dew point temperature from (1986-2017)

Month	tmp_max	tmp_min	hmd	dewpt	TMPSTDMX	TMPSTDMN
Jan	24.06	9.08	52.43	7.91	1.08891	0.632809
Feb	25.2	10.28	49.89	8.12	1.183935	1.175905
Mar	25.47	11.62	52.34	9.4	1.195215	0.833791
Apr	24.82	12.29	56.53	10.41	1.273911	0.64497
May	25.23	12.54	53.9	9.94	0.811743	0.587647
Jun	23.49	11.64	64.09	11.38	0.912399	0.619822
Jul	21.25	11.51	71.75	11.75	0.623948	0.498029
Aug	21.1	11.52	73.99	12.15	0.549792	0.533399
Sep	21.95	11.34	67.62	11.19	0.824267	0.706342
Oct	23.12	10.34	52.91	7.83	0.940521	0.794815
Nov	23.39	8.8	49.61	6.7	0.984296	0.780583
Dec	23.41	8.36	49.78	6.6	1.128299	0.64993

Where,

TMPMX: Ave. maximum air temperature for month (ºC)

TMPMN: Ave. minimum air temperature for month (ºC)

TMPSTDMX: Standard deviation maximum air temperature for month (ºC)

TMPSTDMN: Standard deviation minimum air temperature for month (ºC)

Appendix - E

Table 0 - 4 Statistical analysis of daily precipitation (1986-2016)

Month	PCP_MM	PCPSTD	PCPSKW	PR_W1	PR_W2	PCPD
Jan.	45.77	32.304	30.7378	0.0498	0.3896	2.48
Feb.	32.63	4.1069	4.9024	0.0956	0.5325	4.97
Mar.	64.56	6.7544	6.5664	0.1557	0.5556	8.42
Apr.	87.3	7.2116	4.7202	0.2432	0.6053	12.1
May.	83.28	6.7168	3.7706	0.2052	0.6023	11.19
Jun.	149.06	6.8577	2.2712	0.4926	0.7758	21.29
Jul.	266.03	8.9911	1.6394	0.8652	0.8807	28.13
Aug.	292.87	9.9205	1.8791	0.881	0.8837	28.29
Sep.	178.81	9.3379	2.5056	0.4444	0.7404	20.13
Oct.	46.05	5.252	7.5756	0.0853	0.6303	6.81
Nov.	15.55	2.5422	7.3519	0.0353	0.5823	2.55
Dec.	17.38	3.2441	10.8097	0.0316	0.5789	2.45

Where,

PCPMM: Ave amount of precipitation falling in the month (mm)

PCPSTD: Standard deviation for daily precipitation in the month

PCPSKW: Skew coefficient for daily precipitation in the month

PCPD: Average number of days of precipitation in month

PR_W1: Probability of wet day following a dry day in month

PR_W2: Probability of wet day following a wet day in month

PCPD: Ave. number of days of precipitation in the month

Appendix - F

Table 0 - 5 Average half hour rain weather generator station preparation

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RAINHHMX	15.3	10.9	21.5	29.1	27.8	49.7	88.7	97.6	59.6	15.4	5.2	5.8

Appendix - G

Table 0 - 6 Average solar radiation result of weather generator station

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SOLARAV	9.43	12.1	14.7	19.9	22.75	23.1	23.1	21.6	18.3	15.1	11.4	8.42

Appendix - H

Table 0 - 7 Average wind speed result of weather generator station

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WNDAV	0.69	0.72	0.74	0.69	0.669	0.52	0.45	0.43	0.51	0.71	0.72	0.69

Appendix – I

Table 0 - 8 Percentage change of land use/cover for the selected sub basins

Sub basin	land use/cover	1989	2003	2017	% age change 1989-2003	%age change 2003-2016	%age change 1989-2016
98	Barren land	20.65	12.19	1.16	-25.76	-82.62	-89.36
	Forest mixed	7.62	5.52	1.37	-15.98	-60.23	-69.52
	Agricultural land	25.38	20.7	23.12	-10.16	5.52	-4.66
	Forest-ever- green	2.36	0.16	0.63	-87.30	59.49	-57.86
	Residential/built up	45.61	63	75.34	16.01	8.92	24.58
51	Barren land	20.14	19.74	9.17	-1.00	-36.56	-37.43
	Forest mixed	33.91	24.73	22.14	-15.65	-5.53	-21.00

	Agricultural land	0.4	0.3	10.27	-14.29	94.32	92.50
	Forest-ever- green	18.75	15.96	6.78	-8.04	-40.37	-46.89
	Residential/built up	23.23	35.7	48.07	21.16	14.77	34.84
108	Barren land	20.24	10.33	0	-32.42	-100.00	-100.00
	Forest mixed	4.34	17.56	4.75	60.37	-57.42	4.51
	Agricultural land	64.65	57	39.24	-6.29	-18.45	-24.46
	Forest-ever- green	1.86	0	2.48	-100.00	100.00	14.29
	Residential/built up	10.53	16.73	55.15	22.74	53.45	67.94
111	Barren land	19.43	10.98	1.87	-27.79	-70.89	-82.44
	Forest mixed	3.96	9.64	1.79	41.76	-68.68	-37.74
	Agricultural land	75.09	73.3	58.43	-1.21	-11.29	-12.48
	Forest-ever- green	0.37	0.22	0.07	-25.42	-51.72	-68.18
	Residential/built up	2.54	7.17	39.45	47.68	69.24	87.90
114	Barren land	5.53	2.67	1.43	-34.88	-30.24	-58.91
	Forest mixed	12.42	18.32	1.18	19.19	-87.90	-82.65
	Agricultural land	76.89	77.14	77.7	0.16	0.36	0.52
	Forest-ever- green	3.04	0	0	-100.00	0.00	0.00
	Residential/built up	1.18	2.61	20.87	37.73	77.77	89.30
	water	2.55	0.87	0.43	-49.12	-33.85	-71.14

Appendix – j

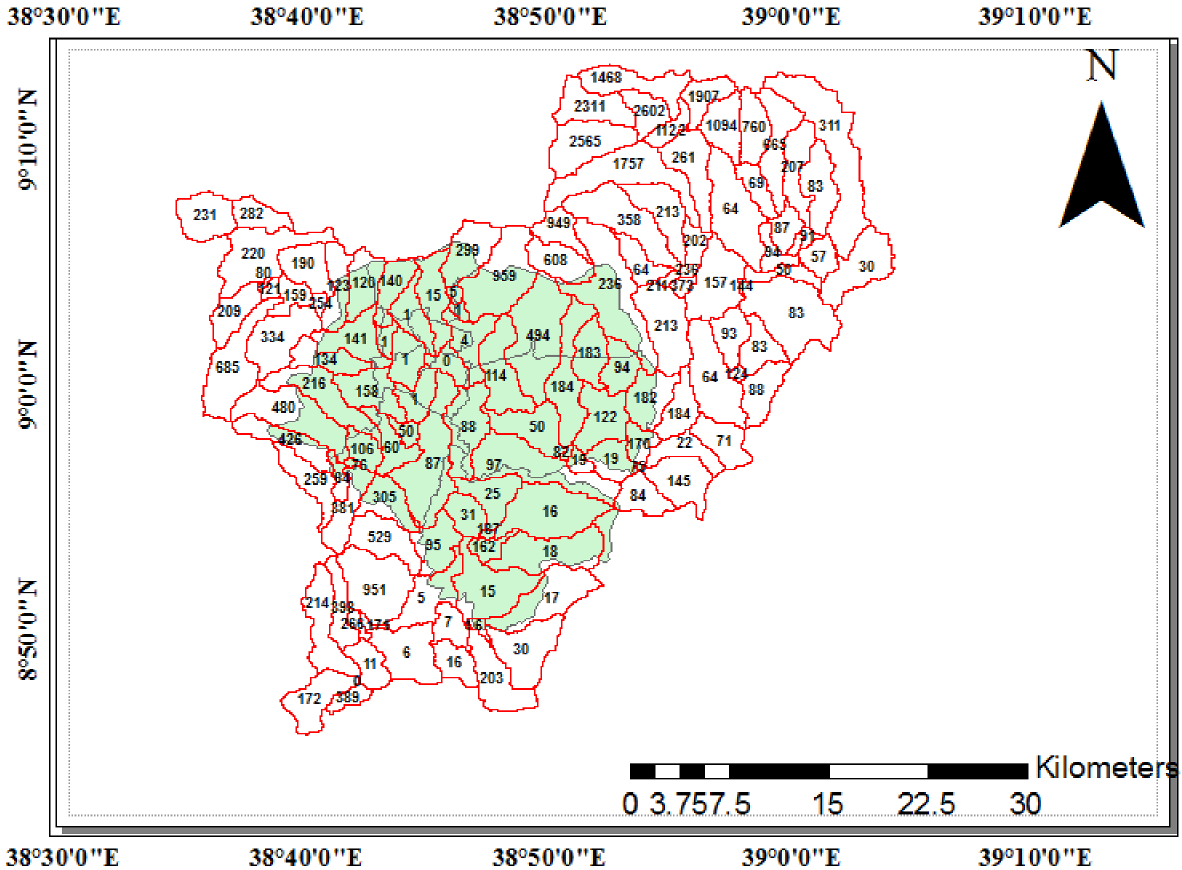


Figure 0 - 2 Spatial variation of sediment load

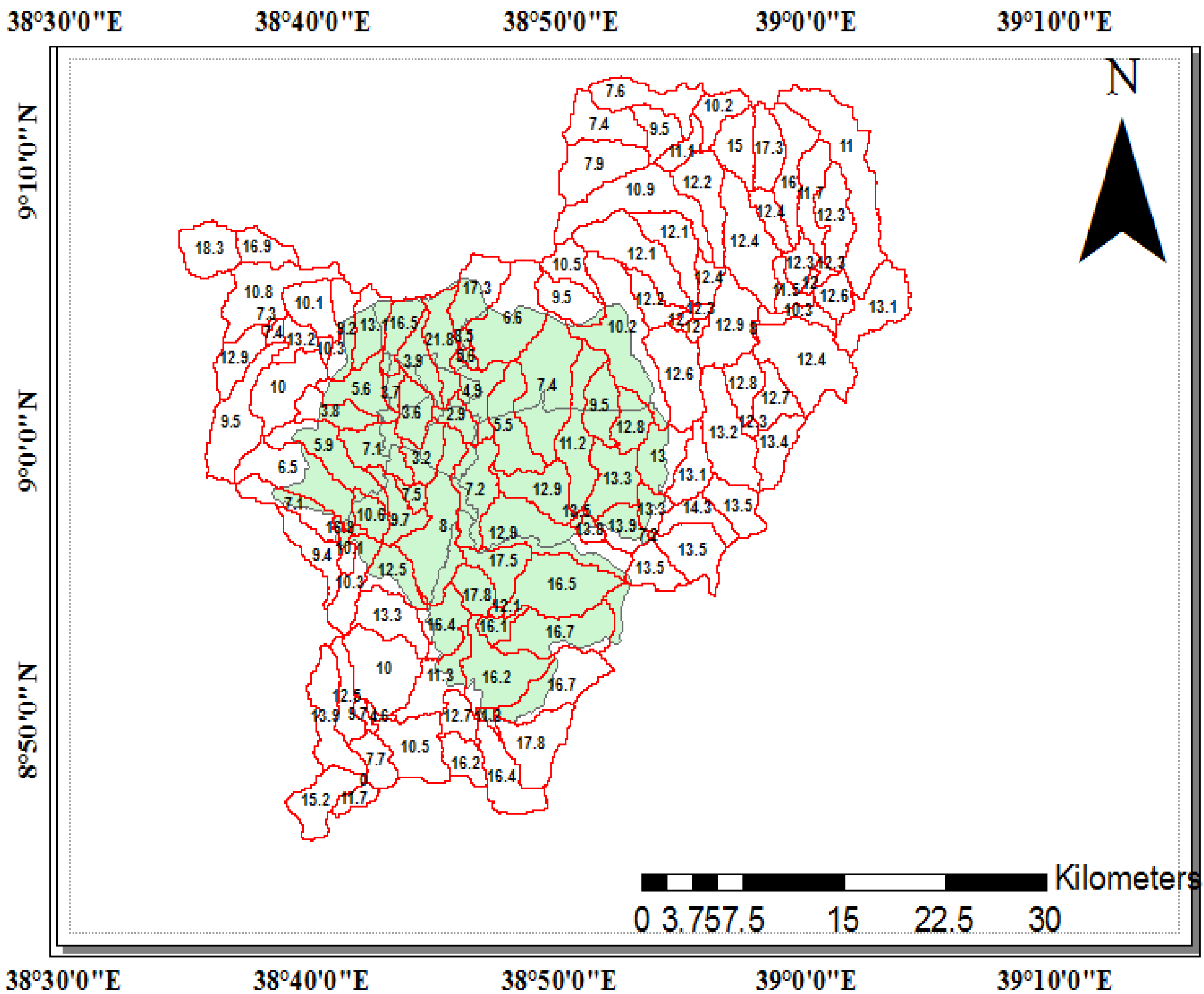


Figure 0 - 3 Spatial variation of TN

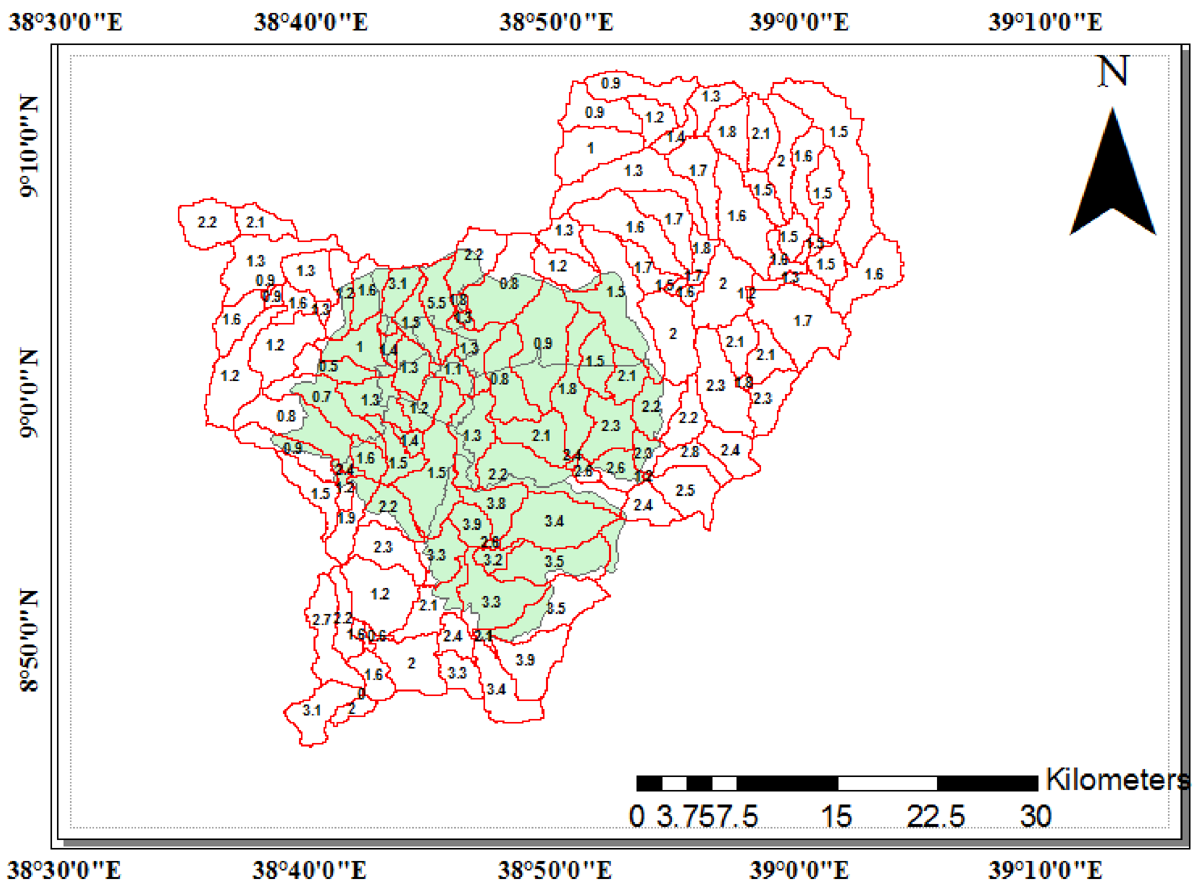


Figure 0 - 4 Spatial variation TP load

Appendix – k

Table 0 - 9 Magnitude and temporal variation of sediment load for all sub basins

Sub basin	1989SYLDt_ha	2003 SYLDt_ha	2016 SYLDt_ha	%age change from(1989-2003)	%age change from (2003-2016)
1	1467.706	902.332	719.127	-23.9	-11.3
2	2310.846	1595.325	1249.284	-18.3	-12.2
3	2601.972	1640.158	1271.18	-22.7	-12.7
4	1121.596	395.565	476.016	-47.9	9.2
5	1907.27	401.773	315.757	-65.2	-12.0
6	2565.267	1559.265	1200.089	-24.4	-13.0
7	1094.281	310.628	279.866	-55.8	-5.2
8	760.498	265.971	402.108	-48.2	20.4

9	69.453	51.913	65.639	-14.5	11.7
10	665.359	174.454	342.476	-58.5	32.5
11	230.945	162.738	139.882	-17.3	-7.6
12	282.091	182.759	160.668	-21.4	-6.4
13	1756.915	674.702	690.219	-44.5	1.1
14	261.262	190.546	239.244	-15.7	11.3
15	207.244	139.088	187.356	-19.7	14.8
16	83.423	65.769	58.279	-11.8	-6.0
17	91.33	69.081	83.786	-13.9	9.6
18	87.293	65.666	69.796	-14.1	3.0
19	176.899	197.557	141.655	5.5	-16.5
20	310.768	237.95	257.766	-13.3	4.0
21	57.413	42.635	53.099	-14.8	10.9
22	30.155	25.457	27.339	-8.4	3.6
23	948.751	328.191	152.093	-48.6	-36.7
24	213.457	154.093	156.377	-16.2	0.7
25	201.791	122.748	69.739	-24.4	-27.5
26	607.754	343.848	290.741	-27.7	-8.4
27	63.801	37.514	6.649	-25.9	-69.9
28	358.097	190.938	177.741	-30.4	-3.6
29	64.235	44.829	55.086	-17.8	10.3
30	93.819	67.858	66.191	-16.1	-1.2
31	211.224	117.136	20.656	-28.7	-70.0
32	235.86	146.555	31.723	-23.4	-64.4
33	143.668	69.639	97.653	-34.7	16.7
34	49.993	44.907	45.568	-5.4	0.7
35	220.215	186.138	151.67	-8.4	-10.2
36	80.492	55.713	47.905	-18.2	-7.5
37	299.058	218.279	146.451	-15.6	-19.7
38	208.778	171.62	151.919	-9.8	-6.1

39	120.932	109.397	103.362	-5.0	-2.8
40	372.61	241.751	170.451	-21.3	-17.3
41	189.635	165.675	73.544	-6.7	-38.5
42	157.344	66.195	68.768	-40.8	1.9
43	158.792	112.489	85.211	-17.1	-13.8
44	254.301	300.16	139.681	8.3	-36.5
45	5.118	0.666	35.489	-77.0	96.3
46	123.291	206.317	0.963	25.2	-99.1
47	120.165	117.807	1.042	-1.0	-98.2
48	1.452	0.425	14.698	-54.7	94.4
49	958.669	846.369	870.98	-6.2	1.4
50	83.383	62.018	80.529	-14.7	13.0
51	139.607	115.71	1.264	-9.4	-97.8
52	333.541	289.474	197.292	-7.1	-18.9
53	0.586	0.492	0.558	-8.7	6.3
54	15.39	149.116	1.059	81.3	-98.6
55	0.565	0.483	0.553	-7.8	6.8
56	685.128	799.18	625.942	7.7	-12.2
57	134.238	460.378	249.33	54.8	-29.7
58	140.776	147.284	15.682	2.3	-80.8
59	236.316	213.841	116.817	-5.0	-29.3
60	213.378	157.232	111.835	-15.1	-16.9
61	93.217	51.458	63.383	-28.9	10.4
62	123.867	52.508	92.413	-40.5	27.5
63	83.304	51.141	75.656	-23.9	19.3
64	87.786	49.134	74.207	-28.2	20.3
65	0.545	0.457	0.521	-8.8	6.5
66	0.445	0.372	0.425	-8.9	6.6
67	3.724	0.434	17.633	-79.1	95.2
68	183.028	253.449	12.313	16.1	-90.7

69	94.362	61.508	9.131	-21.1	-74.1
70	494.181	348.401	26.218	-17.3	-86.0
71	114.255	98.244	3.161	-7.5	-93.8
72	64.054	34.409	47.51	-30.1	16.0
73	158.203	131.552	13.668	-9.2	-81.2
74	0.511	0.431	0.484	-8.5	5.8
75	71.099	17.919	21.129	-59.7	8.2
76	182.319	124.458	23.328	-18.9	-68.4
77	183.934	135.775	16.711	-15.1	-78.1
78	50.161	27.522	4.324	-29.1	-72.8
79	183.986	108.034	8.749	-26.0	-85.0
80	215.615	494.112	424.206	39.2	-7.6
81	50.057	9.964	8.971	-66.8	-5.2
82	60.426	54.855	4.772	-4.8	-84.0
83	122.159	65.525	15.136	-30.2	-62.5
84	480.251	591.581	450.397	10.4	-13.5
85	105.723	246.285	8.789	39.9	-93.1
86	81.694	24.037	17.101	-54.5	-16.9
87	19.237	17.879	19.297	-3.7	3.8
88	76.16	42.15	0.254	-28.7	-98.8
89	169.663	122.329	26.01	-16.2	-64.9
90	22.493	21.247	25.04	-2.8	8.2
91	108.289	10.378	36.187	-82.5	55.4
92	18.698	18.209	19.794	-1.3	4.2
93	75.317	134.874	68.536	28.3	-32.6
94	144.792	114.752	95.688	-11.6	-9.1
95	426.359	408.917	382.279	-2.1	-3.4
96	63.764	47.762	20.616	-14.3	-39.7
97	259.162	323.75	140.932	11.1	-39.3
98	88.017	6.592	8.695	-86.1	13.8

99	97.004	9.365	9.578	-82.4	1.1
100	83.824	17.306	21.135	-65.8	10.0
101	380.653	388.251	24.41	1.0	-88.2
102	87.186	58.726	4.95	-19.5	-84.5
103	305.429	349.867	17.622	6.8	-90.4
104	30.82	27.397	8.002	-5.9	-54.8
105	24.559	26.474	9.874	3.8	-45.7
106	187.321	321.068	24.233	26.3	-86.0
107	16	17.595	8.725	4.7	-33.7
108	162.152	19.501	10.109	-78.5	-31.7
109	17.597	20.086	9.291	6.6	-36.7
110	529.028	535.138	170.816	0.6	-51.6
111	95.432	28.885	9.097	-53.5	-52.1
112	14.83	14.515	4.304	-1.1	-54.3
113	951.125	385.995	192.436	-42.3	-33.5
114	4.548	4.628	2.141	0.9	-36.7
115	6.496	8.746	4.205	14.8	-35.1
116	1.474	1.078	1.414	-15.5	13.5
117	17.411	19.114	8.896	4.7	-36.5
118	171.421	153.348	68.012	-5.6	-38.6
119	398.432	346.959	126.227	-6.9	-46.6
120	266.335	339.179	104.265	12.0	-53.0
121	30.06	33.858	14.795	5.9	-39.2
122	6.6	7.309	4.083	5.1	-28.3
123	16.379	19.38	9.379	8.4	-34.8
124	6.359	7.416	4.613	7.7	-23.3
125	203.419	193.565	15.495	-2.5	-85.2
126	213.597	204.282	13.069	-2.2	-88.0
127	0	0.006	0	100.0	-100.0
128	11.153	14.139	7.655	11.8	-29.8

129	171.664	171.298	24.48	-0.1	-75.0
130	388.987	13.016	105.921	-93.5	78.1

Appendix - L

Table 0 - 10 Magnitude and temporal variation of total nitrogen for all sub basins

SUB basin	1989 ORGNkg_ha	2003 ORGNkg_ha	2016 ORGNkg_ha	%age change from(1989-2003)	%age change from (2003-2016)
1	7.579	7.345	7.12	-1.6	-1.6
2	7.427	7.202	6.985	-1.5	-1.5
3	9.479	9.049	8.736	-2.3	-1.8
4	11.137	9.491	11.623	-8.0	10.1
5	10.197	6.952	6.464	-18.9	-3.6
6	7.879	7.537	7.322	-2.2	-1.4
7	14.972	8.655	8.879	-26.7	1.3
8	17.27	8.091	10.01	-36.2	10.6
9	12.415	11.108	11.411	-5.6	1.3
10	16.028	8.768	10.936	-29.3	11.0
11	18.318	17.486	16.315	-2.3	-3.5
12	16.903	16.264	15.287	-1.9	-3.1
13	10.894	8.869	11.244	-10.2	11.8
14	12.189	14.098	14.567	7.3	1.6
15	11.724	12.206	12.447	2.0	1.0
16	12.288	11.296	11.152	-4.2	-0.6
17	12.267	11.238	11.315	-4.4	0.3
18	12.272	11.261	12.582	-4.3	5.5
19	12.005	11.545	13.233	-2.0	6.8
20	11.022	10.691	11.743	-1.5	4.7
21	12.625	10.838	11.436	-7.6	2.7
22	13.143	10.147	11.408	-12.9	5.9
23	10.507	6.517	8.465	-23.4	13.0

24	12.081	13.135	15.837	4.2	9.3
25	12.413	14.591	15.738	8.1	3.8
26	9.531	9.127	13.052	-2.2	17.7
27	12.164	12.594	12.553	1.7	-0.2
28	12.126	11.032	17.091	-4.7	21.5
29	12.35	12.266	13.954	-0.3	6.4
30	11.469	11.788	14.362	1.4	9.8
31	11.965	13.843	17.594	7.3	11.9
32	12.331	14.29	20.117	7.4	16.9
33	8.022	10.943	12.107	15.4	5.0
34	10.321	11.011	12.733	3.2	7.3
35	10.75	10.875	10.56	0.6	-1.5
36	7.294	4.977	4.586	-18.9	-4.1
37	17.305	4.478	3.152	-58.9	-17.4
38	12.88	14.719	13.76	6.7	-3.4
39	7.417	8.605	11.123	7.4	12.8
40	11.997	13.72	17.907	6.7	13.2
41	10.059	8.146	6.584	-10.5	-10.6
42	12.862	15.84	19.043	10.4	9.2
43	13.169	11.256	11.461	-7.8	0.9
44	10.287	11.787	10.056	6.8	-7.9
45	8.452	5.116	24.952	-24.6	66.0
46	9.214	6.933	3.826	-14.1	-28.9
47	13.056	5.176	2.248	-43.2	-39.4
48	5.63	3.623	16.644	-21.7	64.2
49	6.565	6.22	5.316	-2.7	-7.8
50	12.374	13.059	14.319	2.7	4.6
51	16.483	4.457	3.098	-57.4	-18.0
52	9.95	11.812	8.64	8.6	-15.5
53	3.883	4.623	7.15	8.7	21.5

54	21.832	5.561	3.779	-59.4	-19.1
55	3.683	4.439	6.932	9.3	21.9
56	9.511	9.036	8.557	-2.6	-2.7
57	3.832	10.922	8.694	48.1	-11.4
58	5.593	6.772	17.213	9.5	43.5
59	10.156	14.881	13.878	18.9	-3.5
60	12.644	14.762	19.183	7.7	13.0
61	12.763	15.53	17.605	9.8	6.3
62	12.336	10.874	15.119	-6.3	16.3
63	12.69	15.43	17.06	9.7	5.0
64	13.365	17.243	18.809	12.7	4.3
65	3.566	4.244	6.595	8.7	21.7
66	2.914	3.475	5.391	8.8	21.6
67	4.904	4.171	13.592	-8.1	53.0
68	9.523	14.255	12.188	19.9	-7.8
69	12.768	15.705	10.868	10.3	-18.2
70	7.352	5.366	12.537	-15.6	40.1
71	5.528	4.786	7.092	-7.2	19.4
72	13.217	16.457	18.709	10.9	6.4
73	7.07	8.539	15.492	9.4	28.9
74	3.156	3.827	5.818	9.6	20.6
75	13.523	18.15	20.825	14.6	6.9
76	12.994	15.908	15.879	10.1	-0.1
77	13.079	15.778	20.278	9.4	12.5
78	7.484	8.66	9.961	7.3	7.0
79	11.239	14.728	12.403	13.4	-8.6
80	5.899	9.171	13.218	21.7	18.1
81	12.918	15.567	14.66	9.3	-3.0
82	9.724	11.847	10.599	9.8	-5.6
83	13.319	17.187	14.909	12.7	-7.1

84	6.467	7.944	15.124	10.2	31.1
85	10.648	16.397	14.409	21.3	-6.5
86	13.472	18.898	17.289	16.8	-4.4
87	13.809	17.723	18.424	12.4	1.9
88	16.783	17.05	3.99	0.8	-62.1
89	13.279	16.669	16.406	11.3	-0.8
90	14.329	19.16	21.616	14.4	6.0
91	11.971	11.004	17.648	-4.2	23.2
92	13.904	18.25	18.777	13.5	1.4
93	7.16	15.773	19.547	37.6	10.7
94	13.535	17.543	19.943	12.9	6.4
95	7.125	9.952	7.557	16.6	-13.7
96	10.106	13.755	15.27	15.3	5.2
97	9.386	14.197	15.346	20.4	3.9
98	7.195	6.659	8.681	-3.9	13.2
99	12.879	15.949	16.601	10.6	2.0
100	13.487	18.099	20.993	14.6	7.4
101	10.257	25.456	16.925	42.6	-20.1
102	7.98	9.461	8.451	8.5	-5.6
103	12.458	32.024	14.656	44.0	-37.2
104	17.847	35.55	9.715	33.2	-57.1
105	17.482	45.124	13.968	44.2	-52.7
106	12.127	44.736	15.361	57.3	-48.9
107	16.528	39.854	14.583	41.4	-46.4
108	16.073	29.224	9.808	29.0	-49.7
109	16.678	42.19	13.803	43.3	-50.7
110	13.286	28.63	18.67	36.6	-21.1
111	16.444	46.487	12.221	47.7	-58.4
112	16.159	30.997	8.073	31.5	-58.7
113	9.988	12.704	13.733	12.0	3.9

114	11.319	19.996	7.884	27.7	-43.4
115	11.2	27.545	11.694	42.2	-40.4
116	5.069	5.853	5.755	7.2	-0.8
117	16.702	41.476	14.547	42.6	-48.1
118	4.612	11.524	8.443	42.8	-15.4
119	12.493	27.03	16.348	36.8	-24.6
120	9.749	22.842	13.083	40.2	-27.2
121	17.792	48.831	17.481	46.6	-47.3
122	12.695	23.273	11.878	29.4	-32.4
123	16.179	39.407	16.315	41.8	-41.4
124	10.508	23.054	12.7	37.4	-29.0
125	16.357	41.141	19.922	43.1	-34.7
126	13.868	31.604	17.287	39.0	-29.3
127	0	0.018	0	100.0	-100.0
128	7.695	22.294	10.249	48.7	-37.0
129	15.225	38.204	21.218	43.0	-28.6
130	11.662	26.015	20.648	38.1	-11.5

Appendix - M

Table 0 - 11 Magnitude and temporal variation of total phosphorus for all sub basins

SUB basin	1989 ORGPhg_ha	2003 ORGPhg_ha	2016 ORGPhg_ha	%age change from(1989-2003)	%age change from (2003-2016)
1	0.931	0.899	0.87	-1.7	-1.6
2	0.913	0.882	0.857	-1.7	-1.4
3	1.166	1.11	1.067	-2.5	-2.0
4	1.366	1.26	1.484	-4.0	8.2
5	1.251	0.869	0.81	-18.0	-3.5
6	0.968	0.924	0.897	-2.3	-1.5
7	1.835	1.066	1.09	-26.5	1.1
8	2.115	1	1.223	-35.8	10.0
9	1.52	1.358	1.393	-5.6	1.3
10	1.963	1.123	1.336	-27.2	8.7
11	2.242	2.137	1.991	-2.4	-3.5
12	2.069	1.988	1.866	-2.0	-3.2
13	1.335	1.143	1.457	-7.7	12.1
14	1.733	1.862	1.948	3.6	2.3
15	1.591	1.595	1.589	0.1	-0.2
16	1.504	1.381	1.526	-4.3	5.0
17	1.502	1.374	1.381	-4.5	0.3
18	1.502	1.376	1.592	-4.4	7.3
19	1.47	1.411	1.707	-2.0	9.5
20	1.452	1.363	1.466	-3.2	3.6
21	1.545	1.325	1.396	-7.7	2.6
22	1.609	1.24	1.419	-13.0	6.7
23	1.318	0.81	1.133	-23.9	16.6
24	1.652	1.739	2.132	2.6	10.2
25	1.819	1.971	2.369	4.0	9.2
26	1.173	1.119	1.778	-2.4	22.7

27	1.667	1.704	1.891	1.1	5.2
28	1.627	1.455	2.337	-5.6	23.3
29	1.633	1.588	1.819	-1.4	6.8
30	1.558	1.545	1.896	-0.4	10.2
31	1.465	1.816	2.66	10.7	18.9
32	1.718	1.938	2.894	6.0	19.8
33	1.225	1.507	1.702	10.3	6.1
34	1.263	1.346	1.628	3.2	9.5
35	1.339	1.331	1.291	-0.3	-1.5
36	0.893	0.611	0.561	-18.8	-4.3
37	2.186	0.574	0.419	-58.4	-15.6
38	1.584	1.799	1.68	6.4	-3.4
39	0.927	1.053	1.489	6.4	17.2
40	1.63	1.818	2.523	5.5	16.2
41	1.287	1.008	0.968	-12.2	-2.0
42	2.035	2.177	2.684	3.4	10.4
43	1.638	1.378	1.485	-8.6	3.7
44	1.288	1.442	1.377	5.6	-2.3
45	1.781	1.414	4.441	-11.5	51.7
46	1.178	0.856	0.834	-15.8	-1.3
47	1.632	0.71	0.421	-39.4	-25.6
48	1.323	1.077	2.937	-10.3	46.3
49	0.832	0.787	0.685	-2.8	-6.9
50	1.741	1.714	1.881	-0.8	4.6
51	3.084	0.68	0.613	-63.9	-5.2
52	1.236	1.444	1.128	7.8	-12.3
53	1.46	1.551	2.066	3.0	14.2
54	5.54	0.941	0.84	-71.0	-5.7
55	1.351	1.407	1.987	2.0	17.1
56	1.201	1.107	1.045	-4.1	-2.9

57	0.481	1.335	1.93	47.0	18.2
58	0.977	1.184	3.339	9.6	47.6
59	1.466	2.002	2.355	15.5	8.1
60	1.992	2.013	2.714	0.5	14.8
61	2.078	2.157	2.421	1.9	5.8
62	1.772	1.48	2.014	-9.0	15.3
63	2.064	2.142	2.332	1.9	4.2
64	2.302	2.424	2.628	2.6	4.0
65	1.339	1.379	1.914	1.5	16.2
66	1.113	1.128	1.62	0.7	17.9
67	1.259	1.405	2.576	5.5	29.4
68	1.481	1.917	2.769	12.8	18.2
69	2.148	2.196	2.001	1.1	-4.6
70	0.915	0.922	2.884	0.4	51.6
71	0.834	0.949	1.546	6.4	23.9
72	2.261	2.307	2.602	1.0	6.0
73	1.281	1.71	3.049	14.3	28.1
74	1.237	1.255	1.784	0.7	17.4
75	2.443	2.579	2.96	2.7	6.9
76	2.172	2.198	2.651	0.6	9.3
77	2.239	2.195	2.86	-1.0	13.2
78	1.424	1.522	1.867	3.3	10.2
79	1.78	2.102	2.505	8.3	8.7
80	0.735	1.336	2.359	29.0	27.7
81	2.122	2.228	2.298	2.4	1.5
82	1.549	1.789	1.837	7.2	1.3
83	2.288	2.416	2.54	2.7	2.5
84	0.803	0.978	2.534	9.8	44.3
85	1.565	2.188	2.38	16.6	4.2
86	2.392	2.691	2.892	5.9	3.6

87	2.616	2.527	2.767	-1.7	4.5
88	2.351	2.36	1.027	0.2	-39.4
89	2.279	2.328	2.88	1.1	10.6
90	2.792	2.739	3.101	-1.0	6.2
91	1.91	1.573	2.434	-9.7	21.5
92	2.644	2.599	2.815	-0.9	4.0
93	1.238	2.135	2.771	26.6	13.0
94	2.454	2.446	2.846	-0.2	7.6
95	0.881	1.338	1.604	20.6	9.0
96	1.238	1.923	2.246	21.7	7.7
97	1.454	1.933	2.528	14.1	13.3
98	1.34	1.347	1.939	0.3	18.0
99	2.217	2.283	2.676	1.5	7.9
100	2.415	2.577	2.988	3.2	7.4
101	1.868	3.161	2.878	25.7	-4.7
102	1.471	1.568	1.976	3.2	11.5
103	2.224	3.96	2.625	28.1	-20.3
104	3.94	4.477	1.744	6.4	-43.9
105	3.772	5.634	2.407	19.8	-40.1
106	2.573	5.479	2.739	36.1	-33.3
107	3.419	5.006	2.478	18.8	-33.8
108	3.19	3.684	1.761	7.2	-35.3
109	3.514	5.279	2.371	20.1	-38.0
110	2.251	3.566	3.061	22.6	-7.6
111	3.344	5.795	2.128	26.8	-46.3
112	3.304	3.93	1.414	8.7	-47.1
113	1.223	1.599	2.08	13.3	13.1
114	2.121	2.548	1.296	9.1	-32.6
115	2.149	3.503	1.915	24.0	-29.3
116	0.843	0.722	0.912	-7.7	11.6

117	3.515	5.194	2.48	19.3	-35.4
118	0.565	1.431	1.289	43.4	-5.2
119	2.168	3.345	2.604	21.3	-12.5
120	1.554	2.839	2.066	29.3	-15.8
121	3.947	6.072	3.011	21.2	-33.7
122	2.421	2.956	1.945	9.9	-20.6
123	3.31	4.952	2.736	19.9	-28.8
124	2.041	2.927	2.069	17.8	-17.2
125	3.377	5.122	3.387	20.5	-20.4
126	2.674	3.953	2.896	19.3	-15.4
127	0	0.003	0	100.0	-100.0
128	1.645	2.797	1.707	25.9	-24.2
129	3.115	4.728	3.679	20.6	-12.5
130	1.98	2.46	3.432	10.8	16.5

Appendix-N

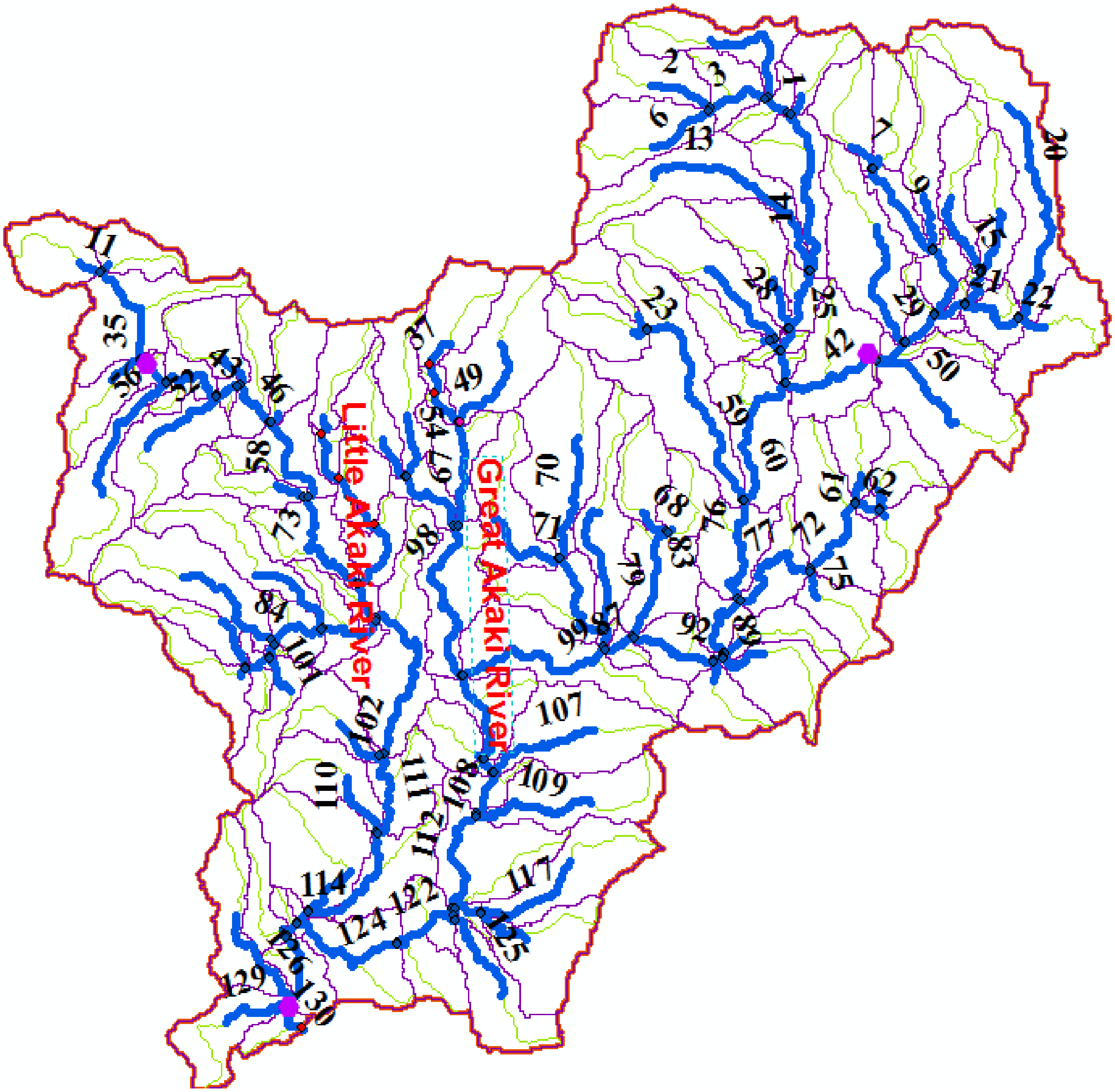


Figure 0 - 5 reaches of the catchment area