Effects of Land Use land Cover Dynamics on Watershed Hydrology and Reservoir Sedimentation in Chancho and Sorga Sub-Watersheds, Diga District and Nekemte City, Oromia, Ethiopia

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Dedication

This thesis is dedicated to my lovely father Megersa Gudeta.It is because of you I started the study,but missed you in the mean time of my study. My father you have especial place in my heart throughout my life. Thanks and rest in peace

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LISTS OF ABBREVIATION

ADSW	Agriculture Dominated Surface water
BMPs	Best Management Practices
DEM	Digital Elevation Model
FAO	Food and Agricultural Organization of the United Nations
FDSW	Forest Dominated Surface water
FFW	Food for Work
GIS	Geographical Information System
GPS	Global positioning System
Ha	Hectare
HRU	Hydrological Response Unit
IWMI	International Water Management Institute
LULCC	Land Use Land Cover Change
LSD	List Significant Difference
MoARD	Ministry of Agriculture and Rural Development
Mg/L	Milligram per Litter
SCS	Soil conservation service
SDR	Sediment Delivery Ratio
SWC	Soil and Water Conservation
SWAT	Soil and Water Assessment Tool
TDS	Total Dissolved Solid
TN	Total Nitrogen
TP	Total Phosphors
TSS	Total Suspended Solid
UDSW	Urban Dominated Surface Water
RUSLE	Rivesied Universal Soil Loss Equation
USA	United State of America
UN	United Nation
USGS	United State Geological Survey

Effects of Land Use land Cover Dynamics on Watershed Hydrology and Reservoir Sedimentation

Tolera Megersa,Addis Ababa University, 2019

Abstract

Land use/cover and their change have an impact on watershed hydrology Human activities,such as steep slope and reservoir buffer zone cultivation and urban land expansion at the expense of forest and wetland causes for the dynamism of the watershed in the study area. The study were undertaken to quantify water balance change, water quality change, reservoirs sedimentation, and degradation of forest and wetland, due to difference in land use/cover,slope gradient and soil types in Chancho and Sorga sub-watersheds. The SWAT model was used to quantify hydrological components, sediment and nutrient loss and RUSLE model for soil loss estimation, sediment yield and subsequent sedimentation of reservoirs. Surface water quality was assessed by taking water sample from each surface water and analyzed in the laboratory for TN, TP, TSS, TDS, and PH. Three times historical images of 20 years were used to assess the effects of urban land expansion on the natural environment (water, forest, and wetland). The combined impact of land use/cover, slope gradient and soil types on watershed hydrology were also estimated by the SWAT model. It is found that the predictive capacity of the SWAT model for hydrological and water quality variables was evaluated by using recorded river flow and sediment yield and showed a good agreement with simulated values. The result indicated that urban land produced more surface runoff (642mm) than other land types, followed by cultivated land; it is because of the impervious nature of urban land and steeper slope and continues cultivation of farmland with no soil conservation practices. Forestland and grassland produced (621mm and 610mm) of surface runoff and water yield,respectively, as compared to cultivated and urban land because of their higher infiltration capacity, evapotranspiration and percolation in the study area. Human activities such as land cultivation and expansion of urban built-up areas are the main factors responsible for change of the watershed hydrology in terms of change in water balance and water quality deterioration. The slope gradient, soil type and land use/cover type also contribute for the change in water balance in the watershed. As the slope increased from 0% to 20%, surface runoff and water yield increased in cultivated, grass, and forest lands and then declined, whereas it increased in urban land as the slope increased beyond 20%.. The combined effects of land use/cover and soil types had no significant impact on hydrological components. The highest soil loss produced in the cultivated land which accounted for 76% (30.38ton/ha/yr) of the total soil loss and the least soil loss was recorded in the grass and forestland (15.33 & 17.08ton/ha/yr), respectively, in the study sub-watersheds. Agriculture dominated sub-watershed produced 8524.34 t/yr and forest dominated sub-watershed larger area produces 14909t/yr of sediment and subsequently result in sedimentation of the reservoir differently. Agriculture-dominated surface water was greater in total nitrogen, total suspended solids, and acidity than the other two land uses. Urban-dominated surface water was greater in total dissolved solids than others. Forestland and wetland continuously decreased from 17% and 14% in 1996 to 5.1% and 2.7% in 2016, respectively, due to an increased average in the annual urban growth rate by 3.6% in the past 20 years. Therefore, the study areas are exprinced in an increased mean annual local temperature, variability of rainfall and relative humidity, and surface water quality reduction. Land use/cover and its change, slope gradient, and lesser extent of soil types are the most influential factors in affecting the hydrology of the watersheds in terms of water balance, water quality reduction, storage capacity loss of reservoirs and forest and wetland resource degradation. Therefore, appropriate land use practice and watershed management strategies should be implemented

Key Words : Land use/cover, slope gradient, soil, reservoirs, sub-watershed, watershed hydrology

1. INTRODUCTION

1.1 Background

Catchments are sensitive to LULCC (land use and land cover change) induced by human activities. Land cover changes are predicted to have an important effect on river flows and sediment yields from the specified catchment. Hydrological response dynamics (an integrated indicator of watershed conditions) and water response in different river basins are attracted by changes in land use and climate (Vipul et al., 2010). Land use activities, development, and management of water resources are interdependent. Sedimentation in water resources is the outcome of soil erosion in its catchment area. Soil erosion fundamentally has an impact on the physical and chemical characteristics of soils and causes on-site nutrient loss and off-site sedimentation and nutrients enrichment of water resources (Upadhya et al., 2012).

Hydrologic modeling and water resources management studies are inter-related with each other to the spatial processes of the hydrologic cycle at watershed, sub-watershed and basin levels. This cycle is intensified by several factors which include natural and anthropogenic activities, especially, land use/land cover (LULC) change has a significant impact on the watershed hydrology by affecting the magnitude and pattern of surface runoff, groundwater and soil moisture content (Setyorini et al., 2017).

The LULC change is mainly caused due to high population growth and it is most common in developing countries, like Ethiopia. The dynamic nature of land use arising from an increasing population is increasing at an alarming rate in Ethiopia (Haile and Assefa 2012). The anthropogenic activities result in an expansion of agricultural land and urbanization thereby causing deforestation.

Soil loss estimation is affected by complex factors of erosion and the availability of data at the regional scale (Sharma et al., 2011). Despite the difficulty of precise estimation or prediction of erosion caused by the complexity of the variables, advances in geospatial technology have presented efficient monitoring, analysis, and management methods of land resources (Berhan et al., 2015). Quantitative assessment of soil loss is required to infer the extent and severity of erosion problems, so that efficient land management strategies can be developed and implemented.

In recent times, various studies have been carried out to estimate the potential implications of LULC dynamics on soil erosion hazard at different spatiotemporal scales (Sharma et al. 2011; Gizachew, 2014). In Ethiopia and many other developing countries where basic data for erosion assessment is not adequate, robust soil loss models with the available resources are employed for the analysis (Kaltenrieder, 2007). Accordingly, several parametric models like USLE and its revised forms are the most widely used empirical equations to estimate annual soil loss from agricultural lands (Prasannakumar et al. 2012). USLE is one of the many models to examine the impacts of land cover on soil erosion potential.

Soil is an important source of goods, services, and resources that are essential to humankind. Soils can clean water sources, thus improving human health (Helmke and Losco, 2013). Most importantly, the soil system is the key component of the Earth system that controls the water, mineral and organic matter cycles. There is a need to research different aspects of the soil and land degradation that affect the fate of the Earth system (Brevik et al., 2015).

Developing countries like Ethiopia, where agriculture serves as a backbone of their economy and ensures the wellbeing of the people, the adverse effects of LULCC are diverse. Besides, various water resource development sectors (e.g. hydropower, irrigation, and urban and rural water supply.) have persistently been affected by both temporal and spatial changes of LULC (Mengistu & Sorteberg, 2012).

Expansion of agriculture, urbanization, deforestation and the day-to-day activities of mankind resulted in a temporal and spatial change in LULC and have affected water flow pathways and water balance (Rawat & Manish, 2015).

Water quality deterioration in reservoirs usually comes from excessive nutrient inputs, eutrophication, acidification, heavy metal contamination, organic pollution, and obnoxious fishing practices. The effects of these “imports” into the reservoir do not only affect the socio-economic functions of the reservoir negatively, but also bring about loss of structural biodiversity of the reservoir. Huang et al. (2013) have used the Physico-chemical properties of water to assess the water quality of a reservoir. The use of the Physico-chemical properties of water to assess water quality gives a good impression of the status, productivity, and sustainability of such a water body. The changes in physical characteristics like temperature and transparency and chemical elements of water such as dissolved oxygen, chemical oxygen demand, nitrate, and phosphate provide valuable information on the quality of the water, the source(s) of the variations, and their impacts on the functions and biodiversity of the reservoir.

The urban changes may be associated with population growth as well as industrial development during this period. Simultaneously, a close relationship of spatial urban expansion was shown with the geometric center of a city and distance from major roads, indicating that the most significant drive to urban expansion was road networks and pavements port and leisure facilities. Associated with the rapid expansion of urbanization, a lot of lands has been converted from rural to urban settlement. Expansion of the already existing urban fabrics through rapid construction sites of residential units, commercial and industrial units, roads and other impervious surfaces has led to a continuous expansion of built-up surfaces in the different corners of the Bahir Dar area (Binyam et al.,2015). Another study by Rahman et al. (2011) on LULCC in Mekelle city, Ethiopia, showed a positive change of 200 % in the urban area

The Ethiopian highlands of the Blue Nile basin are characterized by rainfall of between 900 mm and 2500 mm. However, this relatively high rainfall is not easily retained in the form of surface water or groundwater. The frequent occurrence of intense precipitation in the highlands causes much of the water to be lost to runoff making life difficult for the majority of people whose livelihoods are rain-dependant. As the landscapes in the highlands are ecologically fragile, poverty and marginalization are typical characteristics of the rural villagers living in the areas. Poor land management practices and a lack of focus on effective Rain Water Management (RWM) programs exacerbate the situation. Southwestern Ethiopia is known for its natural vegetation cover before some 25 years ago, where remnant natural vegetation of a country is expected to exist. But currently, the area is under severe pressure of deforestation and land degradation, because of population increase and their encroachment to forestlands especially in untouched low land areas of the region. This intensive destruction of natural vegetation had occurred during the last two decades which is in turn accompanied by climate variability(Birhanu Z. et al.,2011)

Chancho watershed which is located in Diga District, East Wollega Zone is characterized by rugged topography, intensively cultivated land, poor soil and water conservation practices, high-intensity rainfall, high population pressure from human and livestock and a sparse vegetation cover resulted in a significant direct runoff generation leading to accelerated soil erosion and risk of soil and water degradation (water quality and reservoir sedimentation. Sorga watershed, which partially located in Diga and Nekemte city is relatively covered by natural vegetation and few plantations as compared to Chancho watershed but, urban expansion contributes to the dynamism of a watershed inters of the release of urban effluent and wastes to the nearby stream water. Quantifying the role and contribution of each land use/cover type for the dynamism of the watershed hydrology is very helpful for planning appropriate watershed management strategies.

Therefore, this research intended to assess the combined effects of land use/cover and slope and soil types on water balance,soil loss,reservoir sedimentation and water in Chancho and Surge sub-watersheds

1.2. Statement of the problem

Watershed degradation through intensive cultivation may alter soil infiltration properties which consequently affect how a watershed partitions rainwater into various components of the water balance (e.g. surface runoff, lateral flow, groundwater recharge) (Recha et al., 2013). This shows how human activities on land (watershed) affect the availability and quality of water resources (Crossman et al., 2013). This linkage between water, land, and people makes it necessary to widen the scope of watershed management beyond the ‘water resources’ (Butler et al., 2013).

The present study areas (Southwestern Ethiopia) are known for their natural vegetation cover some 30 years ago. They are areas where the remnant natural vegetation of the country is expected to exist. Currently, however, the area is under severe pressure of deforestation and land degradation because of population increase and consequently, farmland was expanding at the expense of forest and wetland in the study areas.

Chancho sub-watershed is characterized by intensive cultivation of land with poor soil and water conservation practices resulted in a significant more soil erosion resulted in on-site removal of topsoil and off-site water quality deterioration and reservoir sedimentation. Meka Dam in Chancho subwatershed was constructed in 2011 to supply drinking water for 150,000 people living in Nekemte Town. The estimated total area of the watershed is 2,109 hectares including the water bodies. The Meka reservoir, located on a plain land, occupies 250 hectares of land and surrounded by agricultural fields and few grazing land and settlement.

Sorga sub-watershed is relatively covered with a considerable amount of natural and manmade vegetation as compared to chancho but urban built-up within a watershed has impacts on surface water quality. Most of the cultivated lands are under steep slope cultivation, resulting in runoff and soil losses. Sorga Dam was constructed for fish production and recreational purpose within Surge sub-watershed. There were few attempts made to manage the watersheds through government initiated program but they have not been effective due to lack of knowledge about the impacts of land use on watershed dynamics by the farmers.

Human activities (agriculture) on a rugged topography cause soil loss by runoff, sedimentation of a reservoir and water quality deterioration in Chancho sub-watersheds. Sorga sub-watershed Urban (point-source) and the non-point source influences surface water quality and sedimentation. These increased nutrients and sediment loading downstream over the years, acting as a nutrient and sediment sink, have led to increased eutrophication in the reservoirs. The contribution of land use/cover dynamics on watershed hydrology and reservoir sedimentation has not been yet quantified in terms of water balance, water quality, and storage capacity loss of the reservoirs. Climate impact may be high as one uses a historical land use/cover change for analysis on watershed hydrology, but it may be minimum when the impact is analyzed for the existing land use on watershed hydrology.

Almost all research works had been conducted on the effect of land use/cover change on watershed hydrology without considering the contribution of the the combined effects of land use/cover,slope and soil type on watershed hydrology. That is why this research was intended to assess and quantify the contribution of each land use/cover and its combination with slope gradient and soil types on watershed hydrology and resrvior sedimentation which helps to recommend the appropriate watershed management measures. Nekemte town which is partially located in Sorga subwatershed is expanding alarmingly at the expense of the natural environment mainly forest and wetland. The impacts of human activities in terms of urban construction have also an impact on watershed hydrology and hence, the rate of urban expansion and its effect on natural resources was included in this research.

Therefore, this research was aimed to assess and quantify the combined effects of different land use/cover, slope and soils on hydrological component, sediment, and nutrient transported from hydrological response unit and its effect on reservoirs water quality and sedimentation. Then, appropriate watershed management strategies were recommended for the study areas and other areas with similar cover types and agroecology.

1.3 Objectives and Research Questions

Main objective of the Study

The main objective of the study was to assess the impacts of land use/cover dynamics on watershed hydrology and reservoir sedimentation at varying soil and slope gradient in the study sub-watersheds.

The specific objectives are to:

1. Investigate the effects of land use/cover dynamic on watersheds hydrology
2. assess sediment and nutrient loss status of land use/cover at varying slope gradient and soils;
3. estimate soil loss and sediment yields of land use/cover in the watershed and its effect on reservoirs;
4. analyze the impacts of different land use /cover on surface water quality; and
5. analyze the effects of land use/cover change on forest and water resources

Research Questions

To guide the study, the following research questions have been framed.

1. What are the difference between land use/cover in affecting watershed hydrology?

2. How much the combination of land use, soil types and slope gradient affect nutrient and sediment loss in the watershed?

3. How much soil is lost from each land use/cover types and its effect on reservoirs sedimentation?

4. What is the relationship between different land use/cover and surface water quality?

5. How peri-urban forest and water are affected by land use/cover change?

1.4 Scope of the Study

This research was conducted at Diga District and Nekemte town of East Wollega Zone, Oromia Regional State. The research was undertaken in two sub-watersheds, namely, Chancho and Sorga sub-watersheds found in Diga District and Nekemte town, respectively. It emphasized on the impacts of the land use/cover dynamics on watershed hydrology and reservoirs sedimentation only in terms of water balance, water quality, reservoirs sedimentation, and land cover change in two sub-watersheds

1.5 Significance of the Study

The study assessed the impact of land use /cover dynamics on watershed hydrology and reservoirs sedimentation. It is believed that the research will enhance the perception of households, institutions, public sectors, national and international partners on the relationship between land uses /cover and dynamism of the watersheds for planning an appropriate watershed management measures. Hence, the results of the study will help on how to improve the land-use system for sustainable watershed management. The research findings will also serve as additional input for a researcher willing to work in a similar studies.

1.6 Structure of the thesis

The thesis is organized and discussed in six chapters. Chapter 1 mainly deals with introduction, study background, statement of the problem, objectives, research questions and significance of the study. Chapter 2 deals with a review of the literature on theoretical and practical perspectives related to the title under study at the different parts of the world in general and the Ethiopia condition in particular. In Chapter 3, the general methodology and specific methods used in the study are described briefly including the biophysical and socio-economic conditions of the study watersheds. In Chapter 4 result and discussion under a subheading 4.1,The effects of land use/cover dynamis on watershed hydrology in terms of water balance of the sub-watershed are discussed. 4.2 The effects land use/cover dynamics on sediment and nutrient losses under varying slope gradient and soil types of the a sub-watershed are assessed by SWAT hydrological model output and the results are compared between each land use/cover type. 4.3 Soil loss and sediment yield of different land use/cover types and their effect on reservoirs are analyzed. 4.4, the impacts of different land use /cover type on surface water quality are assessed based on laboratory results of water quality parameters. 4.5 The effects of land use/cover change on the natural environment (forest and water) are analyzed through historical land satellite image interpretation and surface water quality tests. Finally, in Chapter 5 The final summary of the results Chapter 6: Conclusions and recommendations are provided based on the main findings of the research

2. LITERATURE REVIEW

2.1 Watershed, land use and land cover: concept and definition

A Watershed is an area of land that drains all the streams and rainfall to a common outlet. Essentially, a watershed is all the land and water area which contributes runoff to an outlet in the main flow channel (FAO, 1985). Watersheds are significant because the streamflow and the water quality of a river are affected by human-induced or natural activities happening in the land area "above" the river-outflow point. The environment worsening of a watershed is a common occurrence in most parts of the world. Amongst several causes, the major one is the improper and unwise utilization of watershed resources observed in developing countries (Gulls, et al., 2017).

Watershed management implies the rational utilization of land, soil, and water resources for optimum and sustained production with minimum hazards to natural resources and environment (Gulls, et al., 2017). Soil erosion is a serious global issue because of its rigorous adverse economic and environmental impacts. Its economic impacts on productivity may be due to the direct effects on crops/plants both on-site and off-site, while the environmental consequences are primarily off-site related to the damage to the civil structure, siltation of waterways and reservoirs, and additional costs involved in water treatment.

The land is a basic natural resource used for a variety of purposes from survival to satisfaction of a wide range of human needs. Land cover is the physical and biological cover of the surface of the land, whereas land use is the result of human activities such as agriculture, forestry, and construction that alter the land surface processes (Karis and Jettou, 2013). The conversion of natural land to cropland, pasture, urban area, reservoirs, and other anthropogenic landscapes represents a form of human impact on the environment (McGranahan et al., 2005). Deforestation, wetland drainage, and grassland degradation have all amounted to a globally significant alteration of the land cover. Large scale environmental phenomena such as land degradation and desertification, biodiversity loss, habitat destruction, and species transfer are consequences of land-use changes by converting natural land covers (Amare, 2013; Amare & Kameswara, 2012).

Watershed dynamics consists of the investigation of a watershed to understand the flow of water through the watershed, how human activities within the watershed both depend on and impact its hydrology, and how land-use changes can affect the plant and animal communities in the watershed. Surface Hydrology is the study of the waters of the earth on the surface of the planet. Hydrology also involves the study of the various properties of water and its relationship with the living and nonliving environment (modeling and analysis)

2.1.2 Land use/land cover and climate change

Climate and land use/land cover (LULC) changes are key factors that can modify flow regimes and water availability (Sherwood and Fu, 2014; Wang et al., 2014). Since the 20th century, climate variability is believed to have led to changes in global precipitation patterns (IPCC, 2007), thereby changing the global water cycle and resulting in the temporal and spatial redistribution of water resources (Murray et al., 2012). LULC changes are primarily caused by humans and affect the partitioning of water among various hydrological pathways, including interception, evapotranspiration, infiltration, and runoff (Sterling et al., 2012). The influences of climate and LULC changes on hydrological processes and water resources will likely continue to increase, especially in arid and semi-arid regions characterized as vulnerable (Vorosmarty et al., 2010).

The impacts of LULC and climate changes on runoff can generally be identified by using hydrological models (Praskievicz and Chang, 2009). These models provide valuable frameworks for investigating the changes among various hydrological pathways that are caused by climate and human activities (Wang et al., 2010). Distributed hydrological models, which use input parameters that directly represent land surface characteristics, have been applied to assess the impacts of LULC and climate changes on runoff in water resource management areas (Chen et al., 2016).

The Soil and Water Assessment Tool (SWAT), a robust, interdisciplinary, and distributed river basin model, is commonly used to assess the effects of management practices and land disturbances on water quantity and quality (Gassman et al., 2007). The hydrological responses to LULC and climate changes are often investigated through scenario simulations using the SWAT model. Although substantial progress has been made in assessing the impacts of LULC and climate changes on water resources (Krysanova and White, 2015), most studies have focused on individual factors (i.e., either LULC or climate); thus, the combined effects of LULC and climate changes are not well understood because their contributions are difficult to separate and vary regionally (Wang et al., 2014). For example, some studies have suggested that surface runoff is affected more by climate change (increased precipitation) than by LULC changes (Fan and Shibata, 2015), and other studies have found that urbanization contributes more to increased runoff than precipitation (Olivera and Defee, 2007). According to Krysanova and White (2015), less than 30 papers were published between 2005 and 2014 on topics related to the combined effects of LULC and climate changes and the SWAT model, whereas 210 and 109 papers presented studies of climate and LULC changes, respectively. However, water resource management requires an in-depth understanding of the isolated and integrated effects of LULC and climate changes on runoff (Chawla and Mujumdar, 2015). Notable evidence of drying trends exists in semi-arid and semi-humid regions (Li et al., 2011). These regions have experienced serious water shortages in addition to intensive human activity and climate change (Ma and Fu, 2003). In this case, the effects of LULC and climate changes on runoff are considerably more sensitive, and a dry climate can result in serious environmental degradation and water crises (Jiang et al., 2011; Leng et al., 2016).

Aduah (2016) concluded that land-use changes have altered the hydrology and the ecology of the Bonsa catchment of Ghana (a representative rainforest catchment of West Africa), with both increases in peak and low flows. The future scenarios of land-use change in the catchment point to higher increases in both peak and low flows and a higher potential for ecological alterations. However, since the study did not consider the effects of climate, it is not known how climate changes and the combined impacts of land-use changes and climate changes will affect the hydrological cycle components in the near and far future. Since land use and climate changes affect each other (Dale, 1997;D'Orgeval and Polcher, 2008) and their joint impacts are sometimes non-linear (Li et al., 2009), it is necessary to determine both the joint and separate impacts on the hydrology of the catchment to improve knowledge and understanding of global change impacts in the region.

2.1.3 Soil erosion and Sedimentation

The assessment of soil erosion and sedimentation requires a basic understanding of the spatial patterns, rates, and processes of soil erosion, and sediment transport at the watershed scale. However, spatial data are often scarce; thus, our ability to model the spatial patterns of sediment delivery and to identify the source areas of sediment is very limited (Haregeweyn et al., 2013). When a precipitation event occurs, the eroded soil is transported by several routes into local streams (Maidment, 1999). The soil erosion is controlled by the abundance and type of vegetation, the nature of the underlying soil, and the water flow, which eventually produces saturated overland flow.

The ratio of sediment yield at the outlet of a basin to soil erosion over the basin is called the sediment delivery ratio (SDR) or the transport capacity coefficient (KTC). The KTC must be determined before sediment production can be estimated. However, this quantity cannot be easily measured. Recent studies have demonstrated the effects of field boundaries on sediment deposition and the SDR values of different parts of watersheds. These results emphasize the importance of the spatial variability of soil deposition and sedimentation rates that occur due to the existence of different land-use types and the connectivity of watershed characteristics. To overcome these problems, spatially distributed, process-based models can be used.

Several attempts have been made to use such process-based models such as the Water Erosion Prediction Project Model (Gete, 1999; Haregeweyn et al., 2013), the Agricultural Nonpoint Source Pollution Model (Haregeweyn and Yohannes, 2003) or the Limburg Soil Erosion Model (Hengsdijk et al., 2005). However, such models require large amounts of input data whereas the return in increased accuracy of soil erosion prediction is limited (Jetten et al., 2003). If such models are applied in conditions where the necessary data are not available and/or a proper calibration cannot be performed, the results may become completely unreliable (Haregeweyn et al., 2013). Spatially distributed empirical or conceptual models may form an alternative to the complex physics-based spatially distributed models.

Modeling soil erosion is the process of mathematically describing soil particle detachment, transport, and deposition on land surfaces. There are at least three reasons for modeling erosion:

(a) erosion models can be used as predictive tools for assessing soil loss for conservation planning, project planning, soil erosion inventories, and for regulation; (b) physically-based mathematical models can predict where and when erosion is occurring, thus helping the conservation planner target efforts to reduce erosion; (c) models can be used as tools for understanding erosion processes and their interactions and for setting research priorities (Nearing *et al*., 1990).

The Universal Soil Loss Equation (USLE) is the most widely known and used empirical soil loss model all over the world (Wischmeier and Smith, 1978). Later in the 1980s, the United States Department of Agriculture-Agricultural Research Service (USDA-ARS) modified the model to the Revised Universal Soil Loss Equation (RUSLE), which was an improved version of USLE incorporating new approaches and corrections of the USLE limitations. The RUSLE computes sheet and rill erosion by taking into consideration several determining factors such as the soil erodibility factor, rainfall intensity factor, slope length and steepness factor, cover, and management factor, and support practice factor. But it does not estimate gully or stream-channel erosion.

Although USLE has many shortcomings and limitations, it is widely used, especially at the regional and national level, because of its relative simplicity and robustness (Desmet & Govers 1996), and because it represents a standardized approach. USLE has not been designed to operate at a large scale, however; it was noted that there is room for improving the accuracy of results by using more detailed digital elevation models, satellite data, with enhanced geometric characteristics, and more detailed soil information.

2.1.4. Watershed and Groundwater Models

Watershed models can be classified as lumped, distributed, or a hybrid of the two (termed "semi- or quasi-distributed"). Lumped models are generally expressed using ordinary differential equations and therefore do not take into account spatial variability in watershed processes, input data, boundary conditions, watershed geometry and output (Singh, 1995). Lumped models describe some processes with differential equations based on simplified hydraulic laws and they represent other processes with empirical algebraic equations. For example, the lumped watershed model ANSWERS-Continuous (Bouraoui et al., 2002) simulates overland runoff using Manning's and the continuity equation, resulting in an ordinary differential equation that is temporally variable and spatially uniform. This same watershed model simulates subsurface flow using empirically-derived parameters such as 'tile drainage coefficient' and 'groundwater release fraction' (Borah and Bera, 2003). In contrast, distributed models use partial differential equations, thereby explicitly accounting for spatial and temporal variability in watershed processes, input data, boundary conditions, watershed geometry, and model output. Watershed models are also classified based upon the simulation time-scale and can be either event-based or continuous-time simulation. Event simulation models are interested in developing a flood hydrograph for a given precipitation

The hydrologic simulation capability of most watershed-scale models focuses on overland flow (surface runoff), precipitation, evapotranspiration, and water storage in the soil profile (root zone). Explicit simulation of saturated groundwater flow is typically absent. To account for this, models such as SWAT use empirical parameters to partition shallow aquifer recharge versus deep aquifer recharge and in part use that information to estimate the volume of daily base flow to the stream. Models such as AnnAGNPS (Bingner and Theurer, 2001) ignore groundwater flow altogether and assume that all downward percolation below the soil profile is lost from the hydrologic system

2.1.5 Soil and water assessment tool (SWAT) Model

The soil and water assessment tool is a continuous, long term, physically distributed model designed to predict the impact of land management practices on the hydrology, sediment yield, and water quality in agricultural watersheds (Arnold et al., 1998). The SWAT model was developed by US Department of Agriculture – Agriculture Research Service (USDA-ARS) at the Grassland, Soil, and Water Research Laboratory in Temple, Texas as an integrator of simulators such as SWRRB "Simulator for Water Research Basins", ROTO "Routing Outputs to Outlets", CREAMS "Chemical, Runoff, and Erosion from Agricultural Management Systems", GLEAMS "Ground Water Loading Effects on Agricultural Management Systems", and EPIC "Erosion-Predictability Impact Calculator" (Arnold et al., 1998).

2.1.5.1 The structure of SWAT

The SWAT model, which operates on a daily time step with up to monthly/annual duration, can be considered as a hydrological transport model at the catchment scale consisting of weather, hydrology, erosion/sedimentation, nutrients, channel routing, plant growth, and agricultural management components. The model, based on a water mass balance, uses the stream power equation of (Bagnold,1966), which also simulates hydrology as comprised of land hydrology and channel hydrology for each hydrologic response unit (HRU), which is a unique combination of soil and land-use characteristics. SWAT divides a watershed into HRUs assuming there is no interaction between HRUs; in other words, each HRU is non-spatially distributed. According to Neitsch et al. (2005), simulation computational costs can be minimized within the HRU delineating process by lumping similar soil and land-use areas into a single unit. The main structure of the working order of the program is initially computing fluxes for each HRU, then aggregating the results to sub-basin outputs based upon the fraction of the HRUs, and finally routing sub-basin outputs through a river reach within the channel network. A physically-based hydrological model, SWAT also predicts snowfall and melt, and vadose zone processes including infiltration, evaporation, lateral flow, plant uptake, percolation, and groundwater flow (Neitsch et al., 2005

2.1.5.2 Sensitivity Analysis for the SWAT model

Model sensitivity analysis helps to assess the relative sensitivity of model outputs concerning the changing of model parameters, which is generally the first step of model calibration. Sensitivity analysis can determine which parameters in the watershed are most sensitive and these parameters need to be adjusted based on the sensitivity analysis. The model calibration requires identifying the controlling parameters and parameter precision (Ma et. al., 2000). Sensitivity analyses are performed in different ways: local, which involves changing values one at a time, and global, which is the ability to change all the parameter values simultaneously. Because the sensitivity of each parameter depends on the other related parameters, the results may vary.

2.1.6 Sedimentation and Erosion

Soil erosion and consequent sedimentation are the major watershed problems in many developing countries like Ethiopia. Soil erosion and sediment yield from catchments are therefore key limitations to achieving sustainable land use and maintaining water quality in streams, lakes and other water bodies (Morris, G. L. 2014). Eroded material derived from the watershed, riverbed, and banks transported with the flow as sediment transport, either in suspension or as bedload. Ultimately, this sediment redeposits and often causing problems in downstream areas. On the other hand, the sediment load passing the outlet of a catchment forms its sediment yield. Sediment yield can bee emanated from point source discharge (mining and construction process) and non-point sources (runoff from agricultural land and bank erosion). Sediment load is reliant on factors of soil loss and sediment delivery ratio (Benedict MM & Andreas K 2006)

The Tekeze Hydropower dam is the tallest arch dam in Africa, generating 300 MW power from a 180 m dam height but its reservoir is threatened by massive sedimentation. Even though the design period of the dam is for 50 years, it will not exceed 25 years to be filled by sediment (Aforki, 2006). The sustainability of the Tekeze dam reservoir is under the risk of sedimentation. Besides this, the life expectations of many reservoirs in the area built for irrigation or water supply in the dry season are threatened by massive sedimentation (Vanmaercke et al., 2010). But still little is known about the amount and dynamics of sediment transport in the Northern Ethiopian Highlands.

Now a day runoff and soil erosion in catchment areas and its subsequent deposition in rivers, lakes, and reservoirs are of great worry of humanity (Vipul, et al., 2010). Even though several watershed models (empirical and physically-based) are available (Arnold, 1998). SWAT 2009 model was used for different studies. There is a lot of evidence for the application SWAT for hydrological response modeling under different land uses and related issues (Mengistu & Sorteberg (2012); Asres & Awulachew (2010); Fiseha, et al., (2012); Nathan and Bosch, 2011).

Sedimentation can adversely affect reservoirs, waterways, irrigation systems and coastal zones, with negative implications for aquatic biology, fish production, and biodiversity. The relationship between erosion rate and quantity of sediment transported by rivers is complex and depends on the geographical scale under consideration. Erosion and sedimentation vary widely according to geologic, climatic and other conditions.

There is clear evidence that farm-level land-use practices can have a significant impact on the rate of erosion. Changes in land cover from forest to agriculture, for example, usually increase soil erosion, while good agricultural practices reduce it. The impact of land-use practices on the overall sediment yield of river basins is very difficult to assess. Most of a river's sediment load originates from specific locations within the watershed and arrives in the river during extreme climatic events. The delivery of sediment to a river basin is relatively slow. Over the life span of a reservoir, very little sediment from the upper watershed travels more than 100 to 200 km. Thus, any impact that land-use practices have on the sedimentation rate of a large river will be felt only several decades later, when it is very difficult to distinguish between natural and human-induced sediment load, (FAO, 2006)

The scale is one of the most important parameters in assessing the impact of land use on water, which is based on numerous case studies, classifies the potential impact of land use on different aspects of water regime and quality, as a function of basin scale. Land use is likely to have a significant impact on water regime and water availability in only very small watersheds. As the watersheds increases in size, the impact of land use on the hydrological regime becomes insignificant compared with that of natural factors, such as the intensity of extreme rainfall events. At larger scales, however, land use does have an impact on water quality, and the cumulative effects of pollution, for example, can be observed in large river basins (FAO, 2006)

Reservoirs are built across rivers for irrigation, water supply, power generation, discharge regulation, and flood control. A reservoir will generally be located towards the end of a large watershed and receives inflows from major rivers (Jorgensen et al., 2005). On the other hand, reservoirs have a shorter residence time but a much larger watershed which can be more difficult to control (Randolph, 2004). Rainfall, runoff, snowmelt, and river channel erosion provide a continuous supply of sediment that is hydraulically transported and deposited in rivers and streams. The major advantages of dams are in flood control and in transferring water to areas with a deficit of water. Many reservoirs can no longer perform their design functions because much of their original active storage volume has been filled by sediment (Ijam and Al-Mahamid, 2012). The transported silt eventually gets deposited at different levels of a reservoir and reduces its storage capacity (Udayabaskar, 2010). When the river flow enters a reservoir, due to the very low velocity in reservoirs, they tend to be very efficient sediment traps. Hence transport capacity is reduced and the sediment load is deposited in the reservoir. This deposition which takes place gradually reduces the active provides the outputs of water with passage of time.

Even though soil erosion can be caused by the geomorphologic process, accelerated soil erosion is principally favored by human activities. Rapid population growth, deforestation, unsuitable land cultivation, uncontrolled and overgrazing have resulted in accelerated soil erosion in the world principally in developing countries like Ethiopia (Adebe and Sewnet, 2014; Tamene et al., 2006). All reservoirs formed by dams on natural rivers are subject to some degree of sediment inflow and deposition. Worldwide, around 40,000 large reservoirs suffer from sedimentation and it is estimated that between 0.5% and 1% of the total storage capacity is lost per year. Therefore, the amount of sedimentation all through the life of the project needs to be estimated, so that suitable conservation measures can be taken. Periodical capacity surveys of the reservoir helps in assessing the rate of sedimentation and reduction in storage capacity (Jeyakanthan and Sanjeevi, 2013).

A Geographical Information System (GIS) can be used to model bathymetry and the spatial distribution of sediments. Several attempts have been made to calculate the quantity of sediment using remote sensing technology (Sri Sumantyo et al., 2012; Narasayya et al., 2013; Yeo et al., 2014). Using the Remote Sensing techniques, it has become very efficient and convenient to quantify the sedimentation in a reservoir and to assess its distribution and deposition pattern. Remote sensing technology offers data acquisition over a long period and broad spectral range can provide synoptic, repetitive and timely information regarding the sedimentation characteristics in a reservoir. The water spread area of the reservoir for a particular elevation can be obtained very accurately from the satellite data. Reduction if any, in the water spread area for a particular elevation indicates the deposition of sediment at that level. When it is integrated over a range of elevations using multi-date satellite data enables computing volume of storage lost due to sedimentation (Narasayya et al., 2013)

2.1.7 Pollution and deterioration of water quality

Understanding and modeling water quantity and quality is crucial to protect and use water resources effectively. It is well known that water is used extensively in urban areas for the disposal of wastes (Zoppou, 2001). Therefore, water can also have some problems due to the impacts of human activities. These problems increase in urban catchments when the direction of natural stream beds and impervious areas change in the watershed. Especially in urban catchments, water resources are highly polluted with pathogenic, organic and inorganic substances that are a public health threat.

Water pollution is gradually becoming a major issue in lakes and rivers. Water quality models can be useful tools for simulating and predicting pollutant transport (Bai et al. 2011; Huang et al., 2012; Wang et al., 2013). Surface water quality models have made enormous progress from estimating single factors of water quality to representing multiple drivers and aspects of water quality, from steady-state to dynamic models, from point source models to models that couple point and non-point sources, and from zero-dimensional models to one-, two-, and three-dimensional models (Wang et al., 2011). These models can be categorized by researchers based on water body types, the methods used to establish the models, the water quality coefficients, model properties, water quality components, reaction kinetics, and spatial dimension. However, all water quality models have constraints (Wang et al., 2013), so, new models or modifications of existing models continue to emerge. Mathematical models of water quality have been important in evaluating the impact of wastewater discharge into surface waters in recent years (Yetik et al., 2014). Also, there have been major developments in water quality modeling for rivers

2.1.8 Land use/cover change and Watershed hydrology

Changes in watershed land use affect the hydrology of a watershed. Bare or impervious areas and a more developed stormwater drainage system result in greater volumes of high-energy storm flow, and reduced base-flow in a stream. A measure of this effect is the average storm flow component of the total flow of a watershed, in percent. An indicator of overall watershed development is transportation land use. Understanding the influence of land use on water quality remains an important yet elusive goal for ecologists and resource managers alike. Although numerous studies have demonstrated an association between watershed land use and nitrogen (N) and phosphorus (P) loading to surface waters, relationships between land use and water quality are surprisingly variable at the scale of entire watersheds (Omernik 1977; Jones and others 2001; Allan 2004). Some of this variability may be due to inherent differences in the structure of watersheds that affect their ability to convey materials, that is, a watershed's transport capacity. Nutrient loading is a function of both the availability of nutrients in a watershed and their potential for movement to receiving waters (Lewis and Grimm 2007). After all, it is not whether nutrients exist in a watershed that matters to water quality, it is the rate at which they move to water that impairs aquatic ecosystems.

The hydrology, geology, soils, and topography of a watershed can all influence watershed transport and in so doing, may affect the extent to which land-use impacts water chemistry. For example, Kleinman, (2006) found that site hydrology, as modified by soil properties, interacted with rainfall intensity and landscape position to determine mass losses of N and P, leading to high temporal variation in lake nutrients. They concluded that it was the coincidence of high nutrient availability and high transport potential controlling nutrient loss from the soil, rather than either factor alone (Kleinman, 2006). Similarly, Lewis and

Grimm (2007) showed that the hydrologic responsiveness of catchments often varies and can determine N loading following a storm event. Although watershed size does not affect nutrient transport directly, it may alter the extent of land use impacts by modifying the spatial scale at which land use within a watershed contributes to water quality.

Several studies indicate that near-shore land use tends to be more important in smaller watersheds than in larger watersheds, where the entire watershed often contributes to nutrient loading (Strayer and others 2003; Buck and others 2004). Hunsaker and Levine (1995) suggested that this could be due to differences in the amount of energy available to move water and materials, which arise when the percentage and location of land cover varies.

Lakes are strongly linked to their watersheds through the transport of materials carried by surface runoff (Mu¨ ller and others 1998), and many studies have demonstrated that land use composition can affect nutrient loading to lakes by altering nutrient availability at this scale. An important part of water quality restoration is, therefore, a nutrient reduction from watershed inputs (Jeppesen and others 2005), although successful restoration often involves additional measures (Jeppesen and others, 2007). Because the reduction of watershed nutrient flux is an essential precursor to restoration, it is important to determine how watershed characteristics mediate the relationship between land use and lake water quality. Lake landscape position can be a key factor in understanding variability among lakes, In particular, lake order, which measures connections to streams by stream order can account for a considerable amount of variability in water chemistry (Martin and Soranno 2006).

Artificial drainage can also affect hydrologic connectivity (David and others 1997) and may increase connectivity to the point that the impact of land use on lake water quality is more severe than in lakes draining less altered watersheds. These factors have only rarely been examined in the context of land use exports, however, in our study we used a suite of agriculturally dominated watersheds to investigate how the influence of land use on lake and reservoir water quality varies with watershed transport capacity. Specifically, we asked whether differences in transport capacity affect the relative importance of different land-use-related variables for explaining in-lake concentrations of N and P. Because watershed transport capacity cannot be measured directly, we used the temporal variability of Lake Nutrient concentrations as a proxy to infer conditions associated with transport. This approach is based on the assumption that variables that increase transport will enhance the inter-annual fluctuation of nutrient concentrations when nutrient availability (due to land use) is fixed and precipitation is the primary source of variability.

Hydrologic modeling and water resources management studies are inter-related with each other to the spatial processes of the hydrologic cycle at watershed, sub-watershed and basin levels. This cycle is intensified by several factors which include natural and anthropogenic activities. Especially, land use/land cover (LULC) change has a significant impact on the watershed hydrology by affecting the magnitude and pattern of surface runoff, groundwater and soil moisture content (Setyorini et al. 2017). Thus, understanding the interaction between LULC and the hydrological cycle is imperative. The LULC changes are caused by several natural and human driving forces (Meyer and Turner 1994). The LULC change mainly caused due to high population growth and it is most common in developing countries like Ethiopia (Tekle and Hedlund 2000). The dynamic nature of land use arising from an increasing population at an alarming rate in Ethiopia (Haile and Assefa 2012). The anthropogenic activities result in an expansion of agricultural land and urbanization thereby deforestation.

Several studies are carried out on hydrology of the watershed by utilizing LULC data in the different regions of the World and Ethiopia using Soil and Water Assessment Tool (SWAT); Haile and Assefa 2012; Geremew 2013; Adeba et al. 2015; Getahun and Haj 2015; Meshesha et al. 2016; Chaemiso et al. 2016 Tibebe et al. 2017). Only a few studies have focused on explaining the effects of LULC change on river flow with hydrologic modeling (Kimaro et al. 2006). Many hydrological studies have shown that LULC changes have affected the hydrology of various watersheds of the World (Ambika 2012). The LULC change can alter both the infiltration and runoff amount by following the falling of precipitation (Hougton 1995).

Haile and Assefa (2012) reported that the mean wet monthly streamflow was increased by 39% and dry average monthly flow decreased by 46% for 2011 land cover as compared to 1985 land cover due to LULC change on Angereb watershed in Ethiopia. Geremew (2013) found that LULC change affected the streamflow of Gilgel Abbay watershed, Ethiopia. The mean monthly streamflow for wet months had increased by value 16.26 m/s while the dry

The season had decreased by 5.41 m/s during the year 1986 to 2001 due to the LULC change.

However, such studies are lacking in the case of the Awash basin, where LULC and climate Variability has significant impacts on the hydrology of the basin. Therefore, providing a scientific understanding of how LULC change affects the watershed hydrology is very important. The Awash basin is the most intensively utilized in Ethiopia. Mainly, the Upper Awash basin is characterized by urbanization and wetter hydrological regime due to relatively high rainfall in the highlands of the upper basin (Belete and Semu 2013).

The major effect of land use cover change is likely to alter the hydrologic response of the sub-basin and change in water availability (Getachew Haile & Melesse Assefa, 2012). The Land cover under little vegetation is subjected to high surface runoff and low water retention (Tufa et al.,2014). Whereas, the high vegetation covers increase, evapotranspiration and decreases the mean annual river flow. The Land use-cover plays a fundamental role in driving hydrological processes within a sub-basin (Gwate O et al.,2015). These include changes in water demands such as irrigation, changes in water supply from altered hydrological processes of infiltration, groundwater recharge, and runoff, and changes in water quality from agricultural runoff. Therefore, a far better understanding of land use-cover change, its effect, and interaction with the hydrology of a basin are highly essential.

Regional-scale hydrological models can play a vital role in river basin management. They simulate impacts on possible future changes of LULC and help to find measures improving the adaptive capacity of river basins (Valentina et al., 2014). Expansion of agriculture, urbanization, deforestation and the day-to-day activities of mankind resulted in temporal and spatial change inland use land cover have affected water flow pathways and water balance (Rawat & Manish, 2015). Developing countries like Ethiopia where their agriculture serves as the backbone of the economy and ensure the wellbeing of the people; the adverse effects of land use land cover change are diverse. Besides these various water resource development sectors (hydropower, irrigation, urban and rural water supply, etc.) have persistently been affected by both temporal and spatial changes of LULC (Nigussie & Yared, 2010).

2.2.2.Erosion control measures and sediment yield

In resource constraint areas, carrying out land management measures in only chosen hotspots of erosion can significantly decrease total soil loss (Berhan and Mekonnen, 2009). 20 Studies have also shown that spatial variations in land cover are responsible for the disproportionate loss of soils (Bewket and Teferi, 2009). Thus, it is indispensable and tactical to prioritize land cover for curing with proper soil and water conservation technologies. Prioritizing land cover means grading different land covers according to the category in which they ought to be taken up for curing with conservation technologies (Bewket and Teferi, 2009). Furthermore, the result of this study implies that soil erosion is the most urgent agricultural problems, which present major jeopardy to land productivity in the study area. In the face of escalating population pressure, the land is constantly cultivated with cereal crops such as maize, wheat, tef, and barley. Croplands are characterized by a lack of comprehensive land management practices, which can contribute to high erosion hazard. Farmers in the study area practiced complete tillage, while minimum or zero tillage was completely abandoned. Minimum or zero tillage is an important soil conservation technology in Sub-Saharan African countries as it reduces soil erodibility (Ndah et al., 2015). This form of tillage results in the long-term maintenance of the soil structure and an increase in water retention and hydraulic conductivity

The effects of erosion control measures on sediment yield will be most readily felt on-site. There is an inverse relationship between basin size and sediment delivery ratio. In basins of several hundred km2 improvements may only be noticeable after a considerable time lag (Decades), due to storage effects (Bruijnzeel, 1990). Downstream sediment yields cannot always be ascribed to the changing of upstream land-use practices. Human impacts on sediment yield may be substantial in regions with stable geological conditions and low natural erosion rates. In regions with high rainfall rates, steep terrain, and high natural erosion rates, however, the impact of land use may be negligible. In the Phewa Tal watershed in Nepal, for example, only six percent of the total sediment yield has been calculated to stem from surface erosion.

2.2.2 Soil loss/ Sedimentation in the Upper Nile basin

Sediment yield refers to the amount of sediment exported by a basin over a period, which is also the amount that will enter a reservoir located at the downstream limit of the basin (Moriasi *et al*., 2007). Soil erosion is a serious problem in the Ethiopian highlands that increased sedimentation of reservoirs and lakes. Sediment export rates in the Ethiopian highlands are characterized by important changes in sediment supply to the downstream settlers (Descheemaeker *et al*., 2006; Nyssen *et al.,* 2011). The Ethiopian government has undertaken the construction of more than 50 micro dams in response to the government policy to cope with rainfall variability, periodic drought and food insecurity in the Tekeze and Abbay basin, the main water suppliers of the Nile basin (Belete, 2007). Among others, the Tekeze dam, a 185 m high arch dam with a reservoir length of 60 km, is planned to store about 9109m3 of water drained from a 30,390 km2 catchment area mainly to generate 300 MW electric power, the Grand millennium dam which is designed to generate 6000MW hydroelectric power and irrigation development is working (Belete, 2007).

However, the life expectancy of these dams is under question because of sever soil erosion and the siltation of the dam as a result of poor upland management and land degradation. For instance, few studies realized that most of the smaller reservoirs in the Tekeze basin are filled with sediments before their planned life expectancy has passed while some reservoirs harvest much less water than the amount expected (Haregeweyn *et al*., 2006; Belete, 2007).

Nyssen *et al.* (2011) also studied the effect of conservation tillage (permanent bed system) in northern Ethiopia. The result revealed decreased runoff (51%) and soil loss (81%) which allows protection of the downslope areas from flooding. Thus, continuous investment in water resource management in the Blue Nile Basin suggests a need for efficient and effective mechanisms to improve water capture and agricultural output in the highlands of Ethiopia. Approximately two-thirds of the area within the Blue Nile Basin is located in the highlands of Ethiopia. This area receives relatively abundant rainfall (800 to 2,200 mm per year), with the majority falling during the direct rains (June-September) that supply the main meter cropping season. Agricultural production in the highlands is dominated by cereal crops, which necessitates frequent soil mixing and provides very little ground cover during the direct rains, thus rendering it more susceptible to erosion and land degradation (Haileslassie *et al.,* 2008).

In terms of soil loss due to erosion, estimates vary by location, which reflects the varying Ethiopian landscape, management practices and soil characteristics within and between sub-basins. Hurni *et al.* (2010) measured soil erosion rates on test plots and estimated a loss of 130 to 170mt/ha/year on cultivated land. Furthermore, the average annual soil loss in Medego watershed in the north of Ethiopia was estimated at 9.6mt/ha/year (Tripathi and Raghuwanshi, 2003). Moreover, the average annual soil loss due to erosion in the Chemoga watershed in the Blue Nile Basin (northwest Ethiopia) was estimated at 93mt/ha/year (Bewket and Sterk, 2005). Shiferaw and Holden (1999) also estimated soil loss in Borena district in south Wollo using the Revised Universal Soil Loss Equation (RUSLE, which allows for spatial modeling of soil loss) and found that annual soil loss ranged from no loss in the flat plain areas to over 154 mt/ha/year in some steeper areas. Research by Habtegebrial *et al*. (2007) analyzed soil erosion and sediment delivery processes, which are responsible for high sediment transport and the associated export of sediment-bound nutrients to deposition areas in the catchments, are influenced by landscape characteristics (Haregeweyn *et al.,* 2008b).

Therefore, the impact of sedimentation is the removal of nutrient-rich topsoil in upland areas and subsequent reduction of agricultural productivity in those areas (Omuto *et al*., 2009). The on-site effect of erosion, which results in the loss of nutrient-rich topsoil and hence reduced crop yields, is chronic in the country. The soil nutrient depletion reduces crop production by 885, 330 tons/year, which is about 14% of the agriculture contribution to Ethiopian GDP. About 80% of the losses would result from reduced crop production and the remaining 20% coming from reduced livestock production (Abdelsalam and Hamid, 2008).

The history of Lake Haramaya catchment is not different from other parts of the country, because the catchment is not properly conserved. There are different causes for detachment of topsoil, the formation of medium and excessively large gullies, erosion, transport, and deposition of sediments in the lake area. Also, the area has suffered from adverse effects of deforestation and unwise irrigation practice, land degradation due to intensive cultivation, conversion of marginal lands into crop cultivation, and climate change-induced droughts. The severity of soil erosion is evident in the Lake Haramaya catchment by the common occurrence of deep and wide gullies that are extreme forms of soil erosion

(Muleta et al., 2006). These call for immediate measures to save the physical quality of soil and water resources, rehabilitate the highly affected erosion areas, reduce the negative effects of soil erosion and siltation of the lake area. Thus, as a way towards the formulation of management options, soil erosion and sedimentation should be considered as these are concurring environmental processes with varied negative and positive impacts. In the study area, soil erosion and sedimentation caused the reduction of fertile topsoil from the agricultural upland area, reduction in storage capacity of the lake which later became one main cause for the disappearance of Lake.

To tackle the on-site and off-site threats of erosion, there is an urgent need for improved catchment-based erosion control and sediment management strategies (Millward and Mersey, 2001). Thus, to reduce the sediment transport into the lake area, contributing areas with high soil erosion rates need to be identified, their sediment yield has to be quantified and targeted for soil erosion control measures.

2.2.3 Sedimentation of Reservoirs

The accumulation of sediments reduces the water storage capacity of a reservoir (Alam, 2016) and eventually eliminates the capacity for flow regulation which is crucial for assuring the reservoir functions of water supply, energy production, navigation, and flood control (ICOLD, 2012; Morris & Fan, 1998). For instance, if reservoir sedimentation becomes dramatic, the production of valuable peak energy in hydropower dams is endangered (Schleiss & De Cesare, 2010).

The excess of sedimentation in a reservoir leads to sediment entrainment in waterway systems and hydraulic schemes (Faghihirad, Lin, & Falconer, 2015). Depending on the degree of sediment accumulation, outlet structures may be clogged. Blockage or damage of intakes and outlets, not designed for sediment passage, may generate security problems. Abrasion of hydraulic machinery, decreasing their efficiency and increasing the maintenance costs, is a possible consequence of an excess of sediments in a reservoir. Furthermore, cooling circuits adjacent to turbines which capture water directly from the reservoir were observed to be clogged by sediments in suspension

2.2.4 Land Use and Cover Change in Response to Urban Growth

Land use and land cover changes in response to urban growth also reported by some studies that, an expansion of urban areas annually from 1957 to 2009 has been identified by (Haregeweyn et al., 2012), shows that, in the urban fringe of the Bahir Dar area as a consequence of increasing population. Expansion of the already existing urban fabrics through rapid construction sites of residential units, commercial and industrial units road and other impervious surfaces led to the continuous expansion of built-up surfaces in the different corners of the city". Another study (Tahir et al., 2013), on LULCC in Mekelle city, Ethiopia showed a positive change of 200 % in the urban area. The urban changes may be associated with population growth as well as industrial development during this period. Simultaneously, a close relationship of spatial urban expansion was shown with the geometric center of a city and distance from major roads, indicating that the most significant drive to urban expansion was road networks and pavements port and leisure facilities. Associated with the rapid expansion of urbanization, a lot of lands has been converted from rural to urban (Lee et al., 2009).

From the land use and land cover change point of view, the expansion of urban areas is of greater importance because of its strong effect on other land cover classes, such as agricultural lands, non-built areas, forests, and others. Ethiopia, having the second largest population in Africa has a total of 105.6 million population in 2017 according to UN estimates. It has a 2.49% annual growth rate and having 5% average annual urban growth rate. In spite of its low urbanization rate compared to other African countries, the impact of land use and land cover changes become a big challenge to the country. Satellite image pre-processing before the change detection phenomenon is very important to establish a more direct affiliation between the acquired data and biophysical phenomena (AbdEl-Kawya et al., 2011). Due to the acquisition system and platform movements, remotely sensed data from aircraft or satellites are generally geometrically distorted. Satellite Remote Sensing and GIS are the most common methods for quantification, mapping, and detection of patterns of LULCC because of their accurate geo-referencing procedures, a digital format suitable for computer processing and repetitive data acquisition (Tahir et al., 2013)

Expansion of agriculture, urbanization, deforestation and the day to day activities of mankind resulted to temporal and spatial change in land use land cover have affected water flow pathways and water balance (Rawat & Manish, 2015). Developing countries like Ethiopia, where their agriculture serves as the backbone of the economy and ensure the wellbeing of the people; the adverse effects of land use land cover change are diverse. Besides these various water resource development sectors (hydropower, irrigation, urban and rural water supply, etc.) have persistently been affected by both temporal and spatial changes of LULC (Nigussie & Yared, 2010).

2.2.4 Urban Growth in Ethiopia

The urban changes may be associated with population growth as well as industrial development during this period. Simultaneously, a close relationship of spatial urban expansion was shown with the geometric center of a city and distance from major roads, indicating that the most significant drive to urban expansion was road networks and pavements port and leisure facilities. Associated with the rapid expansion of urbanization, a lot of lands has been converted from rural to urban. From the land use and land cover change point of view, the expansion of urban areas is of greater importance because of its strong effect on other land cover classes, such as agricultural lands, non-built areas, forests, and others. Ethiopia, having the second largest population in Africa has a total of 105.6 million population in 2017 according to UN estimates (World Population Prospects, 2017). It has a 2.49% annual growth rate and having 5% average annual urban growth rate. In spite of its low urbanization rate compared to other African countries, the impact of land use and land cover changes become a big challenge to the country.

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3. RESEARCH METHODOLOGY

3.1. Description of the Study Area

The research was conducted at Chancho, Sorga-sub-watersheds and Neqemte town in East Wollega Zone, Oromia, Ethiopia. The study area is located at a distance of 328 km from Addis Ababa along the main road from Addis Ababa to Asosa. Chancho sub-watershed is found in Diga District located 15Km from Nekemte town to the West. It is located at 9°01' North and 36°28.2'East at about 2km from Diga town (Figure 1).

Chancho Subwatershed is dominantly covered by cultivated land and rural settlers and Sorga sub-watershed mainly covered by cultivated, forest and urban land. Nekemte town is located in Sorga sub-watershed also included in to assess the impacts of LULCC on watershed dynamics in terms of altering physical and biological environments of the area. The total area of Chancho sub-watershed including the water bodies is 2109 hectares; out of these, 250 hectares of the land is covered by water. Meka Dam was constructed in 2011G.C to supply drinking water to 150,000 people living in Nekemte town, which is located in this sub-watershed. The reservoir is located at the bottom of the watershed surrounded by large farmland and partly by settler and grazing land. Agricultural activities with poor land management practices have contributed a large amount of sediment, plant nutrient and chemicals to the reservoir. The main source of water to the reservoir is rainfall and one stream, namely Meka. The altitude of the watershed ranges between 2100 and 2260 m.a.s.l.

Sorga sub-watershed is found in Nekemte town partly in Diga District, East Wollega Zone, Oromia. It is located in the Western part of the region along the main asphalt road from Nekemte to Asosa. The total area of the watershed is 3817 hectares including a reservoir, which occupies 30 hectares with its buffer zone and surrounded by manmade and natural vegetation. Nekemte town is found partially in Sorga sub-watershed and occupies 326 hectares of land. The Dam is 2.9km far away from Nekemte town, 8km from Diga District, and 3km from the Meka reservoir. Sorga Dam was established by Lutheran Mekane Iyesus Church in 1992 for fish production and recreational area for Nekemte town and the surrounding community.

Land use/cover change was analyzed for the Nekemte town land expansion. Nekemte town is located at 328 km distance from Addis Ababa. It is the capital city of East Wollega Zone. The town has two layers of governmental structure: city government and sub-city administrations. The total demarcated area of the city is about 5380 hectares; from these, 326 ha are included in Sorga sub-watershed, but this research focused on the area currently under construction which is 1732.5 hectares of land. The study site lies at an altitude range of 2044 to 2168 meters above sea level (m.a.s.l).

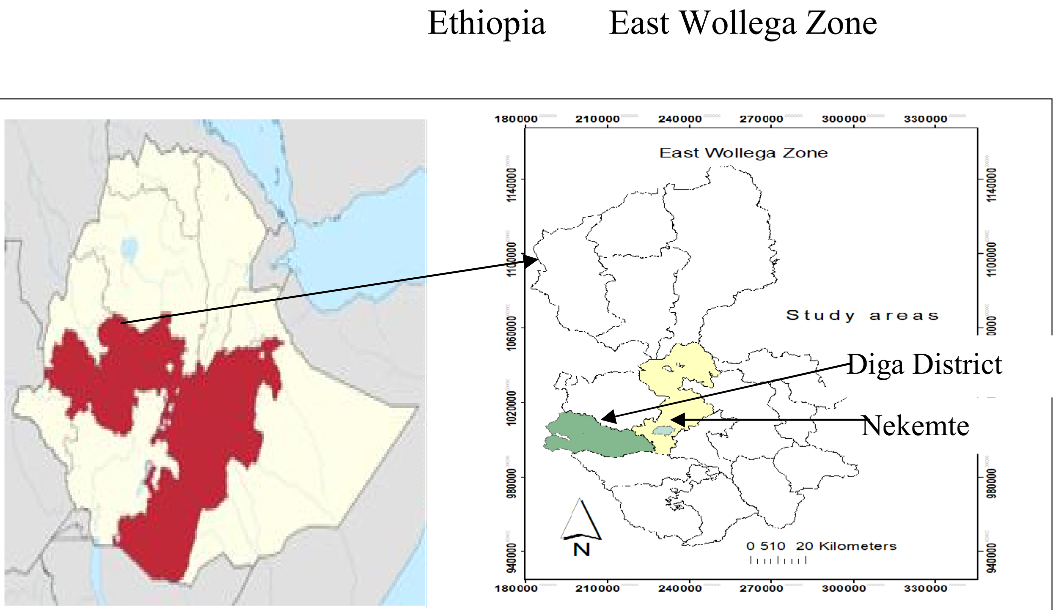


Figure 1.Map of the study area

3.1.1 Topography

The topography of the Sorga sub-watershed is rolling with closely existing small hills and a shallow valley between the hills. All hills have slopes ranging from 15 to 30% with some localized steep slopes above 30% on the hills chests and gentle to flat on top and bottom of the sub-watershed. All slopes are oriented towards valleys of their respective area and all valleys join at the center of the catchment, which is the dam reservoir area. Chancho subwatershed is a relatively flat and u-shaped shallow valley and gentle to a steep slope and the valley joins at the bottom edge of a reservoir.

3.1.2 Soil types and characterization

The major soils of the two sub-watersheds are acrisols, cambisols, lixisols, and nitsols. Fluvisol is found only in Sorga sub-watershed specifically at Nekemte town (Oromia water work and design interprise, 2016). The soils have good inherent fertility for agricultural production although those on the hillsides are prone to soil erosion. The soil erosion on the hillside slopes and sedimentation at the valleys have already taken place because of intensive agriculture without adequate soil erosion protection measures. In the case of Sorga sub-watershed, the area is relatively covered by vegetation and grassland and subsequently, reservoir sedimentation is minimum. The soil of the study areas is described below based on USDA soil description (USDA, 2007).

Acrisols

Acrisols correlate with several subgroups of Alf sols and Ultisols of the USDA system of classification. These are acidic, highly weathered soils (but less weathered than the ferralsols) with an accumulation of low activity clay in an Agric subsurface horizon with low base saturation. They are found mainly on old land surfaces with hilly or undulating topography with wet monsoonal climate. Acrisols under a protective forest cover have a porous surface. If cleared, the topsoil degrades and slakes to form hard surface crusts that inhibit the infiltration of rain leading to soil erosion. The microstructure is weak; nutrient levels are low, and aluminum toxicity and phosphate retention are common.

Cambisols

Most of these soils are classified as Inceptisols in the USDA system and Sol's burn in the French system. They are weakly developed soils with at least the beginning of horizon differentiation in the subsoil evident from changes in structure, color and clay content. Cambisols in the humid tropics are low in nutrient status but still higher than Ferralsols and Acrisols. Cambisols in alluvial flood plains make for relatively good agricultural lands, but they do not do the same on steep slopes.

Fluvisols

These are equivalent to Fluvents in the USDA Taxonomy. They are relatively young soils. A special type of Fluvisol is the Thionic Fluvisol, which is subject to the development of extreme soil acidity. Fluvisols are wet in all or part of the profile because of stagnating groundwater and/or flood water from rivers and tides. Terraces are better drained than the active flood plain (due primarily to the latter's low landscape position). Wet clays and silt soils that have lost little water since deposition are soft and 'unripe' and have low 'bearing capacity'/trafficability. Chemical fertility is relatively good but salinity in coastal areas can be a constraint on crop production. Thionic Fluvisols consist of potential acid sulphate soils and the latter have very low pH (less than 3.5) because of the oxidation of pyrite (FeS2): FeS2 +7/2 O2 + H2O = Fe2+ + 2SO42- + 2H+ . Ferrous iron toxicity for rice also becomes a problem.

Lixisols

Lixisols are highly weathered soils with an argic subsurface horizon with low activity clay and moderate to high base saturation. They occur in areas with pronounced dry seasons on old erosional depositional surfaces. Most Lixisols are well-drained. They have a strong structure but slaking and surface crusts are still problems. The level of available nutrients is low but their chemical fertility is higher than Ferralsols and Acrisols because of higher base saturation and pH and the absence of severe aluminum toxicity.

Nitosols

They correlate with kandic groups of Alfisols and Ultisols of the USDA system and Soil fersialitiques or ferrisols of the French system. Nitosols are deep, well-drained, red tropical soils, highly weathered but more productive for agriculture than other red tropical soils. Their consistency is hard when dry, ranging from very friable to firm when moist and sticky and plastic when wet. Gravel and stones are rare but fine iron-manganese concretions may be present. Cation exchange capacity and phosphate retention capacity are relatively high.

3.1.3 Climate

Meteorological data is needed for running the SWAT model for simulation of hydrological component and water quality parameters at the sub-basin and HRUs. The meteorological data required for this study was collected from the Ethiopian National Meteorological Agency (ENMA). The meteorological data collected were precipitation, maximum and minimum temperature, relative humidity, and wind speed and sunshine hours. The climatic data (1986-2016.G.C) recorded for 30 years at three stations (Nekemte and Leka Dulecha meteorological stations) and International water management institute (IWMI) which is located in Sorga sub-watershed was used for this study. The climate of the study watersheds is moderately cool, representing a typical medium (moist middle altitude) agro-climatic zone.

3.1.3.1 Rainfall data

The study area received a maximum amount of rainfall of 2520 mm during the year 2014, and the minimum recorded rainfall was 1524 for the year 1989. Then, the mean annual rainfall of the study area was 2022mm. Figure 3 shows the trend of average monthly rainfall of 16 years and a single year of 2016. The average monthly rainfall pattern of a long year is greater than a single year.

There are two seasons in a year, namely, a rainy season, which occurs from May to October and a dry season from November to April. Yearly and monthly distribution of rainfall for the last 30 years showed the variability of rainfall (Figure 2).

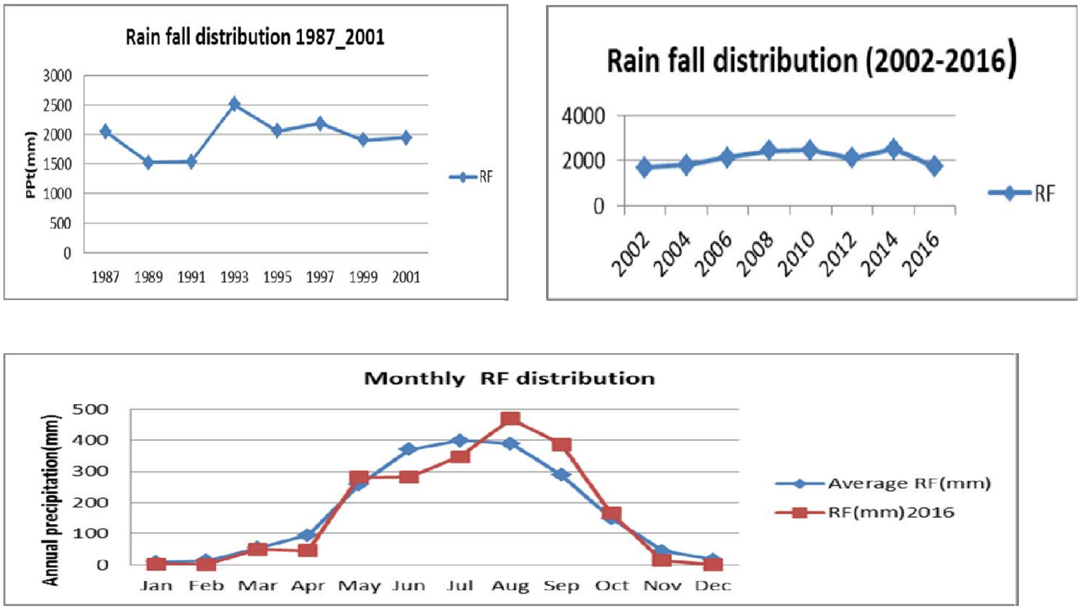


Figure 2: 16 years annual and monthly rainfall distribution and annual rainfall of 2016 (Source: National Metrological Agency, 2017)

3.1.3.2 Temperature

Both sub-watersheds have a recorded temperature from the same stations for 1986 to 2016, the same length of the year with recorded precipitation data. The daily maximum and minimum air temperature were available with an almost insignificant amount of missing data and the annual average temperature was 19.85^{o}c.(Figure 3).

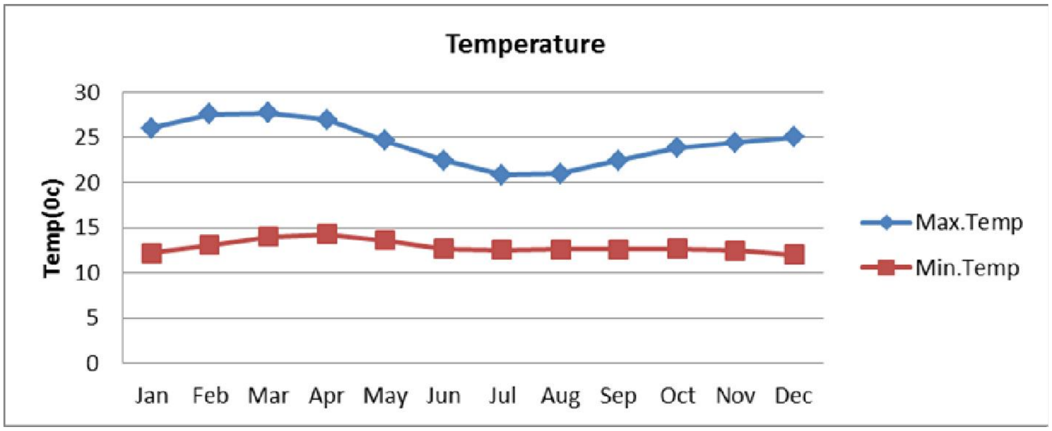


Figure 3: Max and min monthly temperature distribution in the study area (Source: National Metrological Agency, 2017)

3.1.5 Population

The total number of population in Chancho sub-watershed is estimated to be 1150. The average family size is about five people per household and females are dominant in number. The estimated total population of Sorga sub-watershed is 6160 (Table 1). The nature of the settlement pattern of the Chancho subwatershed is dominantly rural. Clusters or homesteads of tukuls are sparsely scattered throughout the area. The villages are located on the escarpment and foothills of the watershed. On the other hand, Sorga sub-watershed is inhabited by both rural and urban settlers, where the urban settlers are larger and more densely populated.

Based on the national population and housing census conducted in 2007, the estimated or the projected total population of Nekemte town in the year 2016 was 98334 (Ethiopia Central Statistics Agency, 2016). The population at a subwatershed level was taken during a survey by a development agent because it is difficult to project from the kebele population as the watershed is trans-boundary to local administrative kebele

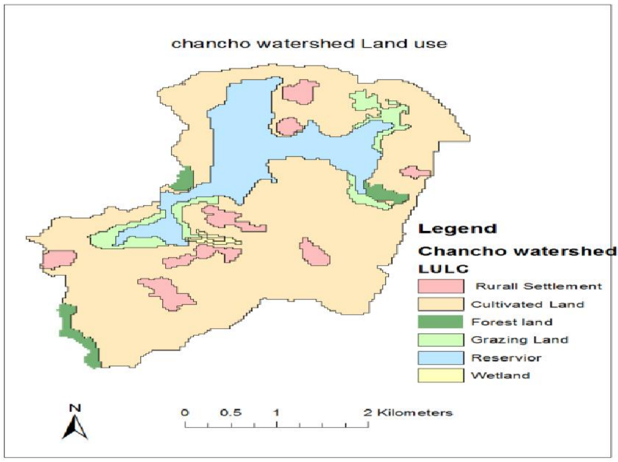
Table 1: Population size of the study watersheds

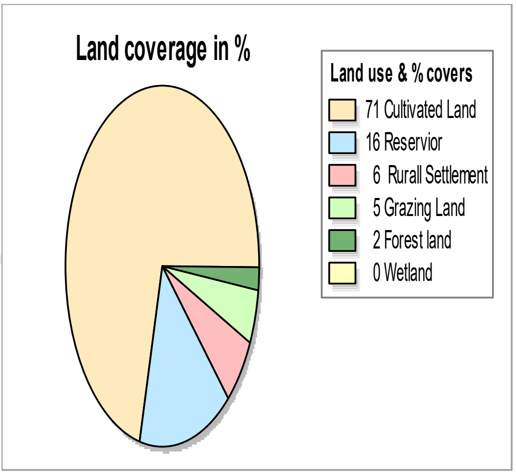
Study Areas	Watershed/Town	Total Population		
		Rural	Urban	Total
Diga	Chancho	1150		1150
Nekemte	Sorga	5160	1000	6160
	Nekemte town	5160	98334	103494

(Source: Own survey, 2016 and CSA, 2016)

3.1.6 Land use and farming ssystem

Chancho-sub-watershed





Sorga sub-watershed

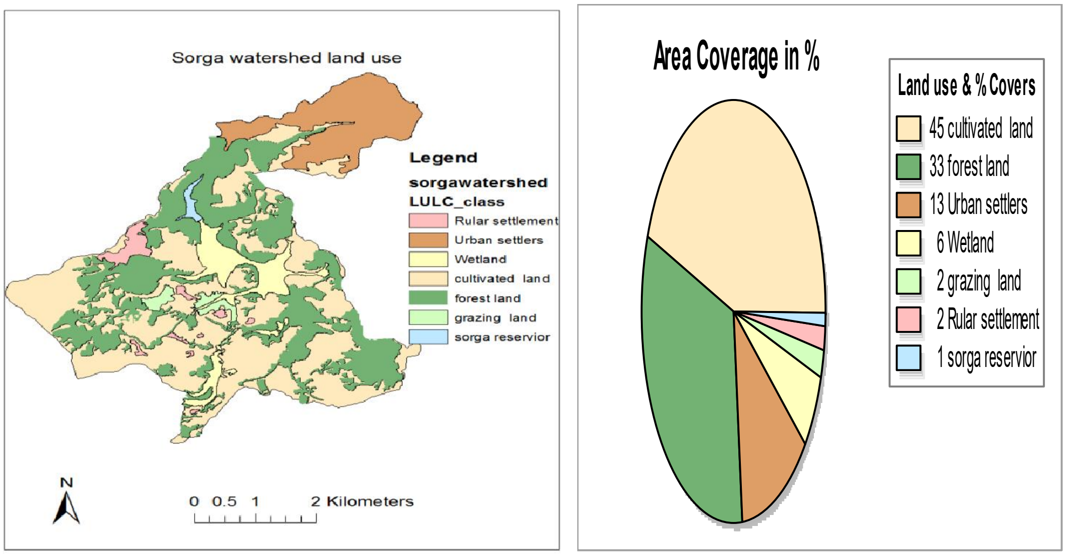


Figure 4: Land use/cover types of the study sub-watersheds

The major land use of the sub-watersheds which was manually digitized fron the google Earth, includes; cultivated/fallow land, grassland, swamp or wetland, rural and urban land, forest and riparian land.

Cultivated and fallow land: This is the major land-use type covering an area of 74% of the Chancho and 68% of Sorga sub-watersheds. Annually, this unit of land is entirely or partially put under the cultivation of field crops. The unit includes the land usually left fallow, mainly practiced to regenerate fertility of the soil. The cultivated fields are the main sources for sedimentation and nutrient load in the valleys mainly the reservoir area. These field crop areas are always bare after harvesting and first plowing is exposed to severe soil erosion during rain onset time. Since limited traditional soil conservation measures are undertaken in the fields, runoff contributes a large amount of soil to the reservoir annually. Farmland situated on steep slopes and along sides of the valley contributes a greater sediment load to the valley bottoms than the field situated on gentle slopes.

Grassland

This unit of land is covered by various species of grasses that are generally grazed by livestock. There are no large areas allocated for grazing; and some are found along with field crops, marshy areas, and small fallow lands. The unit represents about 7% of the total Chancho sub-watershed and 16% of Sorga sub-watershed and occurs during dry and wet conditions.

The wet grassland areas are found mainly in the valley bottoms and along streams and springs. These areas are moist throughout the year with good ground cover due to the high water table, and it provides the main grazing area for livestock. The grasslands are the major buffer zones that filter the soil particles and clean up the water. However, the buffer area of the reservoir is being progressively converted to farmland and overgrazed during the dry season; as a result, the Meka reservoir is under greater pressure of siltation and nutrient load.

Wetland and reservoir

Swamp or wetland areas are located at the low lying and depression parts of the watersheds, which are seasonally inundated by water. They serve as dry season grazing land and flood recession farming locally known as 'Bone farm". The water body known as reservoir occupies 250 hectares of land in Chancho and 30 hectares in Sorga sub-watershed, and few wetlands in Nekemte town is used as a bone farm during the dry season.

Forest and Vegetation

This unit occupies 0.27% of the land area in Chancho and 21.5%% of Sorga-sub-watersheds. Chancho sub-watershed is characterized by sparse vegetation cover, whereas Sorga watershed is relatively covered by natural and manmade forests. In Nekemte town, there are more of the manmade forest than natural vegetation cover at ever corner and valley areas of the town.

Built-up area

The unit comprises roads and buildings (Churches, Schools, Peasant Association and Service cooperative offices) and covers 4.5% of Chancho, 8.9% of the Sorga sub-watershed areas, and 70.5% of Nekemte town (Figure 4).

Farming system

The farming system of the study area is mixed type dominated by oxen cultivation and subsistence agriculture of cereal cropping mainly teff, finger millet, and maize, followed by broad beans, field peas, and linseed, and livestock production. Other crops worth mentioning in the area include rapeseed/mustard, anchote, potato, and sorghum, which are mainly grown around the homestead.

The bone farm is a unique farming system in the area and widely practiced in the valley bottoms, wetlands, and along with seasonal river courses. The system is based on planting crops along with flood retreat areas. Bone farming serves as catch cropping and harvesting coincides with the critical food shortage period of June to middle July. Maize is the main crop commonly planted in this farming system followed by vegetables.

The landholding is small and fragmented, only to support the livelihood of the families. Draught animals are used for the cultivation of farmland and threshing of harvests. Crop fields are often plowed four to five times before sowing. The farming practice is essentially age-old, characterized by backward and used the unrecommended amount of input, resulting in low productivity of the land. However, the use of modern input such as improved seeds, fertilizers, and agrochemicals is currently practiced in the watersheds.

3.1.7 Livestock husbandry

Livestock husbandry is not only an integral part of crop production and household economy, but it is also considered as a factor of land degradation through excessive grazing. Poultry is the most dominant populated livestock contributing 52% and 44% of the total number of livestock in Chancho and Sorga sub-watersheds, respectively, followed by cows, which account for 8.8, 21.5%, and 2.1% in Chancho and Sorga sub-watersheds and Nekemte town, respectively. Livestock depends on available fodder resources including crop aftermath and limited grazing areas located at the valley bottoms, wetland, and field borders. The wetland and valley bottom grazing areas are particularly important during the dry season. Since grazing alone cannot supply the feed requirement of the livestock all year round, farmers in the area practice conserving hay from grasses as well as wheat, barley, and teff straws.

Grassland is shrinking year after year because of farmland expansion and increased livestock population puts more pressure on the existing grazing land. Consequently, the Chancho subwatershed is extensively overgrazed resulting in soil erosion and land degradation.

3.2 Methods and Materials

The study sites (sub-watersheds) were selected purposively based on soil erosion problems, availability of different land-use practices, and reservoirs sedimentation within the watersheds. Chancho and Sorga sub-watersheds were selected to assess the impacts of land use /cover dynamics on watershed hydrology and resrvoirs sedimentation. The land use within a watershed includes cultivated land, grazing land, forestland, urban land, wetland, and reservoir.

The existence of reservoirs in the subwatersheds and different land use/cover type were used to compare the impacts on watershed hydrology between the two sub-watersheds. Information about the nature of land use /cover and its management system has been taken from Zonal, District, and local level administrations before field engagement to gain an understanding of the overall performance of the watersheds. It helps to observe the gaps to be addressed and to internalize the watersheds problem and its management strategies.

Most of the previous research works were focused on the impacts of land use/cover change on hydrology, but this research focused on quantifying the effects of each land use/cover dynamics on watershed hydrology and reservoir sedimentation at varying slope gradients and soil types. Both sub-watersheds were classified into different land use/cover types, slope classes, and soil types. The combined effects of land use/cover, slope gradients and soil types on water quality variables and water balance, soil loss and reservoir sedimentation were predicted based on SWAT and RUSLE models, respectively. Effects of land use/cover on surface water quality were analyzed based on a water sample taken from three dominant land uses(Agriculture, forest and urban dominated surface water) and tested in the laboratory. The ecological effects on forest and wetland was also assessed based on three years historical imagies of land use/cover change of the study sub-watershed. The position of influences and significant relationship between each land use/cover type (independent) and hydrological and water quality variables (dependent) were also analyzed by partial least squares regression model (PLSR)

A field survey was made to get a general insight into the study areas and for preliminary identification of the land use /cover type and the location of the study population. A parallel activity was performed to identify focus discussion groups, key informants, and other relevant data generation tools.

land management practices and the nature of the landscape were identified during the field survey. Water sampling sites were selected based on land use/cover types undertaken at every side of surface water.

Investigation of the effect of land use /cover on the watershed hydrology is the focus of this research. Hence, the roles of various agents at Zonal, District and local levels are paramount important and their views and opinion were assessed. This helps to understand how much the problem of watershed degradation is serious and their perception regarding soil loss and sedimentation of reservoirs. The nature of discussion and their significance in watershed management issues were determined by the multidisciplinary approach at a different level of government administrative structure during the preliminary survey process. Some of the participants were development workers, agriculture office experts, water resource office experts, land and environmental protection office expert, Keble representatives, elders, and watershed teams.

Secondary data was accessed from published and unpublished sources of various research work,organizations, development partners, and agents involved in agricultural activities, watershed management, land use planning, and water quality assessment unit. Also, to cross-sectional data, trend data was considered to examine changes over time especially on climatic data and land use/cover types. These sources have supplied both quantitative and qualitative information to adequately characterize the study area.

The possible sources of secondary data were Woreda Agriculture Office, development workers, PA, Woreda, and Regional and Zonal water supply offices, land and environmental protection office, Statistical Agency, and Meteorology Agency. These were identified and refined during visits to the Zonal and Woreda offices and surveys to the respective local offices.

SWAT model

SWAT (Arnold et al., 1998) is a physically-based, continuous simulation model developed to assess the short- and long-term impacts of management practices on large watersheds. The model requires extensive input data, supplemented with GIS data and the model interface

The study uses SWAT-CUP which is an analysis and calibration software, specially created for the calibration, validation, uncertainty and sensitivity analysis of SWAT-generated models. The software is a time-saving and user-friendly alternative to the manual calibration in SWAT. All the input and output data created and generated in SWAT were used in the SWAT-CUP. After the calibration iteration, SWAT CUP suggests parameter adaptions, which can be applied for the next iteration. Several uncertainty issues are connected to watershed model calibration and need to be considered (Abbaspour, 2007)

3.2.1 Watershed delineation

Arc SWAT uses Digital Elevation Model (DEM) data to automatically delineate the watershed into several hydrological connected sub-watersheds. The watershed delineation operation uses and expands ArcGIS and Spatial Analyst extension functions to perform watershed delineation. The first step in the watershed delineation was loading the properly projected DEM. To reduce the processing time of the GIS functions, a mask was created over the DEM around the study area. Next, a polyline stream network dataset was burnt-into force SWAT sub-basin reaches to follow known stream reaches. Burning-in a stream network improves sub-watershed delineation. After the DEM grid was loaded and the stream networks superimposed, the DEM map grid was processed to remove the non-draining zones.

The initial stream network and sub-basin outlets were defined based on the drainage area threshold approach. The threshold area defines the minimum drainage area required to form the origin of a stream. The interface lists a minimum, maximum and suggested threshold area.

Watershed delineation and slope mapping were undertaken by Arc-GIS based on the digital elevation model of each subwatershed. The watersheds were subdivided into sub-basin and further into several hydrological response units (HRUs) that are characterized by dominant land use/cover, soil type, slope and land management.

3.2.2 SWAT Input Data

3.2.2.1 Land Use/Cover

. The study sub-watersheds are covered by different land use/cover types in which both sub-watersheds are classified into five land use/ cover types (Figure 4). Cultivated land is the dominant land use type and accounts for 73.6% of the total area, followed by 11.8% reservoir areas in Chancho sub-watershed. Forestland occupies only 0.27% of the total areas of Chancho sub-watershed. In Sorga sub-watershed, cultivated land is the dominant land use type followed by forestland and occupies 68% of the total area, followed by 21.5% of forest land areas. Urban land covers an area of 340 ha (8.9%) of the total area of Sorga subwatershed (Figure 5). Land use/cover in the vector map was converted to raster and used as input for the SWAT model

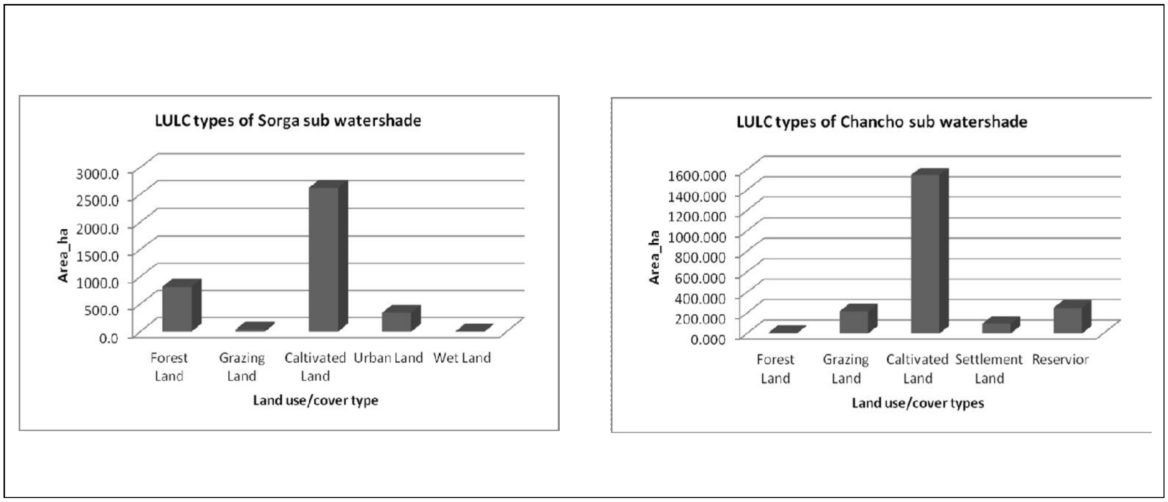


Figure 5: Land use/ cover types of the study watersheds

3.2.2.2 Soil Data

As indicated in the soil map of the study watersheds four types of soil were classified in Chancho and five for Sorga sub-watersheds (Figure 4&5). The dominant soil type in Chancho sub-watershed is nitisols occupied 51.3% followed by cambisols (26.7%). Acrisols and lixisols occupy (16.7% and 5.3%), respectively. In Sorga sub-watershed, lixisols occupies 35.3%, cambisols (26.5%), nitisol (21.7%), acrisols (15.2%) and fluvisols (1.3%) (Figure 6).

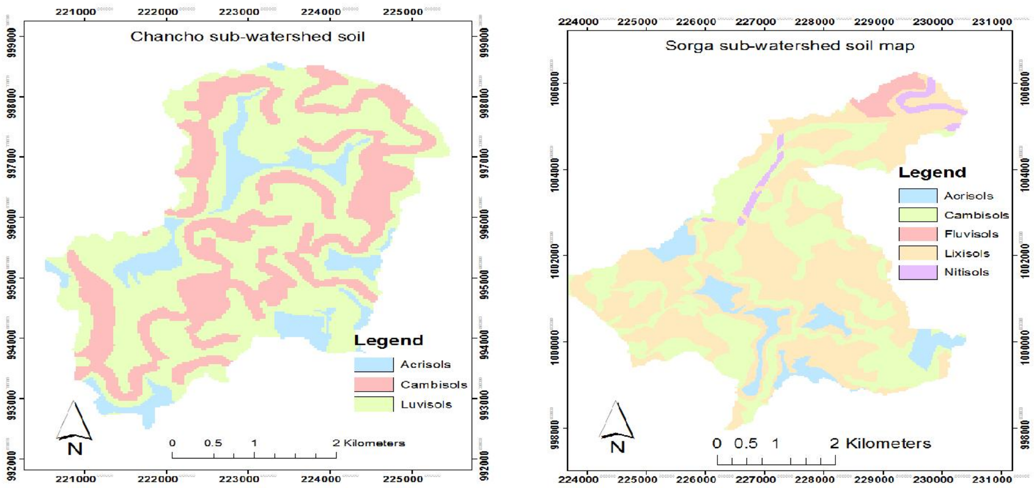


Figure 6:Soil map of the study sub-watersheds

3.2.2.3 Slope

As shown in Figure 7, the slopes of the study areas were classified into six slope ranges. According to Hurni (2005) slope classification, 781.8ha (45%) area of Chancho sub watershed and 1340ha (41%) of Sorga sub-watershed classified as the steep slope (8-15%). 547.8ha (26%) of the total land area of Chancho and 1303.8 ha (35%) of Sorga sub-watersheds were under very steep slope classification (15-30% and >30). On the other hand, 16% of Chancho and 11% of Sorga slope was classified under relatively flat land (0-5%), while 17.7% of Chancho and 13.6% of Sorga slope is classified under gentle slope (5-8%). Almost 71% f Chancho and 76% of Sorga slope were classified under steep to very steep slope land. Distribution of this slope classes to each land use/cover indicated that 85% of cultivated land in both sub-watersheds is classified under steep to the very steep slope but steeper slope lands were under cultivation in Sorga as compared to Chancho sub-watersheds. Forestland accounts for 87% of steep to very steep land, in which the share of very steep land is higher than that of steep land. Almost 95% of urban land and grassland of the study area are also classified under steep to very steep land. More land with Slope gradient >30% was used for agriculture in Sorga than the Chancho subwatershed (Table 3).

Table 3: Slope gradient share of each land use/cover of the study areas

	Sorga sub watershed				Chancho sub watershed		
Slope class	Cultivated	Forest	Urban	Grass	Cultivated	Grass	Residential
0-5%	218.28	47.12	21.60	-	202.92	25.96	10.35
5-6%	288.31	51.59	43.49	-	244.80	21.95	12.52
8-15%	835.50	267.57	106.67	3.26	622.67	84.21	26.22
15-30%	687.19	347.46	101.23	11.97	452.77	50.27	12.85
>30%	91.24	63.86	-	4.83	34.60	1.58	-

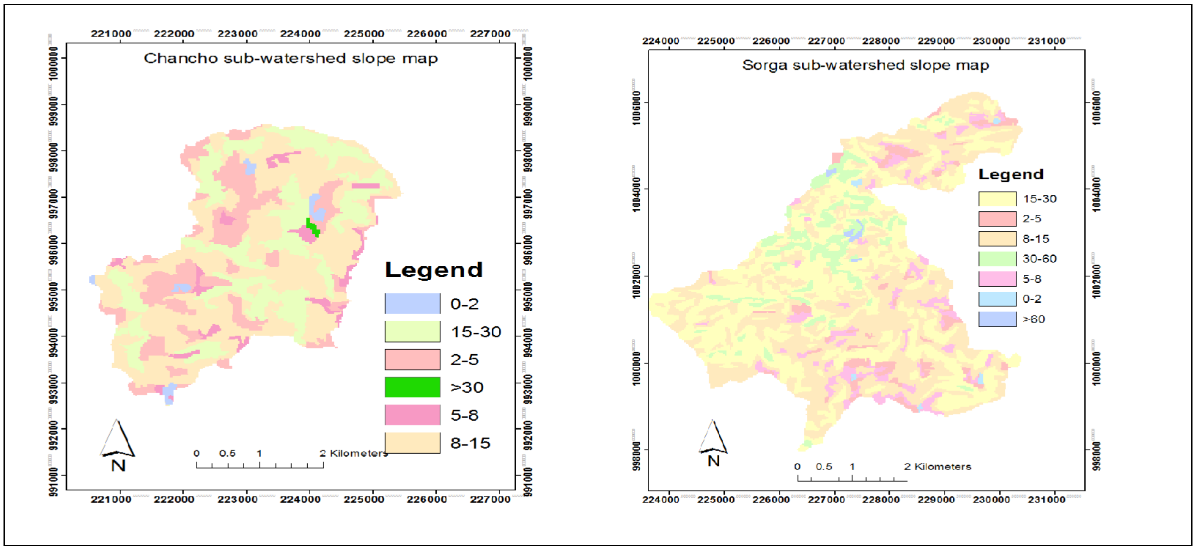


Figure 7. Slope Map of the study Watersheds

3.2.2.4 Hydrological Response Unit (HRU) of the Sub-Watersheds

As a physical-based model, SWAT creates Hydrological Response Units (HRUs) to represent spatial heterogeneity based on the overlay of 10%, 10% and 5% threshold percentage of land use, soil types, and slope, respectively, and resulted in a total of 222 HRU in Sorga and 301 in Chancho sub-watershed which has a unique land use, soil and slope. The slope map and its database are used for the simulation of hydrological component and water quality parameters by using integrating the SWAT model with Arc-GIS. (Figure 8)

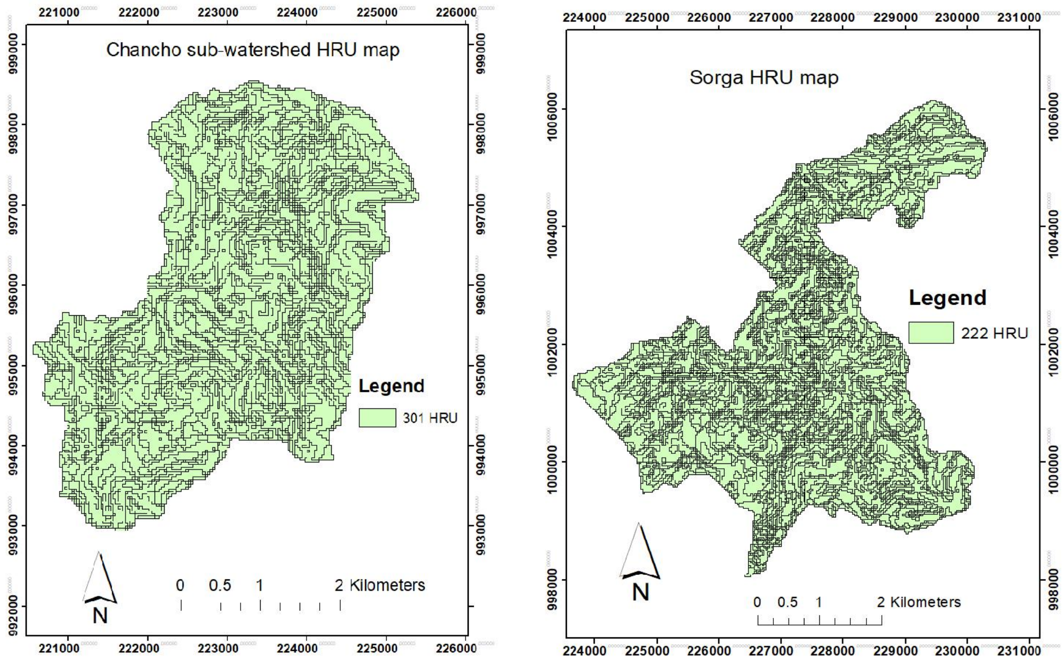


Figure 8. Hydrological response unit maps of the study sub watersheds

3.2.3. Model Setup

The study watersheds were divided into 19 and 21 sub-basins and 222 and 301 hydrological response units for Sorga and Chancho sub-watersheds, respectively. The dominant land use is cultivated land in both sub-watersheds followed by grassland in Chancho and forestland in Sorga sub-watersheds. Five and four soil types were identified in Chancho and Sorga sub-watersheds, respectively. Nitosols is the dominant soil type in both sub watershed and accounts for 56% for Chancho and 35% for Sorga, followed by cambisols in both sub-watersheds.

3.2.3.1 Hydrologic Response Unit Analysis

Hydrologic response units (HRUs) are lumped land areas within the sub-basin that are comprised of unique land cover, soil, slope, and management combinations. HRUs enables the model to reflect differences in evapotranspiration and other hydrologic conditions for different land use/ covers and soils.

Land use/cover and soil data in a projected grid file format were loaded into the Arc SWAT interface to determine the area and hydrologic parameters of each land-soil category simulated within the sub-watershed. Land use/ cover types were defined using the lookup table. A look-up table that identifies the 4-letter SWAT code for the different categories of land cover/land use was prepared to relate the grid values to SWAT land use/cover type. After the land use SWAT code assigned to all map categories, calculation of the area covered by each land use/cover. The soil layer in the map was also linked to the user soil database information by loading the soil look-up table and reclassification applied. Then, land use, soil, and slope classes were integrated to define the hydrologic response units. To minimize the number of HRUS, 10% for land use/cover, 10% for slope and 5% for soil thresholds percentage were assigned. The DEM data used during the watershed delineation was also used for slope classification. Based on the suggested minimum and maximum ranges, six slope classes (0- 5, 5-8, 8-15, 15-30 and >30%) were applied and slope grids reclassified. Then, land use, soil, and slope grids were overlaid to produce HRUS based on threshold percentage assigned for each of them

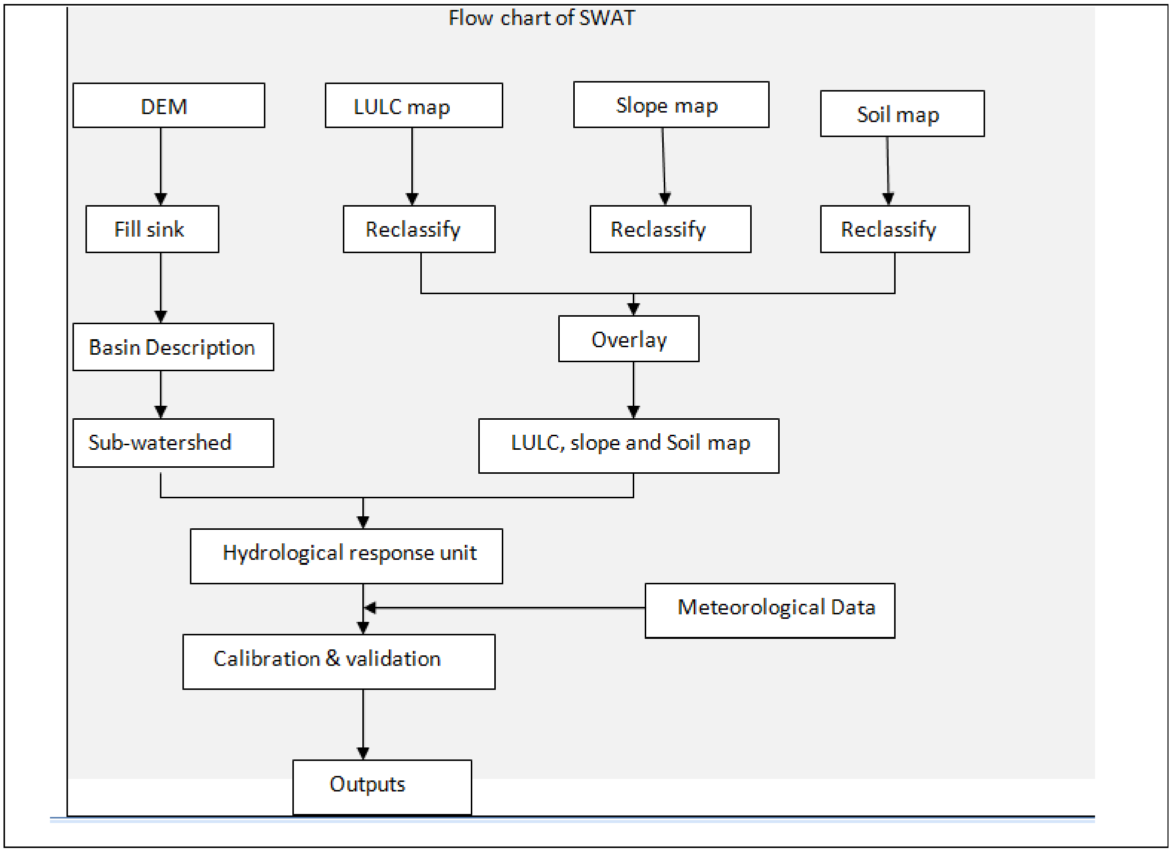


Figure 9:Work flow chart of SWAT

3.2.3.2 Importing Climate Data

The climatic variables required by SWAT includes daily precipitation, maximum and minimum temperature, solar radiation, wind speed, and relative humidity were prepared in the appropriate dbase format. Due to data availability and quality, daily precipitation, and maximum and minimum temperature in dbase format were the climatic input variables imported together with their weather location. And due to lack of complete weather data, we used the Hargreaves method which uses temperature to determine the potential evapotranspiration.

3.2.4 SWAT model Sensitivity analysis

The sensitivity analysis of this study was done using global sensitivity analysis methods. The inputs were the observed daily flow (1994-2013) data from International water management and monthly measured sediment load in the watershed. The sensitive parameters to flow and sediment load evaluated by t-stat and p-value and sensitive parameters were ranked accordingly.

3.2.4.1 Model Calibration and Validation

Two sub-watersheds are selected for this study in which Chancho Subwatershed flow and sediment data used for model calibration and Sorga sub-watershed independent data used for an automated method for model validation. Simulation of the predicted hydrological and water quality parameters were undertaken in the Sorga sub-watershed.

Calibration and validation were carried out in SWAT-CUP 2012 version 5.1.4 using the Sequential Uncertainty Fitting(SUFI-2) algorithm, based on the SWAT-CUP user manual (Abbaspour,2013). SUFI-2 is a semi-automated calibration and uncertainty analytical algorithm (Zhou et al., 2014) that accounts for all sources of uncertainty, including uncertainty in the driving variables (e.g. rainfall), conceptual model, parameters and measured data (Vilaysane et al., 2015). The model was calibrated and validated by using only river flow and sediment data of the study sub-watersheds because it is the only available data in the watershed. Sensitivity analysis was carried out to identify the most sensitive parameters for the model calibration using global sensitivity analysis which is an automatic sensitivity analysis tool implemented in SWAT (Van Griensven and Meixner 2006),

In automated calibration, the list of selected parameters for optimization of the objective function is usually the momentum of the difference of observed and computed values. For SWAT model calibration, there is a manual option in ARCSWAT, and a SWAT-CUP (SWAT Calibration and Uncertainty Programs) program with a link to SWAT output for automated calibration is used. In SWAT-CUP, there are four methods for calibration, uncertainty and sensitivity analysis (Abbaspour et al., 2007). In this study, the SUFI-2 optimization method was applied. In SUFI-2, the uncertainty parameter explains all sources of uncertainties. The degree to which all uncertainties are explained is expressed by a parameter referred to as the P-factor, which is given as the percentage of measured data enveloped by the 95% estimation uncertainty (95PPU). The 95PPU is determined at the percentage of cumulative distribution between 2.5% and 97.5% of an output variable.Model Application A simple framework that is used for hydrologic modeling and calibration by SWAT and SWAT-CUP

Land use/cover and soil maps in Arc shape format(raster) were imported into the Arc SWAT model for HRU analysis. Both maps were classified in Arc SWAT. The slope gradient of the study area was also classified into five slope classes and made to overlay with land use and soil map to subdivide the study watershed into hydrologic response units (HRUs). Subdividing areas into hydrologic response units enables the model to reflect the evapotranspiration and other hydrologic conditions for different land use, soils and slopes. The HRUs are the elementary units with unique land cover, soil and slope angle lumped together. After HRUs are defined, the next step in the model set up is importing the climate data.

Climate data are one of the main sets of input for simulating the hydrological processes in SWAT. The climatic data used for the SWAT model were: precipitation, temperature, solar radiation, sunshine and wind speed. These available climate data were prepared in text (.txt) format and imported into the SWAT model. Then, the SWAT input tables were inserted into the model. The SWAT input files were edited before the model was run for simulation. Soil and slope ranges were also edited. The statistical parameters of daily precipitation and minimum and maximum daily temperatures were also edited.

3.2.4.2 Model Evaluation

The performance of SWAT was evaluated using statistical measures to evaluate the quality and reliability of predictions as compared to observed values. The coefficient of determination (R^2) and Nash-Sutcliffe simulation efficiency (E_{NS}) where the goodness of fit measures used to evaluate the model prediction. The R^2 value is an indicator of the strength of the relationship between the observed and simulated values. The Nash-Sutcliffe simulation efficiency (E_{NS}) indicates how well the plot of observed versus simulated value fits the 1:1 line. If the measured value is the same as all predictions, E_{NS} is 1. If the E_{NS} is between 0 and 1, it indicates deviations between measured and predicted values. If E_{NS} is negative, predictions are very poor, and the average value of output is a better estimate than the model prediction (Nash and Sutcliffe, 1970). The Nash-Sutcliffe coefficient (RNS),Relative error(RE) and coefficient of determination (R2) are commonly used to evaluate model performance (Gyamfiet al., 2016) are shown in Equations below.

$$R^2 = \frac{\left[\sum_{i=1}^{n}(q_{si}-q_s)(q_{oi}-q_o)\right]^2}{\sum_{i=1}^{n}(q_{si}-q_s)^2\sum_{i=1}^{n}(q_{oi}-q_o)^2}$$

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

Partial least square regression (PLSR) model is useful in exploring the individual variables' impacts (Abdi et al., 2014). PLSR model, though it was developed in areas of chemometrics, it was also used in various environmental studies such as by Shi et al. (2013), Fang et al. (2015) and Tekalegn et al. (2017). The robust advantages of the PLSR model are that it gives weight for predictors by developing latent factors. Therefore, one can easily understand the most influencing variables for a particular response (Abdi, 2007). The dependent variables used in PLSR in this study were hydrological component, sediment, and water quality variables while the independent variable was land use/cover type

Partial least squares regression is an extension of the multiple linear regression models (Multiple Regression or General Stepwise Regression). In its simplest form, a linear model specifies the (linear) relationship between a dependent (response) variable *Y*, and a set of predictor variables, the *X*'s, so that

$$Y = b_0 + b_1X_1 + b_2X_2 + \ldots + b_pX_p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

In this equation, *b0* is the regression coefficient for the intercept and the *bi* values are the regression coefficients (for variables 1 through *p*) computed from the data. The regression coefficients in PLSR models were used to reveal the direction of the relationships between changes in individual LULC class and hydrological components (Shi et al., 2013; Yan et al., 2013)

3.2.5 SWAT Model configuration

For this study, the SWAT model was used for the assessment and estimation of water balance components such as evapo-transpiration (ET) and potential evapotranspiration (PET), surface runoff, soil water, percolation, ground and lateral water flow, and water yield. The hydrological cycle is based on the water balance equation, which is represented in the equation:

$$\left(SWt = SWo + \sum_{t=1}^{1} R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

where: SWt – final soil water content [mm]; SW0 – initial soil water content on day i [mm]; t – time [days]; Rday – amount of precipitation on day i; Qsurf – amount of surface runoff on day i; Ea – amount of evapotranspiration on day i; Wseep – amount of percolation and bypass exiting the soil profile bottom on day i; Qgw – amount of return flow on day i.

The SWAT model allows two ways of estimating surface runoff volume. One is using a modification of the SCS curve number method (USDA soil conservation service, 1972) and the other way is the Green & Ampt infiltration method (Green, Ampt 1911). In the curve number method, the curve number (*CN*) varies non-linearly with the moisture content of the soil. The curve number drops as the soil approaches the wilting point and increases to near 100 as the soil approaches saturation. The *CN* method has been used extensively for runoff simulations (Geetha et al. 2007; Chung et al. 2010). Moreover, the method chosen to calculate the surface runoff depends also on the availability of precipitation data for the chosen basin. In this study, the SCS curve number method has been chosen to compute surface runoff.

The SCS curve number equation is defined by:

$$Qsurf = \frac{\left(R_{day} - I_a\right)2}{\left(R_{day} - I_{a+S}\right)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

Where Qsurf is the total runoff [mm H_2O], R_{day} is the precipitation on the day [mm H_2O], Ia is the initial conditions, involving surface storage, infiltration, and interception [mm H_2O] (commonly set to 0.2*S) and S is the retention parameter [mm H_2O].

The retention parameter S is given by the equation:

$$S = 25.4 \times \left(\frac{1000}{CN} - 10\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where *CN* is the curve number for the day. The curve number is a parameter defined by the initial soil water conditions, the soil permeability and the land use

In the SWAT model, the soil profile is subdivided into multiple layers to support the process of infiltration, evaporation, plant uptake, lateral flow, and percolation to lower layers. The soil percolation component of SWAT uses a storage routing technique to simulate flow through each soil layer in the root zone. The percolation to lower layers occurs when the field capacity of the soil layer is exceeded and the layer below is not saturated. Groundwater flow contribution to total streamflow is simulated by routing a shallow aquifer storage component to the stream (Arnold et al. 1998; Abbaspour et al. 2007). Water yield is the total amount of water leaving the HRU and entering the main channel during the time step. It is one of the important components of the water cycle that needs to be estimated for the sustainable management of water resources of the study area (Adeogun et al. 2014). The SWAT model uses the equation (2) to estimates water yield at the basin scale:

$$WYLD = SURQ + LATQ + GWQ - TLOSS \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where: *WYLD* is the amount of water yield [mm H_2O]; *SURQ* is the surface runoff [mm H_2O]; *LATQ* is the lateral flow contribution to streamflow [mm H_2O]; *GWQ* is the groundwater contribution to streamflow [mm H_2O] and *TLOSS* is the transmission loss [mm H_2O] from tributary channels in the HRU via transmission through the bed.

SWAT model output was used to examine the general effects of land use/cover dynamic on the hydrological component of the watershed. It helps to identify which land use/cover mostly affect the watershed hydrology and, thus, need priority intervention. The interaction of effects of land use/cover with soil types and slope gradient on watershed hydrology was also estimated by the SWAT model. GIS is a powerful data integration and spatial analysis tool. In this research, Arc- GIS is used to map land use/cover, soil and slope with the help of DEM of each watershed.

The two sub-watersheds were selected based on the availability of surface water (reservoirs) at the bottom and variability in its land use/cover types. Sorga sub-watershed was chosen for detailed modeling of the relative impacts of different land use/cover types on hydrological component and sediment and nutrient loss. Chancho sub-watershed which is adjacent to Sorga was used for model calibration. Observed river flow data in the Chancho sub-watershed was obtained from the International Water Management Institute for model calibration and validation. Sorga is an ungauged watershed and recorded flow data was transferred from other watershed river flow recorded data where they share a common climatic data for model validation.

All necessary inputs required for the model were properly arranged in the SWAT format and incorporated in the Arc-GIS under SWAT extension. Hydrological variables were simulated for each land use/cover type in Sorga sub-watershed. The model was calibrated and validated by using observed river flow and sediment yield data of the study areas.

3.2.6 Simulation of Hydrological and Water Quality Variables

SWAT uses the SCS curve to calculate surface runoff and the initial curve number was estimated using soil moisture method. The model was calibrated for the years 1994 to 2013 by fixing the warm-up period of three years. The warm-up period of 3 years is generally recommended for the SWAT model to arrive at hydrological equilibrium.

The effects of each land use/cover dynamics on watershed hydrology in terms of water balance was assessed based on 2016 land use/cover type as a base year and evapotranspiration, percolation, soil water, groundwater flow, surface runoff, and total water yields were simulated for 30 years (1986-2016). Change in watershed hydrology due to land use/cover dynamics at varying slope gradient and soil types was simulated based on 30 years of climatic data of the study areas. Therefore, surface runoff of each land use/cover was simulated by using curve number methods embodied in SWAT.

Sediment and nutrient loss variables simulated for each land use/cover in a watershed were sediment loss, organic nitrogen, organic phosphorus, soluble phosphorus, Sediment phosphorus, nitrate in surface runoff and nitrate in groundwater and lateral flow. Therefore, sediment and nutrient losses of each land use /cover at varying slope gradient and soil type were simulated by soil and water loss assessment (SWAT) watershed model and the effect of each land use/cover on sediment and nutrient loss were assessed based on the 30 years mean values of water quality parameters.

SWAT watershed model was used for the simulation of sediment and nutrient losses from different land use/cover under varying slope gradient and soils. Land use/cover of the year 2016, soil and slope map of the same year with 30 years climatic data of the study watershed were used as a set of basic inputs for SWAT simulation process. Model calibration and validation were done by using observed sediment data collected for four year's independently for Chancho and Sorga surface water. Then, Chancho sediment data was used for model calibration and Sorgas for model validation. To identify the most sensitive parameters affecting the model output, global sensitivity analysis was utilized.

3.2.7 Soil Loss and Sediment Yield Estimation

Modified Universal Soil Loss Equation (MUSLE) was used to assess the actual soil loss of each land use/cover type in the sub-watersheds. The sediment yield of each subwatershed was estimated based on the total soil erosion and sediment delivery ratio calculated for each subwatershed. Rate of reservoir sedimentation and its storage capacity loss was also predicted based on the total sediment volume entering the reservoirs minus sediment lost or taken by water out of the reservoirs resulted in final annual storage loss of the reservoirs. Soil loss estimation was performed by considering the following soil erosion factors.

3.2.7.1 Determination of soil loss factors

A. Rainfall erosivity factor(R)

Monthly rainfall records from meteorological stations covering the period 1986-2016 were used to calculate the rainfall erosivity Factor (R-value). The mean annual rainfall was first interpolated to generate continuous rainfall data for each grid cell by "3D Analyst Tools Raster Kriging Interpolation" in the arc-GIS environment. Then, R-value corresponds to the mean annual rainfall of the sub-watersheds was found by using the R-correlation established in Hurni (1985) to Ethiopia condition.

$R= -8.12 + 0.562P$ (1)

Where R is the rainfall erosivity factor and P is the mean annual rainfall (mm).

B. Soil erodibility factor (K)

Soil erodibilty factor (K) of each land use and land cover type of the two sub-watershed was obtained from SWAT model, which utilized USLE and compared with the soil erodibility (K) factor for the sub-watersheds was obtained and estimated based on soil unit types referred from FAO (1989) soil database adapted to Ethiopia by Hurni (1985) and Hellden (1987). Finally, the value produced during the simulation of hydrological parameters by SWAT by using USLE was used as a k factor of each land use/cover type.

C. Slope length and slope steepness

Both the length (L) and the steepness (S) of the land slope affect the rate of soil erosion considerably. The topographic factor defines the expected ratio of soil loss per unit area from a field slope to that from a 22.1 m length of uniform 9 percent slope. All the other conditions are identical.

It is given by;

$LSUSLE = (hill/ 22.1)\ m * (65.41 * \sin 2\ (\alpha hill) + 4.56 * \sin \alpha hill + 0.065)$

Where Lhill is the slope length (m), m is the exponential term, and αhill is the angle of the slope.

The parameter m is calculated with $m = 0.6 * (1 - ex[-35.835 * slp])$

where slp is the slope of the HRU given as rising overrun (m/m). αhill and slp are related by the equation $slp = \tan \alpha hill$

The LS factor to be used for this study was also obtained from the SWAT model using USLE for the simulation of surface runoff

D. Land use/cover data and crop management factor

A land-use and land-cover map of the study area was prepared from the Google Earth image acquired in 2016, and manual digitizing image classification technique was employed using arc-GIS software. A field checking effort was made to collect ground truth information. The acquired image was used to classify the current land use and land cover map of the study sub-watersheds.. In image classification technique, land use and land cover types were classified. Based on the land cover classification map, a corresponding C value was assigned to each land use/cover, during the simulation of surface runoff.

E. Erosion management practice factor (P-value)

The P-factor was assessed using major land cover and slope interaction adopted by Wischmeier and Smith (2002) for Ethiopia's condition. The data related to management or support practices of the watershed were collected during the fieldwork. Therefore, values for this factor were assigned considering local management practices. The corresponding P values were assigned to each land use/land cover classes and slope classes.

Soil loss estimation

Modified Universal soil loss equation (MUSLE) model was used to assess the water erosion rate of different land use/cover types in two sub-watersheds. Soil erosion and subsequent sediment yield affect watershed hydrology through reservoirs sedimentation. The USLE approach is compatible with the GIS environment, which has been applied for soil erosion assessment in both sub-watersheds. Soil erosion was determined with the help of the USLE (Robert and Hilborn, 2000). Mathematically, the USLE incorporates five factors, as indicated below.

$A=R\times K\times LS\times C\times P$……………………………………………………………….(1)

where A is the mean annual soil loss (ton h−1 year−1), R is the rainfall/runoff erosivity factor (MJ mm ha−1 h−1 year−1), K is the soil erodibility factor (ton h MJ−1 mm−1), LS is the slope length and steepness factor (dimensionless), C is the cover factor (dimensionless), and P is the support practice factor (dimensionless).

USLE factors were obtained from SWAT model output during simulation of runoff and sediment yields which include k-value and LS factors. Only P-Value was estimated based on (Hurni, 1985) adopted for Ethiopian highlands.

The sediment delivery ratio (SDR) denotes the ratio of the sediment yield at a given stream cross-section to the gross erosion from the watershed upstream from the measuring point (Julien and Frenetic, 1998). To generate the sediment yield at the outlet, empirical equations were carried out.

$SDR = A^{-0.2}$ equation………………………………. (2)

Where SDR denotes the sediment delivery ratio and area of the watershed. The SDR physically means the ratio of the sediment routed to the outlet over the watershed, both overland, and channel. Sediment yield is commonly estimated by the following empirical formula:

$Sy=E*(1/A^{0.2})$ equation……………………….. (3)

Where, Sy= Sediment yield (ton) at the watershed outlet; E = total erosion (ton); A = watershed area (ha)

The rate of soil loss of the two sub-watersheds from different land use/cover types was estimated by MUSLE Chancho subwatershed (agricultural land dominated) accounts 73% of farmland with a few woodland covers was compared with Sorga with 69%, 21.5%, and 8.9% agriculture, forest, and urban land dominated sub-watershed, respectively. The subsequent sediment yield of the two sub watershed and reservoirs sedimentation was also compared and contrasted between the two sub-watersheds. Then, the impact of land use/cover types on watershed hydrology in terms of water quality deterioration by sediment and reservoirs storage capacity loss by sedimentation was estimated.

Reservoirs capacity Estimation: The capacity of the reservoir was estimated by measuring the surface area at a full supply level, which also assumes the reservoir as a pyramid whose base is the water surface. However, the volume of the reservoirs also estimated from a simple calculation (Hudson, 1998) by the following equation:

$$C= (A*D) \quad (4)$$

Where A= reservoirs surface area and D= water depth

Reservoirs trap efficiency estimation

Empirical models are normally used for predicting trap efficiency (TE) of the reservoirs. Trap efficiency (TE) is the proportion of the incoming sediment that is deposited, or trapped, in a reservoir or pond (Verstraeten & Poesen, 2000). One of the first researchers to link empirical data on TE to reservoir characteristics was Brown (1943). Brown developed a curve that relates TE to a Capacity–watershed area ratio (C/W) based on data from 15 reservoirs, which is described by the equation:

$$TE = \left(1 - \frac{1}{1+0.0021\, D\frac{C}{W}}\right) \quad (5)$$

Where C is the reservoir storage capacity expressed in m^3 and W is the catchment area expressed in km^2. Values of D range from 0.046 to 1, with a mean value of 0.1 and they are dependent on the characteristics of a reservoir.

3.2.7.2 Estimation of Sediment Volume and Rate of Sedimentation

The sediment volume was computed by converting sediment deposited ton/ha/yr into sediment deposited in volume. Then initial storage capacity and estimated storage capacity were determined by using the following formula Adwubi et al., (2009)

$$SV = RSC_i – RSC_{i+n} \quad 6.$$

Where: SV = Sedimentation Volume (m^3); RSC_i = reservoir storage capacity at an initial year, i (m^3); RSC_{i+n}= reservoir storage capacity n years after i (m^3).

The initial (i) year is the reservoir storage capacity when the dam was constructed and the storage capacity n years after an initial (i) year is the estimated storage capacity. The difference between the two volumes is assumed to be the volume of sediment accumulated in the reservoir.

The rate of sedimentation was calculated by dividing the sediment volume to the age of the reservoir (Equation 7). The economic lifetime (life expectancy) was then derived by dividing the reservoir dead storage capacity (Gebrehawariat and Haile, 1999) to rate of sedimentation (Equation 8)

$$SR = \frac{SV}{Y} \qquad \ldots\ldots 7$$

$$LE = \frac{RSC}{SR} \qquad \ldots\ldots 8$$

Where SR is Rate of sedimentations, SV is sediment volume (m^3), Y is the age of the reservoirs in 2016(in years?), LE is Life expectance of the reservoirs in 2016 (in years???), and RSC is dead storage capacity of the reservoirs

3.2.8 Surface Water Quality Assessment

The effects of land use /cover dynamic on surface water quality of the two sub-watersheds were compared based on laboratory analize of chemical properties of water. Water samples were taken from two reservoirs and a stream. Grab samples were collected by using 0.5liter bottles from respective reservoirs and a stream from March 2016 to February 2017. The samples were taken to the laboratory and analyzed for its PH, TN, TP, TDS, and TSS once every month during a moderate rainfall and dry season and twice during a peak period of the rainy season. The catchment was again divided by the sub-catchment area to determine the spatial distribution of the constituents per respective land use /cover type. The results were statically tested for their normal distribution using a box plot (Appendix 7)

3.2.8.1 Water Sampling

The cluster analysis showed that 8 sampling sites were taken from three different surface water subdivided by considering the dominant land-use types. Water sampling sites were determined based on areas of water inlet,center and outlet. The three sites were designated as forest-dominated surface water, agriculture-dominated surface water, and urban-dominated surface water. Water contamination in the surface water is highly dependent on surface runoff in the surrounding drainage areas. Thus, this finding focused on to compare the effects of dominant land use/cover located near to the surface water within a range of 0.5km radius on water quality.

To capture the proportional effects of each type of dominant land use/cover on water quality, a water sample was taken from the surface water for its chemical property analysis.. So, the study reservoirs and stream water areas were delineated using a GIS and digital elevation model (30 m resolution). The water sample was taken from three different sources, namely, Meka reservoir, which belongs to Chancho agriculture dominated sub watershed, Sorga reservoir, which belongs to Sorga forest-dominated Sub-watershed, and Lega Merga Stream, which is found in Sorga urban -dominated subwatershed(built-up and business activities) (Figure 23 &24).

Water quality deterioration due to different land use/cover undertaken within a watershed was investigated by taking a water sample from reservoirs and streams. Grab samples were collected by using 0.5liter bottle from four sampling sites of Chancho Agriculture-dominated surface water, two sampling sites of Sorga Forest-dominated reservoir, and two sampling sites of Urban-dominated stream water. The samples were taken twice in a month during a peak rainy season and once during the rest of months for one year (March, 2016 - Feb,2017). As a whole, 16 samples per month during a peak rainy season (July through Sep), 8 samples for the rest of months, and a total of 120 samples were taken in a year.

3.2.8.2 Analysis Of Chemical Properties

The samples were taken from respective reservoirs and streams from March 2016 to February 2017 during both dry and rainy seasons. For each watershed, PH, TN, TP, TDS, and TSS were analyzed in the laboratory every month. The analysis for each water quality parameter was undertaken according to the standard of chemical analysis procedures. The samples were taken to Addis Ababa Environmental Protection Laboratory within 24 hrs and analyzed for each water quality parameter.

The pH of the water samples was measured by using a pH meter (model HI 98130 HANNA, Mauritius, Iramac Sdn. Bhd.). The pH meter was calibrated with three standard solutions (pH 4.0, 7.0, and 10.0) before taking the measurements. The value of each sample was taken after submerging the pH probe in the water sample and holding for a couple of minutes to achieve a stabilized reading. After the measurement of each sample, the probe was rinsed with deionized water to avoid cross-contamination among different samples.

The measurements of TSS, TDS, TN and TP in water samples were carried out according to the standard methods of APHA (1995) and Sawyer et al. (2003) by the filtration process. Therefore, the accuracy and precision of the employed methods are well approved and cited in scientific literature. A fixed volume of water sample was poured on a pre-weighed glass fiber filter of a specified pore size before starting the vacuum filtration process. The filter was removed after the completion of the filtration process and placed in an aluminum dish in an oven at 100°C for 2-3 hours to completely dry off the remaining water. The filter was then weighed, and the gain in filter weight represented the TSS contents, expressed in mass per volume of sample filtered (mg/L). The TDS of the water samples was determined by the gravimetric method. After filtration for TSS analysis, the filtrate was heated in an oven at above 100°C until all the water completely evaporated. The remaining mass of the residue represents the amount of TDS in a sample.

3.2.9 LULC Change

Effects of urban land use/cover dynamics on watershed dynamics interms of forest,water and wetland resources was analyzed based on time series land-use-land-cover change of the study area. Land-use-land-cover of the study area were digitized from Google earth images of 1996, 2006 and 2016 during September in each year. The digitized LULC of the study period was exported to Arc-GIS in KML format to convert feature classes into a polygon and change detection technique performed by Arc-GIS 10.

Classified image pairs of three different decade data were compared using cross-tabulation to determine qualitative and quantitative aspects of the changes for the periods from 1996 to 2016. A change matrix was produced with the help of Arc-GIS software.

Quantitative areal data of the overall land use/cover changes as well as gains and losses in each category between the study years were then compiled.

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To assess the effects of urban land use on water quality, water samples were taken twice in a month during peak rain seasons (July-September) and once for the rest of months from October 2016 to June 2017. A total of 42 samples were collected from two sources, namely, Mino stream water located in forested area, very close to the study area with good vegetation cover and little interference from humans and assumed to be good water quality and Laga Merga stream water in urban built-up areas, with pavement and buildings, causing high runoff. The two study areas are found within the same agro-climate zone adjacent to each other. The stream water sample was taken to the Laboratory of Ethiopian Environmental Protection Authority and analyzed for PH, Total Suspended Solid (TSS), Total Dissolved Solids (TDS), Total Nitrogen (TN), and Total Phosphorus (TP).

3.3 Data analysis

Relationships among the considered variables were tested using Pearson's correlation with statistical significance set priori at pb0.05. An independent t-test was used to assess whether a statistically significant difference existed among various land use classes in its hydrological and water quality variables. Water quality variables values and their variation between different land use/cover types within a sub-watershed and between the sub-watersheds were evaluated by an independent sample t-test. All statistical analyses were performed using R and STATA statistical package. This assessment was used to estimate and predict the effect of different land use /cover dynamics on watershed hydrology at varying slope gradient and soils.

Spearman's rank correlation analyses were used to explore the relationships between land use/cover and water quality parameters. Analysis of variance was also performed to test if there were any significant differences between land-use categories at varying soil and slope gradient

The mean value of each water quality parameter for each land use type was calculated by using R and STATA statistical software and statistically tested for its normal distribution. The difference in water quality parameters of the dominant land use/cover(Cultivated, forest and urban) were indicated by using box plot. A combination of spatial and temporal analyses was applied to provide more robust results for the relationship between land use and water quality.

The paried t-test comparisms was used to determine whether the values of the water quality parameters were differed significantly, both spatially and temporally. To determine the significant variations in water quality among the dominant land uses of surface water, paired comparisons were performed using the paired t. test at a significance level of p 0.05. The relationships between water quality parameters were examined using Spearman rank correlation.

Partial least square regression (PLSR) was used to estimate the position of influence of each land use/cover types on hydrological and water quality parameters. The precision of the coefficient of the model also measured by the standard error (SE) and p-value used to measure the statistical significant influences/relationship between each land use/cover types and the variables

The hydrological impacts of each land use/cover type were explored using the Partial Least Squares Regression (PLSR) model. PLSR predicts a set of the dependent variable(s) from a set of independent variables (World et al., 2001 and Abdi, 2010). This prediction is achieved by extracting a set of latent factors (also named latent variables) that have the best predictive power (Abdi, 2007)

The key urban land change were performed after converting the vector maps to raster map by conversion tools in Arc-GIS. The cross-tabulation analysis was conducted to determine the quantitative conversions from a particular category to another land cover category and their corresponding area over the evaluated period on a pixel to pixel basis.

Scatter plots were produced to show the relationship between sediment and nutrient losses with the areas of slope gradient. Then weighted average nutrient losses were calculated for each land use/cover type, soils, and slope and their significance differences were shown by independent t-test at a 95% significance level.

3.4 Materials

The materials used in this study include:

- Integrated SWAT with GIS: input data processing and simulation of the output data
- Global Positioning System (GPS); used to take coordinate points of sampling sites
- Plastic bottles; used to take water sample from the surface water

- Laboratory equipment kits; used for chemical property analysis
- SWAT-Cup: used for uncertainity analysis and model calibration and validation
- STATA software: used for data analysis
- R-based programs for xxx
- Etc mention as exhaustively as possible

4. RESULTS AND DISCUSSION

4.1 EFFECTS OF LULC DYNAMICS ON WATERSHED HYDROLOGY

4.1.1 Sensitivity of Model Parameters

Sensitive parameter analysis was carried out to identify the most sensitive parameters determining the model output. The parameter that had the most influence on the hydrology and hydraulic component was Channel effective hydraulic conductivity (V__CH_K2.rte), which is the most sensitive parameter in the determination of the flow in Chancho sub-watershed and had a sensitivity coefficient p-value of close to zero (Figure 10). Table 4 describes sensitive parameters determines the SWAT model output.

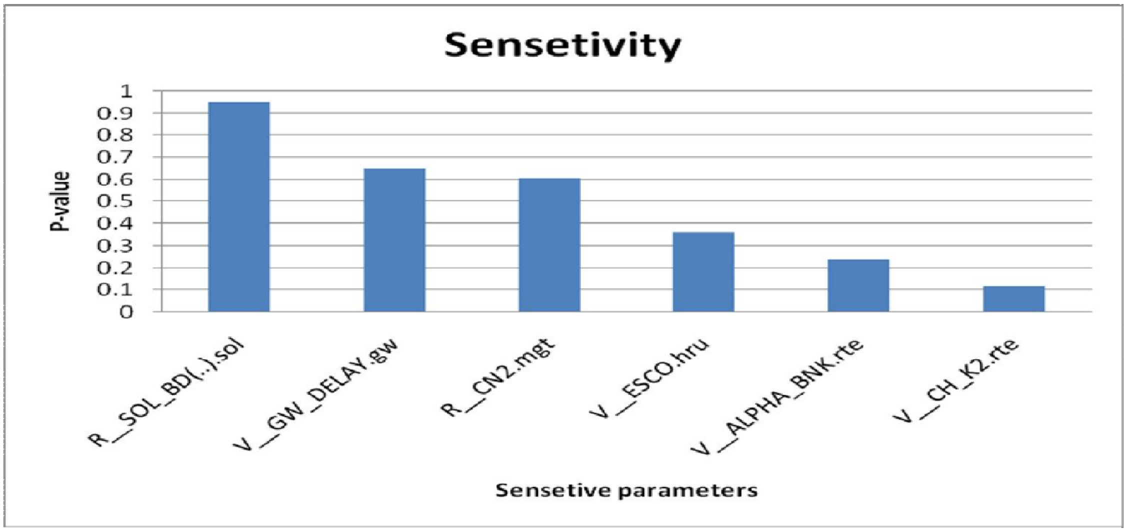


Figure 10. Sensitive parameters to flow in Chancho sub watershed

Table 4: Description of sensitive parameters to simulation flow

Parameter Name	Description
3:R__SOL_BD(..).sol	Soil Bulk Density
2:V__GW_DELAY.gw	Groundwater delay time(days)
1:R__CN2.mgt	SCS runoff Curve Number (*Cn2*)
6:V__ESCO.hru	Soil evaporation compensation factor
4:V__ALPHA_BNK.rte	Base flow alpha factor (days)
5:V__CH_K2.rte	Channel effective hydraulic conductivity (mm/hr)
6.V_GWQMN.gw	Threshold depth of water in the shallow aquifer required for return flow to occur
7.V_ALPHA-BF.gw	Ground water Alpha factor

Global sensitivity analysis uses t-test and p-values to determine the sensitivity of each parameter. The t-stat provides a measure of sensitivity. The larger absolute values indicate more sensitivity. The p-values determine the significance of the sensitivity. A p-value close to zero has more significance. This sensitivity was performed after an iteration process. Therefore, a global sensitivity analysis was used to identify the most sensitive parameters. Accordingly, channel effective hydraulic conductivity (mm/hr) (V__CH_K2.rte) was found to be the most sensitive parameter among six sensitive parameters recognized, followed by the Baseflow alpha-factor (days (V_ALPHA_BNK.rte) for river flow. Groundwater flow Alpha factor (V-ALPHA-BF.gw) was the most sensitive parameter to sediment load followed by the Threshold depth of water in the shallow aquifer required for return flow to occur (V_GWQMN.gw) among four sensitive parameters for sediment (Table 5).

Table 5: Summary of global sensitivity analysis

Variables	Parameter Name	t-Stat	P-Value	Rank
Flow	1:R__SOL_BD (..).sol	-0.06	0.95	6
	2:V__GW_DELAY.gw	0.45	0.65	4
	3:R__CN2.mgt	0.51	0.61	3
	4:V__ESCO.hru	-0.91	0.36	5
	5:V__ALPHA_BNK.rte	1.17	0.24	2
	6:V__CH_K2.rte	1.58	0.12	1
Sediment	1.V_GW_DELAY.gw	-0.15	0.89	3
	2.V_GWQMN.gw	0.39	0.72	2
	3.V_ALPHA-BF.gw	0.45	0.69	1
	4.R_CN2.mgt	-0.85	0.44	4

4.1.2 Calibration and validation of the SWAT parameters

Independently recorded flow data and sediment yield which were monitored and recorded by International water management institute (IWMI) in Chancho sub-watershed and Dhidesa river was used for calibration and validation of the model. Data from Chancho sub-watershed was extrapoliated to be used for model validation in Sorga Sub-watershed

4.1.2.1 Model Calibration

Calibration was performed by using for 20 years flow (January 1994 to December 2013) including three years warm-up periods and 4 years sediment yield in Chancho sub-watershed. The predicted monthly flow and sediment results were compared with the observed monthly discharge recorded from the river flow monitoring station (Figure11). It was found that by using the default parameters, the predicted flow and sediment were very close to the actual data (Figure 12), The SWAT model parameters were calibrated until there was a satisfactory agreement between the predicted flow rate and the observed monitored flow data., the predicted flow was close to the monitored flow rate (Table 6), is also a good agreement between them.

The pridicted monthly sediment load results also compared with the observed monthly sediment load and we found that the pridicted one was close to actual sediment load and the calibration result indicate a satisfactory agreement between them. Generally, the model is regarded to be very good to fit the real-world conditions during calibration and validation periods

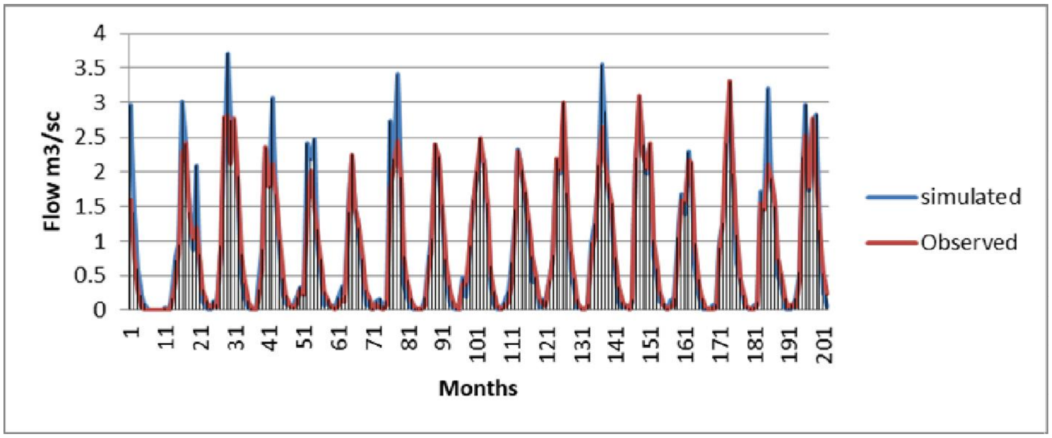


Figure 11: Observed Vs predicted monthly discharge during the calibration period of Chancho watershed

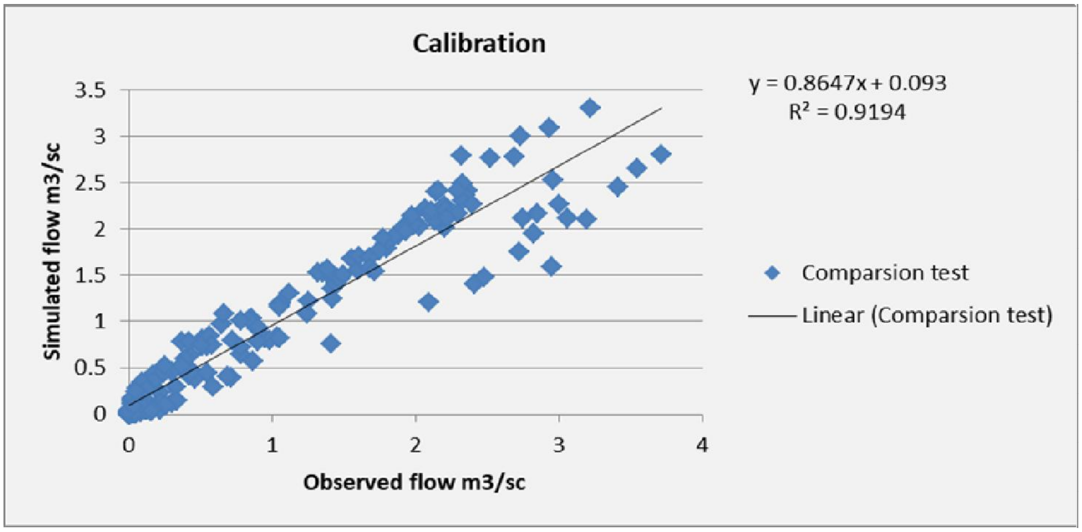


Figure 12: Observed Vs predicted monthly discharge during the calibration period of Chancho watershed

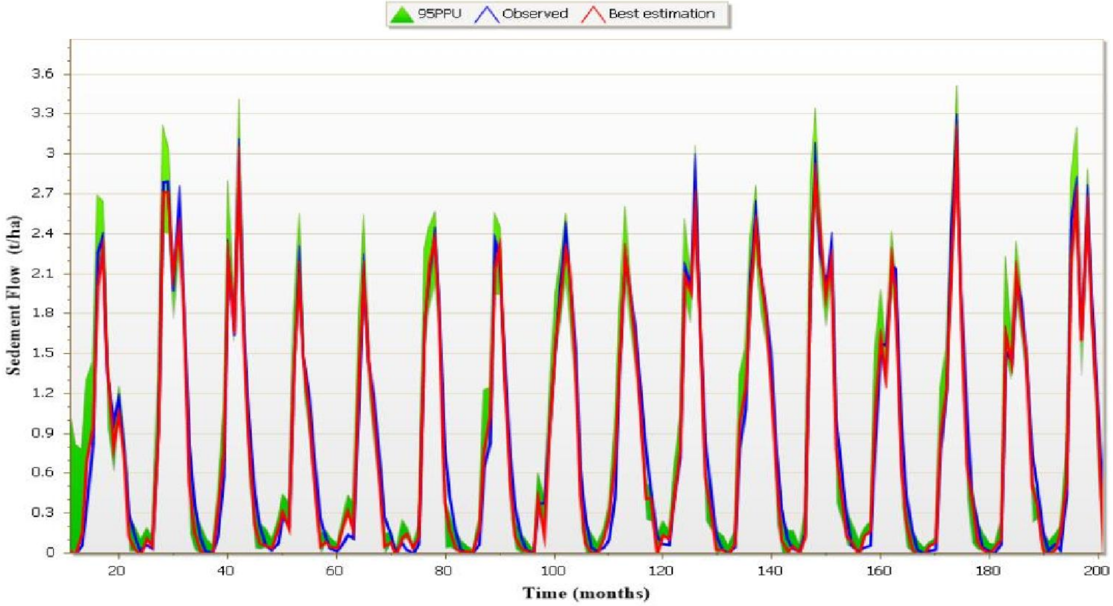


Figure 13: Observed VS pridicted monthly sediment load during calibration periods

4.1.2.2 Model validation

Validation of the model for flow and sediment were done for an independent data obtained form Sorga sub watershed for 20years from 1994 to 2013

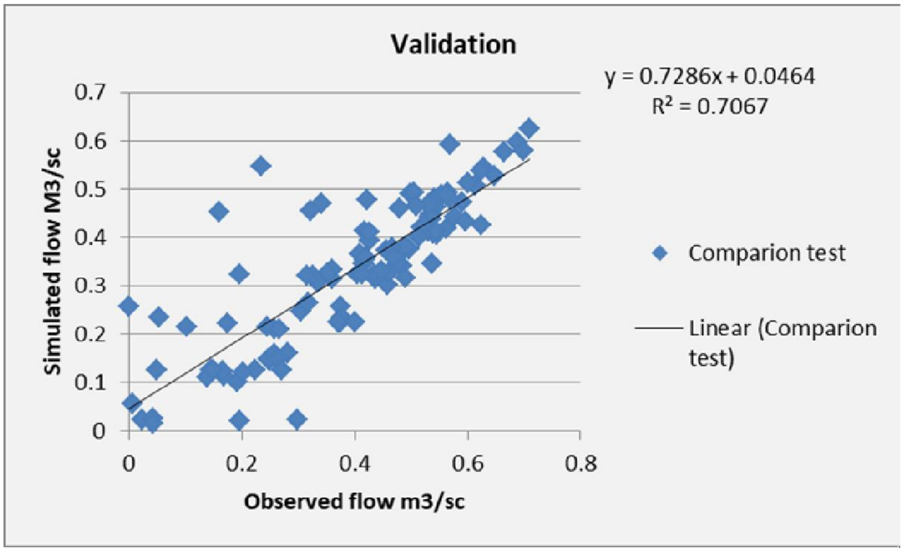


Figure 15: Comparison between observed and predicted river flow for validation period

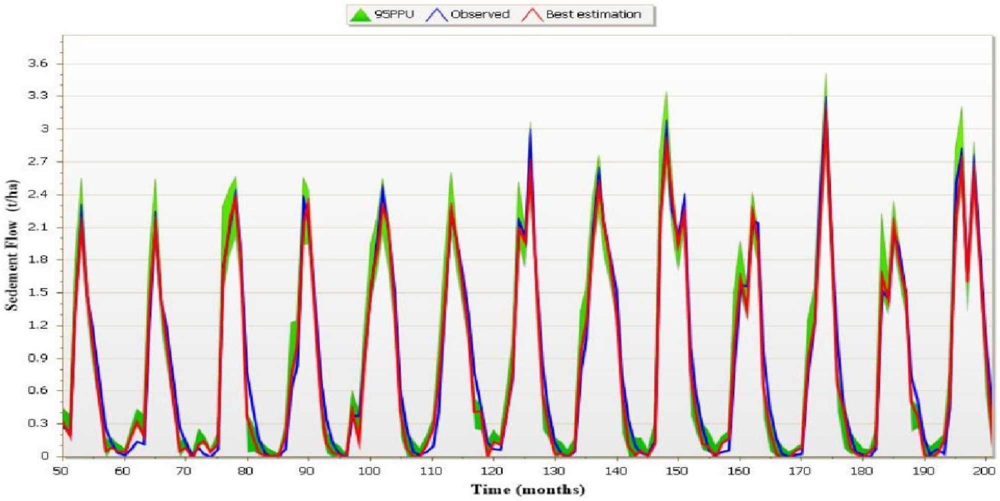


Figure 16: Comparison between observed and predicted sediment flow for validation period

4.1.2.3 Model Evaluation

Model calibration result was found that the model has a strong predictive capability with R^2=0.97, NS=0.96 and RE=0.5 for Chancho sub watershed and model validation is also the very good predictive capacity of the model for river flow rate with a value of 0.83 and 0.74 for R^2 and ENS, respectively. Model calibration and validation for sediment flow also showed a good predictive capacity of the model((Table 6).

Table 6: Evaluation of the accuracy of the SWAT Model

Variables	periods	Coefficient of determination(R^2)	Nash-Sutcliffe coefficients (ENS)	Relative errors (RE)
River flow	Calibration	0.91	0.96	0.5
	Validation	0.83	0.74	0.21
Sediment flow	Calibration	0.78	0.89	0.3
	validation	0.82	0.68	0.211

4.1.3 Effects of Land use/Cover Dynamics on Hydrological Component

The effects of land use/cover dynamics on the watershed hydrology were predicted by SWAT model. The average simulated hydrological component for each land use is relatively different (Table 7)

Hydrological parameters were simulated for different land uses/cover by using 30 years climatic data (1986–2016) soil and topography of the study watershed. This was used to estimate the differences between land use/cover in affecting water balance condition of the study sub watershed. Simulation result of SWAT model indicated that the mean values of Evapo-transpiration (736 ± 16.7) in grassland were higher than cultivated, forest and urban land.The grassland is grater by 27% than cultivated ,20% forest and 29% urban land in ET. The grassland also higher in percolation by 65% grater than cultivated land. The reason for the higher ET of grassland as compared to forestland could be due to dense grass cover of the study sub-watersheds even if the factor (temperature) for ET is the same. The lower value of ETmm. was recorded in urban land (569 ± 7.54), it could be due few vegetation cover in urban area. Grassland is also higher in SW in the study area in which 56%,grater than cultivated ,35% forest and 35% urban land. The higher mean values of surface runoff (642 ± 21) were estimated from urban land followed by cultivated land (641.7 ± 19.2) as compared to the lower surface runoff of forestland (621 ± 14.3) and grassland (610 ± 14.3), this is due impeverious nature of urban and steep slope and continuous cultivation without adequate fallow periods of cultivated land. There were no significant differences ($P>0.05$) between each land use/cover type in ET and surface runoff. Grass and forestland contribute less surface runoff and water yield as compared to the cultivated land; it could be due to more infiltration of grass and forestland (Table 7).

Total water yield (WYLD) gain parameter(Surface runoff, Lateral flow and. ground water flow) and water loss (Evaporation and deep percolation) was taken as the hydrological indicator to investigate the contribution of each land use/cover type to the nearest water stream within the study watershed. All land use/cover types are characterized by uneven contribution of water yield due to difference in land use / cover types. The highest WYLDmm value was simulated in Urban land (1390 ± 29.4) followed by cultivated land(1370 ± 29.4) and the lowest WYLDmm value was simulated from grassland (1343 ±

38) and forestland value 1351 ± 30.5, where increased transpiration and decreased water yield had been recorded. Simulated mean values of percolation and ground water flow were higher in grassland. Lateral flow was higher in urban land as compared to other land use/cover. The mean value of ground water flow (GWmm) was also higher in grassland and the lower mean value of GWmm was simulated in cultivated land with no significant difference detected ($p>0.05$) (Table 5).

Table 7: Simulated mean and staderd error of hydrolgical parameters for 30 years(1986-2016)

Watersheds	LULC	ETmm	SWmm	PERC mm	LAT_Qmm	GWmm	SURQmm	WYLDmm
Sorga	Cultivated	578 ± 8.01 [a]	84. 4 ± 3.4 [a]	694.6 ± 17.3 [a]	76.5 ± 5.9 [a]	653 ± 16.9 [a]	641.7 ± 19.2 [a]	1370 ± 29.4 [a]
	Forest	612 ± 8.4 [a]	97.4 ± 3.4 [a]	702 ± 18.6 [a]	73 ± 5.2 [a]	664 ± 18.1 [a]	610 ± 14. 3 [a]	1351 ± 30.5 [a]
	Urban	569 ± 7.54 [a]	96.8 ± 4 [a]	691 ± 15.16 [a]	79 ± 8 [a]	661 ± 21.08 [a]	642 ± 21 [a]	1390 ± 15 [a]
	Grass	736 ± 16.7 [a]	131 ± 1.9 [a]	736 ± 20.9 [a]	41 ± 1.6 [a]	681 ± 19.1 [a]	621 ± 14.9 [a]	1343 ± 38 [a]

Notes: PERC=Percolation, LAT_Q=Lateral flow, GW= Ground water, SURQ= Surface runoff, WYLD= Water yield and mm=millimeter

[a] Mean values with the same letters are not significantly difference at α = 0.05

The SWAT model has been calibrated to simulate the hydrologic component from land use/cover dynamics in the study watershed. The model application gave satisfactory goodness-of-fit levels. The uneven contributions of mean values of hydrological parameters of each land use/cover types are due to the dominant land use/cover types which result in a change in the water balance of the study sub-watershed.

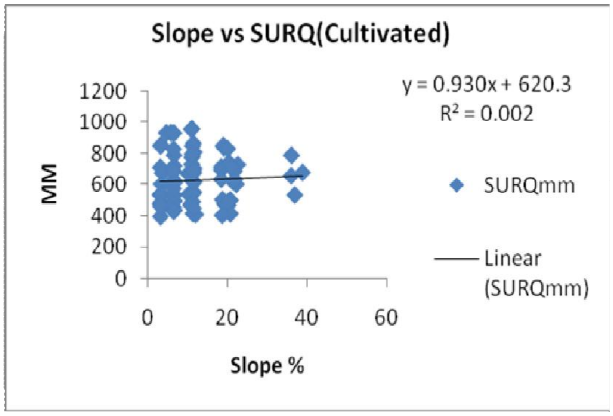
Land use/cover has a strong impact on simulated total water yields in the study sub-watershed. There is a difference in the mean values of ET, SW surface runoff and water yield among land use/cover types. The contribution of each land use/cover type for the spatial distribution of total water yield in sub-watershed was determined based on the relative area distribution of the dominant land use categories in the watershed. The higher surface runoff and water yield were recorded in uraban and cultivated land,respectively than forest and grassland. The result of this study is in agreement with (Karamage et al., 2017) in which surface runoff was increased due to the expansion of cultivated land and urbanization at the expense of vegetation covers in Rwanda. Other studies have also reported the increase of surface runoff due to the expansion of cultivated lands and reduction of vegetative Tekalegn et al. (2017) in Lake Tana catchment and Beles watershed, Ethiopia

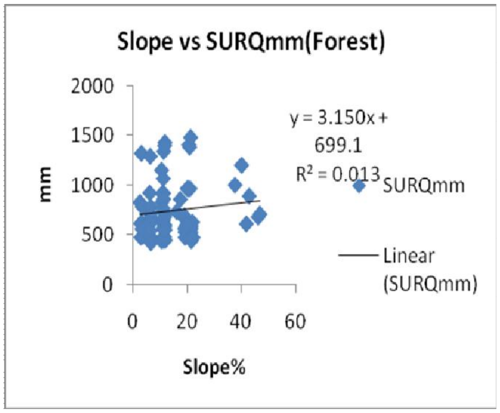
Forest and grassland areas are contributing relatively low water yield due to their higher demand for water and increased evapotranspiration as compared to cultivated and urban land, because of the continuous cultivation of farmland and impervious manmade nature of urban land.

4.1.3.1 The relationship between hydrological variables and slope gradient

This approach evaluated the relationship between the dependent and independent variables to understand any remaining differences. Then, it was found that SWAT simulated variables from different slope gradients of each land use/ cover type at HRUs were subjected to correlation analysis. The result indicated that among hydrological variables, surface runoff was more responsive to changing slope gradient as compared to other variables. There were no relationships between mean values of soil water and lateral flow and slope gradient in all land use/cover types. Percolation is the movement of water to down profile or aquifers which do not contributed water to the stream and assumed as water loss in SWAT. It is not only the combined effects of land use/cover, slope and soil type which influence percolation which was the objective of this research but also the geology matters.

The mean values of percolation, groundwater flow, and water yield were dependent on surface runoff. As surface runoff increased, the values of percolation and groundwater are decreased, whereas water yield value increased and vice-versa, based on this reality, only the correlation between simulated mean values of surface runoff and slope gradient were analyzed by using scatter plot (Figure17). The mean values of surface runoff increased as the slope gradient increased up to 20%, 30%, 15% and then started to decline in cultivated, forest and grassland, respectively, whereas, surface runoff increased as slope gradient increased in urban land (Figure 17). Such a decrease of surface runoff in forest and grassland as slope gradient increases is due to more dense forest and grassland cover beyond 30% and 15% slope gradient, respectively, as overgrazing is widely seen at low lying areas of the study area. In the case of cultivated land, it needs further investigation by using other techniques like; runoff plot. More surface runoff and water yield were recorded at a 15-30% slope gradient.





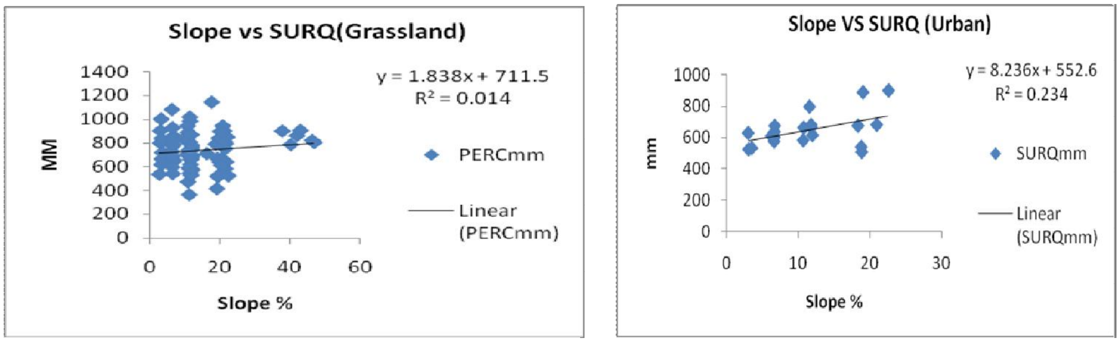


Figure 17: Relationship between ssurface runoff and slope of different land use/cover types

4.1.3.3 Correlation between hydrological variables

The relationship between hydrological component and its role in watershed hydrology based on simulated values of those variables was evaluated. The result of the spearman rank correlation (Table 8) indicates that almost all variables values showed a positive relationship except evapotranspiration and soil water. Water yield, which is the important final output of water balance, depends on water contributing hydrological variables including surface runoff, lateral flow, and ground flow and water losing variables; evapotranspiration, soil water, and percolation which were concluded in the literature. The water percolated to the deep aquifer is assumed to be lost from the watershed system and is not included in the water balance (Neitsch et al., 2011), but the results of this study indicated that percolation showed a strong positive correlation (R^2=0.78) with the total water yield. Percolation also had a strong positive correlation (R^2=0.99) with groundwater. Therefore, surface runoff, groundwater, and percolation had a strong correlation with total water yield, whereas evapotranspiration and soil water content were negatively correlated with water yield (Table 8).

Table 8: Spemann correlation between hydrological variables

	etmm	swmm	percmm	surqmm	lat_qmm	gw_qmm	wyldmm
etmm	1.0000						
swmm	0.3719*	1.0000					
percmm	-0.4039*	-0.0361	1.0000				
surqmm	-0.0557	-0.0399	0.3449*	1.0000			
lat_qmm	0.0139	0.3501*	0.1155	0.0052	1.0000		
gw_qmm	-0.4237*	-0.0499	0.9938*	0.3270*	0.1115	1.0000	
wyldmm	-0.2965*	-0.0171	0.7807*	0.7848*	0.2348*	0.7734*	1.0000

* indicates the parameters have stastically significant relationship at p = 0.05.

The positon of influence of each land use/cover types on the hydrological variables was predicted by using PLSR(Table 9). The precession of the coefficient was measured by Standard error(SE) in which the smaller values indicate the more precise estimate of the model. The statistical relationship between the dependent and independent variables was estimated based on calculated p-value (Table 10)

Table 9: PLSR coefficients showing the influence of LULC types on hydrological variables

Responsive variables	Partial Least Square Regression(PLSR)			
	Cultivated land	Forest land	Grassland	Urban land
ETmm	-0.0424698	+0.013515	+0.2023407	-0.4796288
SWmm	-0.0650835	-0.075013	+0.0791869	+0.063706
PERCmm	-0.4652746	-0.6309885	+0.5090711	+5.989217
SURQmm	-0.5621013	-0.5507281	-1.926571	+4.196231
LAT_Qmm	-0.1005495	-0.1065439	+0.345774	+1.164939
GW_Qmm	-0.4326125	-0.5786489	+0.4876449	+5.593959
WYLDmm	-1.095262	-1.235921	+2.75999	+2.562659

Notes: Positive and negative sign indicates the position of influence of each LULC type

The PLSR result showed that surface runoff was dependent on cultivated, forest and grassland areas on the negative side, while positively dependent on urban land.The negative relashinship indicates that,as area of cultivated,forest and grassland increases the surface runoff decreases but as urban land increases surface runoff also increases(postive infulence) Water yield was negatively dependent on cultivated and forest land and positively on urban and grassland areas. Almost all hydrological variables were dependent on cultivated and forest land areas on a negative side as compared to grassland where all, except ET, were dependent positively (Table 9).

Table 10: Precision of the coefficient and significant relationship b/n LULC and hydrological variables

	Land use /cover types							
	Cultivated		Forest		Grassland		Urban	
Responsive variables	SE	P-value	SE	P-value	SE	P-value	SE	P-value
ETmm	0.082953	0.61	0.105268	0.8983	1.33202	0.8802	0.693942	0.4974
SWmm	0.035557	0.0706	0.059621	0.2133	0.140606	0.5771	0.506138	0.9011
PERCmm	0.165301	0.006	0.273483	0.0246	1.540977	0.7432	1.635484	0.0015
SURQmm	0.149122	0.0003	0.277491	0.0518	1.672324	0.2576	1.436302	0.0084
LAT_Qmm	0.049354	0.0447	0.093966	0.2614	0.101738	0.0018	0.861498	0.1914
GW_Qmm	0.153203	0.0059	0.259867	0.0298	1.455648	0.7397	1.523068	0.0015
WYLDmm	0.245805	0.0000	0.445734	0.0074	3.107862	0.3809	0.910189	0.0107

The precision of the regression coefficients of the model was measured by Standard error analysis (SE) and the result indicated that SW was the more precisely pridicted variable in all land use/cover types than the others combination as its SE were minimum values. LAT_Q, and ET were also precisely predicted in cultivated,forest and grassland as compared to the others combination.Whereas,PERC,SURQ and GW were less precisely predicted as their SE values were higher as compared to the others. The p-values also disclosed the different statically significant relationships between dependent (hydrological variables and independent (Land use/cover types). Percolation (PERC), Groundwater (GW), surface runoff(SURQ) and water yield(WYLD) had a siginficant relationship with cultivated,forest and urban land areas as p-value($P<0.05$).This showed that for the decrease or increase of hydrological variables, vegetation cover is the most important factor in the study area. lateral flow had a signifcant relationship with grassland and cultivated land (Table 10)

4.1.3.4 Interaction effects of land use/cover and soil types on hydrological component

The purpose of this subsection is to assess the effects of soil and land use/cover types on hydrological parameters or water balance of the watersheds. The effect of soil on hydrological component was observed more in cultivated land as compared to other land use/cover types in this study. This approach helps to evaluate the impacts of different soil types of the same land use/cover on hydrological components in order to understand any remaining differences. Accordingly, it was found that SWAT-simulated hydrological parameter values for each land use/ cover and its soil from HRUs were different (Table 11).

In the cultivated land, the mean value of evapotranspiration (ETmm) in the nitisols was 627 ± 32.7, which was higher than that of other soil types. The minimum mean value of ETmm was 590.5 ±19.2 in cultivated land with acrisols. This indicates that nitisols contribute more water losses through evaporation and has a negative effect on the total water yield. Lixisisols in cultivated land were higher in soil water (SW), Percolation (PERC), lateral flow (LAT_qmm), groundwater (GW mm) and total water yield (WYLD) as compared to other soil types. On the contrary, cambisols were higher in the mean of surface runoff as compared to other soil types in cultivated land (Table 9). The mean values of all hydrological parameters from the interaction of cultivated land with soil types have no statistically difference(P>0.05).

In the forestland, the mean value of ETmm was higher in nitisols as compared to other soils and forestland combined. This indicates that forest and nitisols lose more water by evapotranspiration. The mean values of SWmm were higher in forests with cambisols and the combine effects of nitisols with forest were higher in mean values of PERCmm, LAT-Qmm, GWmm, and WYLDmm as compared to other combinations. This result showed that lixisols have more effects on water balance of the watershed in forest land which is similar to the combined effects of cultivated land with lixisols (Table 11).

In the grassland, the combined effects of acrisols with grass cover have more effects on hydrological components than other combinations, except lateral flow and groundwater. In grassland, cambisols and nitisols mean values of lateral flow and groundwater flow were higher than other soils, respectively.

In urban land, mean values of ETmm (588.6 ± 13.5), Swmm (104.8 ± 13.8), and lateral flow (88.4 ± 19.9) was higher in cambisols, and mean values of SURQ, GWmm and WYLDmm were higher in nitisols. The mean values of all variables were not statistically different at (P>0.05).

Table 11: The combined effects of land use/cover and soil types on hydrological parameters(30 years mean values)

		Hydrological variables(mean ± SE)						
Land use	Soil types	Etmm	SWmm	PERCmm	SURQmm	LAT_Qmm	GWmm	WYLDmm
Cultivated	Acrisols	590.5 ±19.2	95.7 ± 8.3	652 ± 37.8	640 ± 29.1	78.5 ± 10	606 ± 35	1324 ± 53.8
	Cambisols	603.8 ± 19.5	76.9 ± 6.6	694.6 ± 37.8	642 ± 31.4	65 ± 9.4	642.8 ± 35	1350 ± 48
	Lixisols	591.0 ±9.17	103 ±4.7	754 ± 24.3	654 ± 31.7	83 ± 7.4	695 ± 22.7	1445.8 ± 49.5
	Nitisols	627.0 ± 32.7	82.7 ± 14.2	631 ± 37.2	628.7 ± 73.8	82.4 ± 19.2	580 ± 35	1291 ± 102
Forest	Acrisols	559.0 ± 14.8	85.6 ± 7.9	685.6 ± 32.8	489 ± 26.5	50 ± 6.2	639.8 ± 30	1179 ± 42.6
	Cambisols	593 ± 11.4	99.8 ± 7.1	706.9 ± 50.8	632.6 ± 55	68.7 ± 5.79	652.5 ± 50.6	1353,9 ± 101
	Lixisols	610 ± 14.4	82 ± 10.8	697.6 ± 60	659 ± 60	79 ± 8.85	646.6 ± 48.3	1385 ± 103
	Nitisols	554.9 ± 15.2	82 ± 11.4	750.9 ± 61	737.5 ± 16.1	67.7 ± 15.4	689 ± 60	1394± 105.9
Grass	Acrisols	727.8 ± 38.3	137 ± 12.6	751 ± 68	750 ± 85.6	35.4 ± 3.8	679 ± 71.7	1425 ± 157.4
	Cambisols	684.7 ± 22.2	132. 6 ±2.04	724 ± 41.6	644.8 ± 49.6	45 ± 2.8	671.5 ± 38.5	1361 ± 87
	Nitisols	754.9 ± 21.9	130 ± 2.68	738.9 ± 26.4	669.7 ±26.5	40.5 ± 2.09	684.8 ± 24.8	1395 ± 51
Urban	Cambisols	588.6 ± 13.5	104.8 ± 13.8	745 ± 29.2	607 ± 8.9	88.4 ± 19.9	687 ± 26.9	1393 ± 13.7
	Lixisols	559.7 ± 13.4	91.2 ± 8.9	750 ± 42.4	589.9 ± 21.8	76.6 ± 20	692 ± 39.5	1402 ± 24
	Nitisols	552.7 ± 13.4	90.5 ±9.18	746 ± 49.6	669.7 ± 49.7	60 ± 15.8	708 ± 46.39	1437 ± 11,5

Notes: ET=Evapotranspiration, PERC=Percolation, LAT_Q=Lateral flow, GW= Ground water, SURQ= Surface runoff, WYLD= Water yield and mm=millimeter

Mean values of all hydrological variables for the combined land use/cover types and soil types are not significantly difference at α = 0.05

The interaction effects of land use/cover and soil types indicated that different soils influence the result of hydrological parameters differently. A combination of cultivated land and lixisols produced a higher mean value of soil water, groundwater flow, percolation, lateral flow, groundwater and total water yield as compared to other interactions. This is due to the well-drained and highly weathered characteristics of lixisols. Cultivated land and cambisols have produced more surface runoff than other combination Cambisols is less in accommodating nutrient as compared to other soil types. Evapotranspiration was higher in cultivated land with nitisols. In forest land, nitisols is dominant in affecting the hydrological dynamism of forest land for all hydrological component of the water balance as compared to other soil types. In grassland and urban land, there were no clear cut impacts of the combination of land cover with its soil types rather influenced by the cover types as compared to cultivated and forestland.

The correlation between hydrological component in this study indicated that in a water balance, evapotranspiration and soil water are losses whereas, percolation, surface runoff, lateral flow, and groundwater flow are gains, but in others water balance equations, they considered deep percolation as a loss. In this study, however, percolation had a positive correlation with total water yield (Table 8).

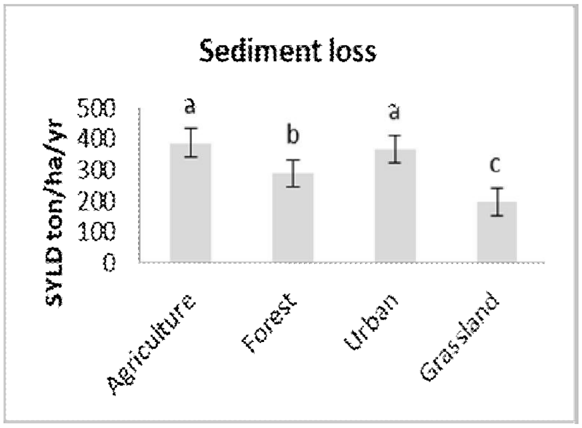
Land use/cover types of a watershed affect the watershed hydrology by infulenceing the hydrological components at HRUs. Cultivated land contributes more runoff and water yield to the downstream reservoir and affects the hydrology of the watershed through the loss of fertile topsoil from the farmland, resulting in low productivity of land and water quality reduction and sedimentation. On the contrary, the land cover with relatively high forest and grass coverage contribute a balanced water input and output and, as a result, it contribute less in the dynamics of watershed hydrology. Change in watersheds hydrology in terms of water balance are mainly affected by the land use/cover followed by the interaction of land use/cover with slope and lesser with soil types. Therefore, the result of this study indicated that the most determinant factor for current and future change in watershed hydrology could have resulted from variation in land use/cover followed by slope and lesser by soil types

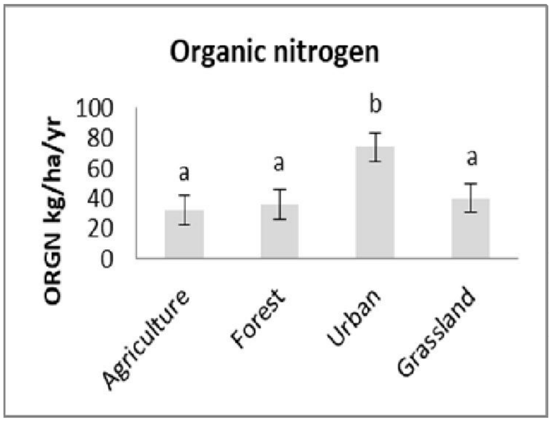
4.2. SEDIMENT AND NUTRIENT LOSSES FACTORS

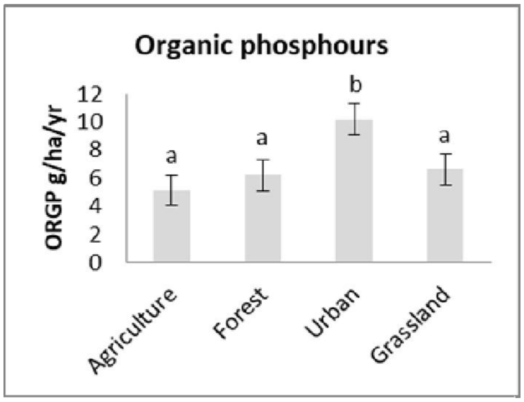
4.2.1 Sediment and nutrient loss status of land use/cover

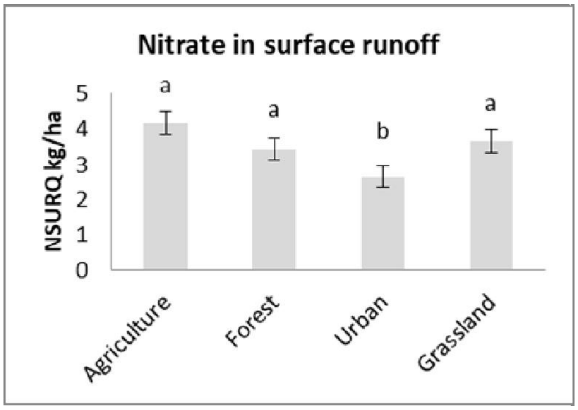
SWAT model calibration and validation result discussed in the previous section indicated that simulated sediment flow is in a good agreement with observed sediment flow in the two study sub-watersheds. Therefore, the model has the capacity to predict sediment and nutrient flow from land use/cover dynamics of study sub-watershed.

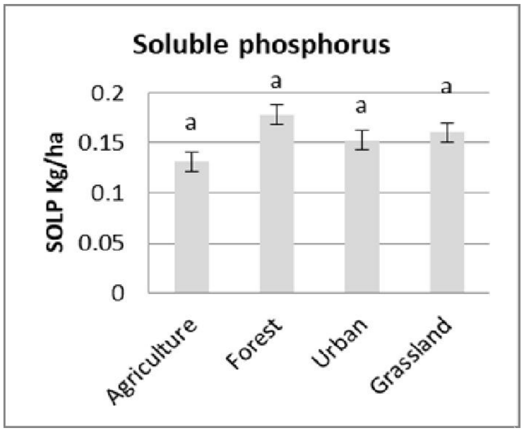
The simulation results of sediment loss t/h/yr disclosed that cultivated land produced more sediment than all other land use/cover types, but statistically had no significant differences. The mean value of sediment loss in cultivated land was 404t/h/yr followed by urban land, which produced 387t/ha/yr. In contrast, the other land use/cover (forest and grassland) produced averagely less amount of sediment (312t/h/yr and 230 t/ha/yr), respectively. Cultivated land was 43% and 22.8% grater in sediment loss than forest and grass lands,respectively.The mean value of sediment loss in cultivated land was significantly different($p<0.05$) than forest and grassland. The highest mean value of sediment in the case of cultivated land is due to continuous cultivation of steep land without fallow and inappropriate soil and water conservation measures (Figure 19)

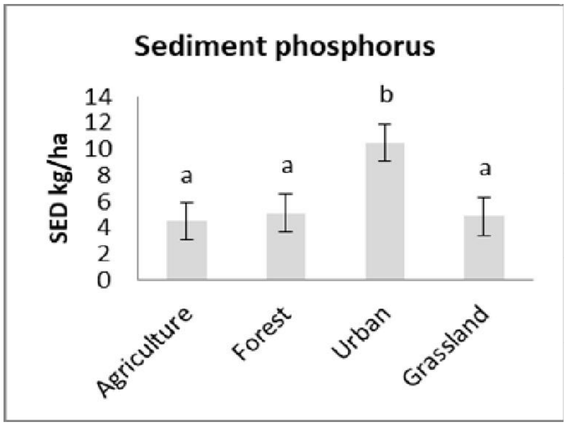


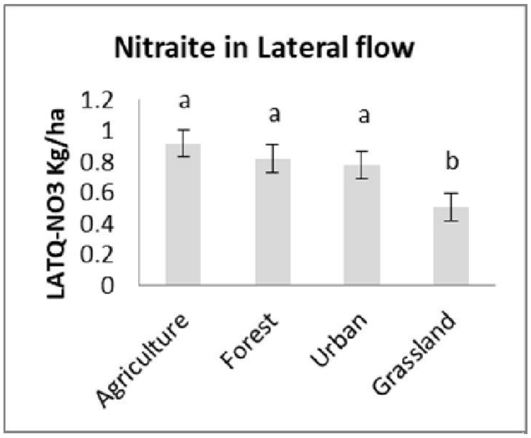


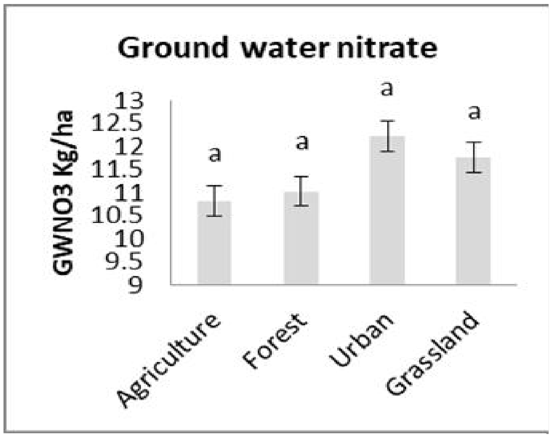

Organic phosphours


Nitrate in surface runoff


Soluble phosphorus


Sediment phosphorus


Nitraite in Lateral flow


Ground water nitrate

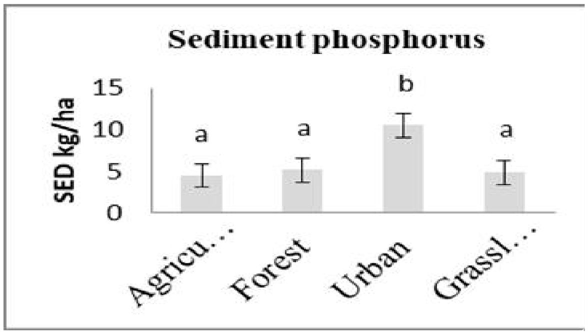


Figure 19. Comparison of simulated values of sediment between different LULC types

The mean values of organic nitrogen (ORGNkg/h) and ORGP kg/ha from Urbanland was significantly higher (P< 0.05) than the other land use/cover types (Figure19). The simulated mean value of ORGN (73.84 kg/ha) was high in urban land as compared to lower values of agriculture (32.17kg/ha), forestland (36.05kg/ha) and grassland (40.25kg/ha).The mean value of organic phosphorus (ORGP) is also higher in urban land (10.17g/ha) than grassland (6.62g/ha), forestland (6.2g/ha) and cultivated land (5.1g/ha).This higher ORGN kg/ha in urban land is due to more urban influent containing ORGN released to the water environment.

The simulated mean values of nitrate in surface water (NSURQkg/ha) was higher in the urban land (12 kg/ha) than cultivated, forest and grassland (11.2kg/ha 11.3kg/ha and 10 kg/ha), respectively, with no statistical difference (p>0.05) between them. The mean values of ground water nitrate (GWNO$_3$kg/ha) was higher for urban land (12kg/ha) than cultivated, forest and grassland (mean= 11.2kg/ha, 11.4kg/ha and 11.9kg/ha), respectively, with no significant difference among them (Figure 19).

More soluble phosphors (SOLP) loss was produced from urban land as compared to other land cover/ uses (mean== 0.18kg/ha) and others land use/cover types almost produce similar amount of soluble phosphorus (Figure 19).

The mean value of sediment phosphors from urban land (10.48kg/ha) was significantly higher (p<0.005) than cultivated (4.49kg/ha), forestland (5.12kg/ha) and grassland (4.85kg/ha) (Figure 19)

The lateral flow of nitrate (LAT_Q_NO_3) was relatively high in cultivated land(0.92kg/ha) as compared to forestland(0.82kg/ha).urban land(0.78kg.ha) and grassland(0.5kg/ha) with significant difference($p<0.05$) with a grassland (Figure 19) .The mean value of ground water nitrate (GWNO_3) flow was higher in urban land(12.2kg/ha) than cultivated,forest and grassland(10.8kg/ha,11kg/ha and11.7kg/ha),but no significant difference between them (Figure 19)

The SWAT model has been calibrated and validated before simulating the water quality variables. The model application gave satisfactory goodness of fits levels. The uneven contribution of mean values of sediment and nutrient transport from HRU of different land use/cover types, soil and slope gradient within watersheds is due to the dominant area coverage of land use/cover types and its interaction with their respective slope categories and soil types.

In cultivated land, sediment losses from HRUs in a particular point indicated higher values as compared to the other land use/cover types in the study sub-watershed. The easy transport of sediment from cultivated field is due to continuous and steep slope cultivation without fallowing and inappropriate soil and water conservation practices. The dynamism of the watersheds was resulted more by the loss of fertile top soil from farmland by runoff, water quality reduction and reservoirs sedimentation. However, the amount of sediment transport from HRU of different land use/ cover type varies, mainly in the slope gradient differences and, to a lesser extent, soil types within that particular HRU. Urban land also contributes more sediment to the downstream next to cultivated land, due to high runoff from impervious and paved surface of land. Grassland and forestland contribute less amount of sediment transport to the downstream reservoir. This less contribution of grass and forestland are due to high resistance to surface runoff and increased infiltration capacity of the land. The simulated mean values indicated that cultivated land transports more sediment by 42% & 22.9% greater than grass and forest land, respectively.

Therefore, more of change in watersheds hydrology in terms of nutrient and sediment loss and subsequantly water quality problem and sedimentation of reservoir mainly arises from cultivated land. Conversion of forest and grassland to cultivated land leads to a change in watershed capacity to support the life of terrestrial and aquatic organisms.

Expansion of urban build-up at the expense of forest and grassland also contributes a considerable transport of sediment to the downstream and results in water quality deterioration and siltation of reservoir.

The simulated mean values of organic nitrogen (ORGN), organic phosphorus (ORGP), and nitrate in surface runoff (NSURQ) kg/ha from urban land uses were higher than the mean values of the other land uses. This is due to the release of solid, liquid and other effluents from urban residence to the nearby stream, a situation which mainly affects the quality of water that is used for irrigation and for animal drink in the study sub-watershed. Therefore, urban land contributes 63% and 51% of ORGNkg/ha greater than grass and forestland to the downstream water bodies from a specific HRU, respectively, and 16% and 5% of nitrate transport with surface water to the water bodies greater than forest and grassland, respectively. The finding of this research confirmed that forest and grassland covers play greater role in safeguarding the dynamisms of watershed hydrology. On the contrary, urban and cultivate land are the main factors affecting the normal function of hydrological process.

The mean value of lateral flow of nitrate (LATQNO_3) from cultivated land was higher than the other land uses; this is due to the addition of inorganic nitrogen fertilizer to the cultivated land and leaching of nitrate to the soil profile. Hydrological effects of land use/cover types in terms of ground water quality reduction due to nitrate loading are mainly observed from cultivated land; hence, cultivated land is estimated to cause 41.8% of nitrate transport to the ground water, more than the grassland does.

4.2.2 The interactions effects of land use/cover and soil types on sediment and nutrient loss

The simulated mean value of sediment and nutrient transported from each HRU from the interaction of different land use/cover types and soil types showed different values based on the combination of the two independent variables(Table 12)

Sediment Loss

The mean value of sediment loss (380t/h) from the interaction of cambisols and cultivated land was higher than the mean values of lixisols, nitisols and acrisols combined with cultivated land (317t/h, 141.04t/h and 243t/h), respectively. Cambisols and lixisols in cultivated land were significantly ($P < 0.05$) greater than nitisols, but no significant difference between the combined effects of cultivated land with cambisols, lixisols and acrisols (Table 12)

The interaction of cambisols and forest land produced a higher mean value of sediment loss (200.29 t/ha) than the other soils and forestland combination. The lower value was recorded in nitisols (138.4t/ha)**.** Cambisols in forestland is not significantly different ($P>0.05$) from nitisols in sediment loss, yet there is no significant difference with lixisols (Table 12)

The combined effects of grassland with cambisoles produced more mean value of sediment loss (357.36t/ha) than the other combined (acrisols and nitisols). There was a significant difference ($p<0.05$) between grassland with cambisols and acrisols.

The higher mean value of sediment loss was recorded in a combination of cambisols with cultivated, forest and grassland; the simulated mean values of the model results were different in terms of the overall sediment loss. Nevertheless, the amount of sediment produced from each combination in order of difference was cultivated land + cambisols >grassland+ cambisols >forest land + cambisols in sediment transport than other soil types in all land use/cover types, whereas, others combined showed the inconsistency of mean value of sediment loss(Table 12)

Organic nitrogen (ORGN) loss

Organic nitrogen transport was higher in acrisols of cultivated land (38.05kg/ha) as compared to the lower mean value of cambisols (26.9kg/ha) and had no significant difference ($P>0.05$) among the other combined (Table 12)

The interaction of forestland with nitisols contributed to more organic nitrogen loss (43kg/ha) than other combinations, and the minimum value was recorded in cambisols (34.8kg/ha). There is no significant difference between the interaction of forestland and soil types in terms of organic nitrogen loss from HRUs (Table 12).

In grassland, cambisols lose more organic nitrogen (43.7kg/ha) than acrisols (40kg/ha and nitisols 37.4kg/ha), and with no significant difference (P>0. 05) among them (Table 10). The interaction of different LULC with soil types showed inconsistency values of organic nitrogen losses. Therefore, Soil is less influential in organic nitrogen transport as compared to LULC type

Table 12: Mean values of sediment and nutrient transport from LULC and soil combined for 30 years (1986-2016)

LULC	Soils	Sediment and nutrient loss from the combination of LULC and soil types					
		Simulated mean values of sediment and nutrient(Mean + S.E)					
		SYLDt/ha	ORGNkg/ha	ORGPhg/ha	NSURQkg/ha	LATQNO3kg/ha	GWNO3kg/ha
Cultivated	Acrisols	243.79 + 65.57^{a}	38.05 + 3.59^{a}	6.42 + 0.68^{a}	16.34 + 9.05^{b}	1.05 + 0.14^{a}	11.77+ 1.12^{a}
	Cambisols	380.25 + 129.8a	26.98 + 4.07^{a}	4.07 + 0.55^{a}	10.82 + 6.35^{b}	0.64 + 0.08^{a}	10.51+ 1.03^{a}
	Lixisols	317 + 67.32^{a}	35 + 2.58^{a}	5.742 + 0.46^{a}	3.67+ 0.34^{a}	0.89+ 0.1^{a}	10.43 + 0.61^{a}
	Nitisols	141.04 + 102.01^{b}	28.73 + 7.97^{a}	5.04 + 1.52^{a}	4.6 + 1.64^{a}	1.08 + 0.37^{a}	10.43+ 2.35^{a}
Forest	Cambisols	200+57.95^{b}	34.99 + 3.14^{a}	6.58 + 0.7^{a}	3.96 + 0.39^{a}	0.94+ 0.15^{a}	11.19 + 0.62^{a}
	Fluvisols	13.65 + 5.86^{b}	25.44 + 10.24^{a}	3.46 + 1.22^{b}	2.37 + 0.01^{a}	0.39 + 0.31^{a}	4.49 + 3.23^{b}
	Lixisols	157.04 + 36.34^{b}	36.15 + 5.78^{a}	6.06 + 0.72^{a}	9.13 + 5.2^{b}	0.87 + 0.13^{a}	11.68 + 0.99^{a}
	Nitisols	138.43 + 46.27a	43.08.94 + 4.95^{a}	7.42 + 1.51^{a}	3.74 + 0.62$_{a}$	0.58 + 0.1^{a}	11.34 + 2.6^{a}
Grass	Acrisols	137.22 + 63.66^{b}	40.86 + 3.56^{a}	8.1 + 1.11$_{a}$	4.54 + 0.49^{a}	0.46 + 0.07^{a}	10.8 + 1.86^{a}
	Cambisols	357.36 + 84.67^{a}	43.78 + 5.33^{a}	6.82 + 0.72^{a}	11.08 + 0.02^{b}	0.46 + 0.05^{a}	10.48 + 1.02^{a}
	Nitisols	211.99 + 44.23^{a}	37.4 + 2.24^{a}	5.81 + 0.3^{a}	3.08 + 0.28^{a}	0.52 + 0.04^{a}	12.57 + 0.66^{a}

Notes: SYLD=sediment loss, ORGN=Organic Nitrogen, ORGPh=Organic phosphors, NSRUQ=Nitrate in surface runoff, $LATQNO_3$=Nitrate in lateral flow, $GWNO_3$=Nitrate in Ground water

[a] Different superscript letters in column indicate significant difference at α = 0.05

Groundwater Nitrate (GWNO3)

Simulated mean values of all variables vary between land use/cover types based on their soil type in the study sub-watershed. The simulated mean value of groundwater nitrate (GWNO3) was high in acrisols combined with grassland and cultivated land (12.57kg/ha and 11.97kg/ha), respectively, as compared to other combined between soil types and LULC types. There is no significant difference ($p>0.05$) between all the combinations of cultivated, forest, and grassland with soil types (Table 12).

Nitrate in Surface runoff (NSURQ)

The results from the simulated mean values showed that the interaction of land use/cover and soil types produced different values of NSURQ in different land use/cover types. The interaction of cultivated land with acrisols was higher in nitrate loss in surface runoff (16.34/ha) than cambisols, lixisols and nitisols values of NSURQ (mean of, 10.8.2kg/ha, 3.67kg/ha and 4.6kg/ha), respectively. The mean value of NSUWQ in cultivated land with acrisols was significantly different ($P<0.05$) than other combined (lixisols and nitisols) with cultivated land (Table 12).

Forestland in combined with lixisols produced more mean value of NSURQ (9.13kg/ha) than cambisols and nitisols and had a significant difference ($p<0.05$) among them. Forestland with cambisols and nitisols was produced a lower value of NSURQ (3.96 kg/ha and 3.74kg/ha).Grassland in combined with cambisols produced more mean value of NSURQ (11.06kg/ha) than acrisols and nitisols (4.54kg/ha and 3.08 kg/ha) and had a significant difference ($P<0.05$) among them. There is no consistency in values of NSURQ from the combination of land use/cover and soil types between the three land use; this showed that cover factor is more influential in controlling surface runoff as compared to soil types (Table 12)

Lateral flow of nitrate (LATQNO3)

The simulated mean values of nitrate transported by lateral flow from each HRU between the interactions of land use/cover types with soil types were compared The mean values of LATQNO$_3$ in the interaction of cultivated land with nitisols (1.08kg/ha) and acrisols(1.05kg/ha) was higher than the other combined but no significant difference among them. In forestland, LATQNO3 was higher in cambisols (0.94kg/ha) than the minimum values of nitisols (0.58kg/ha) with no significant difference ($P>0.05$). In grassland, nitisols produced a relatively high mean value of LAEQNO3 than other combined, but no significant among them. The interaction of different LULC and soil types produced inconsistence mean value of LATQNO3 between each other of the same soil types (Table 12)

The simulated mean values of sediment transported from the interaction of land use/cover and soil types indicated that slight differences are recorded in the same soil type under different land use/cover types. The result of the interaction of cultivated land and grassland with lixisols produced the higher value of sediment transport to the downstream from HRU of a given land use/cover types. This is because lixisols is a highly weathered and well-drained soil with very low nutrient content, according to USDA Soil Classification and Description (USDA, 2007). The interaction of forestland and cambisols produced more sediment transport to the downstream as compared to other soils. Fluvisol and urban land interaction resulted in more sediment transport as compared to other soils, but the combination of lixisols, cambisols, and fluvisols with other land use/cover type showed a minimum value of sediment and nutrients transport from HRU, all resulting in different mean values of sediment and nutrient transported from the interaction of different land-use cover types and soil. No similar mean value recorded between the same soil types under different land use/cover types. This showed that soil types are less influential in determining the amount of sediment and nutrient transported from HRU than land use/cover types.

4.2.3 Combined Effects of land use/cover and slope gradient in sediment and nutrient loss

4.2.3.1 Comparison of sediment and nutrient loss within each land use/cover type and slope gradient

Simulated mean values of sediment and nutrient transported from the interaction of different land use/cover types and slope gradient showed different values among land use/cover types. Each land use/cover type produced different sediment and nutrient losses under a similar slope gradient. Therefore, the combined effect of land use/cover types and slope gradient was analyzed and evaluated for each land use/cover type separately (Table 13).

Cultivated land

The model output indicated that the interaction of cultivated land with slope gradient (15-30%) produced higher values of sediment loss (383t/h/yr) than other combined. The lowest value was recorded at the slope gradient >30 %(269t/h/yr). This result indicated that, as the slope gradient increased from 0-5% to 15-30%, sediment values also increased with no significant difference between mean values of other combined. As slope continues to increase beyond 30% slope gradient sediment loss was started to decline in such combinations.

The result showed that higher mean values of ORGN and SEDP (40.03kg/ha & 4.41kg/ha), respectively, are recorded at slope gradient 15-30% in cultivated land than other interactions. The lowest mean value of both nutrients was observed at the slope gradient >30%. As slope gradient increased, the values of both nutrient also increased until it reaches 30% slope and then started to decline with no significant difference between them(Table 13)

The simulated mean values of organic phosphors (ORGPh), nitrate in surface runoff (NSURQ), soluble phosphors (SOLP) showed a similar trend in responding to changed slope gradient in cultivated land. As the slope gradient increased, the values of those variables also increased, but no significant difference among their mean values (Table 13).

The simulated mean values of NO_3 transported in the groundwater loading from the HRU varied based on the combination of cultivated land and slope gradient. A higher mean value of $GWNO_3$ (12.4kg/ha) was recorded at 5-8% slope gradient and the lowest was produced at >30% slope gradient (9.7kg/ha). Groundwater nitrate transport decreased as slope gradient increased beyond >30%, but have no significant difference (Table 13)

Forestland

The interaction of forest land and slope gradient at (15-30%) slope produced a higher value of sediment (342t/h/yr) than the other combinations, but statistically had no significant difference. The lowest sediment value was recorded at the slope gradient of 0-5%(202t/h/yr).This result indicated that as the slope gradient increased from 0-5% to 15-30%, sediment values also increased, but it later started to decline.

Organic nitrogen (ORGN), sediment phosphors (SEDP), and nitrate in later flow ($LAQTNO_3$) in a combination of forest land with slope gradient showed that higher mean values of those variables were recorded at 5-8% slope gradient. As the slope gradient of forest land increased beyond this range, the values of ORGN, SEDP, and $LATNO_3$) declined. This indicates that high and dense forest is located at the steeper land in the study area.

The simulated mean value of $GWNO_3$ transported in forest land under different slope gradient almost showed a similar trend with no significant difference among them, but it showed a minimum mean value difference where slope gradient 15-30% produced more as compared to others combination (Table 13).

Urban land

A combination of urban land and slope gradient at (15-30%) produced a higher value of sediment (461/h/yr) than the other combinations, with no significant difference among the mean values. The lowest sediment value was recorded at the slope gradient of 0-5 %(309t/h/yr). This result indicated that, as the slope gradient increased from 0-5% to 15-30%, sediment values also increased in urban land (Table 13).

The mean value of organic nitrogen transport produced in urban land showed a decreasing trend as the slope gradient increased. The value decreased from 79 kg/ha to 70kg/ha as the slope gradient increased from 0-5% to 15-30%. Similarly, sediment phosphorus losses also decreased as the slope gradient increased, with no significant difference among the mean values. Nevertheless, the value of $LATNO_3$ in urban land decreased as the slope gradient increased.

The simulated mean values of organic phosphors (ORGPh) nitrate in surface runoff (NSURQ), soluble phosphors (SOLP) from urban land under all slope gradients showed increasing trends in responding to the changing slope gradient. As the slope gradient increased, the values of those variables also increased, but no significant difference among their mean values (Table 13). .Grassland and forest land responded similarly to the changing slope gradient for the values of ORGPh, NSURQ, and SOLP in the study areas.

In urban land, as the slope gradient increased, the mean value of $GWNO_3$ was almost constant and showed no change until it reaches 15% slope gradient and then reduced. The highest $GWNO_3$ (13.1kg.ha) was simulated at15% slope as compared to the lowest mean value (10kg/ha) at >30 slope gradient, with no significant difference among the mean values. As slope gradient increased in grassland, $GWNO_3$ flow reduced (Table 13)

Grassland

Grassland and slope gradient at (15-30%) produced higher mean value of sediment (350t/h/yr) than the other combinations and had a significant difference ($P<0.05$) with lower values recorded at slope gradient 5-8%, 8-15% and >30 % (45t/h/yr) (Table 13).

The combined effects of grassland and slope gradient on organic nitrogen showedinconsistency trend in values. The effects of slope gradient change on grassland had less influence on the amount of this nutrient loss from HRUs. Sediment phosphors value was higher at 0-5 % (5.8kg/ha) slope gradient than the lowest mean value at >30 % slope (2.6 kg/ha) in grassland and had a significant difference at ($P<0.05$) among the mean values. (Table 13)

Table 13: Mean values of simulated sediment and nutrient transport at different slope gradient from land use/cover types for 30 years

LULC	Slope class	Losses of Sediment and Nutrient from different slope gradient							
		SYLDt/ha	ORGNkg/ha	ORGPhg/ha	NSURQkg/ha	SOLPkg/ha	SEDPkg/ha	LATQNO3kg/ha	GWNO3kg/ha
Cultivated	0-5%	316^{a}	38.935^{a}	5.904^{a}	3.114^{a}	0.139^{a}	4.991^{a}	0.713^{a}	11.944^{a}
	5-8%	373^{a}	37.934^{a}	5.965^{a}	2.876^{a}	0.122^{a}	5.017^{a}	0.776^{a}	12.409^{a}
	8-15%	347^{a}	38.562^{a}	6.078^{a}	3.779^{a}	0.160^{a}	4.792^{a}	0.660^{a}	10.990^{a}
	15-30%	383^{a}	40.031^{a}	6.097^{a}	5.610^{a}	0.136^{a}	5.441^{a}	0.731^{a}	12.017^{a}
	>30%	269^{b}	36.948^{a}	6.396^{a}	5.662^{a}	0.162^{a}	4.189^{a}	0.941^{a}	9.790^{a}
Forest	0-5%	202^{a}	37.240^{a}	5.466^{a}	2.470^{a}	0.155^{a}	5.352^{a}	0.727^{a}	10.609^{a}
	5-8%	216^{a}	42.271^{a}	6.486^{a}	3.029^{a}	0.165^{a}	5.501^{a}	0.964^{a}	11.254^{a}
	8-15%	259^{a}	34.872^{a}	6.055^{a}	3.734^{a}	0.198^{a}	5.201^{a}	0.837^{a}	11.427^{a}
	15-30%	342^{a}	34.125^{a}	5.827^{a}	3.596^{a}	0.179^{a}	5.006^{a}	0.875^{a}	11.847^{a}
	>30%	328^{a}	31.759^{a}	7.141^{a}	4.336^{a}	0.192^{a}	4.556^{a}	0.696^{a}	10.020^{a}
Urban	0-5%	309^{a}	79.180^{b}	9.861^{a}	1.957^{a}	0.088^{a}	11.310^{b}	0.711^{a}	12.366^{a}
	5-8%	374^{a}	72.594^{a}	10.158^{a}	2.650^{a}	0.157^{a}	10.704^{a}	1.005^{a}	12.742^{a}
	8-15%	431^{a}	73.250^{a}	10.588^{a}	3.237^{a}	0.200^{a}	10.071^{a}	0.716^{a}	12.396^{a}
	15-30%	461^{a}	70.371^{a}	10.084^{a}	2.769^{a}	0.167^{a}	9.846^{a}	0.697^{a}	11.355^{a}
Grass	0-5%	236^{a}	38.136^{a}	5.618^{a}	2.966^{a}	0.122^{a}	5.828^{a}	0.523^{a}	13.115^{a}
	5-8%	15^{b}	41.868^{a}	7.018^{a}	3.812^{a}	0.171^{a}	4.600^{a}	0.557^{a}	12.135^{a}
	8-15%	35^{b}	39.160^{a}	6.577^{a}	2.946^{a}	0.173^{a}	6.592^{a}	0.438^{a}	11.184^{a}
	15-30%	193^{a}	40.359^{a}	6.165^{a}	3.241^{a}	0.161^{a}	4.564^{a}	0.522^{a}	11.758^{a}
	>30%	45^{b}	41.755^{a}	7.733^{a}	5.287^{a}	0.175^{a}	2.673^{a}	0.5^{a}	10.556^{a}

Notes: SYLD=sediment loss, ORGN=Organic Nitrogen, ORGPh=Organic phosphors, NSRUQ=Nitrate in surface runoff, SOLP=Soluble phosphors, SEDP=phosphors in sediment, LATQNQ=Nitrate in lateral flow, GWNO3=Nitrate in Ground water

Different superscript letters in column indicate significant difference at $\alpha = 0.05$

The positon of influence of each land use/cover types on sediment and nutrient loss was predicted by using PLSR(Table 12).The precession of the coefficient was measured by Standard error(SE) in which the smaller values indicate the more precise estimate of the model. The statistical relationship between dependent and independent variables was estimated based on calculated p-value (Table 14)

Table 14:PLSR coefficients showing the influence of LULC types on sediment and nutrient losses

	Partial Least square Regression(PLSR)			
Responsive Variables	Cultivated land	Forest land	Grassland	Urban land
SYLD	-0.2777759	-1.10005	+0.1475041	+0.2818633
ORGN	-0.0019379	+0.059971	+0.2190819	+0.3118414
ORGP	+0.0640199	-0.0058893	+0.0252104	-0.1527747
NSURQ	-0.000082	+0.0258661	+0.0242768	+0.4705982
SOLP	-0.001643	+4.90E-06	+0.0018076	-0.0143317
SEDP	-0.001643	-0.0059437	+0.056999	+0.0601099
$LAT\_Q\_NO_3$	-0.0004015	-0.0004934	+0.0059795	-0.0086873
$GWNO_3$	+0.002732	-0.0079262	+0.1208354	-0.1036791

Notes: Positive and negative sign indicates the position of influence of each LULC types

The PLSR result showed that sediment was negatively influenced by cultivated and forest land areas and positively to grass and urban land areas. It indicates that as the area of cultivated and forest land increases sediment loss decrease. organic phosphorus (ORGP) was dependent on cultivated area in a negative side and positively to forest, grassland and urban areas. Nitrate in surface runoff(NSURQ) and Soluble phosphorus(SOLP) were negatively influence by cultivated land area and positively to the other land use/cover types. Sediment phosphorus(SEDP) and nitrate in lateral flow($LAT\_Q\_NO_3$) were negatively influenced by cultivated and forest land areas and negatively by grass and urban land areas. Nitrate in groundwater($GWNO_3$) was positively influenced by cultivated and grassland areas and negatively influenced by forest and urban land areas.Therefore, Land use/cover type and its area importantly influence the change in the amount of nutrient loss from HRUs(Table 14)

Table 15: Precision of coefficient of PLSR model and statistical significance relation between dependent and independent variables

Responsive variables	Land use /cover types							
	Cultivated		Forest		Grassland		Urban	
	SE	P-value	SE	Pvalue	SE	P-value	SE	P-value
SYLD	0.477261	0.0971	0.926203	0.6256	3.016294	0.7052	5.262066	0.0000
ORGN	0.015713	0.6603	0.048026	0.0828	0.177053	0.2248	0.55005	0.0122
ORGP	0.002865	0.5168	0.00646	0.0845	0.020813	0.2528	0.068139	0.0068
NSURQ	0.002877	0.3517	0.003182	0.5777	0.017917	0.657	0.006098	0.0000
SOLP	0.000103	0.673	0.000186	0.0802	0.001182	0.3858	0.000436	0.0000
SEDP	0.002861	0.7526	0.0071	0.5999	0.041788	0.2003	0.053909	0.1912
LAT_Q_NO3	0.000613	0.4764	0.001389	0.4545	0.001864	0.0064	0.011486	0.1583
GWNO3	0.004265	0.567	0.008057	0.1811	0.032322	0.0013	0.039911	0.0000

Notes: SE= Standard error

The precision of the regression coefficients of the model was measured by Standard error analysis (SE) and the result indicated that ORGP,NUSQR, SOLP, LATNO3, and $GWNO_3$ were more precisely predicted under all land use /cover type as compared to others water quality variables. The p-values also disclosed the different statically significant relationships between dependent (water quality variables and independent (Land use/cover types). All water quality variables had no significant relationship with cultivated and forestland, While all had a significant relationship with urban land except SEDP and $LATNO_3$. Grassland had a significant relationship with $LATNO_3$ and $GWNO_3$ but no significant relation with other water quality variables(Table 15).This indicates that urban land with no vegetation cover is the most important factor for the watershed dynamisms in terms of nutrient flow within a watershed.

4.2.3.2 The combined effects of land use/cover and slope gradient in sediment and nutrient losses

The model output (Table 13) indicated that, the interaction of urban land with slope gradient (15-30%) produced higher values of sediment loss (461t/h/yr), followed by the interaction of cultivated and forestland with slope gradient (15-30%), which resulted in higher mean value (383 &342t/h/yr) than the other combinations. The minimum value was recorded under the interaction of grassland and slope gradient (15-30%) and 5-8% (mean=190 & 15 t/h/yr), respectively. The reason for the sediment loss decrease beyond 15-30% slope in agricultural land is due to the low frequency of tillage as the soil at steeper land is shallower, but in case of grassland, more grass cover as slope goes beyond 30% in the study area.

Organic nitrogen transported from each HRU of different land use/cover types and slope gradient showed a varied result as the slope increased under all land use/cover types. The interaction of urban land with all slope range produced a higher ORGN kg/ha than other land use/cover types. The maximum mean value of ORGN was recorded from the interaction of urban land with 8-15% slope (73kg/ha/yr) and had significant difference at ($P<0.05$) than other lands of the same slope gradient, that is, cultivated land (47 kg/ha), forestland (34 kg/ha), and grassland (39 kg/ha). The least mean value of ORGN (mean of, 32.9 kg/ha) was recorded from cultivated land at the slope gradient of 0-5% (Table 13).

The simulated mean values of organic phosphors (ORGPh), nitrate in surface runoff (NSURQ), soluble phosphors (SOLP) from forestland under all slope gradient showed increasing trends in responding to changed slope gradient similar to cultivated land. As the slope gradient increased, the values of those variables also increased, with no significant difference among their mean values (Table 13)**.**

The amount of phosphorus stored in the stable organic phosphorus and transported from each HRU of land use/cover types varied at different slope gradient. Each land use/cover type produced different ORGP within and between slope ranges. The highest simulated mean value was recorded from cultivated land (mean = 15.45 g/ha/yr) at the slope range (8-15%), as compared to the other combined followed by urban land, which produced a mean of 10.5g/.ha/yr of ORGP at the slope ranges of 8-15%. The minimum ORGP transported was observed under cultivated land (mean=5.05g/ha/yr) at 0-5% slope. Cultivated land transported higher ORGP than other land types at all slope ranges and had a significant difference at ($P<0.05$) than the interaction of other land uses and slope range except for urban land (Table 13).

The simulated mean value of nitrate transported with surface runoff varies depending on the interaction of land use/cover type with the slope gradient. Cultivated land at 8-15% slope produced more nitrate in surface water than other combinations (mean=4.6 kg/h/yr). Forestland also produced a higher mean value of NSURQ (mean=4.3kg/ha) at 30% slope gradient next to cultivated land and followed by grassland at the slope range of >30% with mean values of 3.8 kg/ha. The minimum value of NSURQ was recorded from urban land at the slope range of 8-15% with a value of (1.59 kg/ha) (Table 13).

The mean values of mineral phosphorus absorbed to sediments and transported from each HRUs of land use/cover and slope gradient was high at 8-15% slope range for all land use/cover types. The higher mean value was produced from urban land at the slope range of 5-8 %(Mean= 11.3 kg/ha) than the other interactions, followed by forest land at the same slope produced SEDP (mean of,5.8kg/ha). The minimum mean value was recorded from grassland at slope range >30 %(men of, 2.67kg/ha).

The simulated mean values of NO_3 transported with the groundwater loading from the HRU vary based on the nature of land use/cover and slope gradient. The higher mean value of $GWNO_3$ was recorded from cultivated land at a slope of 30% than other interactions within and between land use/cover types. Grassland at slope 0-5% produced more $GWNO_3$ (mean=11kg/ha) next to cultivated land and forestland, which produced less or minimum mean value under all interactions as compared to others (Table 13).

The simulated mean value of sediment and nutrient transported from the interaction of different land use/cover types and slope gradient showed different values between land use/cover types. Each land use/cover type was produced different sediment and nutrient losses under a similar slope gradient. Therefore, the combined effect of land use/cover types and slope gradient analyzed and evaluated for each land use/cover type separately (Table 13).

The model output indicated that the interaction of cultivated land with the slope gradient (15-30%) produced the higher values of sediment. AS slope gradient increases up to 30% slope of cultivated land, the value of sediment increased then after the declined. The interaction of forestland and slope gradient at (15-30%) slope produced a higher value of sediment but statistically had no significant difference. This result indicated that as the slope gradient increased from 0-5% to 15-30% sediment values also increased then after declined in cultivated land(Figure 20). A combination of urban land and slope gradient at (15-30%) produced a higher value of sediment with no significant difference among the mean values. This result indicated that as the slope gradient increased from 0-5% to 15-30% sediment values also increased. Grassland and slope gradient at (15-30%) produced a higher mean value of sediment than the combination of the others and had a significant difference ($P<0.05$). The mean value of sediment increased as slope increases from 5-15% slope then after declined (Figure 20)

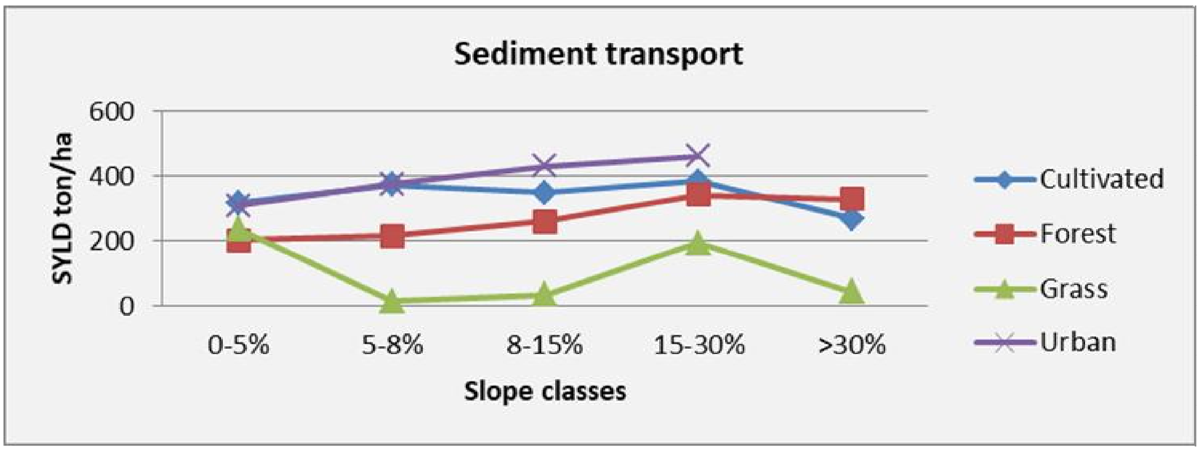


Figure 20: Sediment losses of Each LULC types in a different slope gradient

The higher mean values of ORGN recorded at the slope gradient 15-30% in urban land . As slope gradient increased the values of ORNP increases in urban until it reaches 30% slope.But the combination of cultivated,forest and grass land with slope gradient showed almost a similar ORNP values with no significant difference between them **(**Figure 21)

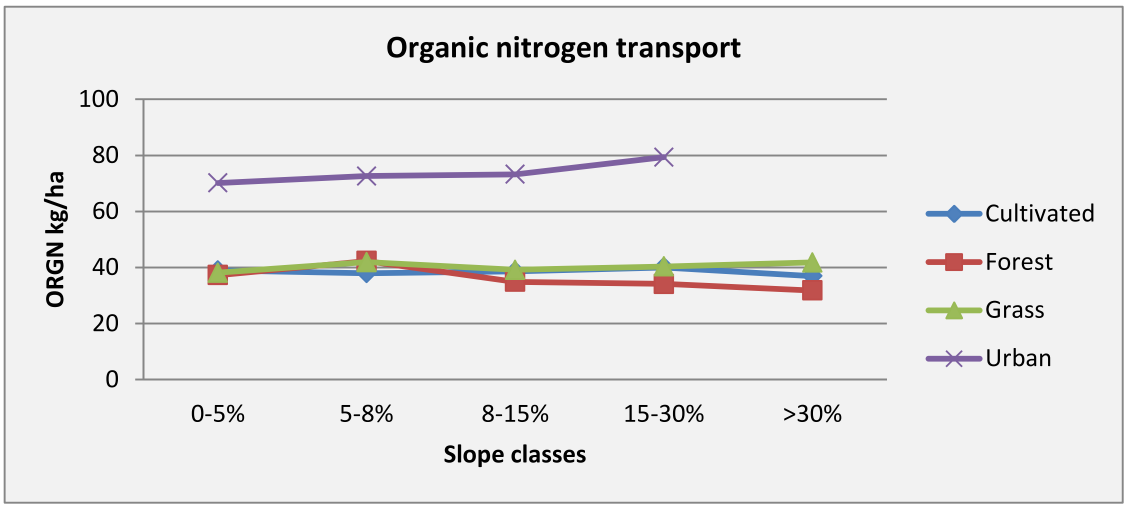


Figure 21: Organic nitrogen losses of Each LULC types in a different slope gradient

Nitrate in the lateral flow (LAQTNO$_3$) in a combination of forest land and slope gradient showed that, the higher mean values of those variables were recorded at 5-8% slope gradient. As the slope gradient of forestland increased beyond this range the values of $LATNO_3$ were declined (Figure **22**) this indicates that high and dense forest is located at the steeper land in the study area.

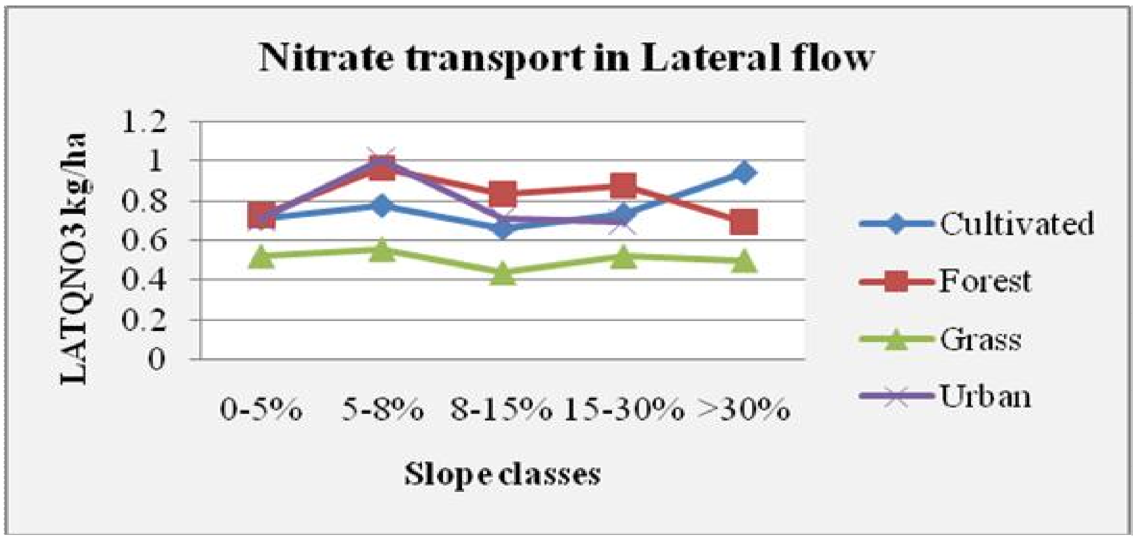


Figure 22 Nitrate losses in lateral flow of Each LULC types in a different slope gradient

The simulated mean values of NO_3 transported into the main channel in the lateral loading from the HRU was varied based on the combination of cultivated land and slope gradient. Nitrate transport in the lateral flow is decreased as the slope gradient increased beyond >30% in cultivated land. The simulated mean value of NO_3 transported in the lateral flow of forestland under different slope gradient was almost showed a similar trend with no significant difference among them (Figure 22). Nitrate loss in lateral flow of Each LULC types in a different slope gradient

The simulated mean values of sediment phosphors (ORGPh), nitrate in surface runoff (NSURQ), were shown a similar trend in responding to the changed slope gradient in cultivated.forest and grassland. As slope gradient increased the values of those variables were also increased until it30% slope and then decline. with no any significant difference among their mean values.Sediment phosphorus value showed a declined trend as slope gradient increases in urban land (Figure 23&24).

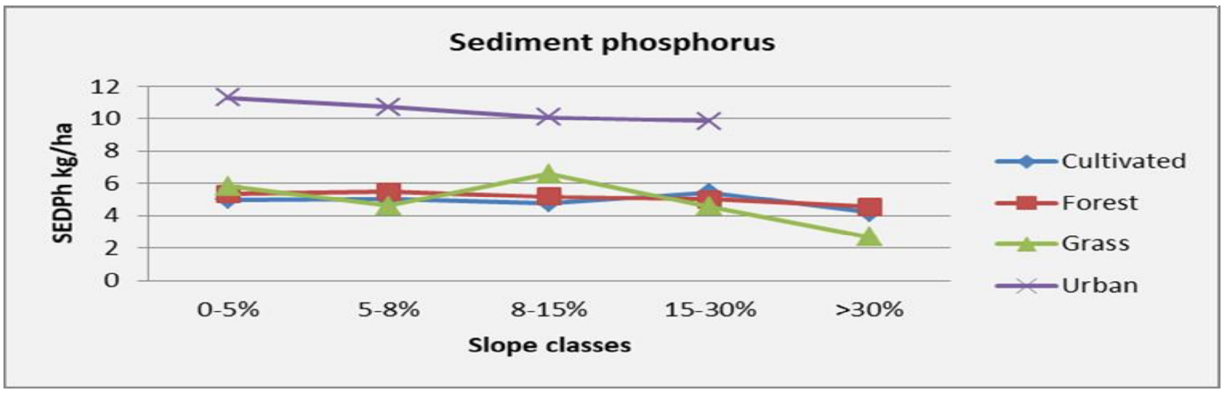


Figure 23: Sediment phosphorus losses of Each LULC types in a different slope gradient

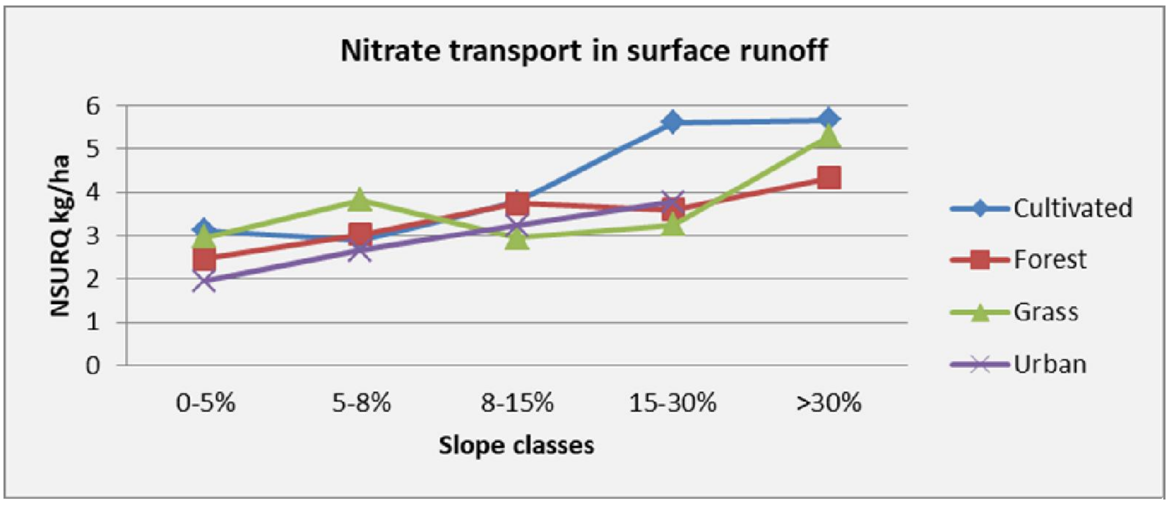


Figure 24: Nitrate losses in surface runoff of Each LULC types in a different slope gradient

The simulated result from the interaction of land use/cover and slope gradient indicated that, as slope gradient increased up to 15%, sediment and nutrient transport/ loss increased and then decline beyond 15% slope in cultivated land. These results are compatible with the findings reported by Xiaowen (2017) in Canada. The positive correlation between gradient and total phosphorus(TP) concentration was clear when the gradient was <15%, while the increase in TP concentrations slowed as the gradient increased, indicating that the TP concentration would not increase limitlessly with an increasing gradient in agricultural fields. In forestland, it increased until the slope reaches 10% and then after, it declined, while it increased as the slope of urban land increased

4.2.3.3 Correlation between sediment, nutrient transport and slope gradient of land use/cover types

Correlation analyses were undertaken between water quality variables and slope in order to understand the relation between variables and slope gradient and with variables**.** The relationships between slope and water quality variables and among water quality variables vary depending upon land use/cover type. Therefore, the analysis was done for each land use/cover type (cultivated, forest, grass, and urban land) (Table 16, 17, 18 &19).

Spearman`s rank correlation analysis indicates that the correlation between slope and sediment transport from HRU of cultivated, forest, and urban land had a slight positive correlation (r=0.106,0.0013 & 0.086), respectively, which means that, as the mean slope increases, the mean of sediment transport showed a slight increase. In contrast, as the mean slope increased, the simulated value of sediment transport under grassland decreased and had a negative relationship with each other.

The correlation between organic nitrogen transported and mean slope indicated that, as the mean slope increased, the value of ORGNkg/ha also increased under cultivated and forest land and had a slight positive relationship between them. As the slope increased, simulated mean values of ORGN under grassland and urban land decreased and had a negative relationship with each other.

The correlation between mean slope and all water quality variables in forestland indicated that, as the slope mean increased, all variables also increased and had a slight positive relationship among them. The mean slope of cultivated land had a slight positive relationship with sediment, organic nitrogen, organic phosphorus, sediment phosphorus and lateral flow of nitrate and had a negative correlation with Nitrate in surface runoff and groundwater nitrate.

The mean slope of grassland had a positive correlation with organic phosphorus, nitrate in surface runoff, and soluble phosphorus transport on the one hand and a negative relationship with other water quality variables, on the other. Urban land had a positive correlation between mean slope and sediment yield, nitrate in surface runoff, soluble phosphorus, and nitrate in lateral flow and had a negative correlation with organic nitrogen, organic phosphorus, and sediment phosphorus.

The correlation among water quality variables showed different relationships depending on their respective land use/cover types.

In cultivated land: Sediment phosphorus and organic nitrogen, organic N and P, soluble P and nitrate in surface flow, groundwater nitrate and nitrate in lateral flow had a strong positive correlation with each other, while sediment yield and soluble P had a strong negative correlation and the others variables had a slight positive and negative relationship with each other (Table 16).

In forestland: Sediment loss and sediment P, organic N and nitrate in lateral flow, organic P and nitrate in lateral flow, soluble P and nitrate in surface flow and organic N & P had a positive correlation with each other, but none of the variables was strongly negatively correlated with each other (Table 17).

In grassland: Sediment loss with organic N and sediment P, organic N & P, sediment P & organic P and soluble P nitrate in surface runoff had a strong positive correlation with each other, and sediment loss and soluble P had a strong negative correlation with each other (Table18).

In urban land: Sediment P and organic N, nitrate in lateral flow and organic N, organic N and nitrate in surface runoff, soluble P and nitrate in surface flow, organic N and nitrate in groundwater had a strong positive correlation with each other, while the reaming variables had a slight positive and negative relationship with each other (Table 15).

Table 16: Spearman`s rank correlation between water quality variables of cultivated land

```
             |    slope  syldtha orgnkgha orgphgha nsurqk~a solpkgha sedpkgha latqno~a gwno3k~a
-------------+---------------------------------------------------------------------------------
       slope |   1.0000
     syldtha |   0.1063   1.0000
    orgnkgha |   0.1006   0.3162*  1.0000
    orgphgha |   0.1101   0.1145   0.8898*  1.0000
   nsurqkgha |  -0.0429  -0.4296*  0.2095*  0.4701*  1.0000
    solpkgha |  -0.0089  -0.6274*  0.1512   0.4190*  0.8374*  1.0000
    sedpkgha |   0.1411   0.7325*  0.6590*  0.4890* -0.3334* -0.3315*  1.0000
 latqno3kgha |   0.0468  -0.1184   0.3826*  0.4112*  0.5175*  0.4352* -0.0336   1.0000
   gwno3kgha |  -0.0349   0.1992*  0.4554*  0.2638*  0.1796*  0.0942   0.3071*  0.5824*  1.0000
```

* indicates the parameters have stastically signifcant relationship at p = 0.05

Table 17: Spearman`s rank correlation between water quality variables of forest land

```
             |    slope  syldtha orgnkgha orgphgha nsurqk~a solpkgha sedpkgha lat_q_~a gwno3k~a
-------------+---------------------------------------------------------------------------------
       slope |   1.0000
     syldtha |   0.0013   1.0000
    orgnkgha |   0.0963   0.2180   1.0000
    orgphgha |   0.1769   0.1046   0.8797*  1.0000
   nsurqkgha |   0.1772  -0.1649  -0.1535   0.0832   1.0000
    solpkgha |   0.0089  -0.2348* -0.1041   0.1167   0.6690*  1.0000
    sedpkgha |   0.0060   0.6442*  0.4050*  0.2630* -0.3925* -0.2056   1.0000
lat_q_no3k~a |   0.1439   0.0894   0.5881*  0.5725*  0.0882  -0.0778   0.1087   1.0000
   gwno3kgha |   0.0989   0.2203*  0.2089   0.0146  -0.1564  -0.0693   0.4801*  0.2192   1.0000
```

Table 18: Spearman`s rank correlation between water quality variables of Grass land

```
             |    slope  syldtha orgnkgha orgphgha nsurqk~a solpkgha sedpkgha latqno~a gwno3k~a
-------------+---------------------------------------------------------------------------------
       slope |   1.0000
     syldtha |  -0.0785   1.0000
    orgnkgha |  -0.1198   0.5223*  1.0000
    orgphgha |   0.0175   0.2078   0.7975*  1.0000
   nsurqkgha |   0.1001  -0.5570* -0.0763   0.3276*  1.0000
    solpkgha |   0.0780  -0.7422* -0.2003   0.1909   0.7963*  1.0000
    sedpkgha |  -0.1118   0.8331*  0.6844*  0.4198* -0.4987* -0.5224*  1.0000
 latqno3kgha |  -0.0190  -0.3957* -0.0019   0.1107   0.5670*  0.3589* -0.3623*  1.0000
   gwno3kgha |  -0.2211   0.2298   0.3706*  0.0522  -0.1168  -0.1327   0.3929*  0.4351*  1.0000
```

* indicates the parameters have stastically signifcant relationship at p = 0.05

Table 19: Spearman`s rank correlation between water quality variables and slope of Urban land

```
             |    slope  syldtha orgnkgha orgphgha nsurqk~a solpkgha sedpkgha latqno~a gwno3k~a
-------------+---------------------------------------------------------------------------------
       slope |   1.0000
     syldtha |   0.0865   1.0000
    orgnkgha |  -0.0301  -0.2222   1.0000
    orgphgha |  -0.0071  -0.4176*  0.7274*  1.0000
   nsurqkgha |   0.0980  -0.5791* -0.0597   0.5249*  1.0000
    solpkgha |   0.0381  -0.6335* -0.1068   0.4607*  0.9108*  1.0000
    sedpkgha |  -0.0235  -0.0115   0.7187*  0.3596  -0.2425  -0.1380   1.0000
 latqno3kgha |   0.1853   0.0660   0.5422*  0.5896*  0.1478  -0.0876   0.1831   1.0000
   gwno3kgha |  -0.0460  -0.4444*  0.7307*  0.3202  -0.0930  -0.1169   0.6524*  0.2110   1.0000
```

. The correlation between slope gradient and sediment yield indicated that cultivated, forest and urban land had a positive relationship, whereas, grassland had a negative relationship with the slope gradient. More nutrients had a positive correlation with the slope gradient of cultivated land, except nitrate in surface runoff, soluble p, and groundwater nitrate. The slope of forestland had a positive relationship with all nutrients. In grassland, more nutrient loss had a negative correlation with the slope gradient, except organic p and nitrate in surface runoff. The slope gradient in urban land had a negative correlation with organic N &P, sediment p and nitrate in groundwater and positively correlated with the other nutrient types. The result of this study indicated that sediment and nutrient transported from the interaction of land use/cover and slope gradient affect the watershed dynamics and hydrology significantly. Moreover, the existing land use/cover types of watershed is the most important factor affecting watershed dynamism.

Therefore, the result of this study indicated that sediment and nutrient transported from each HRU from the interaction between land use/cover and soil types in affecting watersheds hydrology is not significant; rather, it is determined by the existing land use/cover in the watershed and slope gradient. Land use/cover are the most important factors influencing the dyanisms of a watershed hydrology in terms of sediment and nutrient transport from HRU, followed by the slope gradient. The effect of soil variation of land use/cover types showed insignificant change on the amount of sediment and nutrient transport in the study the sub-watershed and soil type is not an important factor in influencing the result of sediment and nutrient loss status of different land use/cover types in the study areas.

SWAT as an analytical tool would help us to predict the plausible sediment and nutrient transport and its consequences on watershed hydrology and it is a very comprehensive water quality analysis tool. The simulated values of sediment flow were close to the actual monitored values and showed that, with little calibration, the model can be used to characterize the different water quality conditions in the different watersheds under similar climatic and geographic areas. The model result also helps to predict the future hydrological dynamisms likely to be occurred under land use/cover dynamics and direction of change and its management strategy to keep the health of the watershed.

The results showed that each land use/cover responded differently in sediment and nutrient losses in the study area. The impacts of land use/cover on water quality could be modeled effectively from HRUs by using SWAT and it was apparent that sediment transported from HRUs of cultivated land as well as impervious urban land use had much more sediment, organic nitrogen, and organic phosphorus transport than grassland and forest land. Grassland contributes a minimum amount of sediment and organic nitrogen loss to the downstream. Again, cultivated land produced more nitrate in surface runoff and groundwater nitrate transport from each HRU than other land uses, followed by urban land use, whereas grassland produced less amount of surface runoff as compared to other land use/cover types. Urban land produces more soluble phosphorus, sediment phosphorus, and groundwater nitrate than cultivated land, grassland forest land. This indicates that cultivated land and urban land contribute more for the dynamism of watershed hydrology, because of the continuous and steep slope cultivation of farmland and paved and impervious nature of the urban land

The combined effects of cultivated land and slope gradient produced more sediment losses than other land use/cover combined, followed by urban land. In cultivated, forest, and grassland, as the slope increased, values of sediment also increased until it reaches 15% and then declined. Therefore, it was concluded that the slope difference of cultivated land had a more significant impact on watershed hydrology in terms of sediment and nutrient transport than other land use/cover in a watershed. Avoiding steep slope and continuous cultivation and implementing integrated watershed management strategies are among the recommended measures to alleviate the impacts of land use on watershed dynamics

The cumulative effects of land use/cover and soil type on watershed hydrology were predicted based on the simulated values of sediment and nutrient transport from HRUs. The interaction of land use and soil types produced almost similar mean values of sediment and nutrient loss and statistically had no significant differences. Therefore, it was concluded that soil difference had an insignificant effect on the simulated mean values of sediment and nutrient transport; rather, the difference in mean values and statistical difference among mean values had been recorded due to differences in land use/cover and slope gradient. Land use/cover are the important factor affecting the natural dynamism of the watershed followed by the combined effects of land use/cover and slope gradient.

4.3. ESTIMATING SOIL LOSS AND SEDIMENT YIELD

4.3.1 Estimating Soil loss of land use/cover in the Watersheds

Revised Universal soil loss equation (RUSLE) model for the estimation of soil erosion requires the integration of erosion factors including Rainfall erosivity(R), Soil erodiablity (K), Slope Length and Gradient (LS), Crop cover(C), and Management practices (P). Most of these factors were obtained as an output during the simulation of runoff and sediment yield by the SWAT model integrated with GIS.

4.3.1.1 Rainfall Erosivity Factor (R)

The mean annual rainfall data of 30 years (1986 to 2016) derived from three rainfall stations of Nekemte. Leka Dulecha and Dapho were considered to estimate R-factor

Table 20:.Rainfall classes and R factors of the watershed

Name of the station	Mean annual rainfall(mm)	R_factor
Nekemte	2010.32	1121.68
Leka Dulecha	1975.64	1102.19
Dapho	1900.54	1060.00
Mean	1962.17	1094

. The annual rainfall of the two watersheds range from 1400-2520 mm. The result showed that the average R-factor value in both sub-watersheds was 1094 MJ.mm.ha.yr (Table 21).

4.3.1.2 Soil Erodibility Factor (K)

In this study, a digital soil classification map was obtained from Oromia water work and design enterprise. Three major soil categories were identified in the chancho sub watershed and five soil types were also identified in Sorga sub-watershed. After assigning values for each soil types the soil map was reclassified using SWAT model output k_values for each Soil type. Erodibilty factor (K) which was obtained during the SWAT simulation process for each dominant soil type of the study watersheds identified and used as input for the soil k_value classification (Table 21).

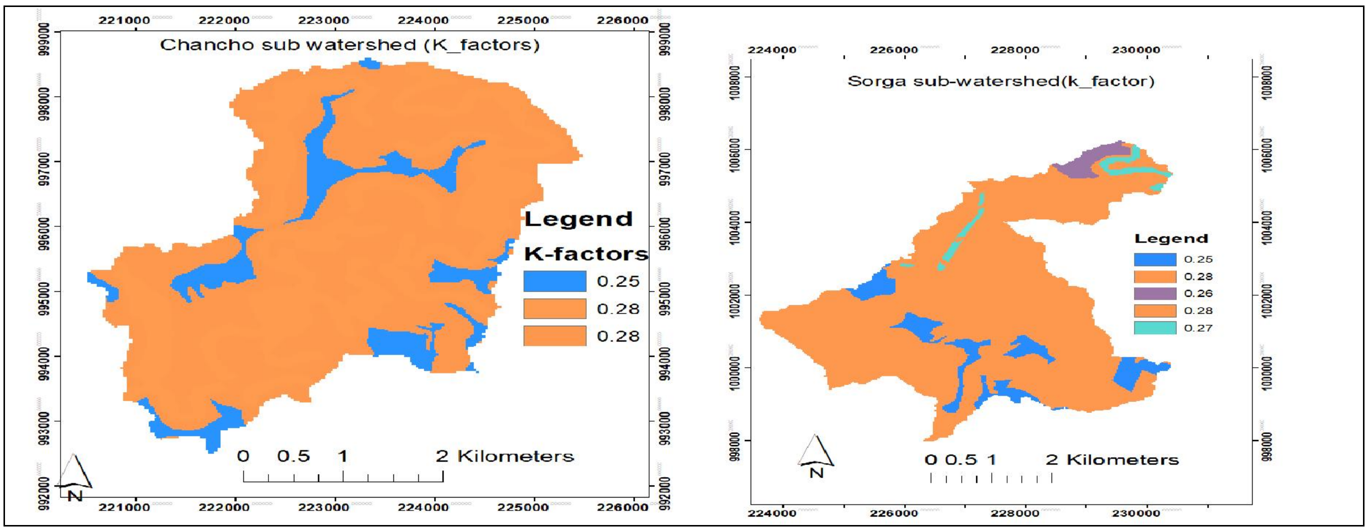


Figure 25:Soil erodibility(K-factor) map of the study area

Table 21: Soil Type and Erodibility Coverage

No	Soil types	Sub-Watersheds					
		Chancho			Sorga		
		K-factor	Area(ha)	%	K-factor	Area(ha)	%
1	Nitisols	0.26	1187	63.8	0.27	828.9	21.8
2	Lixisols	-	-	-	0.28	1345	35.5
3	Cambisols	0.28	568.3	130.5	0.28	1012	26.7
4	Acrisols	0.25	103.7	5.57	0.25	548.8	14.4
5	Fluvisols	-	-	-	0.26	52.1	8.9
	Total	-	1858.97	87.9	-	3786.8	99

4.3.1.3 Slope Length and Slope Steepness Factor

The influence of topography on erosion is complex. The slope gradient (S sub-factor) influences flow velocity and thus the rate of erosion. Slope length (L sub-factor) describes the distance between the origin and termination of inter-rill processes. In RUSLE, the LS factor represents a ratio of soil loss under given conditions to that at a site with the "standard" slope steepness of 9% and slope length of 22 m plot. LS of each land use/cover was and mapped by using Arc-Gis(Figure 26) and (Table 22)

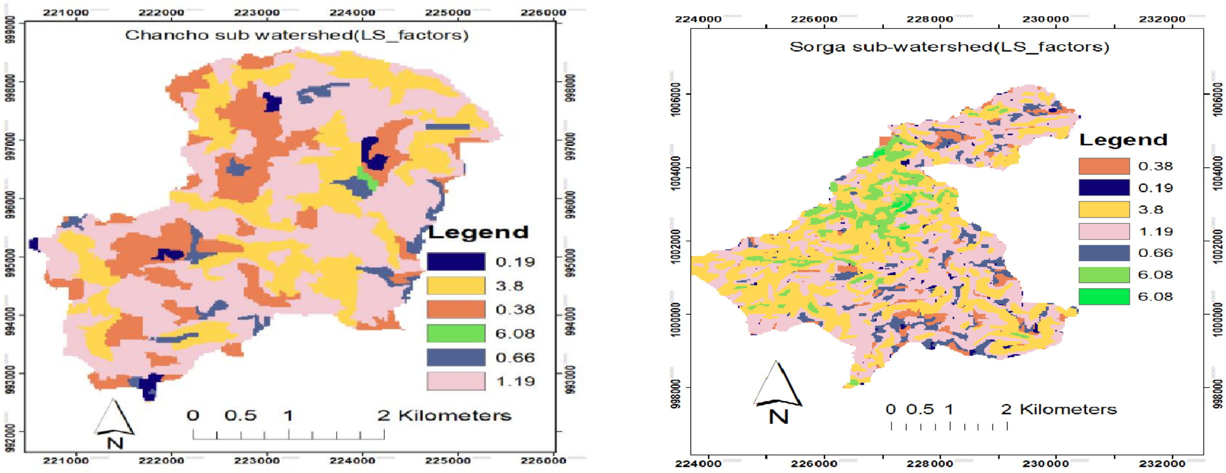


Figure 26: Topographic factors(LS_ factor)

Table 22: Slope Length and Slope Steepness factors produced by USLE in SWAT for both watersheds

Land use	Chancho sub watershed-LS	Sorga sub watershed-LS
Cultivated land	2.17	2.2
Forest land	-	2.7
Grass land	2.25	2.6
Urban land	-	2.07
Residential(Rural)	2.23	-

4.3.1.4 Land Use and Land Cover (C-value)

4.3.1.4 Land Use and Land Cover (C-value)

Cover management(C-value) of each land use/cover type was obtained from image classification analysis by an integrated SWAT model with arc-GIS. C-value of each land use/cover was assigned during the SWAT simulation process for each land use/cover type and the C-factor map was developed (Figure 27) and (Table 23).

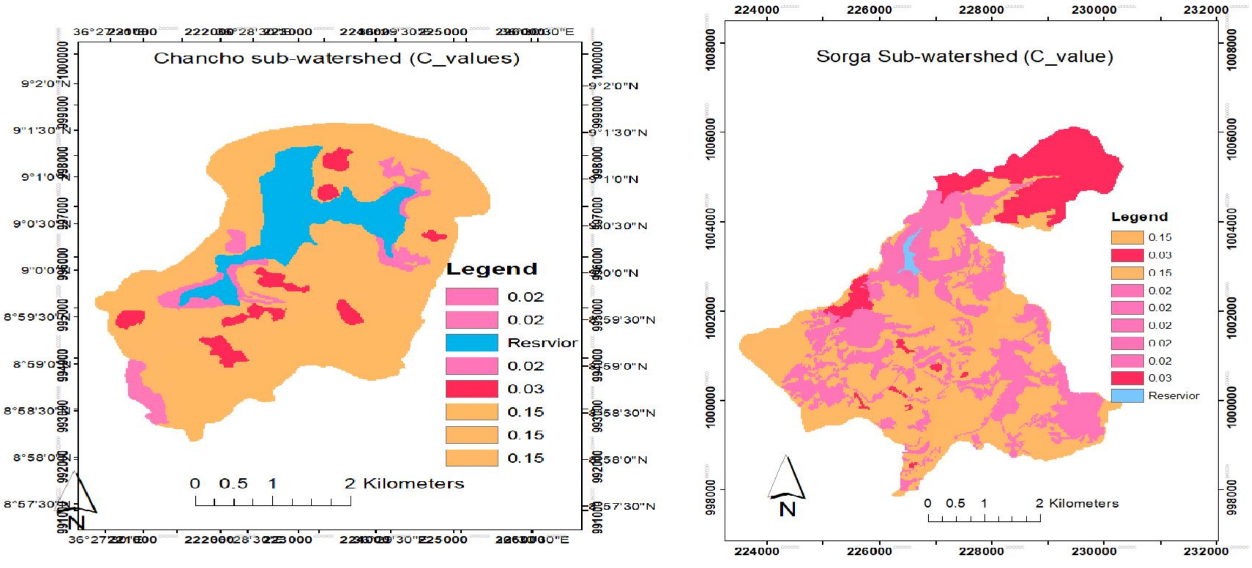


Figure 27: Crop management(C_factor) map

Table 23: Cover Management (C) Factor values of the study area

Types of land use	Chancho sub watershed			Sorga sub watershed		
	Area(Ha)	%	c-value	Area(Ha)	%	c-value
Cultivated land	1545	73%	0.15	2620.3	45%	0.15
Grass land	216.7	10%	0.02	35.8	2%	0.02
Forest	-	-	-	789.8	33%	0.02
Built up(Local)	92.25	4.3%	0.03	-	14.5%	0.03
Built up(Urban)	-	-	-	340.9	8.9%	0.03
Total	1853.97	87.9%	-	3786.8	99%	

4.3.1.5 Management Practice Factor(P-value)

4.3.1.5 Management Practice Factor(P-value)

The conservation practice factor (p-values) reflects the effects of practices that will reduce the amount and rate of the water runoff and thus, reduce the amount of erosion. It depends on the type of conservation measures implemented and requires mapping of conserved areas for it to be quantified. In the study area, there is only a small area that has been treated with terracing through the agricultural extension program of the government, with very little progress as it was implemented without the participation of the local people. The agricultural lands are classified into 4 slope categories and assigned a different P-value while all non-agricultural lands are assigned a similar P-value. The results indicated that most of the Chancho watershed is covered by cultivated land with no forest land and Sorga watershed is more covered by cultivated and forest land. Thus, in assigning *P* factor, values for the study areas were different based on slope range for cultivated lands and the other land cover types were given 1 based on Hurni, (1985) as shown in (Table 24).

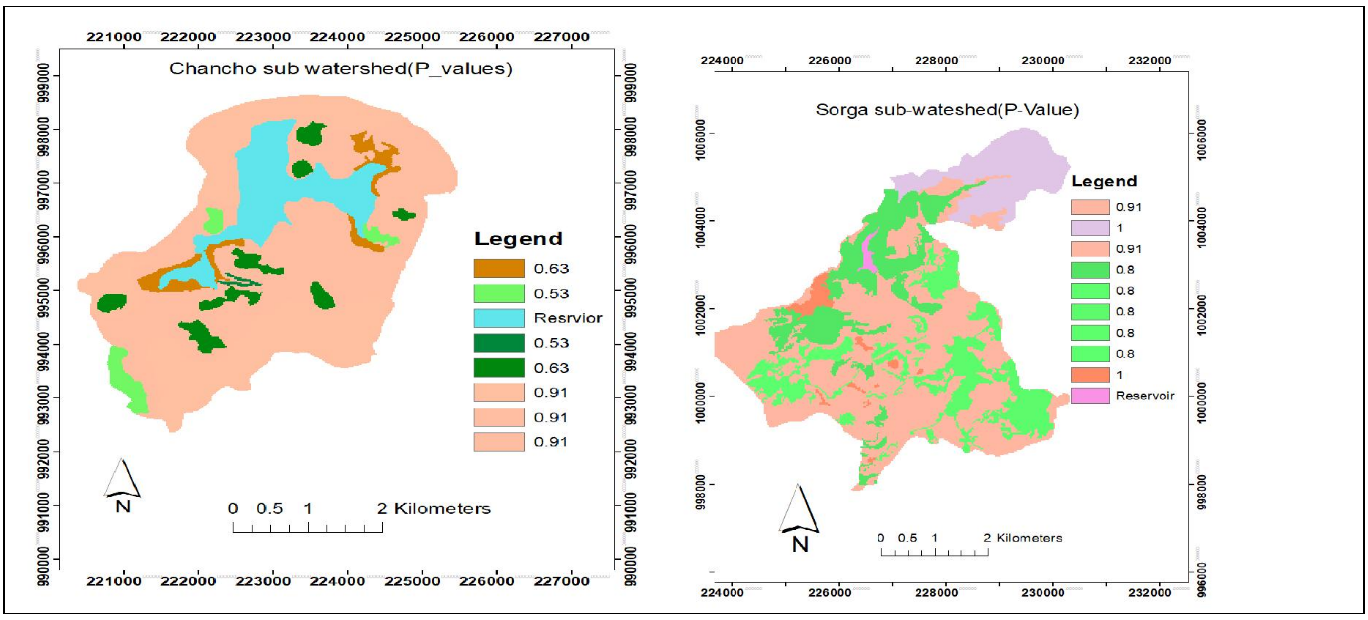


Figure 28: Conservation practices(P_factor) map

Table 24: Land Management Factor (P) values

Land use types	**Chancho sub watershed**		**Sorga sub watershed**
	Slope (%)	P-factors	P-factors
Cultivated land	0-5	0.1	0.1
	5-8	0.12	0.12
	8-15	0.14	0.14
	15-30	0.19	0.19
Others land uses		1	1

4.3.1.6 Soil Loss Estimation

As shown in Table 25, based on some erosion factors estimated by USLE in the SWAT model output, the actual soil loss of different land use/cover types from both watersheds showed varied results. Cover type, slope steepness and gradient factors contribute the most for the difference in soil loss /ha of different land use/cover types. Cultivated land produced the higher value of soil loss (31.16 t/ha/yr and 29.6 t/ha/yr) in Sorga and Chancho watersheds, respectively, and forest and grassland produced less amount of soil loss (17.06 t/ha/yr and 14.22 t/ha/yr) in Sorga and Chancho watersheds, respectively. Urban land of Sorga and residential (rural) areas of Chancho watersheds also contributed almost similar values of soil loss (18.23 t/ha/yr and 18.87t/ha/yr), respectively. Chancho watershed with more cultivated land produced an average of 20.9 t/ha/yr of soil loss. On the other hand, Sorga watershed with more of cultivated land and forest land produced 20.72 t/ha/yr (Table 25)

Table 25: Summary of soil erosion factors and soil loss t/h/year of Chancho and Sorga watersheds

Watershed	LULC Types	Area(ha	R	K	C	LS	P	Soil loss t/ha/yr
Chancho	Cultivated	1545	1094	0.26	0.15	2.17	0.31	29.6
	Grass	216.72		0.28	0.02	2.25	1	14.22
	Residential	92.25		0.25	0.03	2.23	1	18.87
	Average loss	-	-	-	-	-	-	20.9
Sorga	Cultivated	2620.3	1128.2	0.27	0.15	2.2	0.31	31.16
	Forest	789.8		0.28	0.02	2.7	1	17.06
	Grass	35.8		0.28	0.02	2.6	1	16.43
	Urban	340.9		0.26	0.03	2.069	1	18.23
	Average loss	-	-	-	-	-	-	20.72

Notes: LULC=land use/cover, LS=Slope length and gradient

The average soil erosion predicted by USLE was 20.9 t/ha-yr for Chancho and 20.72 t/ha for Sorga sub-watersheds, which were corresponding to 29.6 t/h/yr for cultivated land,18.87t/ha/yr to residential, and 14.2t/h/yr to grassland from Chancho watershed and 31.16t/h/yr for cultivated land,17.06t/h/yr for forest land,16.43t/ha/yr for grassland and 18.23t/ha/yr for Urban land (Table 25).

Based on the severity of soil erosion, both sub-watersheds were classified into one severity class high erosion (> 5 t/h/yr) according to severity classification of FAO (2006). This indicates that both watersheds were classified under high soil erosion class and were beyond the tolerable soil loss 18t/h/yr, except for grassland in Chancho and forestland in Sorga sub-watersheds. According to Hurni (1985), the tolerable soil loss level for the various agro-ecological zones of Ethiopia ranges from 2 to 18 t/ ha/yr. Cultivated, residential, and urban land produced a high soil erosion, followed by forestland, whereas, grassland contributes the least soil erosion to the total soil erosion in both sub-watersheds; this is due to high infiltration and low runoff capacity of grassland by its dense grass cover.

Chancho watershed is classified into three main land use/cover types, accounting for 96% of the entire watershed excluding water bodies (reservoir), but the USLE predicted that soil loss accounts for only 95% of the total amount. Cultivated land areas represent 73% of the total area of the watershed and had a significant impact on the total soil erosion (Table 25), followed by residential and grazing land, respectively. Cultivated land in Sorga sub-watershed areas also represent almost 69% of the total area of the watershed and had a significant impact on the total soil loss, even more, significant than the impact of cultivated land of Chancho sub-watershed due to more steep lands under cultivation. Forest land is also higher, next to cultivated land and accounts for 21.5% of the total area of the Sorga sub watershed and contributed less soil erosion. The urban land area represents 12% of the total land of Sorga sub watershed and contributed a significant amount of soil loss to the total soil loss of the watershed, next to cultivated land; this is due to the impervious and paved land surface of the urban area.

4.3.2 Sediment yield Estimation

The amount of soil loss from the watershed is generally more than the amount of sediment leaving the watershed at the outlet point. Hence, the sediment yield cannot be estimated from direct soil loss estimates within the watershed unless additional data are available. The sediment delivery ratio was calculated, which used for sediment yield estimation (Table 26).

Table 26: Summary of soil loss and sediment yield of the two watersheds

Watersheds	**Soil loss**		**Area**	**SDR**	**Sediment yield**
	Ton/ha/yr	Total t/yr		%	Ton/yr
Chancho	20.9	38747.97	1853.97	22	8524.34
Sorga	20.72	78468.45	3786.8	19	14909

The total annual sediment yields for the Chancho and Sorga subwatershed were calculated based on the total soil loss and sediment delivery ratio of the watersheds. The higher soil loss in both sub-watersheds was from agricultural land, followed by urban land in Sorga sub-watershed. About 76% of the soil loss on average was produced from cultivated land in both sub-watersheds.

The total sediment produced from the watershed outlets was estimated to be 8524.34 t/yr in Chancho sub-watershed and 14909t/yr in Sorga subwatershed (Table 26). For these total sediment yields, each land use/cover type contributed differently based on soil loss estimation, in which cultivated land contributes 69.2%, urban land 9%, forest land 20.8%, and grassland 0.94% in Sorga sub-watershed. However, cultivated land contributes 83%, residential area 4.9%, and grassland 11.6% in Chancho sub-watershed.

The variation of the average values of sediment yield given in t/h/yr between the same land use of the two sub-watersheds was due to the difference in cover (P) and LS factors, which means that the slope steepness of Sorga cultivated land is greater than that of Chancho cultivated land. This indicated that, as SL of cultivated land increased, the amount of sediment loss t/h/yr also increased. Therefore, land use/cover, slope length and gradient differences produced variation in the amount of sediment yield to the total channel outlet of the sub-watersheds; Therefore, human activities contribute more for the watershed dynamics in terms of onsite soil loss and offsite sedimentation of reservoirs.

4.3.2.1 Effects of Sediment Yield on Reservoirs

There are two reservoirs located in the study areas. Meka Dam with its reservoir is located in Chancho sub watershed and occupies an area of 250 ha. Sorga Dam with its reservoir is located in Sorga sub-watersheds with an area of 30ha. Agricultural land is the dominant land use in Chancho sub watershed and considered as a cultivated land dominated surface water (reservoir) at a distance of 0.5 km radius including its buffer zone. Forest land is the dominant land cover around Sorga Dam at a distance of 0.5 km radius including the buffer zone and considered as a forest dominated surface water. Meka Dam was established for the purpose of supplying drinking water for Nekemte town, whereas Sorga Dam was constructed for the purpose of fish production and recreational area for the youth as well as a tourist area. Total Sediment yield produced were all not deposited in the reservoirs in both sub watersheds,due to dam size and land escape and as a result, some deposited at the non-reservoir area, especially in rivers and wetland (Table 27) which was estimated based on the outlets.

.

Table 27: Sediment yield production and deposition

Sub watersheds	Gross sediment yield (Ton/yr)	Sediment load to Reservoirs (Ton/yr)	Sediment load to non-Reservoirs (Ton/yr)
Chancho	8524.34	7586.66	937.68
Sorga	14909	4472.7	10436.3

4.3.2.2 Estimation of reservoir capacity

The sediment volumes were computed from the differences between the initial storage capacity and the study measured storage capacity using the following formula by Adwubi et al., (2009) given as:

SV = RSCi–RSCi + n... 1

Where: SV = Sedimentation Volume (m3); RSCi = reservoir storage capacity at an initial year, i (m3); RSCi+n= reservoir storage capacity n years after i (m3).

The initial (i) year is the reservoir storage capacity when the dam was constructed and the storage capacity n years after an initial (i) year is the study measured storage capacity. The

difference between the two volumes is assumed to be the volume of sediment accumulated in the reservoir. As such, the rate of sedimentation per year was estimated by dividing the number of years the dam has been in operation by the volume of deposited sediments. The average depth of deposited sediment was calculated as sediment volume divided by surface area

Table 28: Characteristics of Meka and Sorga reservoirs

Variables	Unit	Meka	Sorga
Sub-watershed area	KM^2	18.53	37.86
Surface area/reservoirs	Ha	250	30
Reservoir Storage capacity	M^3	37.5m	840,000
Age of the reservoir	years	9	14
Sediment yield	Ton/ha/yr	7510.79	4427.97
Sedimentation	M^3/yr	21268.19	11664.06
Dead Storage	M^3	3.75m	349920
Economic life	years	176	30

To calculate the volume of water contained in the reservoir requires estimating the shape of the reservoir as close as possible. The study reservoirs are usually irregular both in the cross and long sections (Figure 29). A more accurate method of estimating capacity would be to consider an area enclosed by contours at appropriate intervals. The volume between two successive contours can then be calculated and these volumes are then summed up to get the total capacity of the dam. In many cases, small reservoirs are designed without carrying out a full topographic survey, and the storage volume is estimated from the reservoir width, the throwback, and maximum impounded water depth (Lawrence et al., 2004). Thus, the estimation of reservoirs capacities for this study was estimated based on the direct method (Table 29). Several formulae are used for estimating small reservoir storage capacities.

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The capacity of a reservoir is estimated by measuring the surface area at a full supply level, which also assumes a reservoir as a pyramid whose base is the water surface. The water depth of each reservoir was obtained from Oromia Water Work and Design Enterprise.

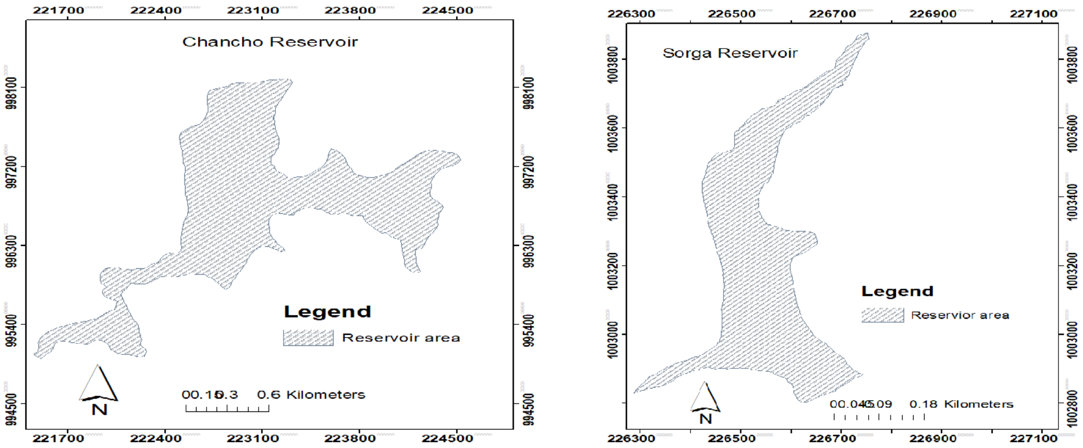


Figure 29: Map of Meka and Sorga Reservoirs

Table 29: Estimation of Reservoir Storage capacity

Name of Reservoirs	Surface area	Water depth	Storage capacity(M^3)
Meka	$2.5X10^5$ m^2	15	37.5M m^3
Sorga	$14x10^4$ m^2	6	840,000 m^3

4.3.2.3 Trap Efficiency (TE) Estimation of the Reservoirs

When estimating reservoirs' sedimentation, it is important to calculate the trapping efficiency (TE) of the reservoir. The result of the USLE model analysis indicated that the mean values of soil loss of land use /cover types were 20.9 and 20.72 t/h/y at Chancho and Sorga sub-watersheds, respectively. The sediment delivery ratio was 22% and 19% for Chancho and Sorga sub-watersheds respectively, resulting in a sediment yield of 8524.34 ton/year at the Chancho outlet and 14909ton/year for the Sorga outlet. From the total 21 outlets of Chancho sub watershed, 19 outlets flow to the Meka reservoir and the reaming outlets flow to non-reservoir areas. Then, the sediment delivered at the Meka reservoir was 7586.66ton/yr. The trapping efficiency of the reservoir estimated was 99.9 %; therefore, the estimated sediment remaining in the reservoir is 7510.79 tons/year. From the total 17 outlets in Sorga sub watershed, only 3 outlets flow to Sorga reservoirs and the others flow to non-reservoir areas. The trapping efficiency of the reservoir estimated was 99.9 %, then, the estimated sediment remaining in the reservoir is 4427.97 ton/year

Table 30: Sedimentation and capacity loss of Reservoirs

Reservoirs	**Age**	**Catchment areas**	**Total reservoirs capacity(M^3)**	**Mean SYLD produced (M^3)/yr**	**Sedimentation (M^3)/yr**	**Storage capacity loss (%)/year**
Meka	9	2109	37.5m	22649.17	21268.19	0.056
Sorga	14	3817	840,000	39613.21	12664.06	1.5

The amount of sediment lost from each land use/cover reaches the common outlet (there are 17 outlets in Sorga and 21 outlets in Chancho sub-watershed. All outlets find their way to either reservoirs or non-reservoirs area of the watersheds. Reservoir dam size and its area are used as a boundary for the non-entrance of runoff and sediment to the existing reservoirs and, as a result, some sediment gets into the reservoirs and is likely to affect the storage capacity of the reservoirs. From the total sediment yield produced from each land use/cover type in Chancho sub-watershed 89 %(19 outlets) of the sediment deposited in the Meka reservoir and 11 %(2 outlets) transported to non-reservoir areas. In Sorga sub-watershed 30% (3 outlets) of sediment deposited in the Sorga reservoir and 70 %(14 outlets) of sediment transported to non-reservoir areas. Non-reservoirs areas include; wetland and rivers in both sub-watersheds. This study is in agreement with Jeyakanthan. & Sanjeevi (2013), which show that, in India, soil erosion occurs at a rate of approximately 0.16 tones km/yr, of which about 10 % is deposited in reservoirs and 29 % is transported to the sea.

4.3.2.4 Sediment volume and Sedimentation

Using a conversion tool from tone to cubic meter, it is found out that 21268.19m3 sediment is deposited in Meka reservoir and 12664.06m3 sediment is deposited in Sorga reservoir per year, resulting in a storage capacity loss of 0.056% of Meka and 1.5% of Sorga reservoir per year (Table 30).

The average rate of reservoir storage capacity loss of this study is in harmony with the estimated total storage capacity loss of reservoir in the world, which is between 0.5% and 1% (WCD, 2000). and another study in India's annual storage loss of reservoir in terms of percentage is 0.46 (Jeyakanthan and Sanjeevi, 2013). Starting from the time of its construction in 2007 and until 2016, the storage capacity loss of Meka Dam was

191413.71m3 or 1.7%, assuming the rate is constant during the lifespan of the reservoir. On the contrary, the Sorga reservoir, within 14 years of its construction (2002-2016), the storage capacity declined by 21% or 177296.84m3. If sediment delivery continues at the same rate from construction periods, the half-life of the Meka reservoir will be reached within 293 years and that of Sorga within 35 years. Water quality loss in terms of sediment and storage capacity losses of reservoirs was mainly affected by cultivated land in both sub-watersheds.

Therefore, sediments from each LULC were transported by runoff and deposited in reservoirs, wetlands, and river channels in the study areas. Hydrology of the study watersheds was impacted by sediment load to surface water and losses of reservoirs storage capacity by sedimentation. Meka reservoir of Chancho sub-watershed, which has more water storage capacity, was highly affected by sediment deposition due to more sloppy land under cultivation including the buffer zone of the reservoir. In Chancho sub watershed, surface water and cultivated lands are at risk of degradation due to sediment deposition, water quality reduction, and loss of fertile topsoil of the upper stream of the watershed as compared to Sorga sub watershed, where forest is the dominant land cover at the buffer zone areas of a reservoir and, as a result, less sediment is deposited in the reservoir per year.

In the two sub-watersheds under investigation, the impacts of land use/cover types on watershed hydrology in terms of soil loss and sediment yield were estimated based on USLE and sediment delivery ratio of the watersheds. Human activity altered the watershed hydrology of the watershed, especially during rainy seasons, in the agriculture dominated Chancho sub watershed to a larger extent, compared to the forest dominated Sorga sub-watershed. The higher soil loss t/ha/yr was recorded in the cultivated land in both sub-watersheds and the least soil loss was recorded in the grass and forestland. This is largely due to continuous and steep slope cultivation of cultivated land and higher infiltration and low runoff of grass and forestlands. Urban land with the impervious and paved surface also had more soil loss, next to cultivated land and followed by rural residential land.

With regards to the estimated sediment yield t/yr from the two dominant lands, agriculture dominated land produced higher sediment yield than the forest dominated land. The annual sediment yield t/yr was higher in Chancho sub watershed, where cultivated land is the dominant and very minimum grassland cover, as compared to Sorga sub-watershed, where cultivated land was also the dominant and relatively has a large forest cover. Therefore, human action (cultivating land) contributes more to the change watersheds hydrology in the form of soil loss and subsequent sediment yield from upland and reservoirs sedimentation.

Therefore, avoiding steep slope and reservoirs buffer zone cultivation and implementing appropriate land use plan according to land use classification. An appropriate watershed management strategies should be implemeted to alleviate the problem of land productivity losses of the upper land and reservoirs sedimentation. .

4.4 EFFECTS OF LAND USE/COVER ON SURFACE WATER QUALITY

The study sites were characterized as Agriculture, Forest and Urban dominated surface water based on land use/cover types at 0.5 km radius. Meka dam is located in agriculture-dominated surface water in the Chancho sub-watershed. Sorga dam is found in forest-dominated surface water in Sorga sub-watershed. Laga Merga is in urban-dominated surface water in Sorga sub-watershed. The watersheds are located in between $9^{o}01'$ North and $36^{o}28.2'$East. The Meka reservoir was constructed for the supply of drinking water to Nekemte town and the Sorga reservoir is used as a site for fish production and recreational area. Laga Merga stream, which belongs to Sorga sub-watershed urban dominated surface water, is used for crop irrigation. The total area of the Chancho watershed is 2109ha and that of Sorga is 3817ha. The sources of water for the reservoirs are primarily raining waters and few streams which flow to each reservoir.

The average annual temperature in the two watersheds is similar and ranges between 15°C and 16°C, with a mean annual rainfall of 2022 mm. Sorga watershed is one of the most densely populated areas in which urban and rural settlers are living as compared to Chancho sub-watershed, where only rural settlers are living. The total population of Sorga and Chancho sub-watershed is 6160 and 1500, respectively. Agriculture is the main economic activity undertaken within the two watersheds, but the urban small-scale enterprise is the prime source of income for urban settlers in Sorga urban-dominated sub-watershed.

4.4.1 Forest dominated surface water

Forest-dominated surface water in Sorga sub-watershed covers an area of 479ha of forest and 30ha of surface water bodies with first-order stream drainage. Land use within the boundary of surface water at 0.5 km radius is dominantly covered by forest with few hectares of the road network. Elevation ranges from 2218 to 2243 m.a.s.l. The slope of the study site ranges from 0-2% for the water bodies and 8-30% for the forested areas. Vegetation consists of mainly natural bushes, forests, and plantation forests. The soil in and around the surface water is classified as 75% lixisols and 25%cambisols. The soil is characterized as well-drained sandy loam soil with an average plaguing depth of 120cm. The land escape is concave joining at the bottom end of surface water. The average temperature and annual rainfall distribution are similar for the three study areas. Even though the area is prone to roadside runoff, no attempts were made to conserve soil erosion; due to assumption that bushes and forest cover protect surface water from runoff although, in reality, bushes and forest land can reduce the amount of sediment entering the downstream surface water as compared to non forested agriculture dominated surface water.

4.4.2 Agriculture-dominated surface water

Agriculture-dominated surface water of Chancho subwatershed is covered by 1112ha of cultivated land and 250ha of surface water. Land use within 0.5 km radius of surface water is covered mainly by cultivated land and few pocket areas of grazing and fallow lands which account only 1% of the study area. The elevation of the cultivated land ranges from 2021 to 2243masl. The slope of the study site ranges from 0-2% for the water bodies and 5-30% for cultivated land. The soil in the cultivated land is mainly classified into 45% lixisols and 55% cambisols, and generally, the soil is characterized as sandy-loam soil with an average depth of 110cm. There were some attempts made to conserve soil through contour bund construction on a few lands with no maintenance and as a result, the attempts were not as effective in reducing runoff entering the surface water. The area is prone to accelerated soil erosion because of continuous and steep slope cultivation and overgrazing. The growth of plant species and algae is widely seen in the buffer zone of the surface water; this is due to the removal of plant nutrients from the farmland to the water environment.

4.4.3 Urban-dominated surface water

Urban-dominated surface water shares some portion of Sorga sub-watershed with an area of 324ha of land. Land use is mainly residential, including a parking lot, paved street, and some woodlots and wetland, which are used as farming sites during a dry season and locally called "Bone farm", which is available at the bottom of subwatershed along the surface water buffering zone. The elevation of the urban land ranges from 2044 to 2211masl. The slope gradient of the study site ranges from 3-5% for the area of surface water flow and 5-20% for residential areas. Most of the houses were constructed on steep to very steep slope land and, as a result, land degradation in the form of gully formation is a problematic issue in the Nekemte town as mainly water erosion has a devastating effect on the unpaved land surface. The soil in the town is mainly classified into two, namely, 20% fluvisols and 80% lixisols, and the soil is generally characterized as sandy-loam soil with an average depth of 70-90 cm. Infiltration is very poor due to slope steepness, paved street, and roofing cover. Consequently, urban liquid and solid wastes with sediment drain directly to the surface water. Sample points from which water samples were taken from each surface water for both sub-watersheds is located on below (Figure 30 &31)

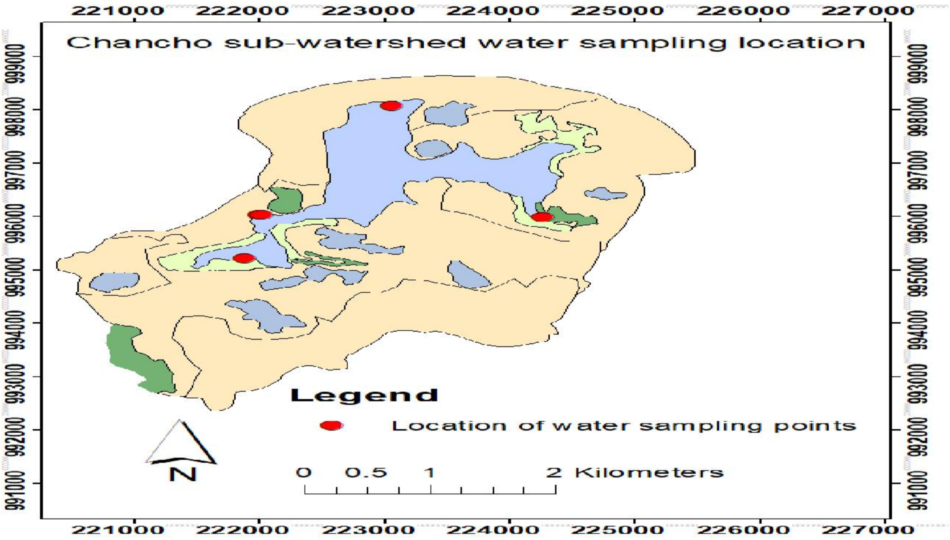


Figure 30: Map and sample points of Chancho cultivated land dominated study Surface wat

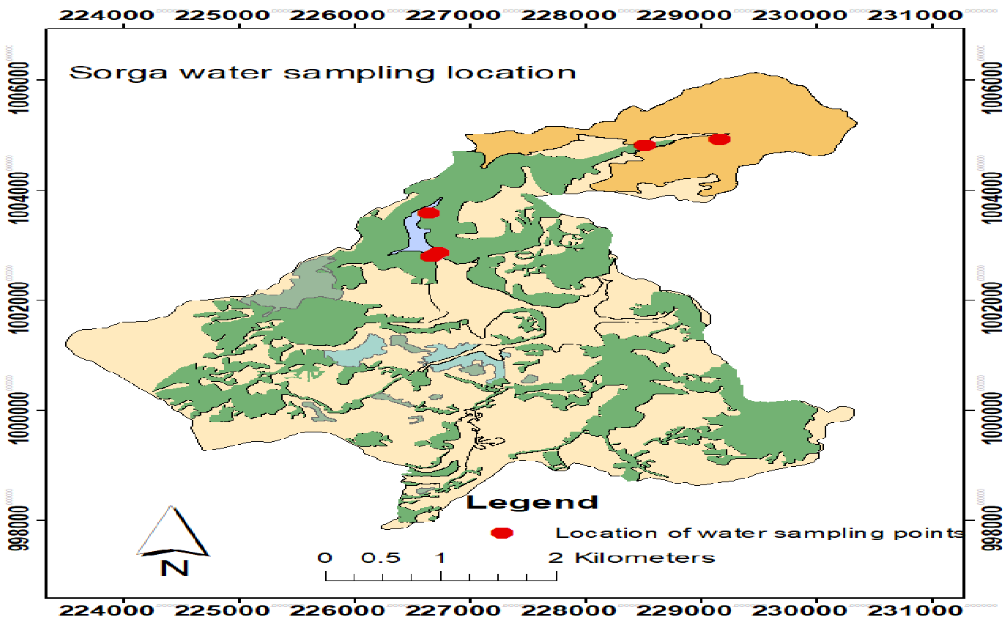


Figure 31: Map and sample points of Sorga forest and urban dominated study Surface water

4.4.4 Water quality Assessment

Water samples were taken from the surface water located at the bottom of two different land uses/cover types, namely, agriculture and forest-dominated surface water and analyzed in the laboratory. The results of multiple comparisons indicated that there were mean variations in all of the water quality parameters between the ADSW and FDSW (Table 32).

The result revealed that the mean value of PH in forest-dominated surface water (FDSW) (5.15) was higher than that of agriculture-dominated surface water (ADSW) (4.85), but no significant difference ($P>0.05$) is found between the mean values of PH surface water. The lesser pH value indicates the higher acidic condition of the water; hence, agricultural-dominated surface water is more acidic than forest-dominated surface water.

The mean value of total suspended solids (TSS) was higher in agriculture-dominated surface water (36.6mg/l) than forest-dominated surface water (18.9mg/l). TSS of agriculture-dominated surface water was not significantly at ($P>0.05$) different from the TSS of FDSW. The mean value of total dissolved solids (TDS) was higher in FDSW than ADSW. The mean value of FDSW (62.66mg/l) is higher than ADSW (28.12 mg/l) and had a significant difference ($P<0.05$). The mean value of total nitrogen (4.5 mg/l) is higher in ADSW than

FDSW (2.7mg/l).with no significant difference between them. Total phosphor (TP) values recorded from the two study areas were similar with a very minimum value less than 0.001mg/l (Table 31)

Table 31. Mean value of physco-chemical parameters of surface water(reservoirs)

Water quality variables(mg/l)	Agriculture dominated	Forest dominated	
	Mean ± S.D	Mean ± S.D	P-values
PH	4.85 ± 0.3	5.15 ± 0.27	0.9975
TSS	36.6 ± 39.9	18.9 ±17.9	0.0784
TDS	27.05 ± 12.4	62.7 ± 17.5	0.0001
TN	4.5 ± 4.8	2.7 ± 4.9	0.1831

Notes; TSS=Total Suspended Solids, TDS=Total Dissolved solids, TN= total Nitrogen, S.D= Standard Deviation,

Table 32: Comparison of the mean values of physco-chemical parameters of the three surface water having three distinct dominant land use/cover type

WQVs (mg/l)	Agriculture(RES)	Urban(STR)	P-values	Forest(RES)	Urban(STR)	p-values
	Mean ± S.D	Mean ± S.D		Mean ± S.D	Mean ± S.D	
PH	4.85 ± 0.3	5.4 ± 0.77	1.000	5.15 ± 0.27	5.4± 0.17	0.994
TSS	36.6 ± 39.9	24.12 ±22.6	0.29	18.9 ±17.9	24.12± 22.6	0.24
TDS	27.05 ± 12.4	111 ± 35.7.5	0.000	62.7 ± 17.5	111± 35.7	0.000
TN	4.5 ± 4.8	4.4 ± 4.06	0.43	2.7 ± 4.9	4.4 ± 4.06	0.169

Notes: RES= Reservoir, STR=Stream, WQVS= Water quality variables

Table 32 shows that the mean value comparison of surface water quality under different land use/cover types to understand any significant differences between them. The comparison also helps to see the impacts of human activities on water quality in terms of cultivating the land, construction of houses and buildings, and forest land used as a checkpoint for both. Agriculture dominated surface water was higher in the mean values of TSS and TN (36.6mg/l and 4.5mg/l) than urban dominated surface water (24mg/l and 4.4mg/l) with no significant difference (P>0.05). The mean value of PH in agriculture (4.87) is less than the mean value of urban dominated surface water (5.4). This indicates that agriculture dominated surface water is more acidic than urban-dominated surface water but has no significant difference in pH values. Urban dominated surface water TDS (111mg/l) was higher than agriculture-dominated (27mg/l) and had a significant difference at ($P<0.05$) between them.

The mean values of PH, TSS, TDS, and TN were higher in urban-dominated than forest dominated surface water.TDS value of urban 111ml/l was significantly different ($P<0.05$) than forest 62.7mg/l while there is no significant difference detected between the other variables.

Water PH

PH is one of the most important water quality parameters. Measurement of pH relates to the acidity or alkalinity of the water. A sample is categorized as 'acidic' if the pH is below 7.0, and 'alkaline' if the pH is higher than 7.0. The standard limits of surface water pH range, according to WHO and as Ethiopia guideline is between 6.5 and 8.5. The pH values of all samples were found in the range of 4.00 to 5.6. The higher values were recorded in forest-dominated surface water than agriculture-dominated surface water, with no statistically significant difference between them. This indicates that agricultural land contributes more acid-forming ions to the water environment due to the use of nitrogen-containing fertilizers.

Total Suspended Solids (TSS)

The maximum TSS limit of surface water set by WHO is 25 mg/L. The mean value of TSS in ADSW is higher than the standard (Table 23). The highest value of 36.6 mg/L was recorded from the agriculture dominated surface water and had no significant difference at ($P>0.05$) with FDSW. The higher TSS value in Agriculture dominated surface water was resulted from the soil loss by surface runoff from cultivated land.

Total Dissolved Solids (TDS)

TDS are inorganic matters and small amounts of organic matter, which are present as a solution in water. The standard or allowable value of the TDS set by WHO and Ethiopia is 1000 mg/L. The TDS values of all surface water samples were by far less than the maximum limit of 1000 mg/L. The highest TDS value of 62.7mg/L was recorded in forest dominated surface water and had a significant difference ($P<0.05$) with agriculture dominated surface water. The higher value of TDS in FDSW is mainly due to high organic matter resulting from the decomposition of tree biomass as compared to cultivated land having less organic matter.. UDSW contributes more TDS to the downstream than both ADSW and FDSW, this due to the removal of the dissolved organic and inorganic substance by runoff in UDSW (Table 33).

Total Nitrogen

The maximum TN limit of surface water set by WHO and Ethiopian is 10mg/l. The highest and the lowest values of TN recorded were 17mg/l and 0.0001mg/l for agriculture-dominated surface water and 15.5mg/l and 0.0001 mg/l for forest dominated reservoir.TN from cultivated and forest dominated surface water exceeds WHO and Ethiopian standards. More amount of TN level was recorded in agriculture-dominated surface water; this is due to the use of nitrogen-containing inorganic fertilizer (UREA) for soil fertility amendment. Thus, some part of the added fertilizer is taken by the plant and others get into the water stream through runoff. Total nitrogen (TN) value was higher during the rainy season in forest dominated surface water than dry periods and during the dry season in ADSW. ADSW is higher in TN load to the downstream water environment as compared to the other two land uses. The reason for this could be due to the combined effects of the removal of topsoil from cultivated land where inorganic fertilizer that contains nitrogen was being used during the rainy season (Table 33).

4.4.4 Spatial-Temporal variation of surface water quality of land use/cover types

The indicators of surface water quality of each dominant land use/cover type were evaluated in spatio-temporal to understand the reaming difference. The result showed that all values of water quality variables were different in spatial (each dominant land) and temporal (during rainy and dry seasons) aspects.

The mean value of pH in the ADSW and FDSW was higher in dry seasons than in rainy seasons, with no significant difference ($p > 0.05$) observed. The mean value of TSS in the ADSW was significantly higher during dry seasons than rainy seasons ($p < 0.05$). On the other hand, the mean value of TSS in FDSW had no significant difference between rainy and dry seasons ($P > 0.05$).

The average value of TDS in ADSW and FDSW was not significantly different in the rainy and dry seasons ($p > 0.05$). Also, total nitrogen values from ADSW and FDSW was not significantly different between rainy seasons (P>0.05), even if it differed in mean values (Table 34)

Temporal variability of TDS values of surface water among the two dominant land use/cover types (ADSW and FDSW) indicated that forest land contributes more TDS during the rainy season. This is directly related to the decomposition of organic matter during the rainy season. The TDS value of agriculture-dominated surface water was high during dry than rainy periods. This is due to high evaporation during dry and higher dilution effects during the rainy season

The higher PH values were recorded similarly to temporal values (October to November) for the two dominant surface water. Total suspended solids (TSS) are higher during dry seasons (November-March) than during rainy seasons (May- October) in both agriculture and forest dominated surface water. The values of total dissolved solids (TDS) were higher during rainy seasons (May-October) in FDSW and higher during dry seasons (November -March) in ADSW. The total nitrogen (TN) value was higher during rainy seasons in FDSW and less in ADSW (Table 33).

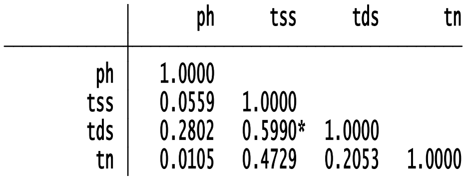
Table 33: Surface water quality during rainy and dry seasons in Agriculture and forest dominated surface water

LULC	Water quality variables	Rainy season Mean ± S.D	Dry season Mean ± S.D	P-values
Agriculture	PH	4.65 ± 0.2	5.05 ± 0.26	0.995
	TSS	22.25 ± 18.7	37.67 ± 31.3	0.0352
	TDS	21.95 ± 2.5	32.15 ± 6.3	0.0619
	TN	3.15 ± 1.05	5.89 ± 2.6	0.2104
	PH	5.1 ± 0.33	5.19 ± 0.51	0.338
	TSS	10.66 ± 3.8	27.17 ± 23	0.0618
	TDS	65.9 ± 25.1	59.56 ± 4.3	0.29
Forest	TN	5.05 ± 6.2	0.35 ± 6.4	0.068

4.4.2.5 Correlation between water quality indicators

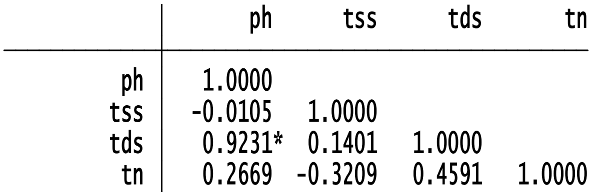
A correlation analysis was conducted to observe the relationships among water quality variables of the three study sites. The results indicated that the water quality values of each dominant land use type were differently correlated with each other. Relationships among the considered variables were tested using Spearman rank correlation with statistical significance set priori at $p < 0.05$.

Table 34: Correlation between water quality parameters of agriculture dominated surface water



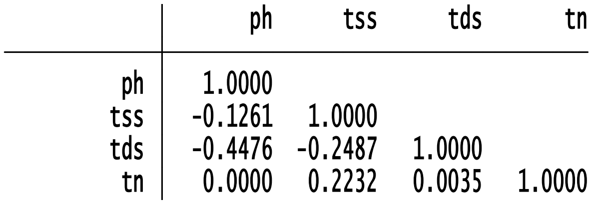
```
             |     ph      tss      tds       tn
-------------+------------------------------------
          ph |  1.0000
         tss |  0.0559   1.0000
         tds |  0.2802   0.5990*  1.0000
          tn |  0.0105   0.4729   0.2053   1.0000
```

Table 35: Correlation between water quality parameters of forest dominated surface water



```
             |     ph      tss      tds       tn
-------------+------------------------------------
          ph |  1.0000
         tss | -0.0105   1.0000
         tds |  0.9231*  0.1401   1.0000
          tn |  0.2669  -0.3209   0.4591   1.0000
```

Table 36: Correlation between water quality parameters of urban dominated surface water



```
             |     ph      tss      tds       tn
-------------+------------------------------------
          ph |  1.0000
         tss | -0.1261   1.0000
         tds | -0.4476  -0.2487   1.0000
          tn |  0.0000   0.2232   0.0035   1.0000
```

Total suspended solids (TSS)

Correlation analysis of urban dominated reservoir showed that TSS had significant negative correlation with TDS(r=-0.346), TN(r=-0.094), and PH(r=-0.265), while the analysis of agriculture dominated reservoir revealed that TSS had significant positive correlation with TDS(r=0.461) and TN(r=0.132) and negative correlation with PH(r=-0.005). Forest dominated reservoir TSS was also positively correlated with TDS(r=0.011) and PH(r=0.064) and negatively correlated to TN(r=0.228) (Table 34, 35, 36).

Total Dissolved Solid (TDS)

TDS of urban dominated reservoir showed a positive correlation with TN(r=0.038) and negative correlation with PH(r=-0.479) and TDS of agriculture dominated reservoir showed a positive correlation with TN(r=0.605) and PH(r=0.209). By contrast, TDS of forest dominated reservoir showed a significant positive correlation with both TN(r=0.821) and PH(r=0.752) (Table 34, .35 &36)

Total Nitrogen (TN)

TN of urban-dominated reservoir showed a positive correlation with PH(r=0.094) and that of agriculture dominated reservoir showed a negative correlation with PH(r=-0.142). TN of forest dominated reservoir showed a significant positive correlation with both PH(r=0.435).

The results of correlation analysis indicated that almost all water quality parameters of forest and agriculture-dominated surface water values were positively correlated with each other, except TSS and TN of forest and TN and PH of agricultural land which was negatively correlated. On the contrary, most of the values of urban dominated reservoir water quality parameters were negatively correlated with each other (Table 34, 35 & 36)

In this study, the difference between land use/cover type and the corresponding water quality was assessed to explore the significant difference of land use/cover types in affecting the water quality of surface water (reservoirs). The study aimed to study the effect of different land use/cover types on water quality. The study indicated that different land use/cover types affect the quality of surface water differently. The higher effects of land use/cover types on water quality were observed in agriculture-dominated surface water as compared to forest-dominated surface water. This indicates that forest land has a capacity of reducing surface runoff by increasing the infiltration rate of the land; whereas, agriculture runoff is the source of suspended sediment and total nitrogen to the surface water. Urban-dominated surface water was more responsive in contributing TDS to the downstream water environment than forest and agricultural land. Temporal variation was observed among land the dominant land use/cover types are affecting water quality. The higher temporal variation in TDS, TSS, PH, and TN was high during the dry season in agriculture dominated surface water, this is due to continuous addition and cumulative effects of nutrients and sediment load during the rainy season. Temporal variation of nutrient and sediment load is minimum in forest dominated surface water, due to reduced runoff and increased infiltration in forest land. All water quality variables were correlated to each other differently. Most of the variables in agriculture and forest dominated surface water positively correlated with each other.

Therefore, surface water is mainly affected by human activities through continuous and steep slope cultivation, use of inorganic fertilizer for soil fertility improvement and urban built up as compared of forest cover surface water quality. Incorporating physical and biological soil and water conservation practice in cultivated land and planting grass and trees at the buffer zone of surface water helps to sustain water bodies in terms of its quality and quantity.

4.5. EFFECTS OF LAND USE/COVER CHANGE ON FOREST,WETLAND AND WATER RESOURCES

4.5.1 Population Dynamics

According to the national population and housing census conducted in 1996, the total population of Nekemte town was 50,188. After 10 years, in 2006, the total population was 65,188 with an increment of about 30%. In 2016, the total population has become 99,334 as projected from the 2007 national census. The total number of population was increased by 30% in 2006, and 52% in 2016, according to the Ethiopia Central Statistics Agency (CSA,2007) (Figure 32).

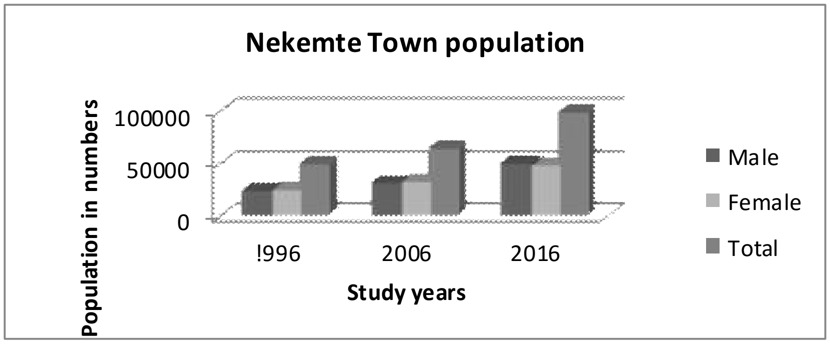


Figure 32: Population size of the study periods

4.5.2 Climatic data of the study periods

A. Rainfall

The rainfall data of the study period (Figure 33) showed that rainfall distribution is almost similar during the study periods, but the total amount of annual rainfall has decreased from 2320mm in 1996 to 2139.4 in 2006 and further reduced to 2044mm in 2016.

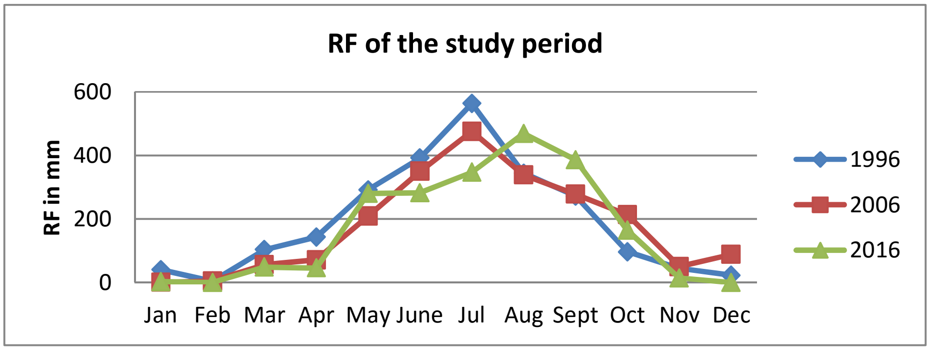


Figure 33: Rainfall distribution of the study period

B. Temperature

As indicated in Figure 34, the maximum temperature of each month was almost similar but the average temperature of the study years had been increasing slightly from 1996-2016. The average maximum temperature of 1996, 2006, and 2016 was 23.80C, 24.30C and 25.50c respectively. This trend shows that temperature has increased during the study periods.

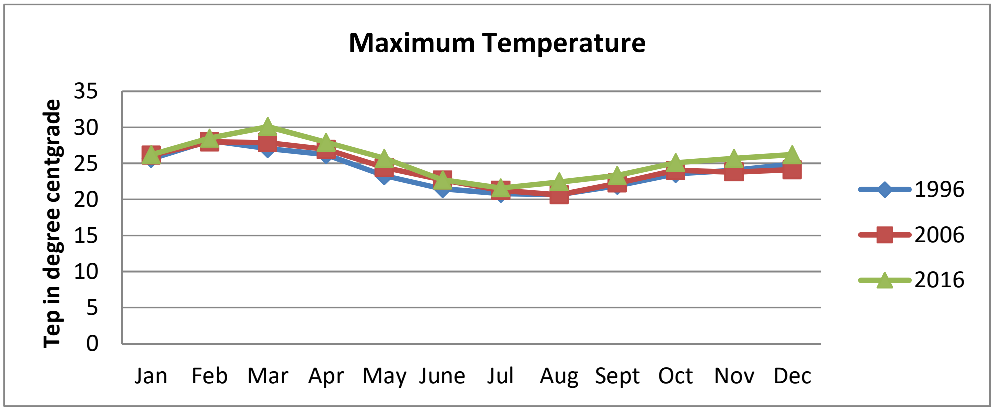


Figure 34: Maximum temperature of the study periods

4.5.3 Land Use/Cover Change Detection

A two-way cross-matrix obtained by the application was used to describe the key change types in the study area. The cross-tabulation analysis was conducted to determine the quantitative conversions from a particular category to another land cover category and their corresponding area was evaluated on a pixel to pixel basis. Thus, a new thematic layer was also produced from the six class maps, containing different combinations of change classes and their description showed in (Table 35)

Table 35: Description of LULC types

Land classes	Description
Built up area	Urban fabric, industrial, commercial, road and non vegetative land
Cultivated land	Arable land, permanent crops, pastures and others agricultural areas
Forest land	Natural and manmade forest
Grazing land	Grassland area with/without trees
Riparian forest	forest cover along the river and stream bank
Wet land	Water bodies or swampy area used as source of water for Bone farm during dry season

4.5.4 Land Use Transition and Spatial Trends of Change

4.5.4.1 Land Use/ Cover Transitions (1996-2016)

The study was intended to evaluate land use/ cover change of the three study periods, namely, 1996, 2006 and 2016. Each land use/ cover map was compared with the reference data to assess the accuracy of the classification. The reference data were prepared by considering training sample points and field knowledge of the study site. Overall, the classification accuracy of Nekemte city during the year 2016 was 86.5%**.** The major land-use type shown by the three maps includes built-up land, cultivated land, forest land, grazing land, riparian forest, and wetland. Forest land includes both natural and plantation forests because of their similar reflectance during classification. As indicated on the map and percentage share of each class of 1996 (Figure 35), the greatest share of land use/ cover type from all classes was built-up, which covers an area of 554.7 ha, contributing 32% of the total area. Forestland and grazing land covers an area of 298 ha (17 %) and 299 ha (17%), respectively in the year 1996... The aerial coverage of cultivated land, wetland, and riparian forest were 258 ha (14.4%) and 244 ha (14%) and 102 ha (6%), respectively. In 1996 forest cover was 17% of the total land cover, followed by built-up and wetland covering 14% of the total. This indicates that much of the land was under forest and wetland cover during that period.

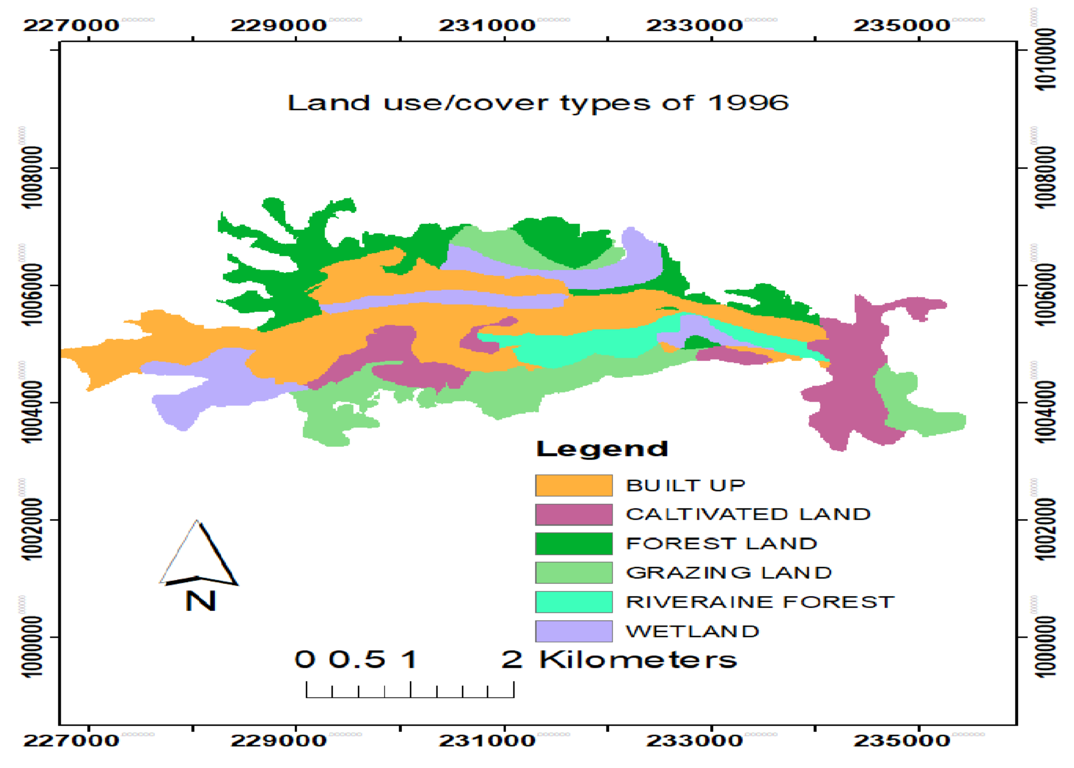


Figure 35: Nekemte town land use/cover map and aerial coverage of 1996

As indicated in Figure 36, area coverage of the 2006 built-up area was increasing more significantly as compared to the rest of land use/ cover classes, covering an area of 746 ha (43%). Cultivated land covers an area of 464 ha (27%), next to built-up from the total areas. Grazing land, forestland, riparian forest, and wetland covers were reduced within ten years period and remain with an area of 189 ha (11%),168 ha(10%),90 ha (5%) and 73 ha (4%), respectively. The built-up area increased from 32% in 1996 to 43% in 2006 at the expense of forestland, grazing land, and riparian forest. This increment in the built-up area is due to population growth and rural to urban migration. The cultivated land cover also increased from 14% in 1996 to 27% in 2006, due to the conversion of more wetland to cultivated land during that period. On the other hand, forest cover was reduced from 17% in 1996 to 10% in 2006, which shows that much of the forest land was converted to the built-up area during this period. The wetland, which was 14% in 1996, was reduced to 4% in 2006 as more wetland was converted to built-up and cultivated land.

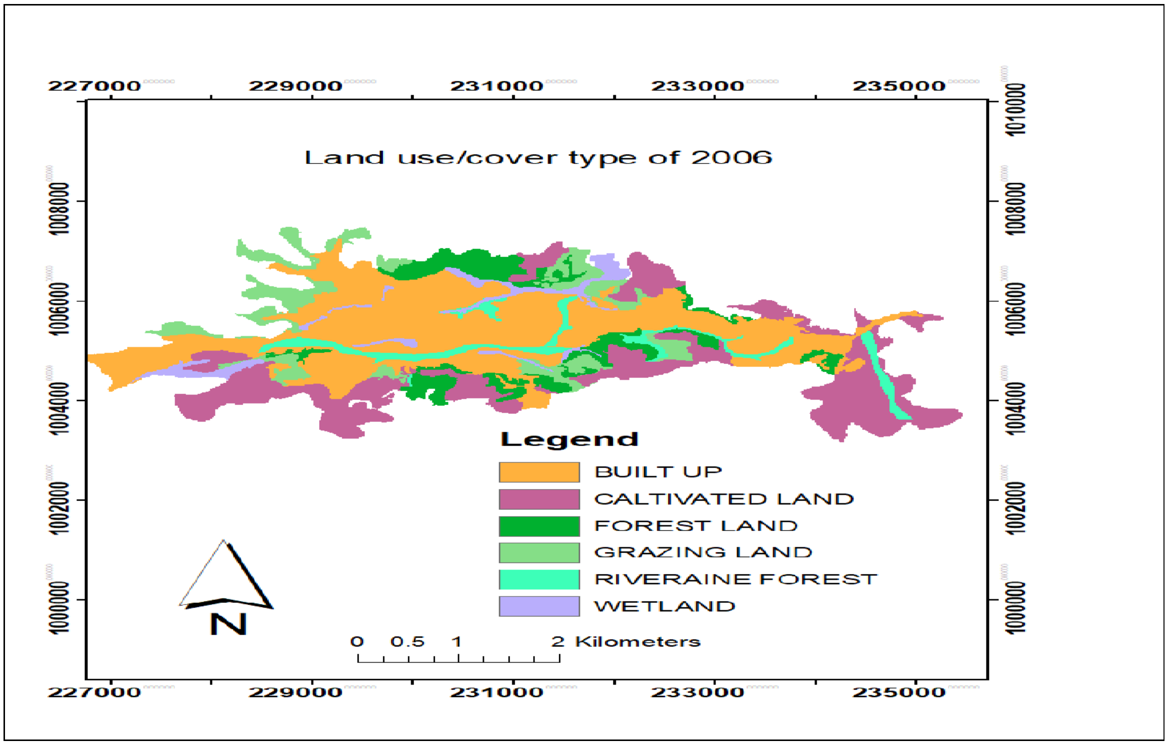


Figure 36: Nekemte Town land use Map and aerial coverage of 2006

As indicated in Figure 37, the LULC map and area coverage of the built-up area covered more areas than all other land classes in 2016, occupying 1321 ha (76%) of the total land cover of the study area. Built-up areas have increased during the study period. Forest and wetland coverage of 2016 was 5% and 3%, respectively. Cultivated land, grazing land and riparian forest cover of the year was 10.4%, 3.1%, and 3.6%, respectively.

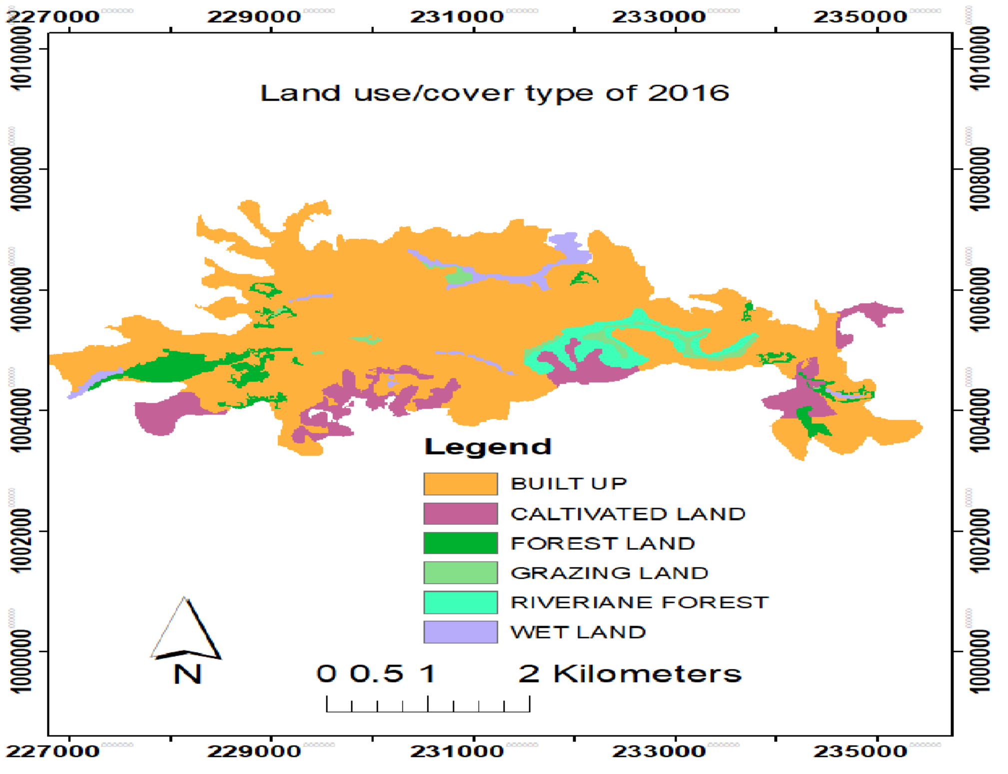


Figure 37: Nekemte Town land use Map and aerial coverage of 2016

Table 38 indicates that area coverage of built-up increased with respective values of 35.5% in 1996, 43% in 2006, and 70% in 2016. Forest coverage decreased from 17% in 1996 to 9.7% in 2006 and further to 5.1% in 2016. Similarly, wetlands coverage was 14% in 1996, but it shrank to 4.2% in 2006 and 2.7% in 2016. This trend indicated that, except for the built-up area, other land use/cover types all showed a decreasing trend.

Table 38: Nekemte Town LULC in Hectares; 1996, 2006 &2016

Land Classes	1996	%	2006	%	2016	%	AARC (%)
Built up	553.74	32.6	746	43.1	1321.5	76	3.65+
Forest	290.3	17	168.39	9.7	87.8	5.1	1.25-
Cultivated	250.5	15.6	464.7	26.8	180.7	10.4	2.3+&-
Wetland	242.8	14	73.05	4.4	46.29	2.7	1.225-
Grazing	292.8	17	189.9	11	30.4	3.1	2.35-
Riparian forest	102.88	5.9	90.7	5.2	65.8	3.8	1.375-
Total	1732.74	100	1732.74	100	1732.74	100	

❖ Rate of change in percentage is calculated as change between the two study years per total change of those years divided by the time interval times 100

❖ AARC= Average Annual Rate of Change

Built-up area increased by 181.16 ha within 10 years interval (between 1996 and 2006), with a rate of 18.1 ha/year and further increased in 2016 with an accelerated rate of change 47.01 ha/ year. The built-up area was expanded at the expense of forestland, wetland, grassland, and cultivated land. This shows that there was a dramatic expansion of the built-up area within the specified time period because of increased population pressure in the town. Forest land had decreased from 1996 to 2006 by 130 ha and changed at the rate of 13 ha/year and further decreased by 80.59 ha from 2006-2016 at the rate of 8 ha/year. The rate of change decreased between 2006 and 2016, as compared to the former ten years because of some restrictions and changes in land distribution policy. The change was induced by the conversion of shrub, forestland, cultivated land and wetland to built-up due to increased population pressure in the town.

4.5.4.2 Change Detection

Change detection helps to determine the actual change of one land-use class to another land-use class. The method used in change detection was the comparative analysis of LULC classifications for t1 and t2 produced independently. The total land area under the study was 1732 hectares. The LULC change matrix indicates the direction of change (Table 42 & 43). The values in each column indicate the unchanged value (bold) and change to other land cover classes, and the value across each row indicates the unchanged value and change to other land cover classes. As indicated in Table 39, all figures in bold indicate unchanged areas of each land use/ cover type within ten years. Moreland use was converted to built-up during the study periods. The built-up area gained 299.8 ha of land from different land-use types in 2006. This shows that the built-up area was increasing at the expense of other land uses, the most affected being forestland and wetland in which 102.5ha and 62.7 ha of land were converted to built-up within 10 years intervals, respectively.

Table 42. Land use change matrix between1996 and 2006

Land cover type	Built-up	Cultivated	Forest	Grazing	Reverie	Wetland	Total
Built-up	**444**	12.7	16.9	31.8	35.2	13.1	553.7
Cultivated	74.7	**128.8**	20.6	3.2	17.9	5.3	250.5
Forest	102.5	38.8	**34.4**	100	0.1	14.5	290.3
Grazing	23.8	163.7	63.4	**24.9**	12.2	4.8	292.8
Riparian	36.1	14.4	20.8	11.8	**16.3**	3.6	103
Wetland	62.7	105.7	12.3	19	10.2	**32.5**	242.4
Total	743.8	464.1	168.4	190.7	91.9	73.8	1732.7

Table 43. Land Use Change Matrix between 2006 and 2016

Land cover type	Built-up	Cultivated	Forest	Grazing	Reverie	Wetland	Total
Built-up	**686.9**	9.9	13.2	10.4	14	9.4	743.8
Cultivated	276.5	**138.7**	36	0.9	10.3	1.7	464.1
Forest	109.7	25	**6.5**	1.5	24.5	1.2	168.4
Grazing	159.8	6.5	14	**0.1**	9.7	0.6	190.7
Riparian	70.3	0.5	0.9	12.5	**6.9**	0.8	91.9
Wetland	16.7	0	18	5	0.9	**33.2**	73.8
Total	1319.9	180.6	88.6	30.4	66.3	46.9	1732.7

As indicated in Table 40 from the total 743.8 ha of built-up area in 2006, about 686.9 ha of built-up area was unchanged, which means that more land areas remain as a built-up area in 2016, as compared to other land-use types. All figures in bold indicate that land uses which were unchanged during the considered periods. Most of the land use types of the year 2006 were converted to the built-up area in 2016. The built-up area had gained 633 ha of land from different land-use types. This shows that built-up area was still expanding at the expense of other land use types, and the most affected were forest lands and wetlands in which 161.9 ha and 40.6 ha of land were converted to other land use types within 10 years, respectively.

4.5.4.3 Gain and Loss of Land Use and Cover Types

Figure 38 shows that there were rapid land use/ cover changes from other land-use types to the built-up area. During the study periods, grazing land, forestland, and wetland were found to be the most dynamic classes which contributed to the expansion of built-up areas. The built-up areas continued to increase with a gain of 831.5 ha and a loss of only 63.5 ha in the study periods. Forest and wetland areas had been decreasing during the three study periods in which both lost 280.9 ha and 220 ha of land respectively. The overall changes which occurred over the last 20 years in forest areas indicate a decrease of 280.9 ha (representing a decrease of 16% of the total study area) and a gain of 79.5 ha (4.5 % of the study areas). Wetland areas have lost 228.8 ha (13.2% of the area) and gained 2 ha or 1.25% of the study area, but the built-up area has gained 48% and lost only 3.6% of the total study area. The other land use and cover types (Cultivated land, grazing land, and riparian forest) have also lost their area coverage due to the expansion of the urban built-up area.

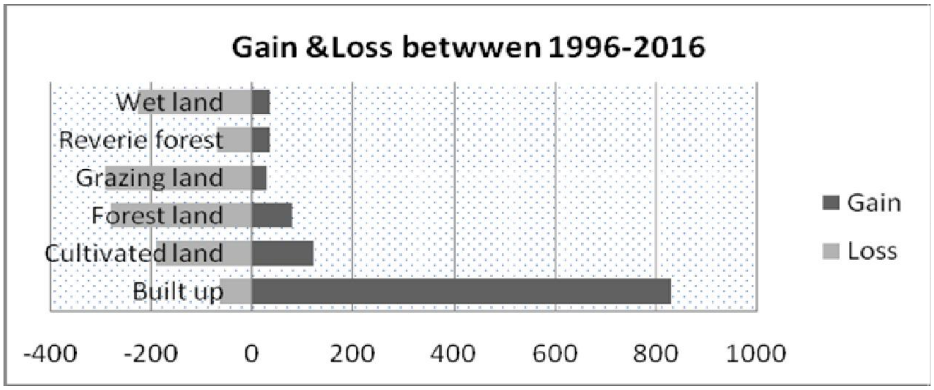


Figure 38: Gain and losses of land cover of each land uses (ha)

Land-use change and forest

The forest cover of the study years (1996-2016) was reduced by 121ha and was remained at 168.3h in 2016. Forest coverage was reduced by 70%, but the mean temperature of the same years increased by 0.04oc within 20 years period. There was no steady trend for a reduction in rainfall over the study period (1996–2016); rather, a fluctuating trend was observed. Forest cover predicts interannual variability in rainfall. So, the removal of forest cover due to urban land expansion has contributed to the mean annual local temperature increment and water quality reduction by urban runoff in the study area.

Land-use change and wetland

Wetland, which is assumed to be the home for many plants and animals, source of water, and an area for flood control, was reduced from 242.8 ha(14%) in 1996 to 46.29 ha(2.7%) in 2016, that is, by 196.51ha(13%) within 20 years period. The urban land expansion was the primary factor for the wetland area reduction. Farming during the dry period (Bone farm) and pollution of urban runoff are other factors threatening the normal functioning of the existing wetland in the study area. Wetland ecosystems are different from other ecosystems, where there is structural and functional overlap between terrestrial and aquatic systems. Thus, wetland area reduction and pollution growth have resulted in the disappearance and disturbance of the normal functioning of both ecosystems.

The reason for the change of a large portion of other land uses to the built-up area were due to rapid population increment during the considered period, as indicated in population data (Figure 1). The rapid population growth in the urban area mainly resulted from the high birth rate and migration of rural to urban areas. Such population increment had a plausible effect on the limited resources and had significantly contributed to the expansion of urban land by deforestation and infilling of wetland, cultivated, grazing, and riparian forest areas.

4.5.4.4 Urban land use and stream water quality

As indicated in Table 44, the result of the physio-chemical analysis showed that urban land use harmed water quality. The mean effects of urban land use on PH, Total suspended solids (TSS), total dissolved solids (TDS) and total nitrogen (TN) of stream water were 5.4, 24.12 mg/l, 111.7 mg/l and 4.31 mg/l respectively. Likewise, the mean effects of non-urban land use on PH, TSS, TDS, TN, of stream water were 5.08, 2.17 mg/l, 55.9 mg/l, and 1.48 mg/l, respectively. Except for the mean value of PH, all mean values of TSS, TDS and TN of urban stream water was greater than non-urban and had a significant difference at ($P<0.05$) between them

Table 44. Mean Value of Physco-chemical parameters for the study areas

Water quality variables	Urban stream water	Non-urban stream water	P-values
	Mean ± S.E	Mean ± S.E	
PH	5.47 ± 0.075	5.08 ± 0.01	0.951
TSS	24.12 ± 6.5	2.17 ± 0.04	0.003
TDS	111.1 ± 10.3	55.9 ± 0.18	0.0001
TN	4.31 ± 1.17	1.48 ± 0.19	0.02

The results of stream water quality indicators showed that urban land use had a significant effect on water quality under all water quality parameters as compared to the non-urban natural environment. Therefore, an increase in urban land use in the study area had a significant impact on the value of TSS, TDS, and TN of surface water.

After the analysis of all values, each variable was tested to find any statistical difference between the two land uses/ cover types by using T-Tests. The result showed that there were statistical differences in TSS, TDS, and TN with p-value (0.003, 0.0001, and 0.02 respectively), but there was no statistical difference in PH, at 95% confidence interval.

The higher in TSS, TDS, and TN of urban land use as compared to non-urban land use were due to urban runoff, resulted from the removal of forest and wetlands. Land-use changes have effects on water quality, either positively or negatively. In forestland with good vegetation cover and little interference from humans, much of the rainfall soaks into the soil rather than running off to the nearby stream, and water quality is relatively good as in the case of non-urban land use. In built-up areas with pavement and buildings, however, little rainfall soaks into the soil, causing high runoff to the surface water and poorer water quality.

Urban land use/cover dynamics analysis revealed that built-up areas have increased during the study period and resulted in a substantial reduction of forest area, cultivated land, grazing land, wetland, and riparian forest. Forestland and wetland, which are the focus of this research, have continuously decreased due to the fast growth of urban land. This land cover change on the category of the built-up surface has exerted an incredible pressure on non-built up surfaces, particularly on forestland and wetland. Expansion of the urban land use was increasing through rapid construction sites of residential units, commercial and road networks, and other impervious surfaces.

During the study period, forest cover has been significantly reduced and resulted in local climate change. Effects of urban land expansion on the wetland through area reduction, farming during the dry period (bone farm), and pollution of urban runoff were threatening the normal function of the existing wetland. The urban land expansion also influences the normal functioning of the water environment through pollution from urban runoff due to the removal of wetland, which is used as pollution absorbent.

Therefore, urban land expansion, due to population growth, migration and economic development at the expense of other land use, has contributed to local climate change, surface water quality deterioration, and reduction of the normal functioning of the wetland ecosystem. Urban growth will continue to increase at the expense of other land-use types unless necessary corrective measures are taken.

5. RESULT SUMMARY AND SYNTHESIS

This chapter synthesizes the findings from the SWAT and MULSE models output and biophysical and chemical analyses and discusses the interconnections of the results based on predetermined research questions to be answered.

Investigated effects of land use/cover dynamics on watershed hydrology

The significance of land use/cover dynamics and its effect on watershed hydrology of the studied cacthments is presented below. The SWAT model was used to assess the impact of LULC types on watershed hydrology mainly runoff and water yield generation. The SWAT model is a continuous, semi-distributed, physically-based model developed by the U.S Department of Agriculture. It is a watershed-based hydrological model developed to predict the impact of land management practices on water, sediment, and chemicals from agriculture within a watershed (Neitsch et al., 2011). This study focuses mainly on the hydrological component of a watershed.

In SWAT, the watershed is divided into multiple sub-watershed and hydrologic response units (HRUs). Each HRU is a designated area having a unique combination of land use, soil characteristics, and slope. It uses a water balance principle to simulate the hydrological component for different land use/cover types of a watershed. The SWAT model using generally available data can be used to simulate the hydrological component parameter from each HRU. Hydrological parameters simulated were includes; ET, surface runoff, deep percolation, soil moisture and groundwater flow and total water yield. The result showed that agricultural land produced more surface runoff than other land uses in a subwatershed, followed by urban land. Forest and grassland produced a minimum amount of runoff, as compared to other land use due to their higher infiltration capacity.

Cultivated and urban land highly affects the water balance components, leading to increased runoff and water yield and decreased groundwater and evapotranspiration. In contrast, forestland and grassland tend to increases groundwater and evapotranspiration of the watershed. Therefore, watershed hydrology is mainly influenced by the type of land use/cover where cultivated and urban contributes more surface runoff and affects hydrological water balance in a watershed. Impact of increased runoff and water yield would be more evident with continuing cultivation and urban land expansion, especially in steep slopes parts of a watershed where more steep land under cultivation, would contribute more surface runoff than others land use/cover types

Spearman rank correlation between hydrological variables indicated that total water yield was positively correlated with percolation, surface runoff, water, and groundwater flow and negatively correlated with ET and soil water.

The interaction effects of land use/cover and slope gradient on surface runoff and water yield indicated that, in cultivated, forest, and grassland, the slope gradient had a positive relationship with surface runoff and water yield until the slope reaches 35%, 30%, and 15%, respectively. Beyond this range, the simulated mean values of runoff and water yield had been decreasing in the three land use/cover types. Land use/cover type of the watershed is the main factor affecting the watershed hydrology followed by the combined effects of land use/cover and slope gradient. While the combined effect of land use/cover with soil types showed an insignificant difference in the values of hydrological variables in the study watershed.

Effects of land use/cover dynamics on sediment and nutrient loss of the watershed

This analysis presents how the combination of land use, soil, and slope affect sediment and nutrient loss in the watershed.

The effects of land use/cover dynamics on sediment and nutrient loss from each HRU indicated that the mean values of sediment loss from cultivated land was higher than the mean scores of other land use/cover types with no significant difference, followed by urban land. Forest and grassland produced less amount of sediment from their respective HRU. Higher sediment loss from HRU was found to be associated with cultivated land and urban land. A significant sediment loss increase was mostly restricted to cultivated land under continuous and steep slope cultivation resulted in more runoff...

The simulated mean values of nutrients showed that urban land produced significantly higher organic nitrogen, organic phosphorus, and phosphorus in sediment than other land use/cover types; this is because of the removal of organic and inorganic substances and liquid and solid waste from paved urban land by runoff. Sediment and nutrient losses from each HRU is mainly influenced by paved nature of urban and continuous and steep slope cultivation of farmland, Therefore, avoiding steep slope cultivation and implementing appropriate soil and water conservation practices on farmland and limiting urban land expansion at the expense of forest and grassland would alleviate the problem of watershed dynamics in terms of nutrient and sediment loss.

The effects of land use/cover and soil types on sediment and nutrient losses

The interaction effect of land use/cover and soil types on sediment and nutrient transport from each HRU showed that soil variation had no significant impact in determining the amount of sediment produced and nutrient transported from HRU of different land use/cover types. The result indicated that the same soil type under different land use/cover showed different results. There were no consistency results obtained from the same soil of different land use/cover types. Therefore, it was concluded that soil factors are not as influential in determining the amount of sediment yield produced and nutrient transported from HRU.

The effects of land use/cover types and slope gradient in sediment yield and nutrient loss

The combined effect of land use/cover types and slope gradient at HRU was more pronounced, showing high variability in sediment yield produced and nutrient transport in a watershed. The same land use/cover type with different slope gradient showed high sediment and nutrient variability from HRUs in a watershed. This is because of more runoff and less infiltration of land at the steeper slope and beyond a certain limit the topography of land getting less steep. A slope of forestland increases, it is getting denser and denser in the study area and this could decrease surface runoff. On the contrary, due to the pave and impervious nature of urban land sediment and nutrient loss increases as the slope gradient increased. This indicates that the interaction of different land use/cover and slope gradient shows a significant difference in sediment transport from HRUs in a watershed.

The simulated nutrient transported values from the combination of land use/cover types and slope gradient showed that, as the slope increased from 0-5% to 8-15%, almost all nutrients transported from land use/cover types also increased and then declined as slope gradient increased further differently. Spearman rank correlation analysis indicates that the slope gradient of each land use/cover type was differently correlated with sediment and nutrient losses, due to differences in cover types

Therefore, the interaction of land use/cover and slope could be considered as an important factor in changing watershed hydrology in terms of sediment and nutrient transported from HRU in a watershed. As more and more sediment and nutrient leave the HRU, they join the water channel and affect the water quality of the study reservoirs.

Soil loss and sediment yield in the watersheds and their effect on reservoirs

The average soil loss by erosion from HRU of land use/cover types predicted by MUSLE was 20.9/ha/yr and 20.72/ha/yr in the Chancho and Sorga sub-watershed respectively... This indicated that there were high variations in the predicted soil loss between each land use/cover type. These high variations resulted from the diverse land use/cover types, soil, and the wide range of land slopes. Cultivated land was the principal land use type that tends to produce high soil erosion in Chancho, followed by urban land in Sorga sub-watershed. Grassland produced a lower amount of soil loss t/h/yr as compared to other land uses.

As compared to the soil loss estimated for Ethiopia as 42 tons ha-1 y-1 from cultivated fields by Hurni (1990, 1993), 21 tons ha-1 y-1 (Machado et al., 1995), and 30-80 tons ha-1 y-

1 (Tekeste and Paul, 1989) in Tigray region, northern Ethiopia, the soil loss estimated in this study was also greater than tolerable soil loss 18t/h/yr for cultivated land(30 ton/ha/yr), residential area (18.8ton/ha/yr) and urban land(18.23ton/ha/yr) whereas, forest and grassland were less than the tolerable rate of soil loss (17ton/ha/yr and 14ton/ha/yr), respectively. This could be due to continuous and steep slope cultivation of land for growing crops, and impervious, paved and construction on steep slope condition of the urban built-up areas.

Sediment yield was estimated based on gross soil loss predicted by USLE and sediment delivery ratio values of each subwatershed. The value of the sediment delivery ratio is highly dependent on the area of the watersheds since as area increases, the value of SDR decreases. The estimated average sediment yield was higher in the Chancho subwatershed as compared to the Sorga sub-watershed. This variation is due to the higher percentage of cultivated land cover in Chancho, which contributes more than 70% of sediment yield as opposed to Sorga sub-watershed, which is covered relatively with more forest, contributes less average of sediment yield. Urban land also contributes more sediment yield, next to agriculture dominated sub-watershed.

The total sediment produced is not deposited in the reservoirs due to variation in sediment trap efficiencies of the reservoirs, drainage surface areas, and dam size. The calculated trap efficiency of both reservoirs was 99.9% and this amount of sediments was deposited in the reservoirs and only 0.1% was taken out by flowing water in both surface water**.** So, the trapping efficiency of the two reservoirs is very high and more sediment deposited and resulted in storage capacity loss of the reservoirs**.**

From the total sediment yield produced in the sub-watersheds only 30% of sediment deposited in the Sorga reservoir and 71% of the sediment deposited in the Meka reservoir. The reaming sediment is deposited in non-reservoir areas, like low lying land, water stream and rivers and the dam size contributed to this variation. Human activities in terms of land cultivation and urban construction have contributed more sediment load to downstream reservoirs and resulted in storage capacity loss of reservoirs. In this study, reservoir storage capacity loss was estimated to be 0.056% and 1.5% for Chancho and Sorga reservoir every year, respectively. This variation in storage capacity loss is due to the difference in the size and total storage capacity of the reservoirs...

Therefore, land use/cover types, size, and storage capacity of reservoirs and the quantity of sediment deposited are the most influential factors determining the life span of the reservoirs.

Impacts of different land use /cover type on surface water quality

The significant relationships between land use/cover type and surface water quality in the studied watersheds is discussed below. The results suggested that agriculture and urban-dominated sub-watersheds had significant impacts on water quality in the study area. The variance analysis showed that subwatershed with more forestland had better water quality. The lesser effects of forest dominated sub watershed in deteriorating water quality are due to low anthropogenic activities and less runoff, as compared to high human interference in cultivated and urban lands. The correlation analysis among water quality parameters indicated that all were correlated to each other differently for each land use/cover type.

Effects of land use/cover change on the prei-urban natural environment (forest and Water)

The magnitude of impact of urban land use/cover changes on the prei-urban natural environment is further investigated. The environmental impact of urban expansion in Nekemte town was analyzed based on three historical land uses/covers obtained from land sat images. The result indicated that built-up areas increased at the expense of mainly forest and wetland and other land use/cover types. This conversion of natural forest and wetland into urban built-up has resulted in surface water quality deterioration and local climate change in the study area. The main driving factors for the urban land expansion identified were: population increase due to high birth rates and migration from rural to urban areas.

6. CONCLUSIONS AND RECOMMENDATIONS

. The SWAT model using generally available data was used to simulate hydrological component, sediment and nutrient losses from each HRU of the watershad watersheds studied.

The impact of increased runoff and water yield would be more evident in continuing cultivation and urban land expansion, especially in the steep slope areas of the watersheds. The study Subwatershed, which has more of steep land under cultivation, would contribute more surface runoff to the downstream surface water. Cultivated land is the main factor that affects the watershed hydrology in terms of water balance in the study areas, followed by urban land. The effects of the interaction of land use/cover with slope gradient on surface runoff and water yield indicated that, in cultivated, forest and grassland, slope had a positive relationship with surface runoff and water yield until the slope reaches 30%, 30%, and 15%, respectively; beyond this range, the simulated mean values of runoff and water yield had been decreasing in the three land use/cover types.

Spatially, significant sediment loss increase was mostly restricted to land with continuous and steep slope cultivation as in the study sub-watershed, where more steep slope land was under cultivation. Therefore, the amount of sediment and nutrient loss from each HRU is mainly impacted by cultivated and urban land and the play a great role in the dynamism of watersheds hydrology.

The interaction of land use/cover and soil types indicated that the same soil type under different land uses/covers showed different results. Inconsistence results have been obtained from the same interaction of soil with different land use/cover types. Therefore, it was concluded that, in this study, soil factors are not as influential in determining the amount of sediment and nutrient transported from HRU; rather, land use/cover type is the most influential factor to be considered in a watershed management practices. The interaction of land use/cover type with the slope gradient is also an important factor in influencing watershed hydrology in terms of sediment and nutrient transported from HRUs. Therefore, almost all hydrological variables had statistically a significant relationship with land use/cover types, except evaporation at $P<0.05$, whereas, water quality variables had no statistically a significant relationship with cultivated and forest land, but significantly related to urban and grassland

Soil loss estimated from cultivated and urban land was greater than the tolerable soil loss 18t/h/yr for Ethiopian highlands but less than the tolerable rate for forestland and grassland. This could be due to the continuous and steep slope cultivation of land for growing crops and impervious, paved infrastructure and construction of the urban built-up. Urban land also contributes more sediment yield, next to agriculture dominated sub-watershed. The total sediment yield produced in Sorga sub-watershed was higher than that in Chancho, due to the larger area of land under crop cultivation and the bigger size of the sub-watershed. Meka reservoir, with larger storage capacity, had more sediment entered and deposit but less storage capacity loss as compared to Sorga, which has a smaller size and less storage capacity with low sediment deposit and had more storage capacity loss per year. Therefore, land use/cover types, size and storage capacity, and the quantity of sediment deposits are the most influential factors that have determined the life span of the reservoirs...

Water quality variables were analyzed in the laboratory to assess the effects of land use/cover types on surface water quality. The result showed that agriculture and urban dominated sub-watersheds had more significant impacts on water quality than forest dominated sub-watershed in the study area. The variance analysis showed that subwatershed with more forest land have better water quality than agriculture and urban dominated sub-watersheds.

Historical images of land use/cover types of Nekemte town were used to examine the biophysical effects of LULCC. The result indicated that urban built-up was increasing at the expense of natural forestland and wetland and, as a consequence, surface water quality was reduced in the study area. The main driving factors identified for the urban land expansion were: population increase due to high birth rate, migration from rural to urban areas, and economic development in the study area

Therefore, land use/cover dynamics, slope gradient, and less extent of soil types are among the most influential factors affecting the watershed hydrology and reservoirs sedimentation in terms of water imbalance, soil loss, water quality reduction, storage capacity loss of reservoirs and forest and wetland resource degradation

RECOMENDATIONS.

Based on the findings and conclusions made thereof, the following recommendations were proposed to solve the problems of the environment in general and watershed hydrology in particular.

1. Cultivated land is the main factor contributing to the dynamism of watershed hydrology; thus, it should be managed both in biological and physical measures to reduce soil loss by runoff.
2. Less fertile soil is more susceptible to lose and, hence, needs to be fallowed for certain periods for restoration.
3. A slope of cultivated land increased, surface runoff and nutrient loss also increased and, therefore, steep slope land should not be cultivated for growing crops; rather, it should be used for fodder and tree crops.
4. Forestland and grassland produce less soil loss and sediment by runoff to the downstream and contribute less for water balance change; hence, the existing natural trees should be preserved and maintained in supplementary with afforestation of degraded and steep land.
5. The reservoir buffer zone is under cultivation in the Meka reservoir, which contributes more sediment to a reservoir. Therefore, a buffer zone including the hillside of a reservoir should not be cultivated; instead; buffer grasses and fodder trees should be planted in the sites.
6. Reservoirs are constructed either to supply drinking water or to serve other purposes sustainably. Therefore, integrated watershed management with modern agricultural practice should be incorporated during the structural design of a dam.
7. Once water quality is deteriorated and sediment is deposited in the reservoirs, the cost of treatment is very high; therefore, protecting the incoming sediment and nutrient through integrated watershed management should be given the highest priority.
8. Urban land expansion at the expense of forestland, grassland, and wetland is the main factor for local climate change and water quality reduction. In this regard, there is a strong need to implement an appropriate urban land use policy and regulation. Therefore, due attention should be given to avoid aerial expansion of urban built-up by focusing on condominium housing, which is currently in progress in the bigger cities of Ethiopia

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APPENDICS

Appendix 1: Maximum and minimum average monthly temperature of the study areas

Months	Max.Temp	Min.Temp
Jan	26.01727758	12.16807056
Feb	27.53529432	13.08271746
Mar	27.7133516	13.96118954
Apr	26.93783333	14.27622771
May	24.65275108	13.60943408
Jun	22.46627592	12.6732082
Jul	20.84349683	12.49122167
Aug	20.99390611	12.61643935
Sep	22.45127564	12.59619583
Oct	23.83778162	12.63911048
Nov	24.4594587	12.43861836
Dec	25.04381149	11.99476452

Appendix 2: Daily and monthly average rainfall of the study watersheds

Months	Average daily RF	Average monthly RF
Jan	5.45	8.883333333
Feb	5.21	13.92666667
Mar	19.14	53.29310345
Apr	26.39	93.7962963
May	45.58	255.9571429
June	49.1	370.6733333
Jul	60.27	398.4666667
Aug	52.46	388.3966667
Sep	43.8	289.1821429
Oct	31.64	148.4566667
Nov	19.41	45.40666667
Dec	9.16	17.27
Year Average	30.63416667	173.6423905

Appendix 3: Average monthly relative humidity, sun hour and wind speed of the study watersheds

Months	RH	Sunhur	WINDLY
Jan	57.07405	8.59387	0.75
Feb	50.27636	8.364237	0.9
Mar	52.9387	7.721272	0.9
Apr	60.10524	7.289891	1.2
May	85.38998	6.995581	1
Jun	85.22364	4.607377	0.8
Jul	88.33551	2.979997	0.85
Aug	90.11861	3.088478	0.85
Sep	83.57865	4.616621	0.7
Oct	73.81664	7.03334	0.9
Nov	66.59476	8.138898	0.8
Dec	58.93518	8.417092	0.7

Appendix 4: Laboratory result of Agriculture dominated surface water quality parameters

months	PH	Tss	TDS	TS	TN	TP
March	4.9	80	58.6	138.6	17	0.0001
April	5	56	43.6	99.6	8.85	0.0001
May	5.01	53	28.6	81.6	0.7	0.0001
June	4.75	32	22.5	54.5	4	0.0001
July	4.6	15	25.5	40.5	5	0.001
August	4.55	4.5	10.5	15	2.5	0.05
Sept	4.42	4	22.7	26.7	0.0001	0.0001
Oct	4.57	25	21.9	46.9	6.7	0.0001
Nov	5.09	9	20.5	29.5	6	0.0001
Dec	5.54	0.036	23.3	23.336	0.0001	0.0001
Jan	5.03	24	23.3	47.3	2.7	0.0001
Feb	4.78	137	23.6	160.6	0.8	3.9
Max	5.54	137	58.6	195.6	17	3.9
Min	4.42	0.036	10.5	10.536	0.0001	0.0001
Average	4.87143	41.18371	28.12143	69.30514	5.089307	0.560857
SD	0.30855	39.97946	12.42099	47.02272	4.848856	1.124562

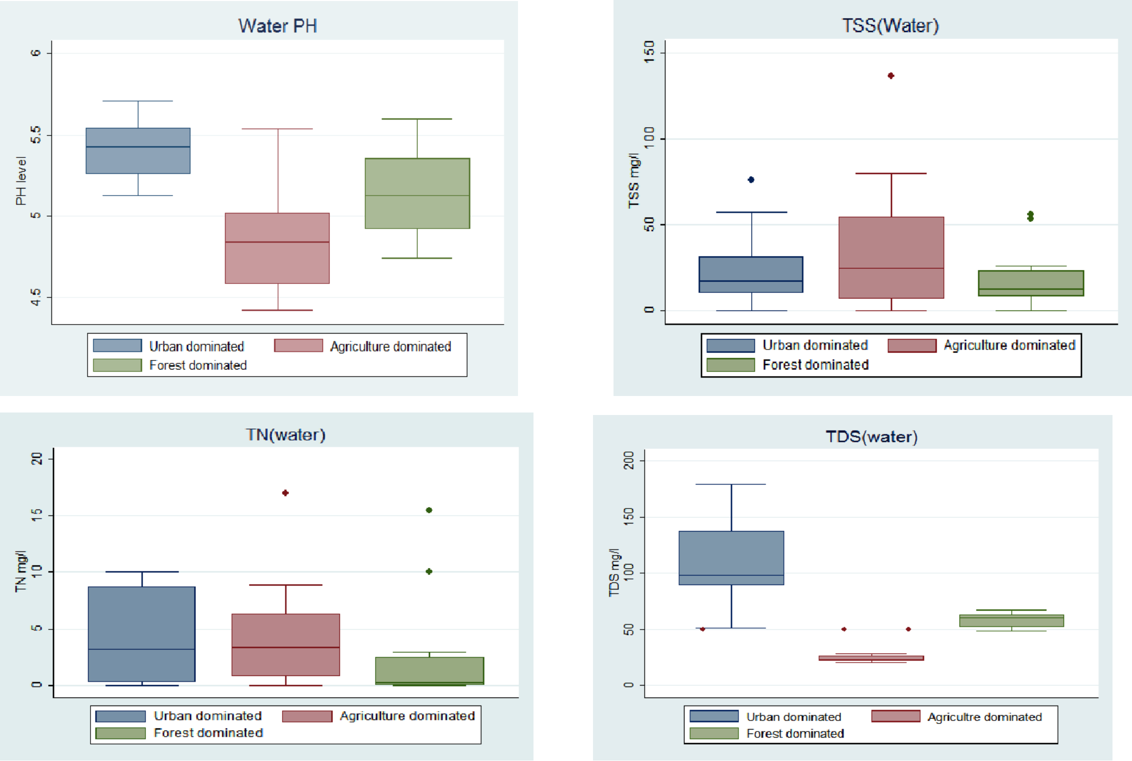
Appendix 5: Laboratory result of Forest dominated surface water quality parameters

months	PH	Tss	TDS	Ts	TN	TP
March	4.85	8	51.7	59.7	2	0.0001
April	5.12	53	59.4	112.4	0.0001	0.0001
May	5.36	8	67.1	75.1	2.9	0.0001
June	5.14	11	63	74	10	0.0001
July	5.6	14.5	115	129.5	15.5	0.0001
August	4.79	10.5	50.2	60.7	0.45	0.0001
Sept	4.74	15	48.6	63.6	0.0001	0.0001
Oct	4.99	5	51.9	56.9	1.5	0.0001
Nov	5.11	20	58.4	78.4	0.0001	0.0001
Dec	5.5	0.041	61.8	61.841	0.0001	0.0001
Jan	5.25	56	62.2	118.2	0.1	0.0001
Feb	5.35	26	63.9	89.9	0.02	0.0001
Max	5.6	56	115	171	15.5	0.0001
Min	4.74	0.041	48.6	48.641	0.0001	0.0001
Average	5.13182	18.27645	62.66364	80.94009	2.950036	0.0001
SD	0.27552	17.95162	17.52729	25.23091	4.929156	2.83E-20

Appendix 6: Laboratory result of Urban dominated surface water quality parameters

months	PH	Tss	TDS	TS	TN	TP
March	5.55	33	51.5	84.5	10	0.0001
April	5.4	2	100.25	102.25	0.0001	0.0001
May	5.24	12	149	161	3.2	0.0001
June	5.27	25	138	163	2	0.0001
July	5.22	11.5	179.3	190.8	8.5	0.0001
August	5.46	9	87.4	96.4	9.9	0.0001
Sept	5.13	76	77.8	153.8	0.1	0.0001
Oct	5.35	12	131	143	5.4	0.0001
Nov	5.5	29	136	165	9	0.0001
Dec	5.71	0.03	90.9	90.93	0.0001	0.0001
Jan	5.54	57	95.6	152.6	3.2	0.0001
Feb	5.57	23	96.6	119.6	0.5	5.2
Max	5.71	76	179.3	255.3	10	5.2
Min	5.13	0.03	51.5	51.53	0.0001	0.0001
Average	5.41286	26.11143	111.725	137.8364	4.414307	0.742943
SD	0.17304	22.62062	35.70877	35.02239	4.062634	1.501082

Appendix 7: Box plot for water quality variables



Appendix Table 8: Livestock population in the sub-watersheds

Types of livestock	Chancho		Sorga		Nekemte Town	
	Population	Percentage	Population	Percentage	Population	percentage
Cows	380	8.8	831	21.4	2493	2.1%
Oxen	594	13.7	92	2.4	275	0.2%
Bulls	576	13.3	288	7.4	864	7.4%
Heifers	285	16	407	10.5	1220	10.5%
Sheep	161	6.6	290	7.5	871	7.5%
Goats	10	0.02	140	3.6	420	3.6%
Donkey	65	1.5	71	1.8	212	1.8%
Horses	6	0.0013	32	0.82	97	0.8%
Mules	3	0.001	7	0.18	21	0.2%
Poultry	2250	52	1724	44.4	5172	44.4%
Total	4330	100	3882	100	11645	100%

Source: Diga and Guto Gida Woreda Agriculture office,2016

Appendix 9: Soil types and texture of the study sub-watershed

		Soil texture						
		Clay		Silt		Sand		
Sub-watersheds	Soil types	clay	%	Silt	%	Sand	%	Total
	Acrisols	201.14	57	84.69	24	67.05	19	352.88
	Cambisols	258.81	46	112.5	20	191.29	34	562.62
	Lixisols	57.42	51	42.78	38	57.93	11	112.58
	Nitisols	695.04	64.3	277.8	25.7	108.09	10	1080.93
	Mean	303.103	54.58	129.4	26.925	106.09	18.5	
Chancho	SD	274.671		103		60.846		
	Acrisols	330.14	57	139	24	110.05	19	579.2
	Cambisols	465.52	46	202.4	20	344.08	34	1012
	Fluvisols	24.23	46.5	13.82	27	14.05	26.5	52.1
	Lixisols	686.15	51	511.3	38	147.99	11	1345.4
	Nitisols	532.98	64.3	213	25.7	82.89	10	828.9
	Mean	407.804	52.96	215.9	26.94	139.81	20.1	
Sorga	SD	249.819		183.1		124.23		

Sources: Oromia water design enterprise, 2017