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EROSION HOTSPOT AREA IDENTIFICATION AND RESERVOIR SEDIMANTATION IN THE CASE OF KOGA DAM (UPPER BLUE NILE BASIN)

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BAHIR DAR UNIVERSITY

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SCHOOL OF RESEARCH AND POSTGRADUATE STUDIES

FACULITY OF CIVIL AND WATER RESOURCE ENGINEERING

EROSION HOTSPOT AREA IDENTIFICATION AND RESERVOIR SEDIMANTATION IN THE CASE OF KOGA DAM (UPPER BLUE NILE BASIN)

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR MASTER OF SCIENCE IN HYDRAULIC ENGINEERING

Advisor: Demsew Alemaw (PhD)

Co- Advisor: Mr. Elias Sime

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Bahir Dar, Ethiopia

DECLARATION

I certify that the work described in this thesis, " Erosion Hotspot Area Identification and Reservoir Sedimantation in The Case of Koga Dam: (Upper Blue Nile Basin)," was completed by me in the Department of Hydraulic Engineering under the supervision of Demsew Alemaw (PhD). All information gleaned from the literature and various organizations has been correctly introduced in the text, along with a list of references.

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I thus attest that I oversaw, read, and assessed Denekew Balew's thesis titled " I certify that the work described in this thesis, " Erosion Hotspot Area Identification and Reservoir Sedimantation In The Case Of Koga Dam: (Upper Blue Nile Basin),"I advise that the thesis be presented for oral defense.

Demsew Alemaw (PhD)

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I hereby certify that the examiners' requested revisions have been implemented and researched in the final thesis.

Name of Student Denekew Balew Signature........ Date 30/12/2014

We, the members of the board of examiners, have reviewed Denekew Balew's thesis, "Erosion Hotspot Area Identification and Reservoir Sedimantation in The Case of Koga Dam (Upper Blue Nile Basin " and we now declare that the thesis is acceptable for the award of the degree of Master of Science in Hydraulic Engineering.

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iv

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ABSTRACT

Dams generate man-made lakes, which are used to store water for water Supply, Hydropower Irrigation, transportation, recreation, and other uses. The construction of a dam for water storage may drastically alter the river's hydrodynamics, having direct consequences for the habitat, river morphology, and ecology of the entire river system. Reservoir sedimentation may be complex to handle and it undermines the valuable life of the reservoir.

The study area lies 42 kilometers southwest of Bahir Dar and 7 kilometers southwest of Merawi, in the Weast Gojam Zone of the Amhara National Regional State's Mecha Woreda. The study's main objective is to investigate erosion hot spot regions and sediment inflow in the Koga dam reservoir. The Garmin GGPSMAP421s was utilized to record the geographic position of the watercraft when recording each profundity estimation, and was utilized to decide the profundity from the water surface to reservoir to collect bathymetry information and RUSLE model used to identify erosion risk areas. The result appeared that diminish of the storage capacity from plan capacity of 83.1 million cubic meter in 2006, 82.7 in 2012 up to 78.91 million cubic meter in 2020. During the last 11 years operation the outcome revealed that the reservoir's storage capacity fell by 4190018.94 m^3, close to 5.04 percent, of its overall volume. It showed that Koga average reservoir capacity loss, which is lower than the predicted global rate of reservoir capacity loss (1%), is 0.38. Although the reservoir's design life is 50 years, its usable life is only expected to last 23.5 years. The bathymetry and RUSLE model's annual average sediment yield of 20.24 and 16.52 tons per hectare per year respectively. The result of the model showed that the Rim main watershed is contributing substantial amount of soil loss and the most erosion hotspot portion of the Koga watershed. For reducing silt inflow into the reservoir upper watershed should undergo the same management and water conservation efforts as the lower watershed. Since RUSEL doesn't consider gully erosion, future studies should be conducted using other technics that can incorporate gully erosion.

Key words**; Bathymetry, Koga Reservoir, Reservoir Sedimentation, RUSLE model**

ABBREVATIONS AND ACRONYMS

ASC	Area storage capacity
BC	Before Chirest
BoEPLUA	Bureau of Environmental Protection, Land Administration and Use
dBD	dry Bulk Density
DEM	Digital Elevation Model
FRL	Full reservoir level
GCP	Ground Control Point
GIS	Geographical Information System
GPS	Global Positioning System
Ha m	Hectare meter
ICOLD	International Commission on Large Dams
IDW	Inverse Distance Weighting
KW	Koga watershed
MCA	Masters in Computer Application
MCM	Million Cubic Meters
MDDL	Minimum Drawdown Level
Mm^3	Million-meter cube
MOWIE	Ministry of Water, Irrigation and Energy
MWL	Maximum water level
NWL	Normal water level
RMSE	Root Mean Square Error
RUSLE.	Revised Universal Soil Loss Equation
SCS	Soil Conservation Service
t/ha/yr	tone per hectare per year
$T/Km^{-2}yr$	Tone Per Kilometer Square Per year
TE	Trapping Efficiency
TIN	Triangular Irregular Network
USACE	United States Army Corps of Engineer

TABLE OF CONTENTES

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

1.1 Background

People have been building dams for thousands of years to utilize fresh water resources provided by our world's rivers, streams, and lakes. It utilized around the world to Supply water system, Hydroelectricity, tourism and multiple-use benefits or other form of diversion irrigation works (Iradukunda and Bwambale ,2021). According to the sedimentation aspect, the dams cause a reduction on the flow velocity, thus causing the gradual deposition of those sediments carried by the stream resulting in the sedimentation and gradually diminishing the reservoir storage capacity. Human activities usually accelerate the processes of erosion, transport, and sedimentation. For instance, soil erodibility is enhanced by plowing and tillage. Dams can store much volumes of silt and show a one of a kind chronological record expanded flooding as the channels lose their stream capacity and impoundments lose capacity(Hui ,2014).The U.S Armed force Corps of Engineers (USACE) right now spends$40 million yearly expelling 2 to 4million cubic yards of dregs from 100 government harbors in arrange to preserve route channels. Much of the precipitation from the extraordinary Lakes Bowl enters streams and waterways and after that in the long run passes through these government harbors carrying dregs and contaminants (Hui ,2014). Disintegration and sedimentation allude to the movement of strong particles called dregs. Nowadays, they can have cause extreme designing, economy and natural issues. Human exercises as a rule quicken the forms of disintegration, transport, and sedimentation in our world. For beyond any doubt, soil erodibility is upgraded by plowing and culturing. The defensive canopy is debilitated by grubbing, cutting, or burning of existing vegetation. Other than creating hurtful dregs, disintegration may cause genuine on-site harm to rural arrive by decreasing the efficiency of rich soils(Tadesse ,2017a). Anthropogenic exercises such as deforestation have driven to the cut of streams with bank disintegration and hence an increment in sedimentation in supplies (Committee and Subcommittee ,2017). As the dam's misfortune capacity, flooding happens and silt overlay on common environments and channels.

A World Bank study illustrated that the average useful life of existing reservoirs in all countries of the world decreased from 100 to 22 years due to sedimentation and the annual cost for promoting the removal of the volumes being accumulated is estimated in

US$ 6 billion (Sheng,Axelsson,and Knutsson ,1995). It has also shown that annual average of reservoirs volume loss due to sediments deposition was of 1% varying from one country to onther, as well as from one region to another.

In Ethiopian which have appropriate environment, need of viable watershed administration frameworks and arrive utilize changes within the scene played a noteworthy part in arrive degradation(Assefa et al., 2015). Alter in silt surrender due to alter arrive utilize within the upstream catchments causes hindering sedimentation.

The north and northeastern highland parts of the country have seen the greatest damage to their soil resources due to soil degradation. These are also the most affected parts of the country by famine due to degradation and recurrent drought. In this case, soil degradation certainly contributes to a higher vulnerability to famine (Lu, 2017).

The problem of land gradation major challenge to Koga reservoir and devasting challenge and downstream regions due to producing runoff releases and forcing embrace silt abdicate, which may result in diminishing water capacity of the dam supply, unless upper watershed administration is implemented (Worku, 2017).

1.2 Statement of the problems

As a consequence of land degradation, the productive capacity of the soils in Ethiopian highlands is reducing at a rate of 2-3% annually. The north and northeastern highland parts of the country have seen the greatest damage to their soil resources due to soil degradation. These are also the most affected parts of the country by famine due to degradation and recurrent drought. In this regard, soil degradation certainly contributes to a higher vulnerability to famine.

Consequently, the government of the country in the last two decades constructs water harvesting projects, especially micro dam projects in north eastern region. In those micro dam projects and irrigation infrastructure, silting of dam reservoirs is the most challenging problem due to un sustainable watershed management. There are many reservoirs that can no longer perform their design functions because much of their original active storage volume has been filled by sediment Sedimentation could be a genuine issue that faces characteristic and artificial supplies. It is the major issue which imperils and debilitates the execution and supportability of Koga reservoir. As result of arrive debasement, the beneficial capacity of the soils in Ethiopia is decreasing at rate of 2-3% yearly (Tadesse, 2017a). Many reservoirs can no longer perform design tasks because sedimentation has filled much of the initial active storage volume. One of these reservoirs is the Koga reservoir dam, which was built to help with production issues (Worku, 2017).Sedimentation reduces the effective flood control volume, reservoir storage capacity, operation of low-level outlet gates valves and structural stability.

The government of Ethiopia, in Blue Nile River basin has been constructed many waters related projects for the purpose of water supply, irrigation, hydroelectric power, navigation and so on. There is a gap with respect to investigate erosion hot spot regions and sediment inflow in the Koga dam reservoir.

As a result, this study is being carried out to determine the amount of deposited sediment in the reservoir and to identify erosion risk regions in the Koga dam reservoir watershed.

1.3 Objective

1.3.1 General Objective

The study's main objective is to investigate erosion hot spot regions and sediment inflow in the Koga dam reservoir.

1.3.2 Specific objectives

- To estimate the annual sediment accumulation using bathymetric survey.
- To quantify the reservoir capacity loss due to sediment
- To estimate useful life of Koga reservoir.
- To identify erosion risk areas using RUSLE model.

1.4 Research questions

1.What is the annual sediment accumulation amount to Koga reservoir?

2.How much is the yearly capacity loss of Koga reservoir?

3.Where is the erosion hotspot area in the Koga reservoir watershed?

4. How much storage capacity the reservoir is reduced?

1.5 Scope of the study

The study's scope is spatially confined in the Koga watershed and its dam reservoir area. The study's main objectives are to assess sediment deposition in the Koga reservoir, estimate the reservoir's life duration, and locate erosion hotspot regions in the reservoir's watershed. Field visits, gathering of secondary information from relevant organizations, bathymetry data from the reservoir's bathymetric survey, and analysis for deposited sediment were all used to meet the study's objectives.

1.6 Significant of the study

The primary difficulties in water resource development are predicting the rate of soil erosion and sediment yield. Particularly in poor countries such as Ethiopia, where sediment controls are a major challenge. Erosion and sedimentation have both good and negative implications, which will aid stakeholders in collaboration and decision-making.

The federal and regional governments in Ethiopia construct a large number of waters harvesting structures, particularly minor dams. However, the sediment load has exceeded the standard design estimates, lowered storage capacity and shortening the useful life of the tanks. Underestimating sedimentation design due to a lack of local sedimentation rate, as well as rash planning and implementation of conservation measures, cause this. This demonstrates the need of having knowledge on local sedimentation rates and erosion allocated to areas for dam design and watershed management. As a result, the findings of this study will be utilized to help design and implement conservation measures aimed at conserving more water and extending the life of the Koga reservoir. This research will be also be used as a resource for designers and academics working on dam design and reservoir management studies.

1.7 Thesis Structure

The report has six main chapters and each chapter has a section and sub-section to explain the contents. The short overview of each chapter is presented as follows. Chapter one: Presentes the introduction of the case study including back ground information, statement of the problems, objective, research questions, scope of the study, significant of the study and thesis Structure. Chapter two: In this section it describes the reviewed literature related to the study on the idea of reservoir sedimentation, understanding of sedimentation problem of dams in Amhara, Ethiopia and also throughout the world, basic principle and main concept about sediment transportation and deposition of sediments in the reservoir. Chapter three: In this section the explanation of materials and methodology used to do the research including description of the study area. The different sediment transport formulas, and sediment deposition types and locations are discussed based on literature. Chapter four: It explains the data analysis and discussion of the results found by the bathymetry survey and Rusle Model and it covers estimating the use full life of the reservoir, sediment yield estimation from the watershed, current deposited volume, estimation of the current trap efficiency of the reservoir, Spatial distribution pattern of deposited sediment and identification of erosion hotspot areas of the watershed. Chapter five: In this section Conclusion and recommendations are presented. Chapter six: In this part References and finally appendixes are included.

CHAPTER 2: LITERATURE REVIEW

2.1 Soil Erosion and Sedimentation

The eroded soil is carried into water courses by flood and storm water resulting in tremendous sediment movement the separation and transportation of soil is known as soil erosion. It's a natural occurrence that happens all across the world. Precipitation, runoff, wind, and the activity of living things are the main causes of soil erosion. Flood and storm water carry the eroded soil into waterways, resulting in massive sediment migration (Tadesse, 2017a). The following topics have been reviewed to assess the state of knowledge regarding the work stated in the objectives of this thesis.

2.1.1 Soil Erosion in the World

Recently, soil erosion is almost universally recognized as a serious threat to man wellbeing. (Assefa et al,. 2015)estimated worldwide costs of soil erosion to be about four hundred billion dollars per year, more than 70 dollars per person per year. Sediment degrades water quality, and carries soil-adsorbed polluting chemicals. Sediment deposition in irrigation canals, streams channels, reservoirs, water conveyance structures, reduces their capacity and would require costly operation for removal (Flores-renteria et al., 2015) indicated that water erosion had accounted for about 55% of the almost 2 billion hectares of degraded soils in the world.

Land degradation is a major concern to many nations and to the international community. Soil erosion affects both developed and developing nations. There is no region of the Glop where soil erosion due to water is not a threat to the long-term sustainability of mankind. For developing nations like Africa, soil erosion is among the most chronic environmental and economic burdens. And many of these nations are in the tropics and in the drier zones. Soil erosion is getting worse in sub-Saharan Africa; For example, it has increased in the last three decades as more and more people are forced to move out of the good bottomlands to fragile hillside. More than one third of Africa is threatened with desertification (Teka, Azeze, and Gebremariam ,1999).

The world is losing an estimated 23 billion tons of soil each year from croplands alone, which is in excess of the soil formation rate (Sheng, Axelsson, and Knutsson ,1995). Total historic soil losses have been estimated at 2 billion ha.

The present arable area of the world is being about 15 billion ha,5 up to7 million ha of soil loss per year as a result of land degradation has been put forward (wolka ,2014).The worldwide loss in reservoir storage capacity is estimated to be between 0.5-1% per annum (Bachiller et al., 2019).

2.1.2 Soil erosion in Ethiopia

Many policy makers, environmentalists and researchers agree that land degradation mainly caused by soil erosion has been one of the chronic problems in Ethiopia. The Ethiopia Highland Reclamation Study (EHRS) estimated that the average annual soil loss from arable land was 100 tons/ha and the average productivity loss on crop land was 1.8% (Schauer ,2015). As a consequence of land degradation, the productive capacity of the soils in Ethiopia highlands is reducing at a rate of 2-3% annual (Bogale1 ,2020).

The north and northeastern highland parts of the country have seen the greatest damage to their soil resources due to soil degradation. These are also the most affected parts of the country by famine due to degradation and recurrent drought. In this case, soil degradation certainly contributes to a higher vulnerability to famine (Lu et al. 2017). According to the study made in Gununo, Sidamo,6% of the cultivated land having slopes between 10-19% has allready lost its topsoil. Sixty five percent of the same land has lots 25-75% of its fertile soil (Pingalii ,1992). The maximum soil formation rate for the whole of Ethiopia is estimated to be in range of 2-22 ton/ha/yr (Bogale1,2020). Practices(2010) studied Gis based conservation priority area identification in mojo river watershed on the basis of erosion risk. The analysis showed that RUSLE and MCA help to categorize landscape units in to different levels of erosion risk. The analysis showed that RUSLE and MCA help to categorize landscape units in to different levels of erosion risk and identify areas that require priority in conservation measures in relative to others. Based on the RUSLE model the potential average annual soil loss of each plot of land in the watersheds ranges from 8.57 to134.46t/ha/yr with mean annual soil loss of 21.2t/ha/yr.

2.1.3 Soil erosion in highlands of Amhara region

The highlands of the Amhara Region suffer from accelerated soil erosion and overall land degradation, which resulted in considerable areas of cropland unable to provide reasonable crop yield. Estimates show that 1.1 billion tone of soil (58% of the nation total loss) are lost from the Region each year (Tegegne ,2008).

About 42% of the estimated soil loss is from onlyn10% of the region, which is classified as very high erosion hazard category. These areas are located in the highlands of North and South Gonder, East and West Gojam, North and South Wollo, Awi, North Shewa and Waghamera zones.

Schauer (2015)indicated that about 50% of the highlands are already eroded, and cautioned that if present soil degradation trends continue, per capital income in the highlands would be reduced on average by 30% in the year 2010.In this Region there were extreme sedimentation such as Borkena dam (Wollo),which cost$35 million US dollar in 1991 and Adrako dam (South Gonder,Ebinat) where the dead storage volume of reservoirs silt up their construction ended(Haregeweyn et al., 2006).

Esa, Assen, and Legass (2018) studied soil loss estimating using geographic information system in Enfraze watershed for soil conservation planning in highlands of Ethiopia. The result showed that about 92.31% (5914.34ha) of the watershed was categorized none to slight class which under sol loss tolerance values ranging from5to11 ton/ha/yr. The remaining 7.68%(492.21ha) of land was classified under moderate to high class about several times the maximum tolerable soil loss. The total and an average amount of soil loss estimated by RUSLE from watershed were 30,836.41ton/yr and 4.81 ton/yr respectively.

(Alemaw et al., 2016) studied that the estimation reservoir sedimentation using bathymetric differencing of Koga reservoir, using echo sounder. The bathymetric survey result showed that the storage volume shrunk from its design storage of 83.1Mm^3 in 2009 to 82.7m^3 in 2012. i.e., sediment in flow volume of 339,500m^3. The total reduction in storage capacity of Koga reservoir due to sedimentation is about 0.4% and specific sediment yield was estimated to be 500ton/km^2 /yrs. Worku (2017) studied the estimation of reservoir sedimentation using bathymetric surveying using echosounder. The bathymetric result showed that the storage volume shrunk from its design storage of 83.1MCM in 2009 to 80.033 MCM in 2017.

2.2 Reservoir sedimentation process

The process of sedimentation usually occurs by; erosion, drawing of particles in to fluid, transportation, deposition, and these processes are highly complex. River systems erode material from the ground they flow over; these sediments are then transported downstream. When a river is obstructed by dam, the speed of the water is slowed down and thus the rivers' ability to transport these sediments is reduced and when the speed is too slow the sediments in the river water will begin to settle down (Iii ,2014).

Delta deposits are formed where the stream enters the reservoir pool and coarse materials are deposited from homogenous flow as velocity and transport capacity diminishes ((Dagnaw, 2020). The engineering interest in reservoir sedimentation is primarily concerned with three physical aspects; total volume of trapped sediment, spatial distribution of deposit volume and sediment load carried by flow releases including its particle size distribution. The location and shape of a delta depends on the slope of the valley, length of the reservoir, particle size, and its distribution, capacity-inflow ratio, reservoir operation, volume of deposits, shape of reservoir and its construction, and delta grows in upstream and downstream direction. Bottom-Set bed depositions are mainly composed of clay and silt fraction, which are transported in the reservoir water body either by the turbulent suspension or by turbidity currents (Randle et al., 2017).Below (figure 2.1) showed Example of reservoir sediment profile (Randle and Bounty, 2017)

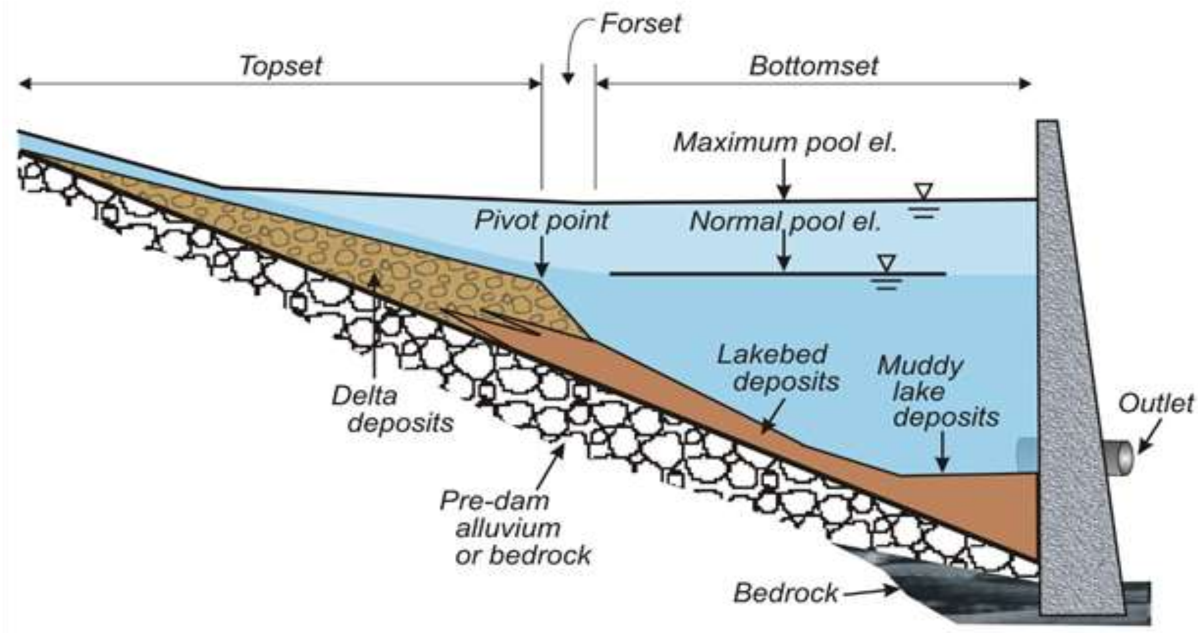

Figure 2.1 Example reservoir sediment profile (Randle and Bounty, 2017)

Topset beds are the delta deposits created by rapidly settling coarse sediment. Forest deposits represent the face of the delta advancing into the reservoir. Forest deposits are differentiated from topset beds by relatively finer grain sediment and a much steeper slope, usually at the angle of repose for the grain sizes composing the delta. The downstream limit of bed material transport in the reservoir corresponds to where the topset beds end and the forset deposits begin. The pivot point at the downstream end of the topset bed will progress downstream with continued reservoir sedimentation. Bottomset beds, often referred to as lakebed sediment, are the fine sediments deposited beyond the delta by turbidity currents or non-stratified flow.

Lakebed sediment often deposit across the entire inundated landscape beneath the reservoir surface, including the reservoir hillslopes. The reservoir deposits may also include woody material of varying sizes. The longitudinal slope of the delta topset may be about one-half of the preamp channel slope. The actual delta slope depends on the sediment grain size, reservoir level fluctuations, and flow velocity or shear stress. The average of forest slopes observed in Reclamation reservoir resurveys is 6.5 times the topset slope. However, some reservoirs exhibit forset slope.

Figure 2.2 showed that Reservoir sediment profile after the reservoir has filled with sediment (Timothy J.ph. D,2016)

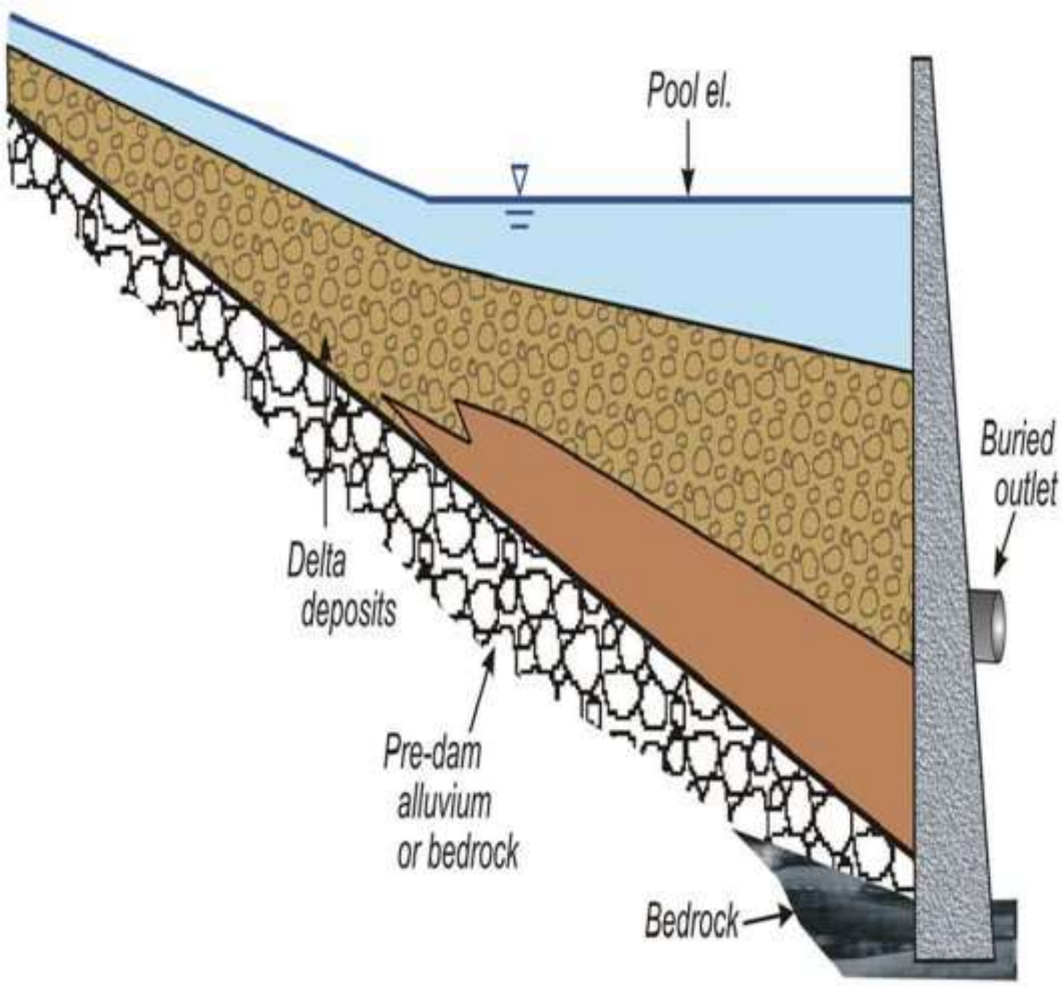

Figure 2.2 Reservoir sediment profile after the reservoir has filled with sediment (Timothy J.ph. D,2016)

2.3 Methods for Estimation of Reservoir Sedimentation Yield

In order to manage and operate a reservoir, it is necessary to assess sediment deposition. The entering sediment will be deposited in different zones of the reservoir depending on the form of the reservoir, the mode of operation, sediment input rates, and grain size distribution. Systematic sedimentation evaluation during the operation stage is required to maintain current knowledge of the reservoir's sedimentation process and to plan reservoir operation for optimal water consumption.

2.3.1 Inflow-out flow Method

In this method, the incoming and out flowing sediment load is worked out on the basis of observation of discharge and suspended sediment load by taking silt samples on the upstream and downstream of the reservoir. The sediment load obtained by sampling is expressed in weight and to convert it into volume to determine the space occupied by it in the reservoir, a certain weight-volume relationship is assumed. Some of limitations of the method are: (i) there is a wide range of variation in daily sediment concentration and fluctuations in a stream flood flow. Evidently sediment measurement once a day at the fixed time irrespective of the passing of high flood cannot give representative data for adaption in reservoir sediment calculations, (ii) Peak flood discharge during the peak stage of the river usually carry maximum sediment but facilities for sediment flow In this method, the incoming and out flowing sediment load is worked out on the basis of observation of discharge and suspended sediment load by taking silt samples on the upstream and downstream of the reservoir. The incoming and outgoing sediment loads are calculated using this method, which involves taking silt samples upstream and downstream of the reservoir and observing the discharge and suspended sediment load.

2.3.2 Empirical and Mathematical Methods

Although empirical approaches are still utilized to examine the effect of sedimentation nowadays, due to technological advancements, mathematical methods are now mostly employed to simulate the sedimentation process in time. The governing equations of transport and momentum are solved using mathematical models. Mathematical models for predicting reservoir sedimentation are becoming more sophisticated as computer technology and mathematical models progress studied by (Dagnaw,2020). Sedimentation is a complex process by its nature. The amount of sediment deposit and distribution patterns could be estimated quantitatively and qualitatively by using empirical methods but also could be simulated by using mathematical methods.

One dimensional mathematical model is used to analyze sediment transport along reaches of rivers, where essential transport processes can be simulated with a one-dimensional flow field. One dimensional model solves the un study, cross sectional averaged equations for the mass balance of suspended sediment (K.Meijer ,1986).

2.3.3 Remote Sensing Method of Estimating Sediment Deposition

Satellite Remote Sensing techniques provide in the recent, past the availability of multispectral satellite data using remote sensing is receiving broader application for capacity surveys of reservoirs. Efficient reservoir management needs periodic assessment of its capacity. To quantify the capacity of a reservoir, the only nessessary information that has to be extracted from the satellite data is the water spread area at different water levels of the reservoir (Randle 2012). Reduction if any, in the water spread area for a particular elevation indicates deposition of sediment at that level and when we integrate it with elevation, we can compute the capacity of the reservoir or volume of storage loss due to sedimentation.

2.3.4 Analytical Model

Analytical models can be most promising method to simulate reservoir sedimentation. However, these models were not considered in Ethiopia due to unavailability of mode verification data, limited availability of the models and time constraints variety of analytical models have been applied for the computation of sediment deposition and delta formation. Most of these models are developed based on sediment transport theory. These models consist of two coupled partial models; one for a computation of the water level in the reservoir based on the energy conservation equation in non-uniform flow and the sediment transport theory.

These models consist of two coupled partial models; one for a computation of the water level in the reservoir based on the energy conservation equation in non-uniform flow and the second model for the computation of sediment deposition in reservoir based on the sediment continuity equation (Interior ,2006).

2.3.5 Bathymetric survey method

Bathymetry surveying techniques are a good way to assess reservoir sedimentation during the operation phase. It is a more precise method of determining the volume of a deposit as well as its pattern in reservoirs because it is a direct measurement approach than indirect method(TADESSE ,2017).

The best survey pattern is determined by taking into account a number of constraints, such as budget, time, and equipment availability, while choosing bathymetric survey approaches (Awulachew et al. 2007).

The main purpose of a reservoir resurvey is to compare the storage capacity with that of past survey (the original survey) and the different will be the sediment accumulation (Penibertori 1982). The end product of the area-capacity computations is a plot of the areas and capacities for the original and new surveys (Deborah Cooper, Research Hydraulic Engineer ,1982).There are two general methods of conducting the reservoir survey. These are the contour survey and range-line. Why I select the method depends on the purpose and scope of study objectives, the size of the reservoir and the degree of accuracy required (Society ,2015).

2.3.5.1 Contour surveys

Contour surveys use more complete topographic or bathymetric information to prepare a contour map of the reservoir. It is the simplest and accurate forming volume and also provides the most complete information on sediment distribution. Recent advances in automated survey techniques now make hydrographic contour surveying very economical for smaller and midsize reservoir require only a few days of field time using automated depth measurement and positioning systems to collect bathymetry data. To use this method, it is important to have a good contour map of the reservoir before filling. The contour method is usually used for small reservoirs, when the highest degree of accuracy is required (Aselmaa and Laprie ,2017). It consists of a survey of the area and perimeter of the water surface at different levels by means of topographical techniques.

2.3.5.2 The range line survey

Range line survey uses a series of range or cross-section lines across the reservoir which are resurveyed at intervals and used to compute volume change by geometric formulas. The number of ranges depends on reservoir size and geometry, with a minimum of three ranges required for even the smallest impoundment (Fund, 2001). Range line survey uses a series of range or cross or cross-section lines across the reservoir which are resurveyed at intervals and used to compute volume change by geometric formulas. Range surveys are faster and more economic to perform than contour surveys because field data requirements are greatly reduced compared to contour surveys. The have historically been the most commonly employed technique to monitor sedimentation, but are increasingly being supplanted by automated contour surveying methods.

Range surveys well-suited for tracking changes in storage as a result of sedimentation, with a minimum of field time. The basic procedure for either method involves the determination of bed elevation on the reservoir. These measurements are almost always made by measuring the water depth beneath a boat and the exact location of the boat on the lake surface. So, two basic types of measurement are required; position measurements and depth or bed elevation measurements. The scientific depth sounding equipment currently available can be used to record bottom profile. By careful calibration, a high degree of bottom profile accuracy can be maintained (Zeleke, Moussa, and El-manadely ,2013). Even if bathymetric survey methods are more accurate as compared with other reservoir sediment assessment methods, the survey has some limitation due to water quality of the reservoir and the instrument used to survey. Some of the limitations of the methods are: The soundings for water depth measurement are susceptible to error due to shallow depth and weed growth in the reservoir. Echo sounder requires frequent checkup and calibration for its reliability and dependability. The readings are plotted on a straight line whereas on practice it is difficult to run the boat in a straight line on the range especially when there are no reference points in the water in between the range lines.

2.4 Reservoir survey frequency

The reservoir survey frequency should be based on individual site characteristics. At reservoir losing capacity very slowly, a survey frequency on the order of 20 years or even longer may be adequate. By contrast, at important sites which are losing capacity rapidly, or where the impact of sediment management is being evaluated, a survey interval as short as 2or 3 years might be used. Reservoir should also be surveyed as soon as a new reservoir is close upstream to provide drainage. The minimum survey frequency depends on the precision of the survey technique and the rate and pattern of storage loss. For instance, if the reservoir is losing capacity at 0.25 percent per year a 4-year survey interval may be too short to produce reliable information (Morris and Fan 1998).

2.5 Reservoir survey section interval

Reservoir survey distance interval within range lines and from one point to another along the survey line depends on the surveying method to be used, the reservoir size, topography of the reservoir, Available resources and other factors. Survey distance intervals from one to another survey point to on according to (Rosmansyah, Achiruzaman, and Hardi ,2019) recommend the following specifications.

Table 2.1 Distance sections and frequency of surveying.

Map scale	Distance between section in(m)	Capacity MCM	Types of reservoirs based on capacity	Survey frequency
1:2000	20	<10	small	Every 2 years
1:5000	50	<10-100	medium	Every 5 years
1:10000	100	>100	large	Every 10 years

2.6 Estimation of Reservoir storage capacity by using TIN model

The point files created by all of the survey data interpolation or extrapolation must be exported and combined with the sounding and boundary files to form a Triangulated Irregular Network (TIN) model for area, volume, and contour calculations using the 3D analyst Extension of Arc GIS. A prismatic volume is computed in a TIN model between the horizontal reference level and each triangle, the triangle being inside the area where the volume must be computed (Báčová et al. 2019).Dagnaw (2020)developed the Triangulated Irregular Network (TIN) model by GIS software in order to establish the area and volume of the Mussel dam reservoir in Tigress River to develop ASC by using bathymetry survey data. He also showed that the maximum deposition and spatial distribution of Musol dam reservoir by using TIN model.

2.7 Useful Life of the Reservoir

The global average for reservoir useful life is fewer than 25 years, according to reports(Issa E Issa et al. 2013). The useful life is a period that the sediment deposited does not affect the economic feasibility and sustainability of water resources demand. In general, useful life of the reservoir is the time period when the reservoirs depleted 50% of its storage capacity or the dead storage is completely filled with sediment (Citation ,2008).

In most cases, the rate of dead storage capacity loss rather than the overall capacity loss is used to calculate the useful life of a reservoir (Dagnaw ,2020). However Issa Elias Issa (2011) described that the volume of dead storage of likely inflow volume of sediment during designed life period, assuming that the entire sediment will be trapped in the dead storage zone but the reality is different. Because this dead storage volume is a function of (I) the expected sediment input from the watershed, (ii) the intended life of the reservoir, and (iii) any planned sediment management to take place after construction of the dam (Mekonnen et al. 2015). When time increasing, the annual sedimentation rate of reservoir capacity decreasing.

2.8 Sediment Yield and Specific sediment yield of watershed

Gross erosion is the sum of all onsite, sheet, and gully erosion in a watershed (Worku, 2017). However, not all eroded material enters the river network; some is deposited at natural or man-made barriers within the watershed, while others may be deposited in the channels and flood plains. The sediment yield refers to the amount of eroded material that does not move through the drainage system to a downstream measurement or control point. The sediment yield rate is the sediment yield per unit of drainage area. Because gauging stations generally do not include bed load transport of sediments, SSY values derived from reservoir sedimentation rate (median:256 tkm-2yr-1, average 808 tkm-2yr-1) are generally higher than those derived from gauging station observations (median:114 tkm-2yr-1, average 493 tkm-2yr-1)because gauging stations generally do not include bed load transport of sediments (Vanmaercke, Obreja, and Poesen ,2014).

By taking average density of sediment 1.2ton/m^3 annual sediment inflow is obtained as 101500 $tonyr^{-1}$(Alemaw et al,. 2016) . The maximum soil formation rate for the whole of Ethiopia is estimated to be in the range of 2-22ton/ha/yr (Yimer ,2007).

2.9 Specific weight of sediment deposit

The dry weight of sediment particles in a total, in-place volume of sediment mass is referred to as specific weight(Survey et al., 2014). The average dry specific weight of the deposited material, defined as dry weight of sediment per unit total volume including empty space, determines the volume occupied by the sediment in the reservoir.

The type of operation, texture and size of deposited sediment particles, and compaction or consolidation rate of deposited sediments were the main elements influencing the density of sediment deposits in a reservoir (To et al., 2003). Sediments deposited in reservoirs that have been subjected to significant drawdown are exposed for long periods of time.

CHAPTER 3: MATERILS AND METHODS

3.1 Description of the study area

3.1.1 Location

The Koga dam lies 42 kilometers southwest of Bahir Dar and 7 kilometers southwest of Merawi, in the Weast Gojam Zone of the Amhara National Regional State's Mecha Woreda. It is located between the latitudes of $11^0 10'$ N and $11^0 25'$ N, and the longitudes of $37^0 02'$E and $37^0 17'$E. The Koga River begins in the Wezem Mountains and drains a 220 km^2 watershed. It is a tributary of the Gilgel Abay River, which rises in the Blue Nile basin's head waters and eventually flows into Lake Tan. At full supply, the reservoir can hold 83.1 million cubic meters of water, covers 18.56 kilometers of land in the 7004-hectare command area. Below figure showed that Location of Study Map Area.

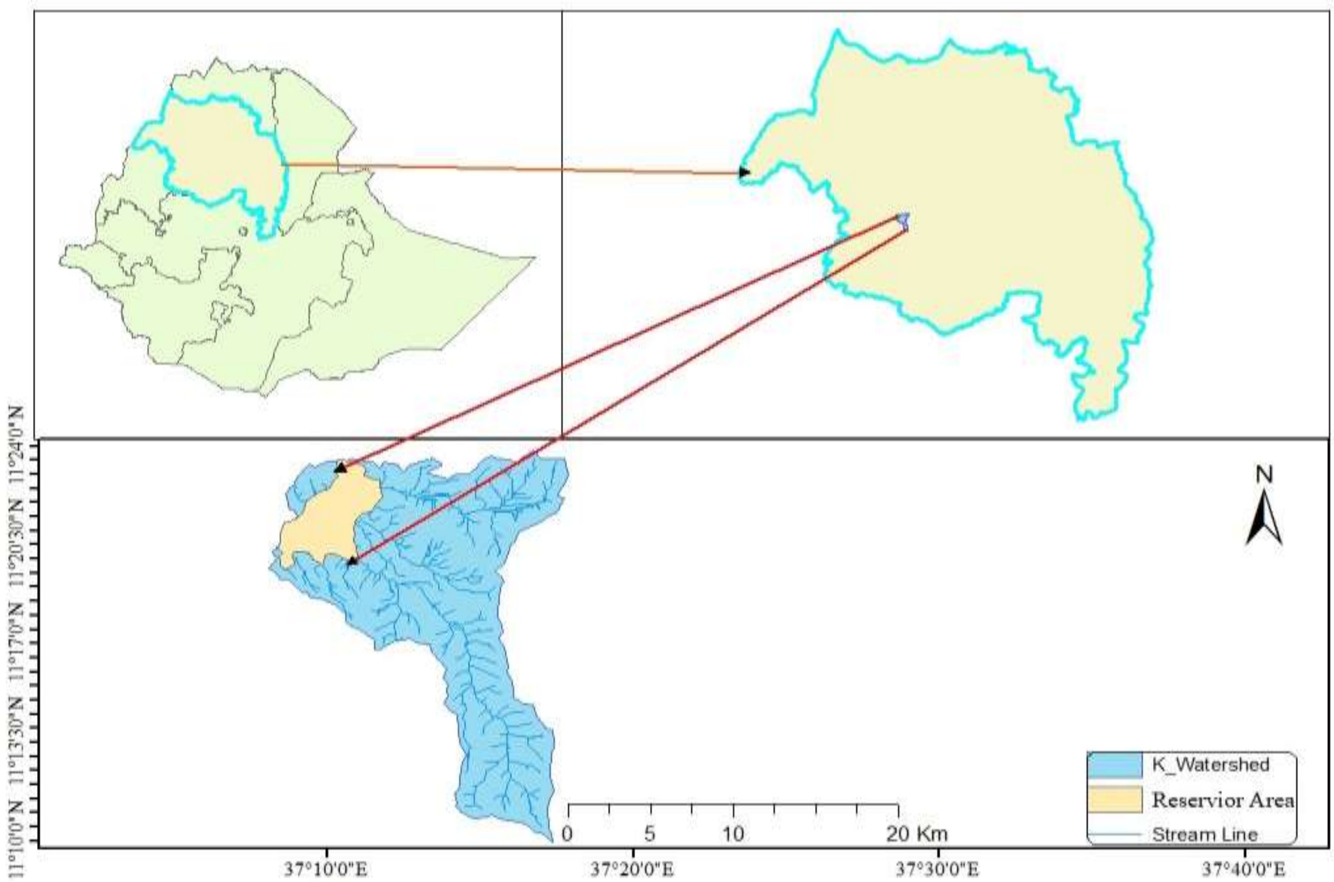

Figure 3.1 Location of Study Map Area

Figure 3.2 Koga reservoir field photos on November 2020

Table 3.1 Salient features of the dam and watershed (source Federal design document).

Item	Unit	Features
Command area	Ha	7004
Dead storage capacity of the reservoir	Mm^3	3.7
Crest elevation of main dam	M	2019.5
Max height of main dam	M	21
Max height of saddle dam	M	9
Crest length of main dam	Km	1.73
Crest length of saddle dam	Km	1.162
Spill way crest elevation	m amsl	2015.25
Spill way crest length	M	21.5
Full supply level	M	2015.25
Irrigation off take max discharge capacity	M^3/s	9.1
Bottom outlet max. discharge cap.	M^3/s	31
Irrigation outlet level	m amsl	2007.5
Total volume of reservoir	Mm^3	83.1
Live storage capacity reservoir	Mm^3	79.4
Dead storage capacity of the reservoir	Mm^3	3.7
Irrigation off take maximum discharge capacity	M^3/s	9.1
Full supply level (FSL)	m amsl	2015.25
Spillway type	m	overflow ogee type

3.1.2 Topography

The slope of the watershed is an important feature that has a dynamic impact on soil erosion. It is critical for comprehending the spatial distribution in the Koga research area. As a result, the research area's slope map was created using ArcGIS and a 35*35m resolution DEM. The slope of the Koga watershed ranges from 0 to 50 percent and above. Below (table 3.2) showed that Koga watershed slope and area map.

Table 3.2 Koga watershed slope and area map

ID	Slope	Count	Description	Area-_ha	percentage
1	0-2	7197	Flat (Gentle)	647.73	30.055
2	2-8	9078	Gentley slope	817.02	37.910
3	8-15	2531	Genley rolling	227.79	10.569
4	15-30	3872	Moderately steep	348.48	16.169
5	30-50	1204	Steep (Hilly)	108.36	5.027
6	>50	64	Verysteep(hill)	5.76	0.267

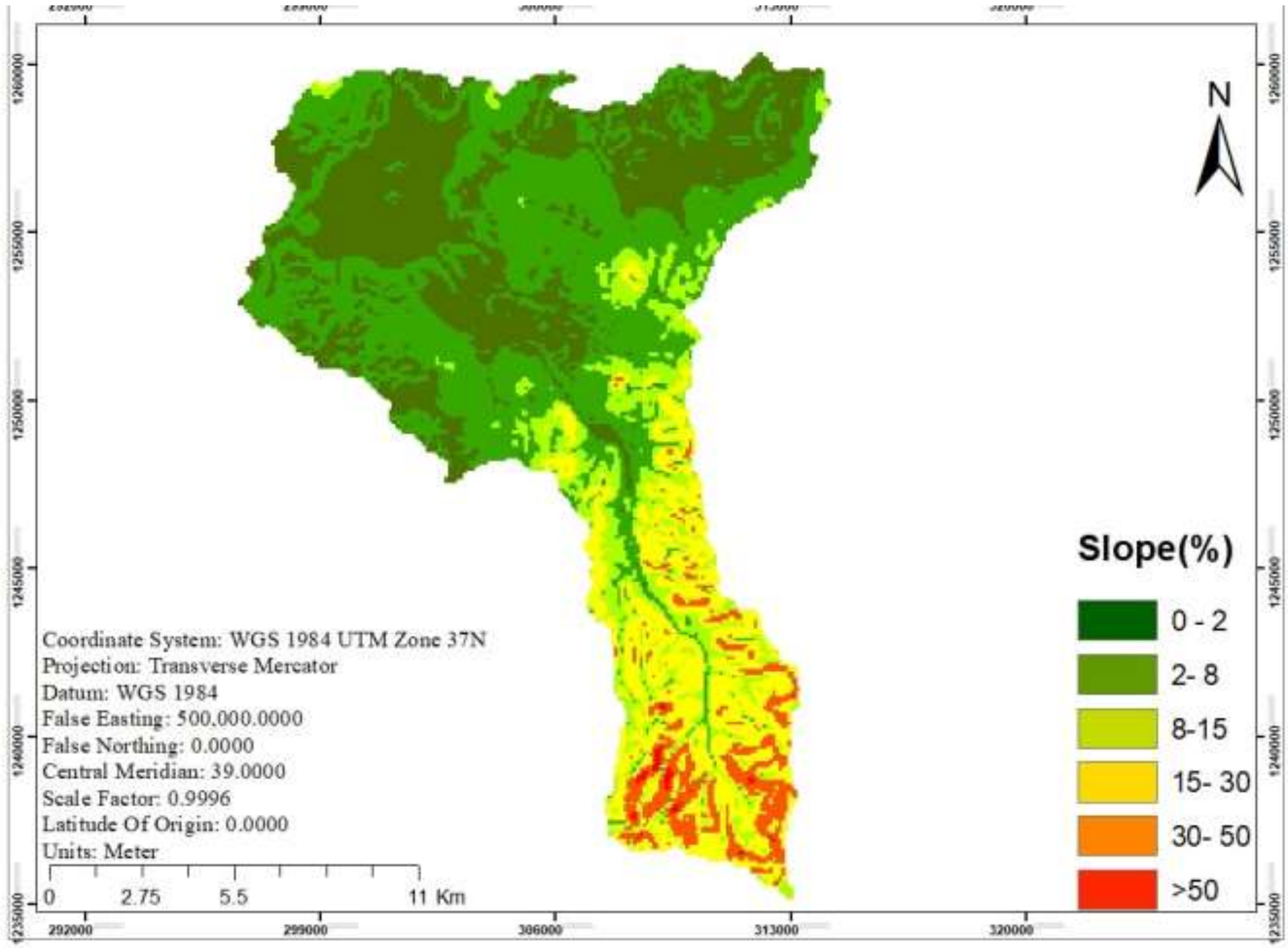

Figure 3.3 Koga watershed slope map

3.2 Materials

The bathymetric survey Chart plotter Garmin GPS Map 421s single beam eco sounder was employed in the Koga reservoir to obtain sediment depth and coordinates. The echo sounder is powered by a 12-volt sealed lead acid battery and is connected to the boat via a stick and below

Table 3.3 List of materials used during Reservoir bathymetric survey

Number	Material name used
1	Garmin GPSMAP 421s
2	Tap meter for instrument calibration
3	Garmin Transducer
4	Stick to keep Garmin Transducer position
5	Rope to join stick with Garmin Transducer
6	Life Jacket
7	DEM &Topographic map of Reservoir area
8	2 batteries for power supply of Garmin GPSMAP 421s
9	Boat

In addition to the above material, ArcGIS 10.7.1, Arc hydro and global map per used for data analysis and interpolation of bathymetric data, TIN model analysis, and all watershed analysis. See that some field materials used during Reservoir bathymetric survey (Appendix-A)

3.2.1 Calibration of the sounding instrument

Calibration with local field conditions should be required before using any instrument to guarantee that it functions properly. So, the echo sounding equipment with Garmin GPSMAP 421s was initially tested at Tana reservoir, then moved to Merawi and tested at Koga night storage, with comparisons to repetitive hand readings with tape meter. Calibration was worked again and again to be sure the measurements are accurate. The trial sample preliminary measurements were collected for primary calibration and the results were reported in (Appendix-B). The depth calibration was measured two times daily i.e. at starting and finishing time during the period of data collection. In order to check the precision in this measurement the square root of the mean of the squared error (RMSE) was calculated below equation (Agriculture ,1983).

$$RMSE=\sqrt{\sum \frac{1}{n}(Z\ data\ I - Zcheck)} \quad \ldots\ldots 3.1$$

3.3 Data Collection Section

Field work and post field work phases were followed to meet the study's purpose.

The pre-field work phase of the study included:

- Selection of suitable research methodology to work the study
- Searching literatures related to the topic from different sources
- Gathering the available data from different sources and
- Collection of materials for field data collection.

Reservoir bathymetric/land survey, equipment calibration, and a walk to evaluate watershed management condition and characteristics for evaluating watershed data acquired from various data sources were all completed during field work. During post-field work activities, data obtained during field and pre-field work was processed. Original reservoir topography map georeferencing and digitization from the Federal Water Work Design and Supervision Enterprise. The bathymetric survey, quantification of sediment deposited in the reservoir, and creation of all essential maps were all completed during this phase of the project.

3.4 Types and approaches for data collection process

Other forms of data were acquired in this study through field work and various institutes. Primary data for the study were acquired from the field (creating bathymetric survey), reservoir depth coordinates utilizing GPS map 421s, and secondary data such as metrological and topographic data found from various institutes.

3.4.1 Reservoir Bathymetry surveying data

For this investigation, a bathymetric survey was used to calculate the quantity of silt buildup in a reservoir. Both a bathymetric survey and a topography survey were conducted for each 3560 spaces along the whole storage regions of the reservoir in order to account for the spatial heterogeneity of sediment deposition within the reservoirs. By contrasting tap meter depth measurements with sonar depth readings obtained from the identical point samples, a digital depth sonar device was verified.

An eco-sounder, a bathymetric survey was conducted across the entire sea surface. Sample points were gathered between November 14 and November 17, 2020, using an eco-sounder. All reservoir depth information was gathered using an eco-sounder, and reservoir bed elevation was determined by scaling back the sounder's and transducer's depth readings (DT=20 cm utilized throughout the survey) as stated in equation below (Dagnaw, 2020).

RBE=WSL-(SD+DT)…………………………………………………………………...3.2

Where,

SD=sounding depth (m)

RBE=reservoir bed elevation (m)

WSL=water surface level (m)and DT=Depth of Transducer from the water surface (m)

At grid spacing of between 35 and 35 meters, a bathymetric survey and a land survey were conducted throughout the reservoir region. However, due to wind and wave action, farmer fishing, and little metal fishing ropes, the boat was unable to follow the set line exactly (cause the sensor Transducer not read depth correctly).

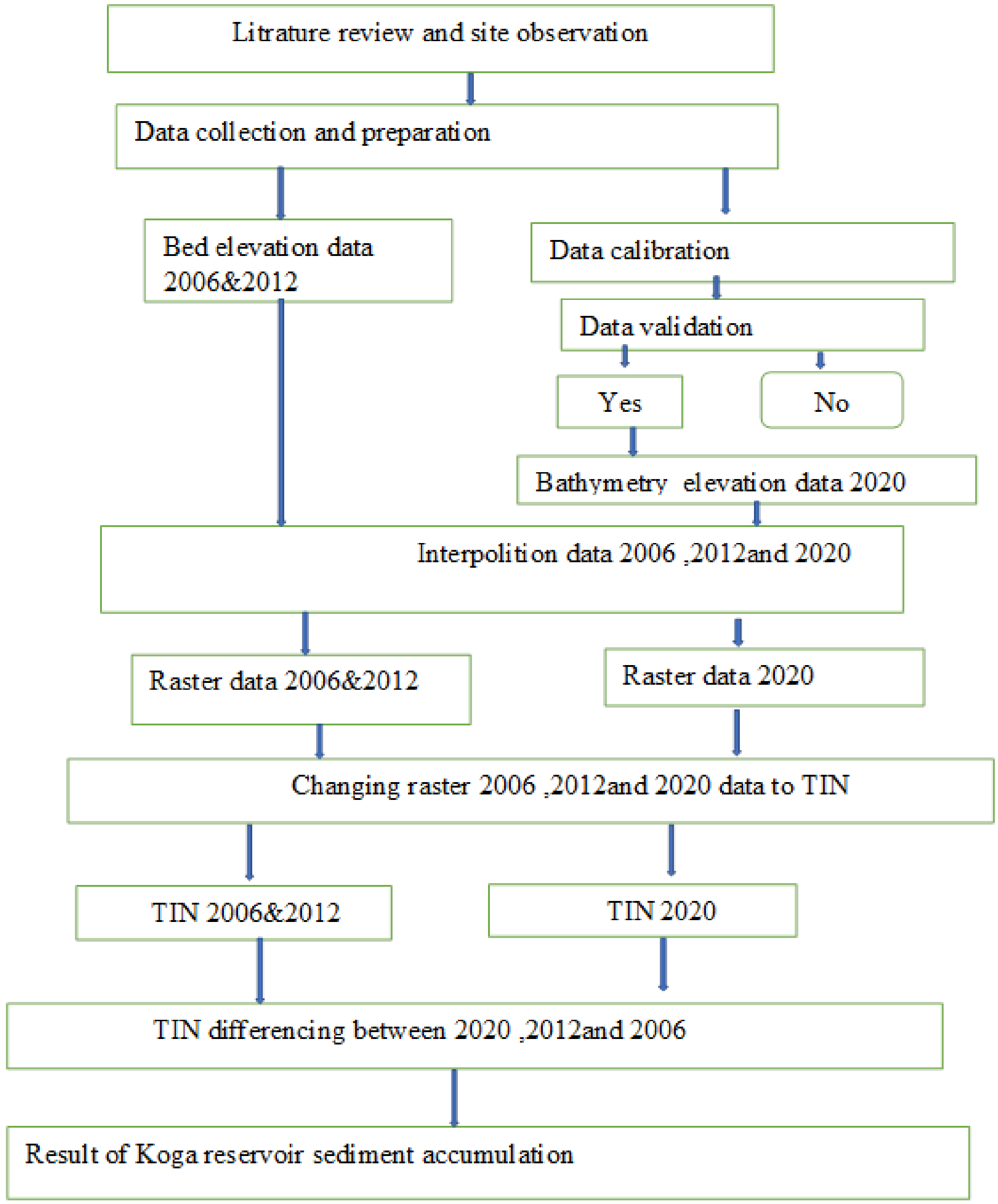

Figure 3.4 flow chart of Koga reservoir sediment accumulation

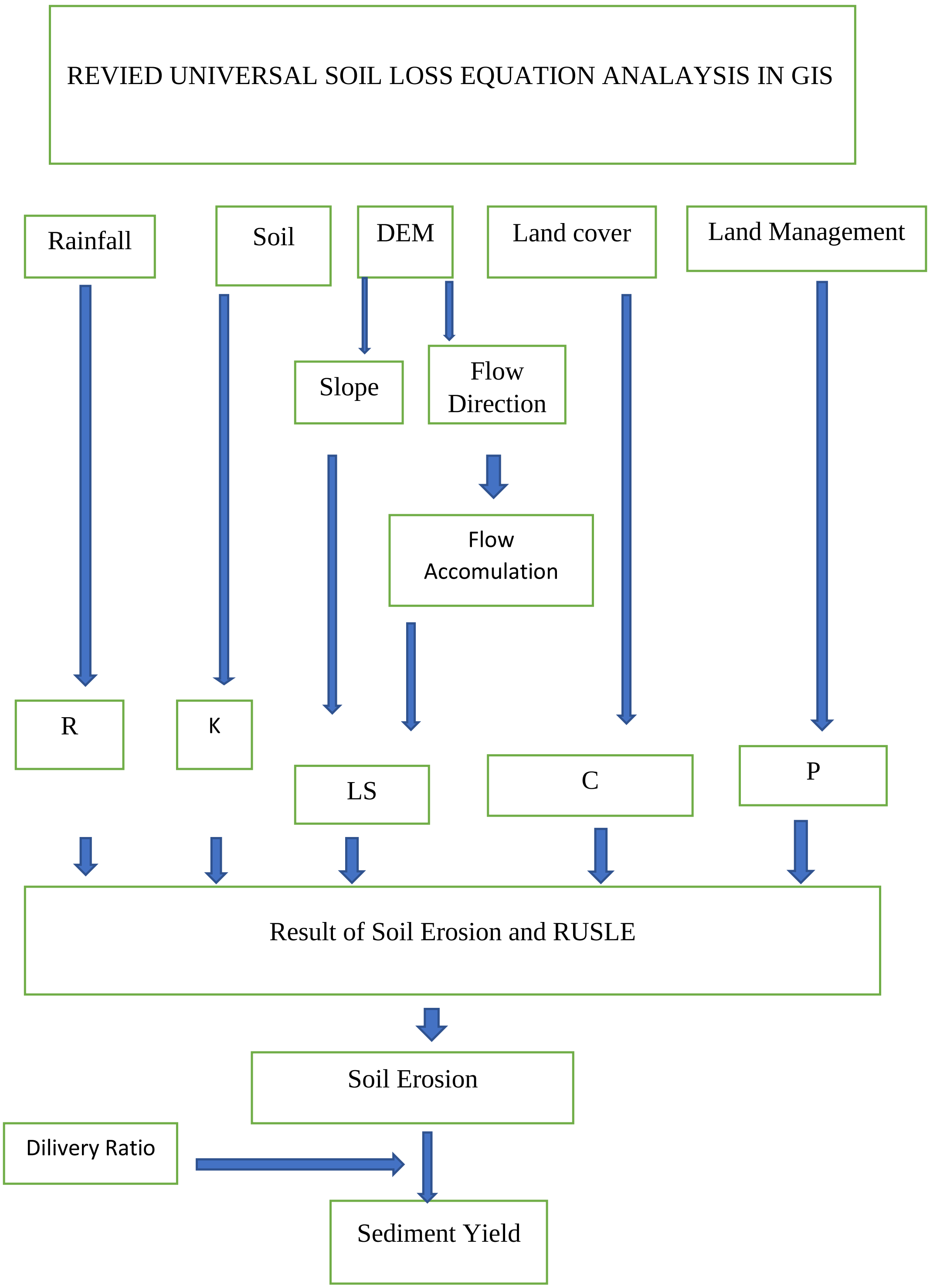

Figure 3.4 procedures of RUSLE Implementation in GIS

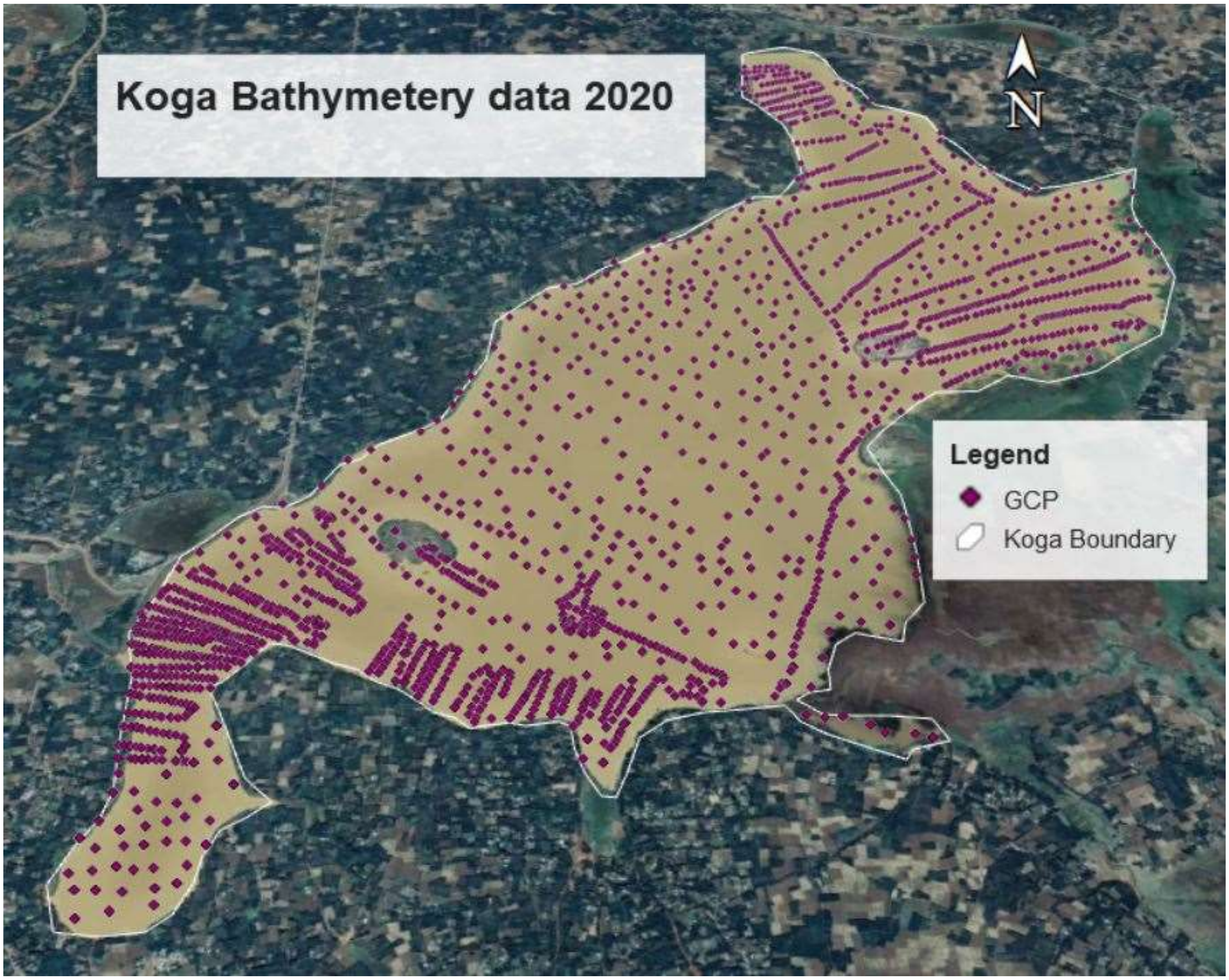

Figure 3.5 Bathymetry data using Bathymetry surveyed (2020*)*

From above figure GCP stands for Ground Control Point.

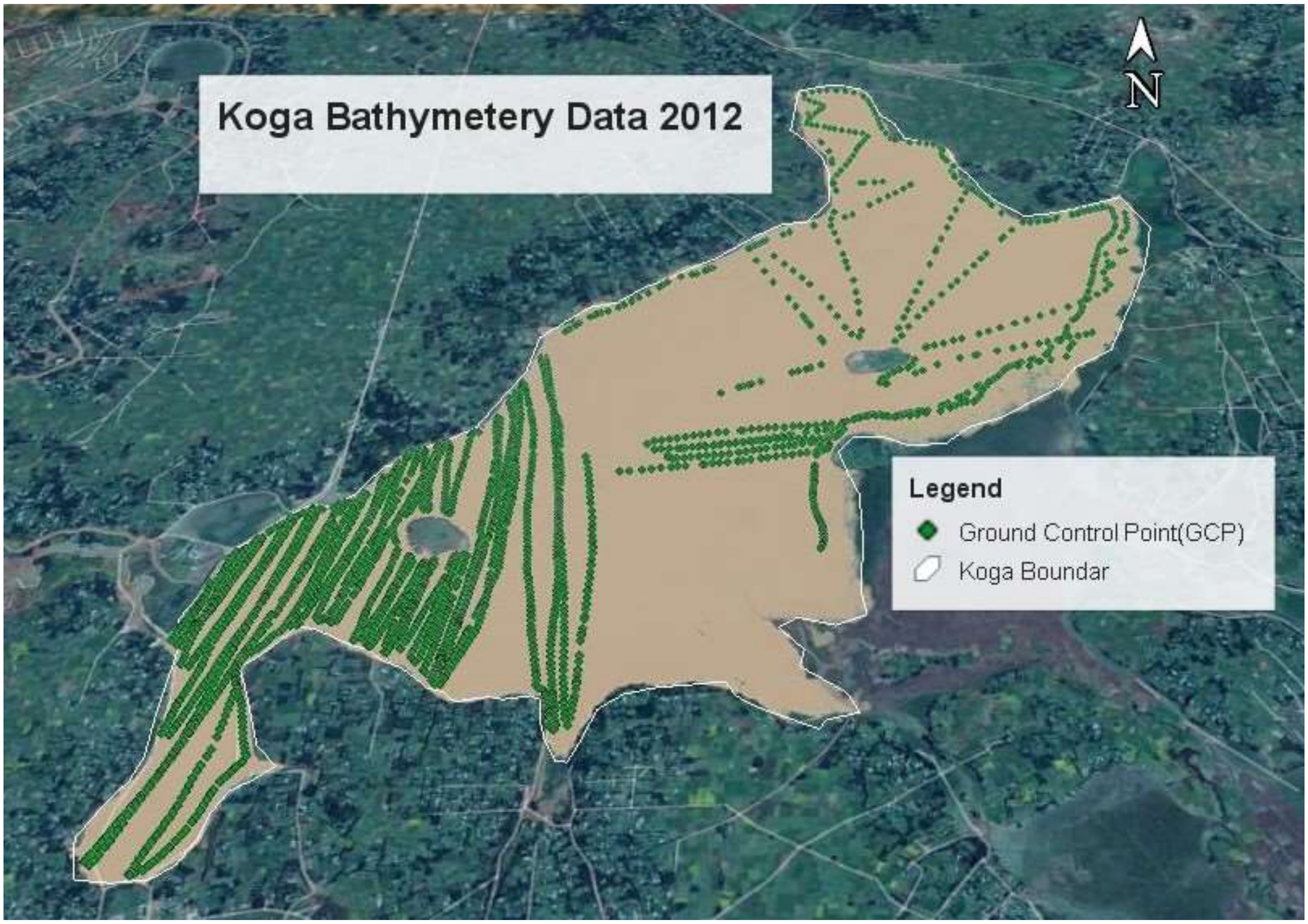

Figure 3.6 Bathymetry surveyed when overlaid on Google earth (Source Elias Seme2012)

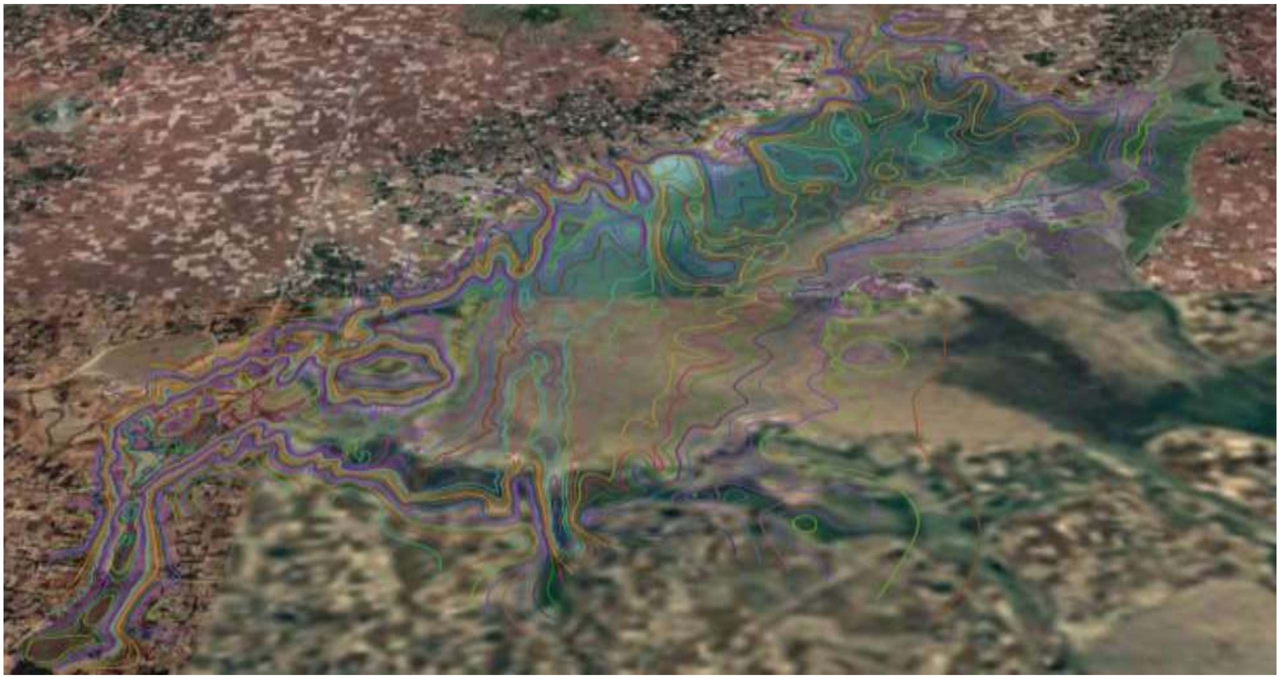

Figure 3.7 Digitized contour line from Koga reservoir topography map (2006, Federal design) when overlaid on Google earth

3.4.2 Topographic data collection

Before the dam was built, the Federal Water Work Design and Supervision Enterprise surveyed the topographic map of the reservoir region. The bathymetric technique is evident in that it is based on a straightforward comparison of reservoir morphology at two different time periods, first during dam construction and then during bathymetry survey. To obtain information on reservoir capacity, a topographical map of the reservoir was necessary.

3.5 Methods for Reservoir trap efficiency determination

Trap efficiency of the reservoir is defined as the ratio of sediment retained in the reservoir to total Sediment inflow to the reservoir i.e., the percentage of sediment inflow which is deposited in the reservoir. Trap efficiency is one of the important parameters in quantifying reservoir sedimentation. There are different approaches to estimating TE of reservoirs. Many researchers used Brune`s method to predict the amount of sediment trapped in reservoirs, because this method is more versatile, accurate and quantifiable with a simple knowledge (Tadesse ,2017b) and the other researchers argue that Brune’s approach is used to much by different researchers to estimate TE because it is not challenge to obtain input data to estimate Example, (Bashar and Khalifa 2009)and (Brown’s) method were used in this study to estimate trap efficiency as follow.

$$TE = 100 \times 0.97^{0.19 \log\left(\frac{V}{I}\right)} \quad \ldots\ldots 3.3$$

TE=trap efficiency, V=reservoir capacity (ha-m) and I=annual average inflow (ha-m)

$$TE = \left(\mathbf{1} - \frac{\mathbf{1}}{\left(\mathbf{1+0.002\times D\times \frac{C}{A}}\right)}\right) \ldots\ldots 3.4$$

Where, TE=trap efficiency, C=reservoir capacity (m^3), A=catchment area (km^2) and D=has constant values ranging from 0.046 to 1 with mean value of 0. 523.yield from the watershed.

(Cogollo and Villela ,1988) worked by performing researches with sampling from existing reservoirs that specific weight for sediment deposits computed according to the kind of operation for the sediment grain size.

Setarge (2017) developed equation to convert volume of sediment to dry weight of sediment on the basis of average specific weight deposits described below was used for this study to quantify reservoir sediment dry weight.

3. 6 Methods for estimating specific weight of sediment deposition

It is considered that unit weight, dry bulk density, or specific weight refers to the dry weight of a deposit per unit volume. (Morris and Fan ,1998) . The volume of surveyed sediments in an existing reservoir should be converted in to mass to estimate sediment yield from the watershed. Cogollo and Villela (1988) worked by performing researches with sampling from existing reservoirs that specific weight for sediment deposits computed according to the kind of operation for the sediment grain size, specific reservoir and level of sediment compaction, which are the most influent factors for deposits consolidation (mothy J. Randle ,2012). TADESSE (2017a) developed equation to convert volume of sediment to dry weight of sediment on the basis of average specific weight deposits described below was used for this study to quantify reservoir sediment dry weight.

$$Dry\ Weight = Total\ volume \times Average\ Specific\ Weight\ of\ Deposits \qquad 3.8$$

Sediment yield defined as the total sediment discharge from watershed in to the reservoir measured

$$SY = \frac{100 \times SV \times dbD}{TE \times Y} \qquad 3.9$$

$$SSY = \frac{SY}{A} \qquad 3.10$$

Where

SY; sediment yield (t/yr), SV is the measured (deposit) volumetric sediment input into the reservoir m^3, dBD: dry bulk density (specific weight) of the sediment deposit (g/cm^3) and TE: sediment trap efficiency of the reservoir in %, Y is the time interval (years) between two successive bathymetric reservoir surveys or reservoir operation time. The area specific sediment yield (SSY) is calculated by dividing SY.

3.7 Method for calculating the reservoir's useful life

From a sediment logical standpoint, a reservoir's usable life begins when sediments reach the intake sill and begin to disrupt or obstruct the operation (TADESSE ,2017b). But Pauly (1979) defined reservoir useful life as, a period in which the initial reservoir capacity will reduce to half of the original reservoir capacity. The useful life is a period that the sediment deposited does not affect the economic feasibility and sustainability of water resources demand.

The actual life of the reservoir will be estimated by using bellow (Yesuph and Dagnew ,2019).

$$LE = \frac{DSV}{SR} \quad \text{..........} 3.11$$

Where, LE is the life expectancy of the reservoirs in terms of years, DSV is the dead storage volume of the reservoir, it is calculated as the capacity loss at the dead level and SR is the sediment rate in terms of m^3/yrs., and calculated by

$$SR = \frac{SV}{\Delta T} \quad \text{..........} 3.12$$

Where, SV is the sediment volume in m^3 accumulated between the year construction and bathymetry surveys below the dead storage level and ΔT is the time interval between two successive reservoir surveys.

3.8 Identifying sites at danger of erosion for conservation planning

In north western Ethiopia, the Koga watershed is one of the key watersheds at the source of the Blue Nile River. It is surrounded by steep mountains (height 3100m at msl) that supply the Koga irrigation dam and low areas with a moderate slope elevation of 1880m amsl in Ethiopia's central highland eco-climatic zones. It deteriorated in terms of geography, soil, climate, density of population, and socioeconomic environment.

3.9 Calculating the rates of soil loss

The interplay of physical, hydrological, and management practices determines the rate of soil loss at the watershed level. Because RUSLE is utilized to compute long time average soil losses from sheet and rill erosion, a hybrid strategy of field investigation and RUSLE modeling was used for soil erosion assessment. Gully erosion and mass motions are not taken into account in the model.

The RUSLE model parameters adapted and validated equations to the Ethiopian Highlands by different re-searchers (Molla and Sisheber ,2017). The soil loss rate was computed by multiplying the six factors in the raster map cell by cell.

According to (Hurin,1985)

$A = R * K * L * S * C * P$……………………………………………………………………3.14

Where: A=annual soil loss(ton/ha/yrs.)

R=rainfall erosivity factor (MJ. mmha^{-1}yr^{-1})

K=soil erodibility factor (MghMJ^{-1}mm^{-1})

L=slope length factor (no unit)

S=slope steepness factor (no unit)

C=cover factor (no unit)

P=land management factor (no unit)

3.9.1 Rainfall erosive (R)

Rainfall data from the project region would be used to calculate and map it. The erosivity factor could be computed using the area's yearly rainfall and the equations used in Ethiopia (Esa, Assen, and Legass ,2018) . But rainfall kinetic energy and intensity data are not available in most cases. Therefore, it was calculated according to the equation given by (Hurin ,1985) for Ethiopia conditions based on the easily available mean annual rainfall(p).

The annual average precipitation was used to evaluate the corresponding average value of R.

$$R = -8.12 + 0.562P \qquad \text{.......} 3.15$$

R is rainfall erosivity Factor ($MJ.mm.ha^{-1}yr^{-1}$) and

P is the mean annual rain fall (mm).

3.9.2 Soil erodibility (K)

It represents the soil susceptibility (surface material exposed to erosion), sediment transportability, and the amount and rate of runoff given a specific rainfall input, as determined under standard conditions. The rate of soil loss per rainfall-runoff erosivity index is represented by this value. Direct measurements on natural runoff plots are the best way to determine soil erodibility factors (K). The proposed method was used to calculate the erodibility of the soil types in the Koga watershed. The erodibility of the soil types of the Koga watershed was calculated using the method proposed (Hurin.1985)shown in appendix D.

3.9.3 Topographic Factors (LS)

A 30 m resolution Digital Elevation Model (DEM) of the watershed will be used to calculate slope length (L) and slope steepness (S) parameters. From (Molla* and Habtamu Muche and Genetu Fekadu ,2019)

$$LS = \left(flow\ accumulation * \frac{cell\ value}{22.1}\right)^{m} (0.065 + 0.045s + 0.0065S^{2}) \qquad \text{.......} 3.16$$

Where LS is slope steepness-length factor, the cell value is the resolution of DEM which is 30and S is slope in percent generated from DEM. The value of m ranges from 0.2 –0.5 depending of the slope (Paper et al. 2017) shown in appendix E.

3.9.4 Land Cover (C)

It represents the effects of management, vegetation, and erosion control practices on soil loss. The land cover (C) value is a ratio comparing the existing surface conditions at a site to the standard conditions of the unit plot shown in appendix F.

3.9.5 Land management practice(P)

The land use practice (management) will be estimated from land use map. The p factor accounts for control practices that reduce the erosion potential of the runoff by their influence on drainage patterns, runoff velocity, runoff concentration, and hydraulic forces exerted runoff on soil. The P factor is commonly calculated by the method developed by Atesmachew Bizuwerk Getahun ,1999)from slope and land use (cover) data. The P values ranges from 0 to 1 depending on the soil management activities. The values for P factor were assigned based on values of (Anteneh ,2021) and different literatures. To account P on watershed scale derivation was made by (Hurin ,1985)when the influences from conservation practices were not considered.

$$P = 0.099 + 0.003 \times S \qquad (3.17)$$

Where P is the land management factor of cultivated land and S is the slope for cultivated land in % shown in appendix G.

3.10 Assessing the sediment output

The sediment loads in the rivers are the result of processes of soil erosion and transport within the watershed. When deposition occurs in midway locations, the amount of sediment reaching the watershed outlet point is generally less than the amount of erosion in that watershed. The role of estimation suspended sediment yield is a great advantage to managers, engineers, leading for proper design of hydraulic structures and investment areas. To estimate sediment yield of the watershed the gross erosion result should be multiplied by SDR.

The research has been performed to estimate the sediment delivery ratio related to watershed width. For Koga study sediment delivery ratio and total amount of sediment actually transported from the eroding sources reach to the reservoir and estimated using the relationship developed by(Dagnaw ,2020).

$SY = E \times SDR$……………………………………………………………………………...3.18

$SDR = 0.5656A^{-0.11}$ ……………………………………………………………………………3.19

Where, SDR=sediment delivery ratio

A=area of the watershed (km^2),220Km^2

SY=sediment yield in (t $ha^{-1}yr^{-1}$)

E=soil loss in (t $ha^{-1}yr^{-1}$)

3.11 Reservoir's depth of water

In order to determine the sediment thickness sediment deposition pattern& raster map was developed predetermined elevation data of bathymetric survey and digitized data found from original topography map using ArcGIS in the following figure.

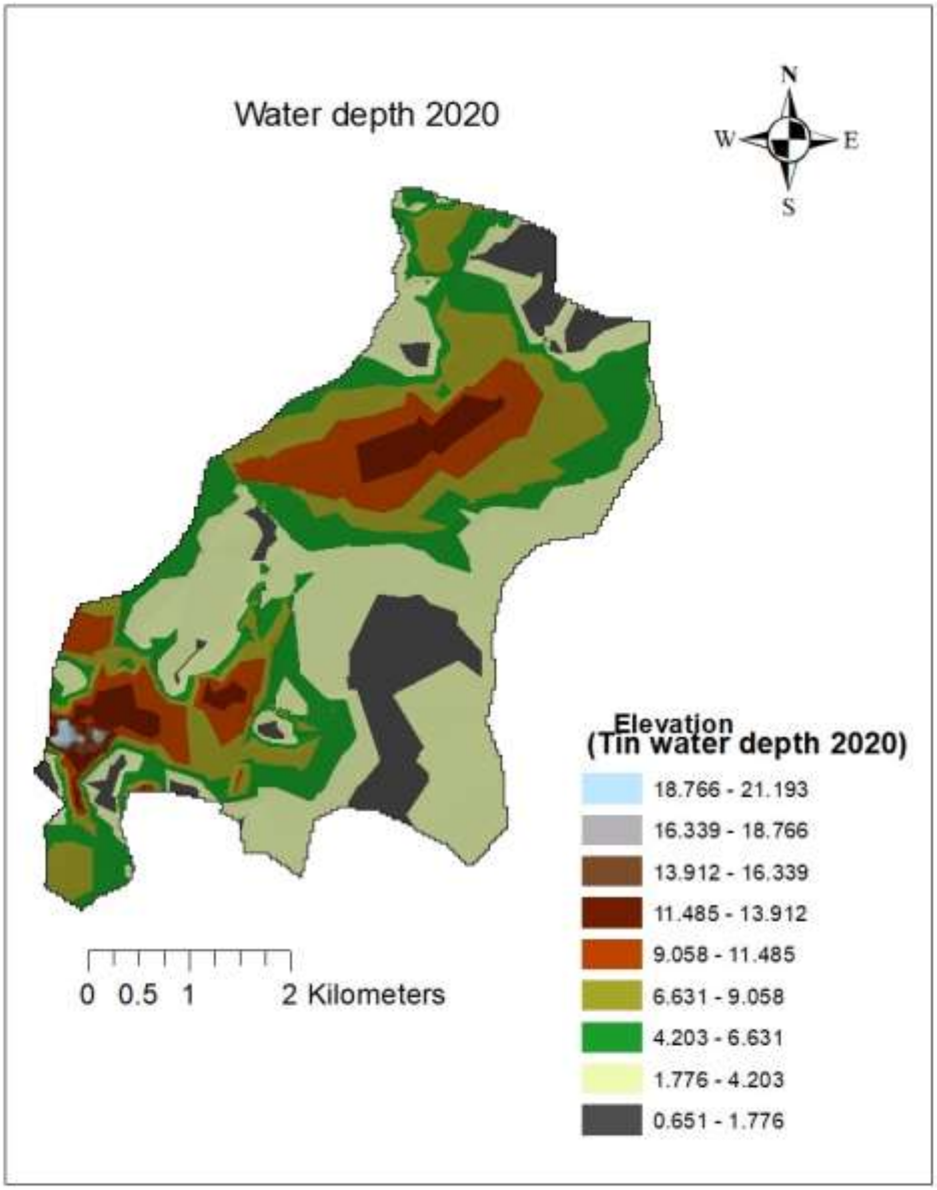

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Figure 3.8 flow chart of Koga reservoir sediment accumulation calculation

3.12 Digital Elivation Model (DEM)

The DEM is the basic input required by ARC_GIS in order to delineate the watershed for RUSLE model. The Koga River watershed was delineated and river networks were extracted from it. For this study, DEM with a resolution of 35 m by 35m obtained from Shuttle Radar Topography Mission (SRTM). Elevation of the study area ranges from 2006 around the dam site to3105 m at the ridges above mean sea level and below figure showed that Koga watershed digital elevation model (DEM).

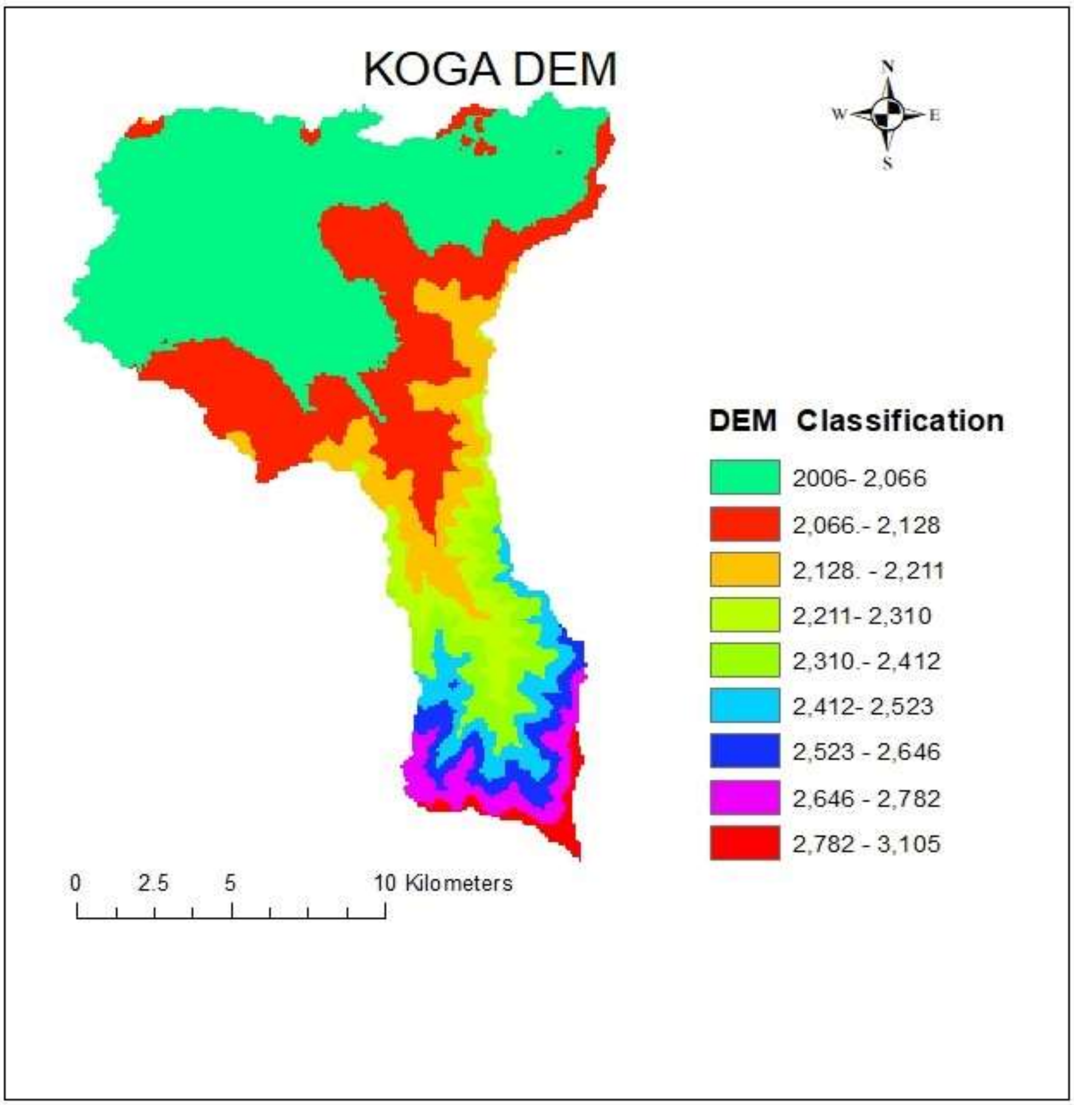


Figure 3.9 Koga watershed digital elevation model (DEM)

3.13 Land use (Cover)

RUSLE modeling required spatial distribution and certain land use characteristics. Using GIS, eight major land use (cover) types in the research area were identified, as illustrated in figure below.

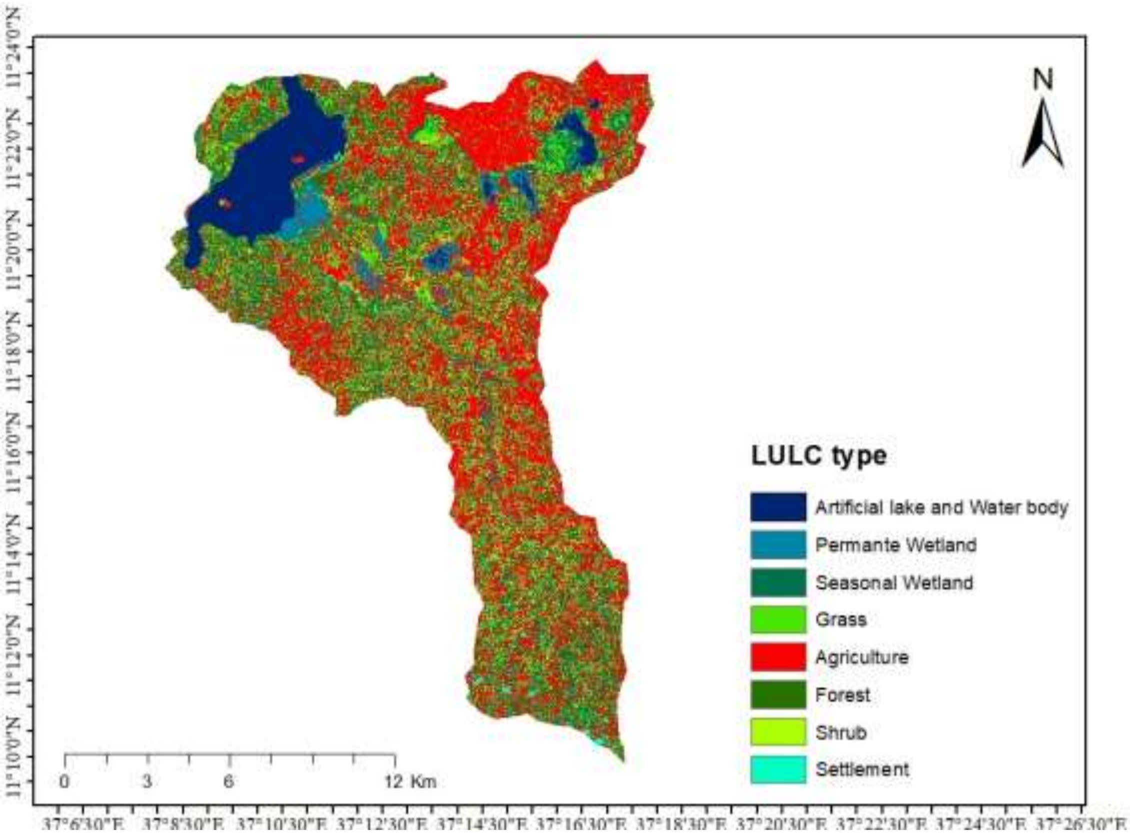


Figure 3.10 Land use (cover) map of Koga catchment

3.14 Soil texture in the Koga watershed

For areas having greater than 8% slope, free survey was used and for areas having a slope less than 8 percent grid survey at 350 m x 500 m was used (ADSWE,2015). According to ADSWE (2015) soil survey data Koga watershed has five soil types. EutricVertisols, Haplic Alisols, Haplic Luvisols, Haplic Nitosols, and Lithic Leptosols are among the soil textures found in the research region, although Haplic Alisols texture is prominent in the watershed, accounting for 37.2 percent maximum and 9.4 percent minimum coverage in the water and below showed that Soil types and area coverage in Koga watershed.

Table 3.4 Soil types and area coverage in Koga watershed

Soil Unit	Area(ha)	Percentage coverage
Eutric Vertisols	3150.53	18.4
Haplic Alisols	7441.92	37.2
Haplic Luvisols	4866.86	15.62
Haplic Nitosols	1299.49	9.4
Lithic Leptosols	3831.52	19.3

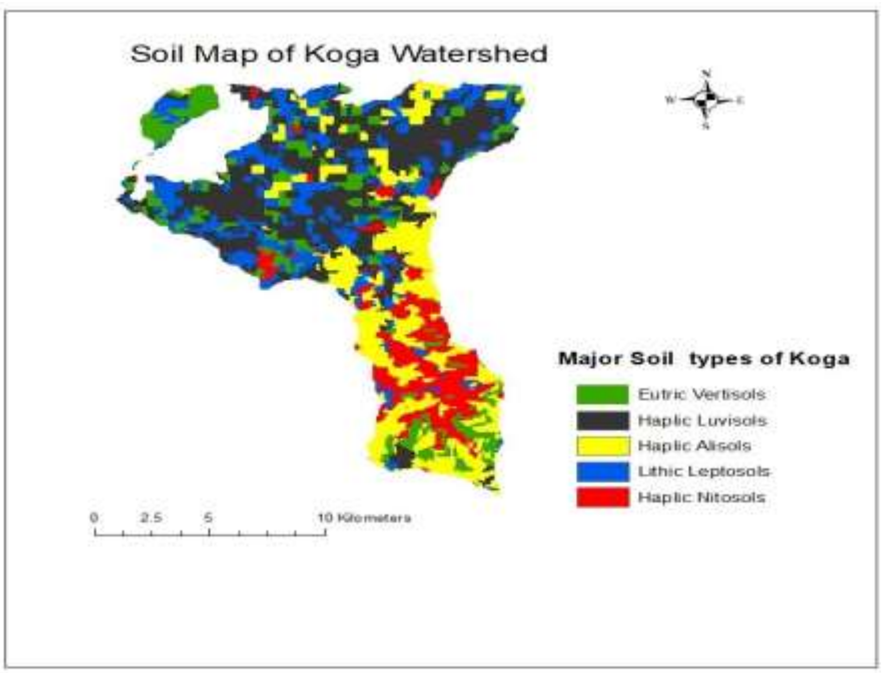


Figure 3.11 Spatial distribution soil in Koga catchment (source ADSWE 2015)

3.15 Climate

The Merawi meteorological station is located near to the project irrigation area, according to the National Meteorological Services Agency (NMSA) Bahir Dar branch. This is the study area's closest and most representative station. This meteorological station, on the other hand, does not keep track of continuous rainfall, minimum and maximum temperatures, wind speed, sunlight hours, relative humidity, or evaporation. As a result, it is advisable to use a nearby station, hence Bahir Dar station is used. The area receives peak rain fall in July and August, averaging 1430mm of precipitation year, according to the station's 30-year rain fall data (1990-2020). Below figure showed that rainfall distribution of Koga watershed.

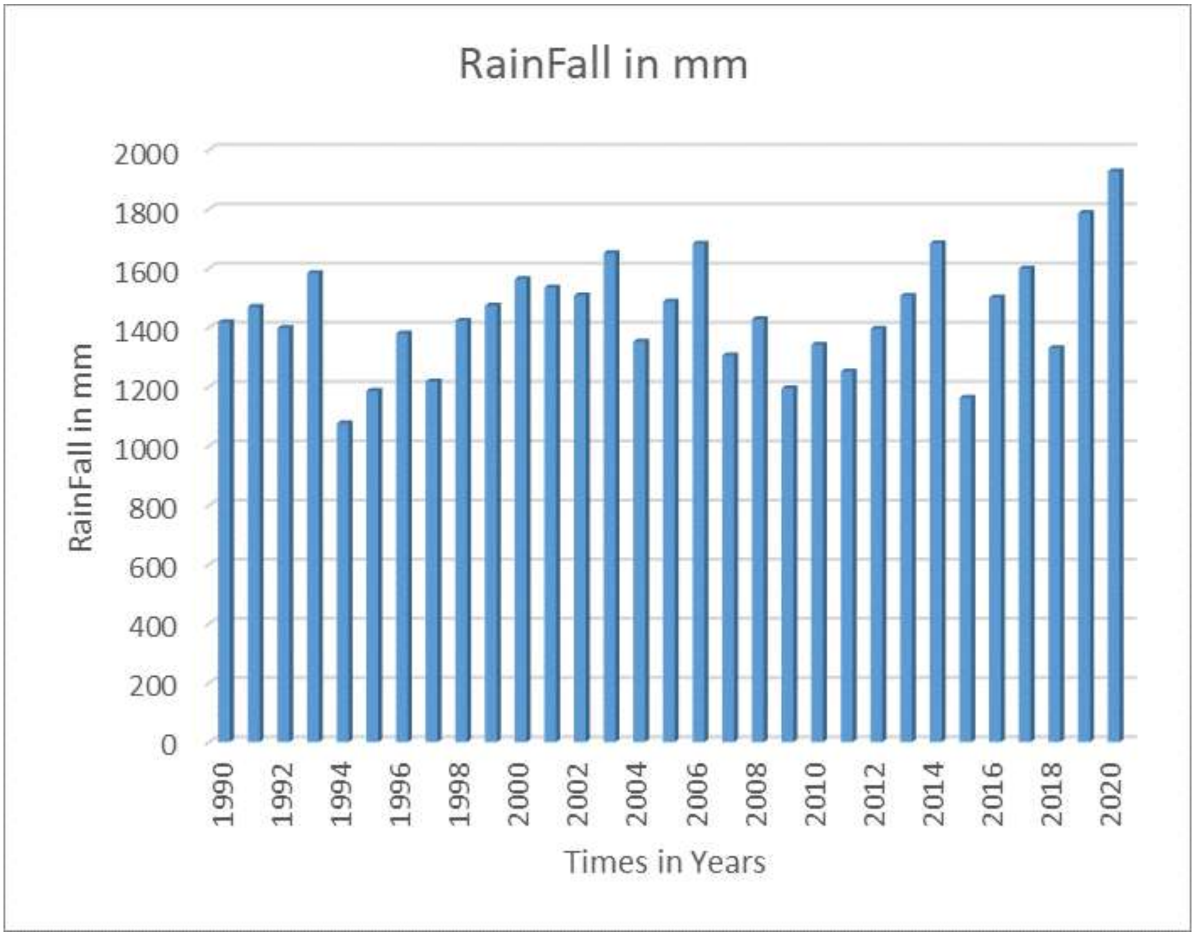


Figure 3.12 rainfall distribution of Koga watershed

CHAPTER 4: RESULTS AND DISCUSSION

The result of the RUSLE and surface differencing for Koga reservoir has shown the four important findings. These are, identify erosion risk areas, estimate the annual sediment accumulation, quantify the reservoir capacity loss due to sediment and useful life of the reservoir. As a result, showed that the reservoir's design storage capacity decreased from 83.1 million cubic meters in 2006 to 78.91 million cubic meters in 2020. The estimated average rate of deposition during the last 11-year operation period is 380909.1m^3/yr, translating to an annual loss rate of 0.38 percent. A study in 2012 showed that the reservoir capacity was reduced to 82.7 billion meter cubic (Alemaw, 2016). These studies revealed that the reservoir capacity is becoming decreasing due to sedimentation. In addition, the water coverage area of the reservoir is decreasing overtime depth.

Table 4.1 summery of reservoir water depth(m) in terms of area coverage

No	water depth(m)	Area(ha) 2020	Area(ha) 2006	percentage coverage 2020	2006
1	0-1.77	255.25	262.19	15.003	14.932
2	1.776-4.2	337.72	340.16	19.850	1.130
3	4.2-6.63	217.89	219.67	12.807	12.510
4	6.66-9.06	330.32	338.23	19.415	19.262
5	9.06-11.49	220.6	221.55	12.966	12.617
6	11.49-13.91	179.2	159.92	10.533	9.107
7	13.91-16.34	160.35	129.05	9.425	7.349
8	16.34-18.77	79.39	81.31	4.660	4.631
9	18.77-22.2	0	3.85	0.000	0.219
	Total	1701.33	1755.93	100.000	100.000

4.1 Reservoir volume

To calculate reservoir water volume and area coverage, as well as sediment deposition and distribution patterns, TIN Development is crucial. A digital representation of the reservoir bed surface known as a TIN surface is provided. This surface is made up of uneven distribution nodes that are produced from contour lines and point measurements with 3D coordinates (x, y, z) and below showed that Koga Reservoir TIN map elevation (2006).

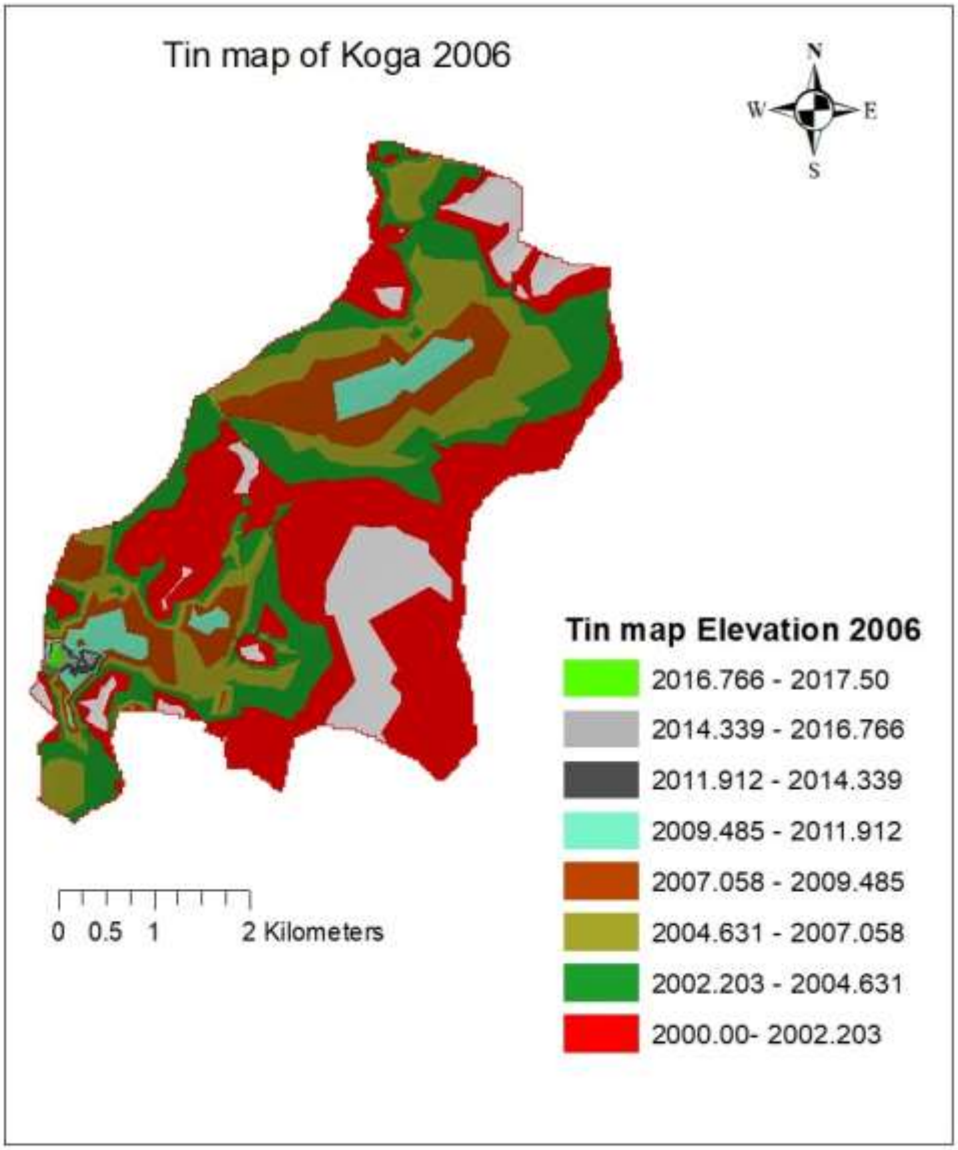


Figure 4.1 Koga Reservoir TIN map (2006)

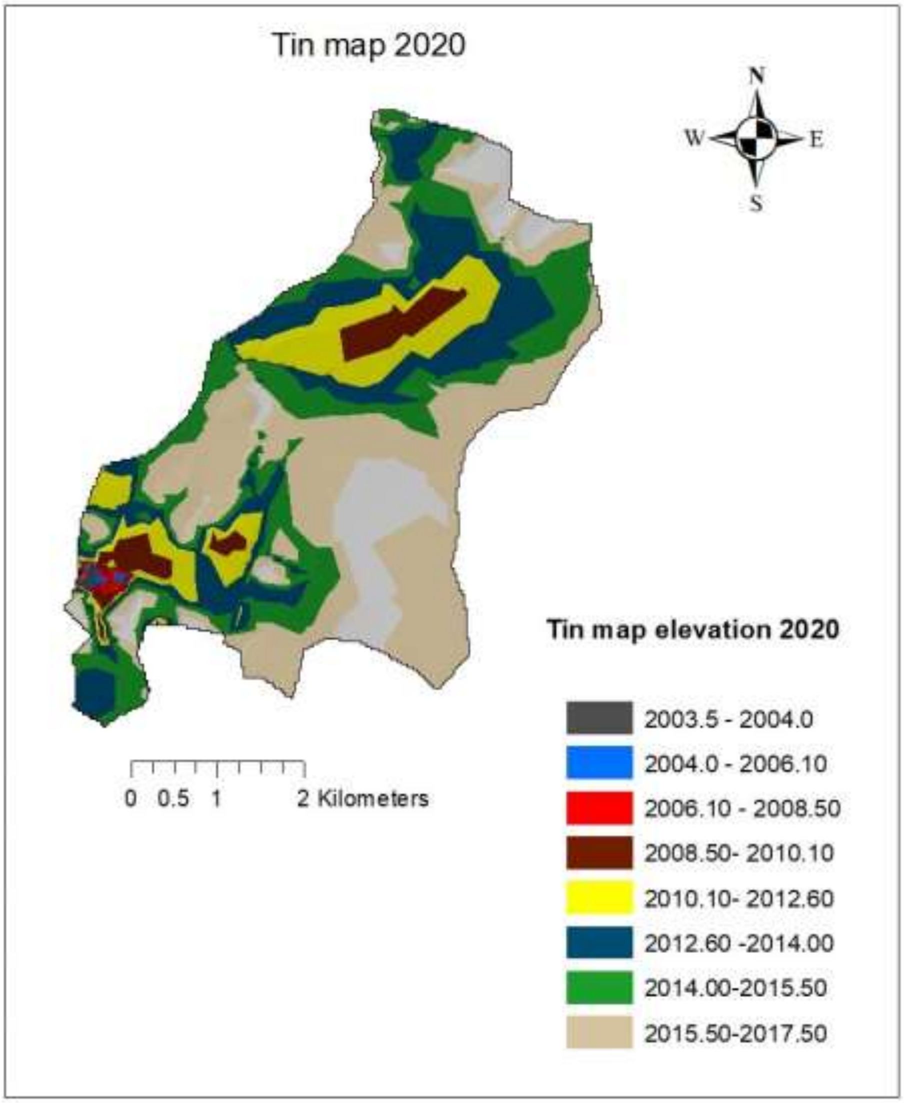


Figure 4.2 Koga Reservoir TIN map (2020)

The Koga Reservoir TIN surface, which was created using digitized data from the reservoir topography map from 2006 and the bathymetric survey data from 2020, was sufficient to determine the reservoir's area and volume. The reservoir polygon volume was calculated using the 3D analysis tool in Arc-GIS to be 83.1MMC in 2006 and 78.91MMC in 2020, both at normal pool level. Due to reservoir area erosion and the rise in elevation in 2015, the reservoir's original outer boundary area decreased from 1755.93 ha in 2006 to 1704.34 ha in 2020. Table 4.2 provided the following reservoir volume and area information for each interval of 1 m elevation.

Table 4.2 Area and volume calculation summery

Elevation(m)	Volume 2020 MCM	volume 2006MCM	Area2020 ha	Area 2006ha	Remark
2000	0	0	0	0	
2001	0	0	0	0.12	
2002	0.01	0.006	0.32	0.6	
2003	0.011	0.03	1.1	5.3	
2004	0.11	0.2	6.54	19	
2005	0.24	0.395	31.23	41	
2006	0.65	1.1	87.16	90	
2007	1.89	2.4	165.78	160	
2007.5	2.85	3.7	225.2	240	
2008	3.89	4.8	254.54	290	
2009	7.96	9.7	418.76	435	
2010	11.2	14	664.98	680	
2011	18.8	22.1	875.12	912	
2012	28.9	32.2	1012.4	1012	
2013	42	44.5	1290.03	1400	
2014	55.4	58.9	1350.45	1490	
2015	71.23	75.2	1624.43	1650	
2015.25	78.91	83.1	1704.34	1755.93	

4.2 Deposit of reservoir sediment

Koga reservoir sediment deposit volume was calculated using the difference in reservoir capacity between the years 2006, 2012, and 2020. The result shown in Table 4.3 indicates that silt buildup caused the reservoir's capacity to drop from its initial volume of 83.1MMC to 78.91MMC. The total volume of sediment deposited between the years of 2006 and 2020 is anticipated to be 4.19MMC, or about 5.04 percent of the volume deposited over the previous eleven years. The yearly sedimentation rate is 380909.1m^3/year when taking the full time period into account at a steady rate. According to this number, the annual decline rate is approximately 0.38 percent. This rate is lower than the global average rate, which is 1%. According to (Tegegne and Enideg Dires,2008)reported annual total capacity loss values of 0.18 to 4% for 13 reservoirs in northern Ethiopia. Moreover, recent studies in the same Tana sub basin showed that annual capacity loss of 1.67%/year for Shina micro-earth dam &2.295%/year for (South Africa and East Africa ,2013). This showed that sedimentation rate is relatively low for Koga as compared to another reservoir with in the basin.

4.3 Previous research on the Koga reservoir and results comparison

Koga reservoir sedimentation analysis was conduct with different techniques at different time. The bathymetric survey result showed that the storage volume shrunk from its design storage of 83.1 Mm3in 2009 to 82.7 Mm3 in 2012, i.e., sediment inflow volume of 339,500m3 (Demsew et al., 2016) and reduced from 83.1 Mm^3in 2009 to 80.33 Mm^3 in 2017(Worku). In addition to Bathymetry surveying, the application of remote sensing techniques for estimating reservoir sedimentation rate in Koga reservoir was conduct in 2016. Results indicated that reservoir volume has reduced from 83.10Mm3 in 2009 to 81.17 Mm3 in 2016, this shows the total storage loss due to sediment deposition was 2.31% and annual storage loss of 0.33% (MichaelM.M.et al, 2017, submitted). The Koga reservoir sedimentation analysis was conducted with Bathymetric surveying and application of remote sensing techniques at different time. Reservoir sedimentation difference with difference techniques at the different time as shown the following.

Table 4.3 Comparation of sediment deposition results with previous studies

Number	Conduct year	Techniques	Capacity difference in MMC	Annual Capacity loss rate in %	Capacity remained in MMC
1	2009-2012	Bathymetry Survey	0.4	0.102	82.7
2	2009-2016	Remote Sensing	1.92	0.33	81.17
3	2009-2017	Bathymetry Survey	3.067	0.46	80.033
4	2009-2020	Bathymetry Survey	4.19	0.38	78.91

Table 4.4 Storage capacity for both live and dead storage zones

			Storage capacity	(SC)	
		Survey ,2006	Survey,2020	Difference in SC	SC Reduction
Unit	Elevation (m)	Mm^3	Mm^3	Mm^3	In %
Maxima	2009	9.7	7.96	1.74	17.93
Dead zone	2007.5	3.7	2.53	1.17	31.62
Live zone	2000-2015.22	79.4	76.21	3.13	3.94
Reservoir	2015.25	83.1	78.91	4.19	5.04

4.4 Sedimentation Distribution

Using the surface difference tool in Arc-GIS, reservoir areas of sediment deposit and scour were calculated in this study from year 2006,2012 and 2020. The results are put in Appendices H, I, and J respectively.

4.5 Trap efficiency

According to the research approach mentioned in chapter three, the formula from (Bashar and Khalifa ,2009) was used to calculate the reservoir trap efficiency. The weight of deposited sediment must be adjusted for reservoir trap effectiveness in order to calculate the average sediment production from the watersheds that contribute to the Koga River. According to Setargie (2017) or (Hydrology factual Report June 2004, Mott Mac Donald) the long-term average river discharge was obtained from the synthesized Koga River flow at dam site for 1960 to 2002 in MMC and its average annual inflow value is 112. 98MM.

Therefore, the average reservoir TE with this inflow was computed using Bashar and Khalifa's trap efficiency equation to be 99.92 percent.

$TE = 100 \times 0.97^{0.19} \log \left(\frac{C}{I}\right)$ where C=83.1 MMC, I=112.98MMC

$TE = 100 \times 0.97^{0.19} log \left(\frac{83.1}{112.98}\right) = 99.92$,whereas Setargie (2017) estimates TE= 96.46%.Why the difference is due to mathematical error(96.64%).

4.6 Koga Watershed's Particular Sediment Yield

According to bathymetric survey research during the previous 11 years, the total volume of deposition in the Koga reservoir is 4.19 MMC. Using eleven years as the reservoir age, the Koga reservoir's yearly rate of sedimentation was 380909.1m3/yr. To calculate specific sediment yield & the sediment yield (SY) used the average trap efficiency of Koga reservoir 99.92% and according to Setargie (2017)average dry bulk density 1.168t/m^3. From equation 3.9 & 3.10 the total annual sediment outflow from the watershed to the reservoir was calculated in terms of SY and SSY as bellow.

SY=$\frac{100\times4.19\times1.168}{99.92\times11}$ =44525.8t/yrs. And

SSY=$\frac{44525.8}{220}$ =202.39t/km^2/yr. or 20.24t/ha/yr. So, the estimated average annual sediment yield distributed to the out let of Koga watershed found 20.24t/ha/yr. The highlands of northern Ethiopia, the sediment yield (SY) value was estimated within range from 1417 t/yr. up to76320 t/yr.by (Ermiyas Ayneku,Solomon and Ejersa2 ,1980). They also showed that the area SSY of the reservoirs reached between 345 and 4935 t/km^2/yr. As a result, the anticipated sediment output is rather close to that predicted by the literature.

4.7 Estimating the reservoir's remaining life

The bathymetric survey outputs were used to estimate the useful life of the reservoir based on the reduction in initial storage capacity, the deposition condition, and the depleted dead storage; otherwise, it was assumed that the sedimentation rate of the Koga reservoir would remain constant over time (as I have seen at field by considering no sediment management activity with in watershed or reservoir). The deposited sediment's useful life at the dead storage level, which is 2007.5 m above sea level, depends on its capacity. The capacity for 2020 was 2.53MMC, and at that elevation, the rate of siltation is 106363.64 m3/yr.

According to the material and procedure portions, equation 3.11 was used to determine the reservoir's life. As a result, the accumulated silt at Koga reservoir's dead storage level UL was determined to be as follows.

$$UL = \frac{DSV}{SR} = \frac{2530000\text{m3}}{106363.64\text{m3/yr}} = 23.5 \text{ years.}$$

On the basis of deposited silt at dead storage level, the useful life of the Koga reservoir was determined to be 23.5 years according to the aforementioned result. Therefore, the primary cause of the reservoirs failing to function for their intended lifespan is the lack of suitable soil conservation methods in the upper watershed area.

4.8 Identification of hot spots to prioritize watersheds

The Koga watershed's yearly average soil loss was estimated using the RUSLE model. The fundamental input for the model used to estimate erosion was the computation of the major causes causing soil loss, which was done in accordance with the customary practices described in many sources. For example (Kimberlin and Moldenhauer ,1977), (Coordinating Committee on Great Lakes Basin Hydraulic and Hydrologic Data 1992), (Monjezi et al. 2017)and some others stated as bellow’s.

4.8.1 Estimating soil loss factors

Rainfall erosivity (R)

The rain fall erosivity is a numerical description of the potential of rain fall to erode soil and is one of the key input parameters for RUSLE modeling (Kao-phetchabun and Yazidhi ,2003). The rainfall erosivity value was calculated from the annual rain fall values of the watershed. The average rain fall distribution of Koga watershed was calculated from 1990 to 2020 years record of 30 years. After converting the monthly rainfall measurements to mean rainfall and interpolating, the watershed was calculated using the standard Kriging method. Then, based on equation 3.19, the Koga area's annual rainfall ranges from 819.987MJ-mm ha/yr to 905.537MJ-mm ha/yr, with distribution shown in the figure below.

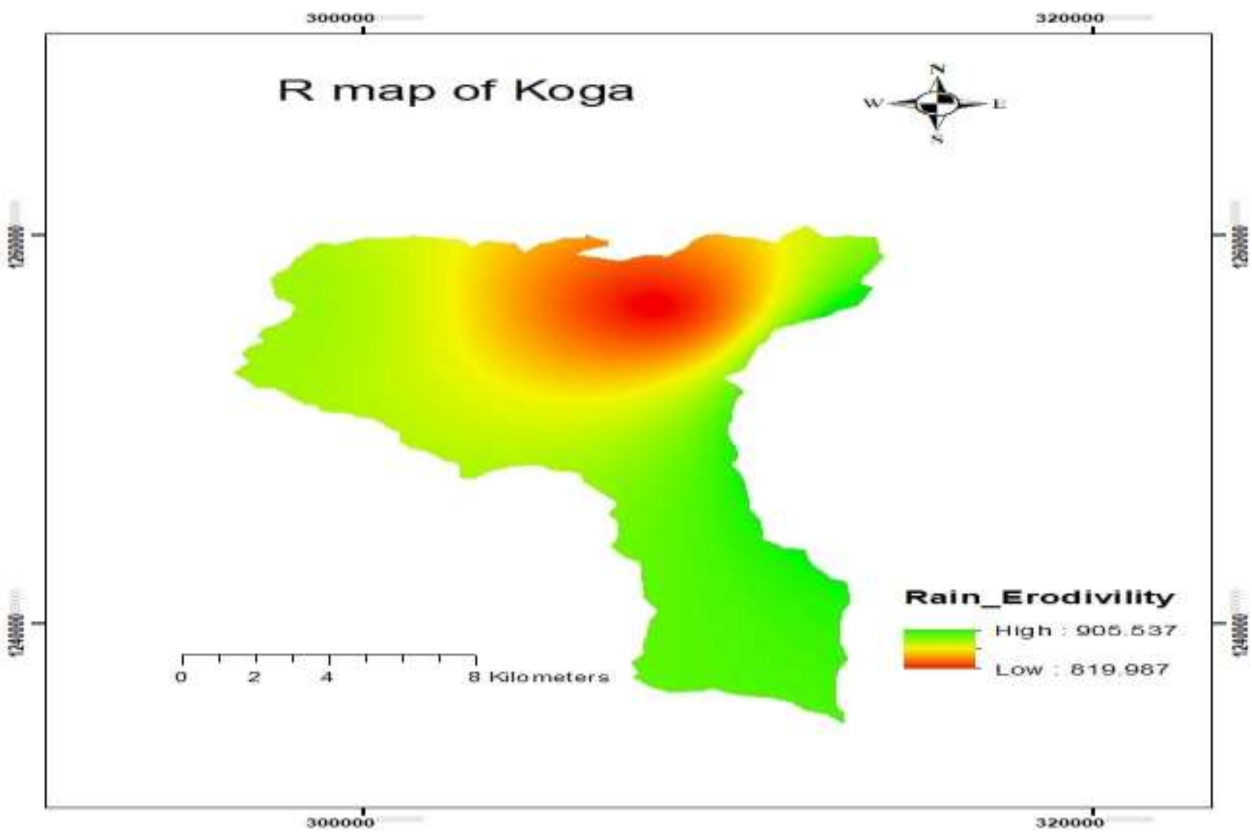


Figure 4.3 Spatial Distribution of rainfall erosivity factor

Soil erodibility(K)

This variable reflects how the soil's characteristics affect soil loss. The estimation of the soil erodibility factor was based on the relationship between K and soil types through the method developed by (Anderson and French ,2019).According to the Minister of Water, Irrigation, and Energy (MOWIAE), there were four soil series in the watershed from which the values at(appendix) were estimated from 0.1 to 0.2 MghMJ-1/mm, where 0.1 indicates soils with the least susceptibility to erosion by water and 0.2 indicates soils with a high susceptibility to erosion by water. The watershed's K mapping results are shown in figure below.

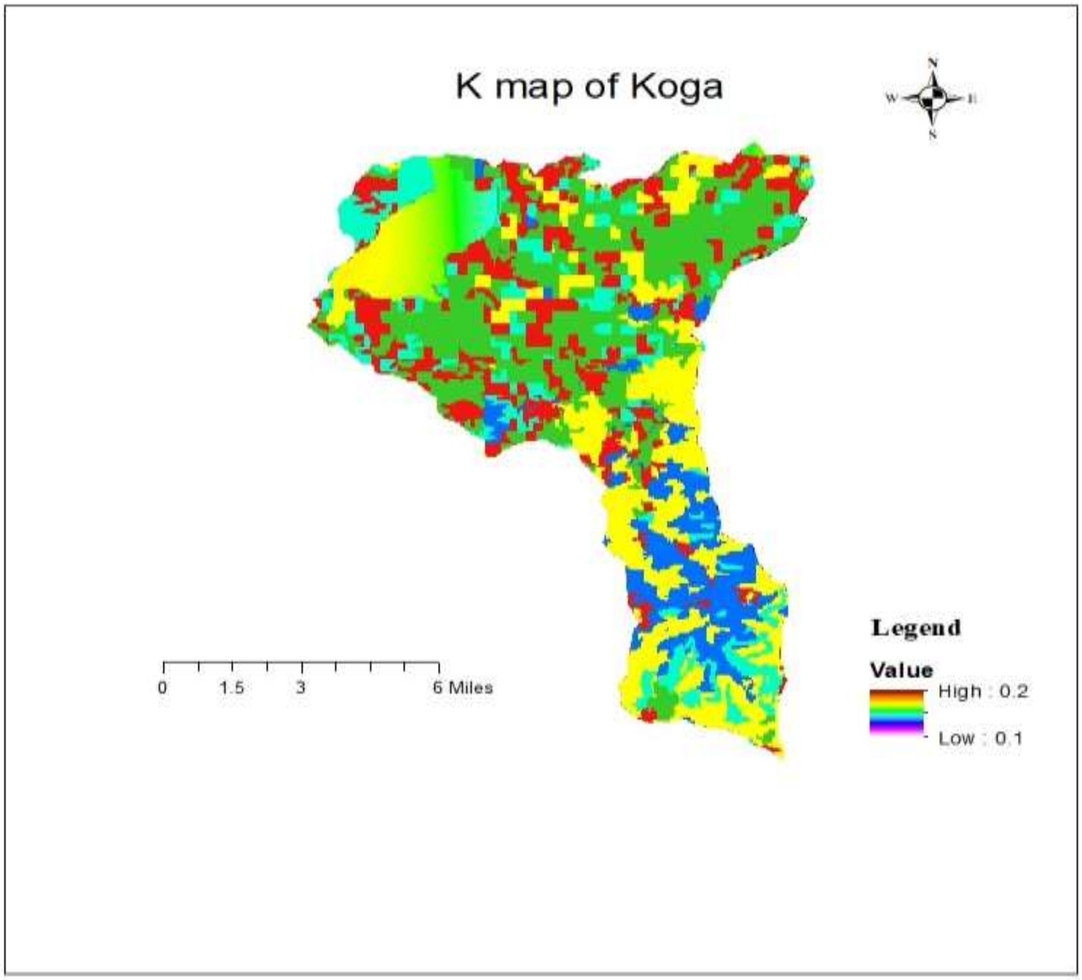


Figure 4.4 Result of mapping for k values

Slope Steepness and Slope length Factor (SL or LS)

The slope steepness and slope length had an impact on soil loss, as demonstrated by the combination of the SL and LS factors mentioned above. The result varied from 0 to 122.435 when the value for each section was computed, as shown in figure below.

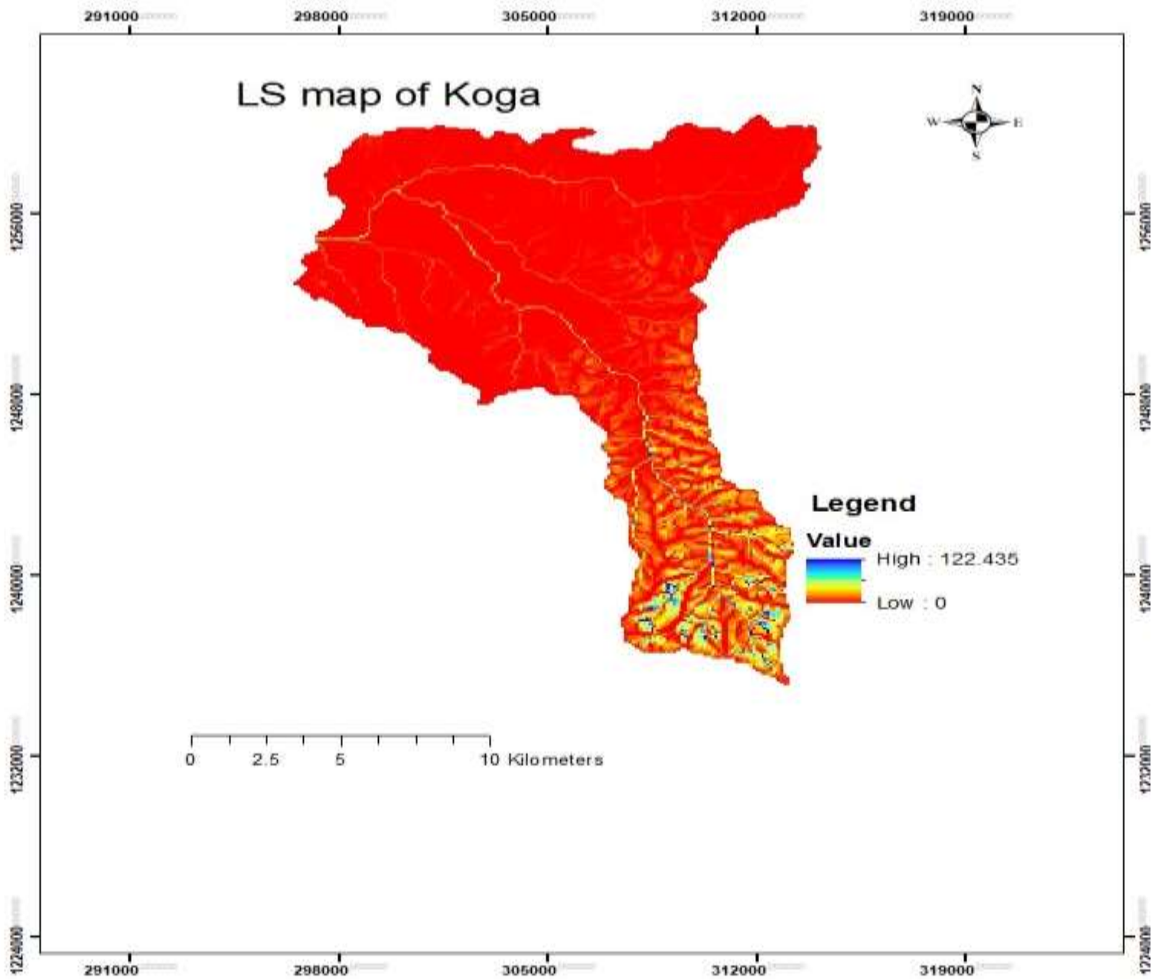


Figure 4.5 Koga LS map

Figure below shows how SL uses Arc-GIS to generate a slope map using the watershed's DEM. The watershed's slope ranges from 0 (in flat areas close to the river's mouth) to >50% on steep hills in the upper zone. The effect of the watershed's slope steepness and slope length was demonstrated by the SL or LS factor combined with the above.

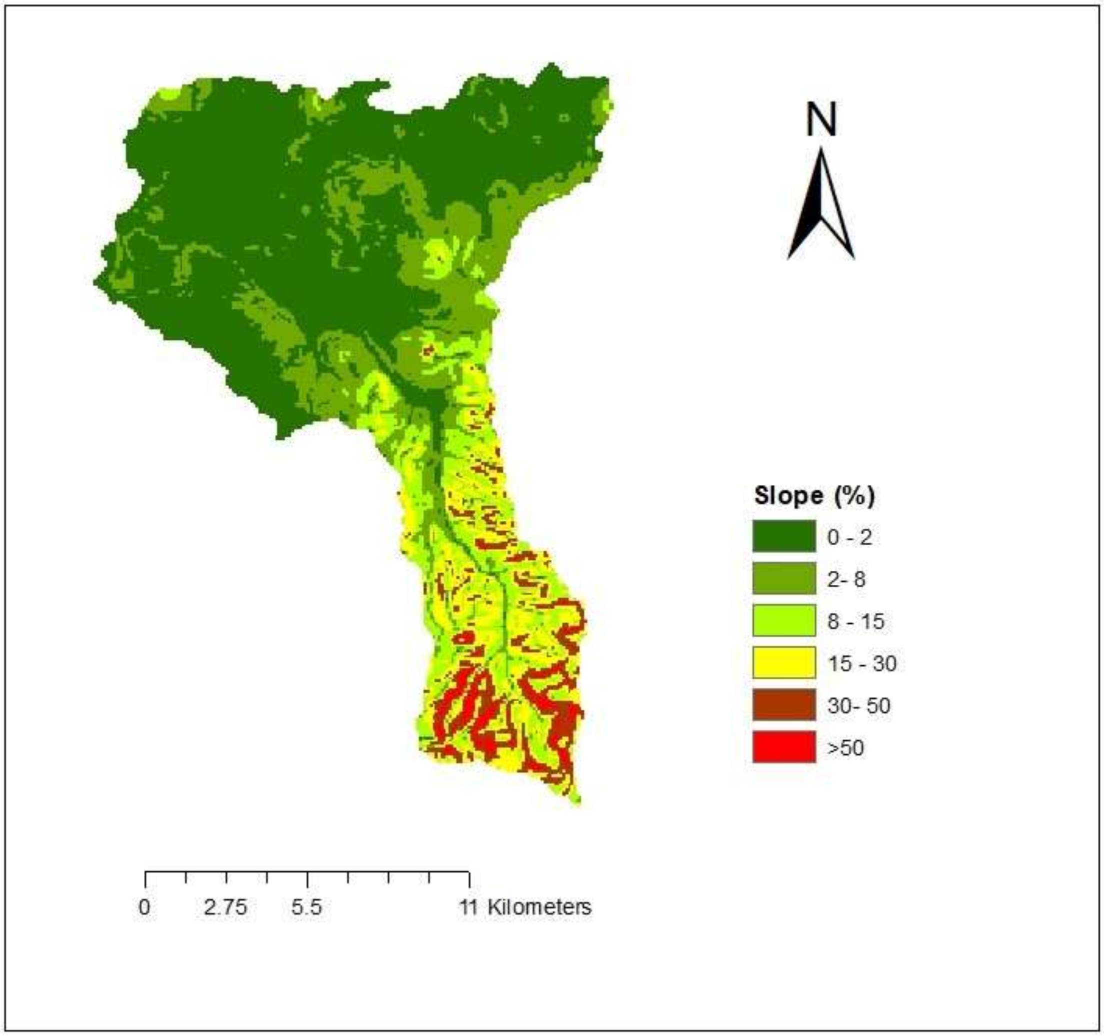


Figure 4.6 Koga watershed slope map

Cover Management Factor (C)

The cover management factor (C), which ranges from 1.0 on entirely bare land (no cover) to 0.0 in aquatic bodies or completely covered land surface, illustrates the impacts of vegetation, management, and erosion control measures on soil loss rates. The area's land use/land cover map will be used to calculate the C factor for the watershed. Below figure showed that C map of Koga watershed.

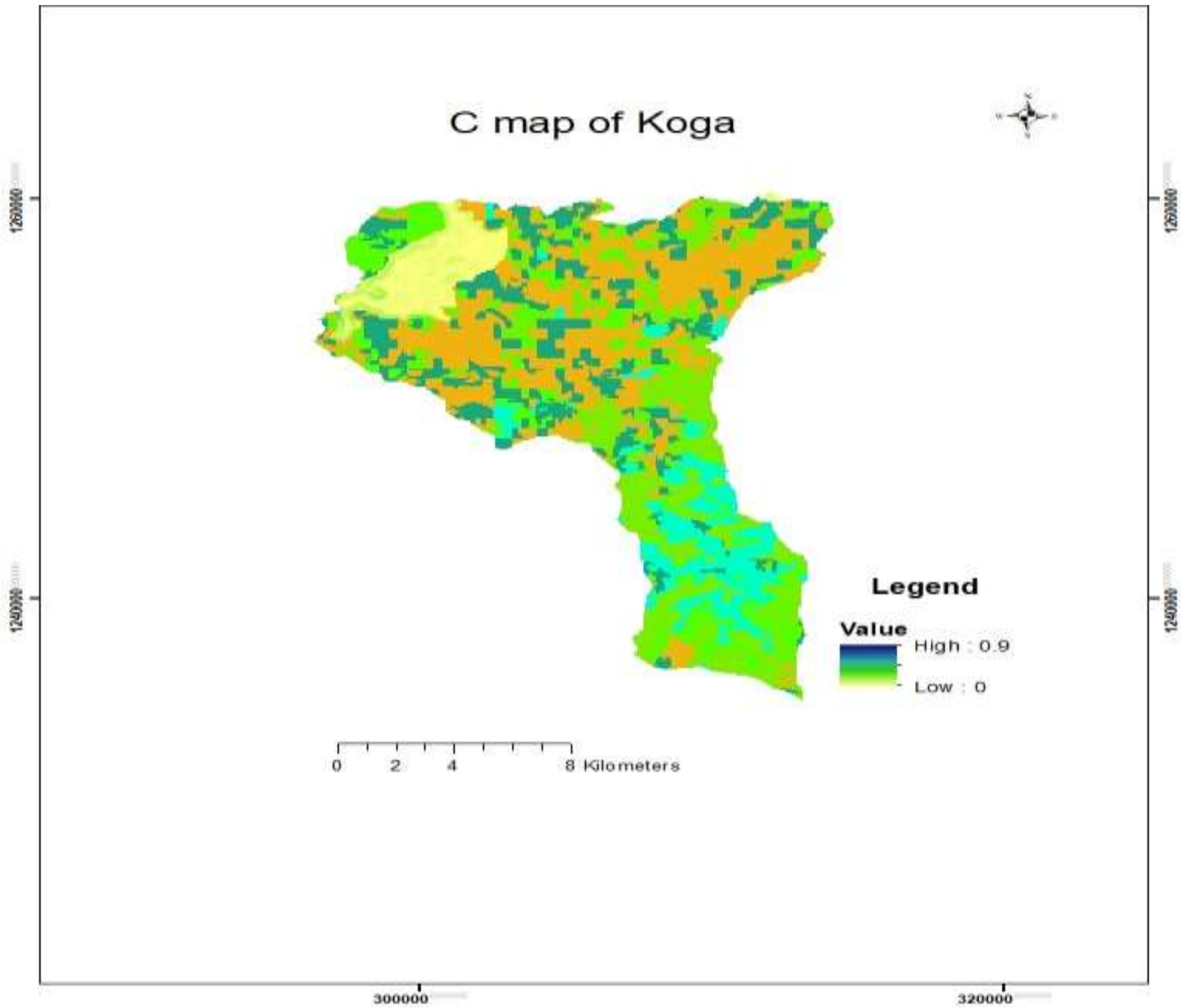


Figure 4.7 Crop management Factor Derived from Cover Type

Conservation practice (P) factor

The management practice factor P shows how conservation measures affect soil erosion on land with sufficient conservation interventions. Specific cultivation practices affect erosion by modifying the flow pattern and direction of runoff and by reducing the amount of runoff (Harold et al. 2010). During the fieldwork, information about the management strategies used by the study watershed will be gathered. As a result, values for this component will be determined by taking into account local management techniques and weighing them against values for other land use types. Below figure showed that P map of Koga watershed.

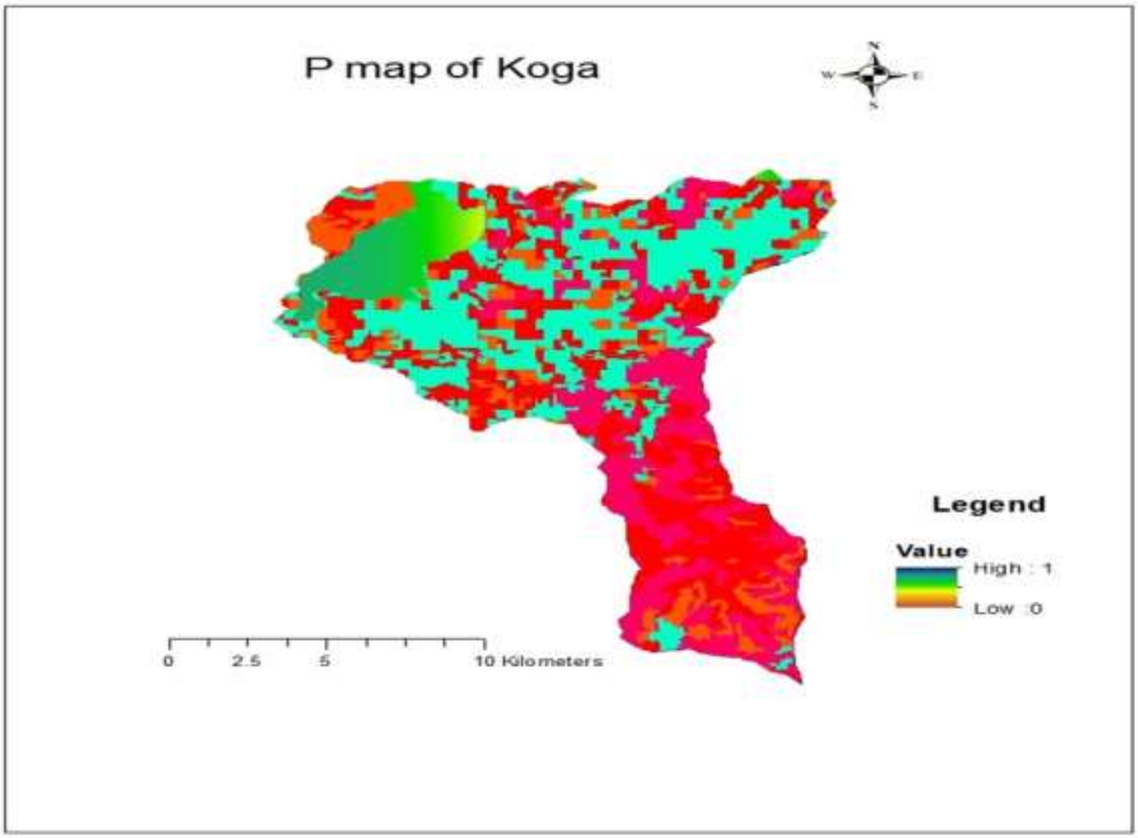


Figure 4.8 Land management factor of Koga

4.8.2 The estimation of soil loss

From minimum to maximum, the Koga watershed's annual soil loss spans from 1.148 to 516.743 tons per hectare, with a mean rate of 53.19 tons per hectare per year. According to (Environment and Climate Change Canada ,2018)stated that the severity of land degradation in the Ethiopian highlands was ranged from 16 to 300 ton/ha/yr.

TADESSE (2017a) showed that the magnitude of soil loss of Tebi watershed values with average annual soil loss rate of 35.71 ton /ha/yr. The following figure map shows soil map of Koga watershed.

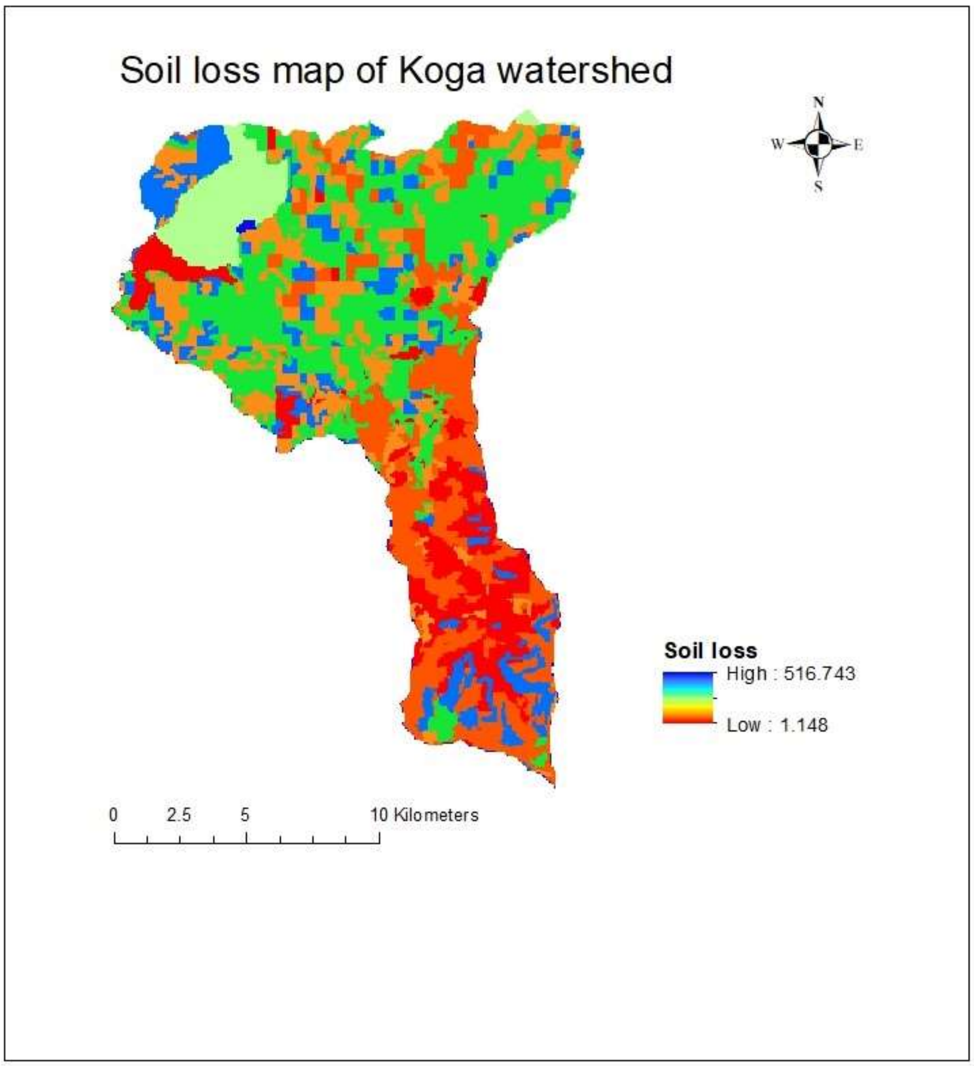


Figure 4.9 Soil loses map of Koga watershed

4.9 Strictness Classification

The Koga soil erosion classes were spreading throughout the watershed and according to (FAO ,2020) Using four major severity groups as a foundation, soil loss was categorized. (Table 4.5) classification showed that 51.24 percent of the total regions fell into the slight category, compared to 30.04 percent moderate, 17.11 percent high, and 1.61 percent very high classes.

Table 4.5 Soil loss and severity class of Koga watershed according to FAO (2020)

Class	t/ha/yr.	mm/yr.	Description	ha	Percentage
I	0-15	0-1	Slight	1060.24	51.24
II	15-50	1-4	Moderate	621.67	30.04
III	50-200	4-16.5	High	354.09	17.11
IV	>200	>16.5	Very High	33.01	1.61

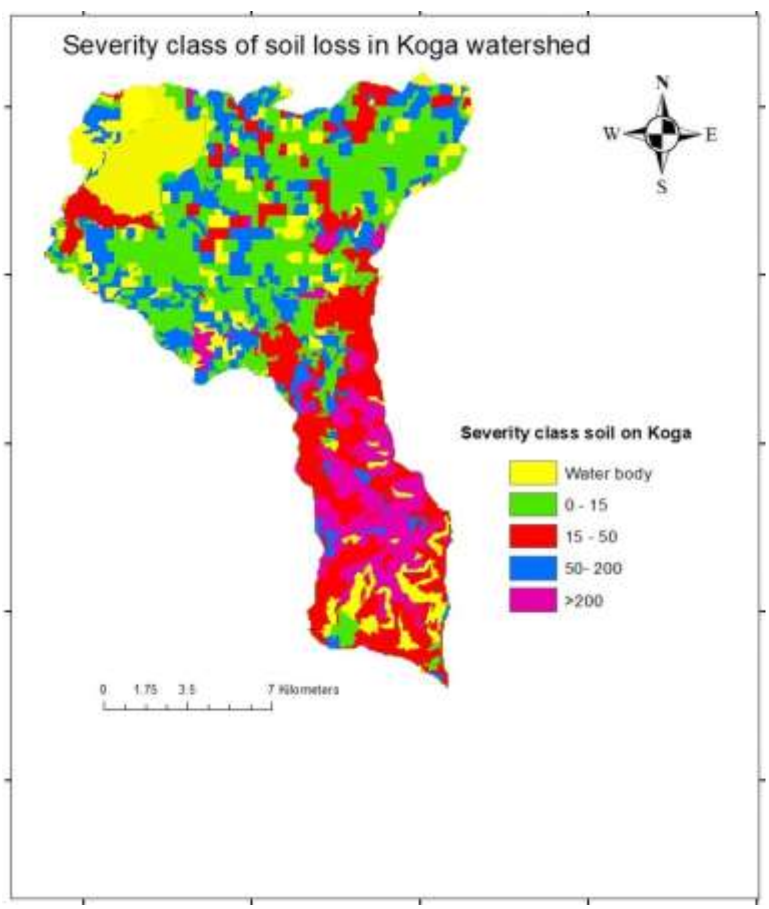


Figure 4.10 Severity class of soil loss in Koga watershed

According to the below table the Rim watershed had the highest average annual soil loss rate of 54.91 t/ha/yr, and the Debreyakob watershed had the lowest average annual soil loss rate of 15.63 t/ha/yr. Asanat and Debreyakob selected their separate conservation efforts at the Koga reservoir watershed based on the amount of soil lost from each watershed's rim in order to slow the rate of reservoir sedimentation. The study of the results from the below (table 4.6) showed that 48.18 percent of the land area was different from extremely high erosion to moderate rates, while 51.82 percent was categorized under slight erosion rates.

Table 4.6 Koga watershed soil erosion loss value

ID	Watershed name	Soil loss t/ha/yr. Class	Averg	Area Ha	percent
1	Debreyakob	1.15-516.174	15.63	303	16.62
2	Asanat	1.17-260	37.23	756	36.53
3	Rim	1.14-517.174	54.91	1010	51.82

.

4.10 Bathymetry and RUSLE model sediment yield output

Sustainable watershed and water management requires accurate measurement of sediment output and the factors that determine Quantify the amount of transported sediment that reaches the reservoir outflow and compare the watershed sediment yield calculated by bathymetry method and the RUSLE model sediment delivery ratio (TADESSE ,2017a). The accounting reduction factor and the sediment delivery ratio of 0.311 for the Koga watershed were used to calculate the quantity of delivered sediment that reached the reservoir through soil by was found by equation 3.18.

$SY = 53.19 \times 0.311 = 16.52$ tons/ha/yr.

The outcome revealed that the mean annual sediment yield was 16.52 tons per hectare per year, with the mean annual sediment load falling between 0.357 and 160.53 tons per hectare per year. According to TADESSE (2017a) Tabi watershed annual average sediment by using RUSLE model was 18.786 whereas the result found from bathymetry survey was 29.371ton/ha/yr. when compared to the Koga watershed's sediment output from the bathymetry survey(20.24tons/ha/yr),the RUSLE model's annual average sediment yield of 16.52 tons per hectare per year was lower by 3.74 tons per hectare per year. The bathymetry approach takes into account channel erosion, gully erosion, sheet erosion, and rill erosion whereas the RUSLE model only uses rill and sheet erosion.

Therefore, in the Koga watershed, sheet and rill erosion was responsible for transporting 16.52 tons of sediment per hectare per year, or 81.62 percent of the total yield of that particular silt, with channel and gully erosion accounting for the remaining 18.38 percent. According to Beatson (1979)the soil loss from RUSLE output (sheet &rill) erosion in Great Lakes Basin area are accounts 67% of gross erosion. By comparing the above finding to the two aforementioned literatures, we can conclude that it is real.

CHAPTER 5: CONCLUSION AND RECOMENDATION

5.1 Conclusion

The bathymetry analysis result revealed that the reservoir's storage capacity was reduced by 4190018.94m3, close to 5.04 percent, of its overall volume. The annual reservoir capacity loss, which is lower than the predicted global rate of reservoir capacity loss (1%), is 0.38. year. TIN map of Koga reservoir, which was derived from the original topographic map based on the 2006, 2012, and 2020 bathymetry survey data, was differentiated using ArcGIS software. The reservoir's volume at intake level has been reduced by 17.93% of its capacity; with this pace of siltation, the reservoir will suffer for the remainder of its useful life. Although the reservoir's design life is 50 years, its usable life is only expected to last 23.5 years.

The result of the model showed that the Rim main watershed is contributing substantial amount of soil loss and the most erosion hotspot portion of the Koga watershed. Bathymetry analysis is found to be an important tool to understand reservoir sedimentation in the Ethiopian highlands.

5.2 Recommendation

In my fieldwork, I observed that there are good conservation efforts at downstream of the watershed but little management or conservation efforts upstream. The following recommended methods for reducing silt inflow into the reservoir are meant to prolong its life and help to achieve its intended purpose.

- The upper watershed should undergo the same management and water conservation efforts as the lower watershed.
- Activities related to traditional fisheries should be limited.
- Since RUSEL doesn't consider gully erosion, future studies should be conducted using other technics that can incorporate gully erosion.
- In spite of its capital-intensive nature, frequent bathymetric survey has to be conducted in the reservoirs.
- Point (sediment dredging) and catchment scale measurements (Soil and water conservation practices) has to be carefully implemented by the Ethiopian government to prolong the service life of Koga reservoir.
- For the sustainability of Koga, the reservoir further study should be checked Enboch on reservoir before it looks like Tana Lake reservoir.

CHAPTER 6: REFERENCE

Agriculture, United States Department of. 1983. *National Engineering Handbook*.

Almaw et al. 2016. Estimating Reservoir Sedimentation Using Bathymetric Differencing and Hydrologic Modeling in Data Scarce Koga Watershed , Upper Blue Nile , Ethiopia." Journal of Agriculture and Environment for International Development (JAEID), 110, 413-427

Anderson, Ray G., and Andrew N. French. 2019. "Crop Evapotranspiration." *Agronomy* 9(10).

Anteneh, Mesfin. 2021. "Patial Estimation of Soil Erosion Using RUSLE Modeling : The Case of Kaffa Zone , South Western Ethiopia." : 1–13.

Aselmaa, Anet, and Anne Laprie. 2017. "The Influence of Automation on Tumor Contouring." *Cognition, Technology & Work*.

Assefa, Tewodros et al. 2015. "Reservoir Sedimentation and Hotspot Areas in Koga Watershed of the Upper Blue Nile Basin, Ethiopia Innovation Lab For Small Scale Irrigation (ILSSI) View Project Water Futures and Solutions (WFaS) Initiative View Project." https://www.researchgate.net/publication/321915486.

Atesmachew Bizuwerk (abizuwerk@cgiar.org)Getahun, Girma TaddeseYasin. 1999. "Application of GIS for Modeling Soil Loss Rate in Awash River Basin, Ethiopia." : 1–11.

Awulachew, Seleshi Bekele et al. 2007. "Water Resources and Irrigation Development in Ethiopia." (978-92-9090-680–3).

A.Bachiller, J.Luis,G.A Rodríguez et al. 2019. "Science of the Total Environment Speci Fi c Sediment Yield Model for Reservoirs with Medium-Sized Basins in Spain : An Empirical and Statistical Approach." *Science of the Total Environment* 681: 82–101. https://doi.org/10.1016/j.scitotenv.2019.05.029.

M.Bacova,J.Krasa,J.Devat et al.2019. "A GIS Method for Volumetric Assessments of Erosion Rills from Digital Surface Models." *European Journal of Remote Sensing* 52(sup1): 96–107.

Bashar, Kamalddin E, and Eltayeb Ahmed Khalifa. 2009. "Sediment Accumulation in Roseires Reservoir." *Improved Water and Land Management in the Ethiopian Highlands: Its Impact on Downstream Stakeholders Dependent on the Blue Nile*: 89.

Beatson, Jack. 1979. "Legislative Control Of Administrative Rulemaking: Lessons From The British Experience." *Cornell International Law Journal* 12: 199.

Carvalho, Daniel Fonseca De, Valdemir Lucio Durigon, Mauro Antonio, and Homem Antunes. 2014. "Predicting Soil Erosion Using Rusle and NDVI Time Series from TM Landsat 5 Temporais de NDVI Do Landsat 5 TM." (1): 215–24.

Ceylan, Ayhan, and Ilke Ekizoglu. 1982. "Assesment Of Bathymetric Maps Via Gis For." : 142–58.

Citation, B Y U Scholarsarchive. 2008. "Estimation of Useful Life of a Reservoir Using Sediment Trap Efficiency." 8(2).

Cogollo, P R J, and S M Villela. 1988. "Mathematical Model for Reservoir Silting." (174): 43–52.

Committee, Advisory, and Water Information Subcommittee. 2017. "Dam Removal Analysis Guidelines for Sediment."

Coordinating Committee on Great Lakes Basin Hydraulic and Hydrologic Data. 1992. "IGLD 1985:

Dagnaw, Tamene. 2020. "Estimation of Reservoirs Sedimentation Using Bathymetry Survey: Case Study on Three Koga Night Storage Reservoir."

David. 2014. "Bathymetry from Space Is Now Possible." 84(5): 37–44.

Deborah Cooper, Research Hydraulic Engineer, US Army Engineer Research and Development Center. 1982. *Usace Reservoir Sedimentation Survey Database (Ressed)*.

Environment and Climate Change Canada, US Environmental Protection Agency. 2018. "Lake Huron Lakewide Action and Management Plan, 2017-2021." : 1–105.

Esa, Ebrahim, Mohammed Assen, and Asmamaw Legass. 2018. "Implications of Land Use / Cover Dynamics on Soil Erosion Potential of Agricultural Watershed , Northwestern Highlands of Ethiopia."

FAO. 2020. Fao *The State of Food and Agriculture 2020. Overcoming Water Challenges in Agriculture*.

Flores-renteria, Dulce et al. 2015. "Land Degradation."

Fund, African Development. 2001. *Ethiopia Koga Irrigation And Watershed Management Project Appraisal Report*.

Gashaw, Temesgen, Taffa Tulu, and Mekuria Argaw. 2018. "Erosion Risk Assessment for Prioritization of Conservation Measures in Geleda Watershed, Blue Nile Basin, Ethiopia

Graham, Frank Porter. 2013. "New Stories from the FPG at a Glance From the Director."

Hagos, Fitsum et al. 2009. "Sustainable Land Management Research and Institutionalization of Future Collaborativ."

Haregeweyn, Nigussie et al. 2006. "Sediment Yield Variability in Northern Ethiopia : A Quantitative Analysis of Its Controlling Factors."

Harold, R et al. 2010. "Description of Document : National Archives National Personnel Records Center (NPRC) VIP List , 2009 December 2007 March 2008 National Personnel Records Center Military Personnel Records 9700 Page Avenue St . Louis , MO 63132-5100 NPRC Staff Has Compile." (December 2007).

Hui, Jennifer. 2014. "Methods For Estimating Sediment Yield And Dam Capacity In The Great Lakes Watershed." *Wayne State University*.

Iii, Volume. 2014. III *Observed Performance of Dams During Earthquakes Observed Performance of Dams During Earthquakes*.

Interior, United States Department of the. 2006. *Erosion and Sedimentation Manual Erosion and Sedimentation Manual*.

Iradukunda, Parfait, and Erion Bwambale. 2021. "Reservoir Sedimentation and Its Effect on Storage Capacity – A Case Study of Murera Reservoir , Kenya Reservoir Sedimentation and Its Effect on Sto - Rage Capacity – A Case Study of Murera Reser - Voir , Kenya."

Issa, Issa E, Nadhir Al-ansari, Govand Sherwany, and Sven Knutsson. 2013. "Sedimentation Processes and Useful Life of Mosul Dam Reservoir , Iraq." 2013: 779–84.

Issa, Issa Elias. 2011. "Doc Tor A L T H E S I S Sedimentological and Hydrological Investigation of Mosul Dam Reservoir Issa Elias Issa."

K.Meijer, L.C. van Rijn and. 1986. "Three -Dimentinal Model,Mathematical Models For Suspended Sediment Transport In Currents And Waves."

Kao-phetchabun, Lom, and Bamutaze Yazidhi. 2003. "A Comparative Study of Soil Erosion Modelling."

Kebede wolka. 2014. "Effect of Soil and Water Conservation Measures and Challenges Its Adoption:Ethiopia in Focus." *Enviromental Science and Technology 7* 4(1994–7887): 185–99.

Kimberlin, Leon W., and William C. Moldenhauer. 1977. "Predicting Soil Erosion." *ASAE Publ* (4–77): 31–42.

Lewis, Stephen E et al. 2013. "Calculating Sediment Trapping Efficiencies for Reservoirs in Tropical Settings : A Case Study from the Burdekin Falls Dam , NE Australia." 49: 1017–29.

Li, Jinshan. 2017. "Particle Size Distribution and Settling Velocity of Sediments in Water Diverted from the Yellow River during Border-Strip Irrigation." VIII: 31–41.

Lifetime, Small-scale reservoir sedimentation rate analysis for a reliable estimation of irrigation schemes economic, northern Ethiopia) (A case study of Adigudom area, Tigray, and 1. 1980. "Small-Scale Reservoir Sedimentation Rate Analysis for a Reliable Estimation of Irrigation Schemes Economic Lifetime (A Case Study of Adigudom Area, Tigray, Northern Ethiopia) " *Journal of the Japanese Society of Pediatric Surgeons* 16(4): 704.

Lin, Xiaodong. 1995. "Instructional Design and Development of Learning Communities: An Invitation to a Dialogue." *Educational Technology* 35(5): 53–63.

Lu, Xiaoyu et al. 2017. "International Soil and Water Conservation Research The Effect of Grid Size on the Quanti Fi Cation of Erosion , Deposition , and Rill Network." *International Soil and Water Conservation Research* 5(3): 241–51. http://dx.doi.org/10.1016/j.iswcr.2017.06.002.

Mekonnen, M. et al. 2015. "Evaluación de Presas de Retención de Sedimento: Medidas Estructurales de Control Del Transporte de Sedimento En El Noroeste de Etiopía." *Cuadernos de Investigacion Geografica* 41(1): 7–22.

Mert, Okan. 2021. "Spatial Analysis of Seasonal Precipitation Using Various Interpolation Methods in the Euphrates."

Mohammed, I N G Mebruk. 2014. "Addis Ababa Institute Of Technology School Of Graduate Studies River Sediment Transport Monitoring To Improve The Life Span Of Dams .AThesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment for the Requirement ."

Molla*, Dereje, and Habtamu Muche and Genetu Fekadu. 2019. "Soil Erosion Risk Assessment and Mapping Using GIS In." 7(9): 118–23.

Molla, Tegegne, and Biniam Sisheber. 2017. "Estimating Soil Erosion Risk and Evaluating Erosion Control Measures for Soil Conservation Planning at Koga Watershed in the Highlands Of." (2014): 13–25.

Monjezi, Ardeshir, Alireza Masjedi, Mohammad Heidarnejad, and Mohammad Hossein Pourmohammadi. 2017. "Effects of Slot Size in the Groin Body on the Riprap Stability in a River Bend." *Fresenius Environmental Bulletin* 26(12): 7034–44.

Morris, G. L., and Jiahua Fan. 1998. 9 *Reservoir Sedimentation Handbook: Design and Management of Dams, Reservoirs, and Watersheds for Sustainable UsE.*

Oliver, Larry, Wendy Gendron, David Olson, and Mindy Simmons. 2018. "Aquatic Ecosystem

Restoration in the Corps Low-Head Dam Removal For.”

Paper, Original et al. 2017. “Comparison of Different Approaches to LS Factor Calculations Based on a Measured Soil Loss under Simulated Rainfall.” 2017(1)

Pauly, D. 1979. “Gill Size and Temperature as Governing Factors in Fish Growth: A Generalization of von Bertalanffy´s Growth Formula.” *Berichte aus dem Institut für Meereskunde Kiel* 63: 1–156.

Penibertori, Robert I. Strand Ernest L. 1982. *RESERVOIR Technical Guideline for Bureau of Reclamation*.

Pingalii, Prabhu. 1992. “Crop - Livestock Interaction in Sub-Saharan Africa.”

Practices, G I S Best. 2010. “Environmental Management.”

Randle, mothy J. 2012. “Reservoir Sustainability Workshop And National Reservoir Sedimentation.”

Randle, Timothy et al. 2017. “Frequently Asked Questions about Reservoir Sedimentation and Sustainability Contribution and Review by the Subcommittee on Sedimentation National Reservoir Sedimentation and Sustainability Team :”

Rosmansyah, Yusep, Mohamad Achiruzaman, and Ariq Bani Hardi. 2019. “A 3d M Ultiuser V Irtual L Earning E Nvironment.” 18: 481–507.

Schauer, Mark. 2015. “THE E CONOMICS OF The Economics of Land Degradation in Africa Benefits of Action the Costs A Complementary Report to the ELD Initiative.”

Seleshi, By et al. 2012. “Improved Water and Land Management in the E Thiopian Highlands and Implications for the Downstream Blue Nile 1.” : 1–12.

Worku. 2017. “Estimating Reservoir Sedimentation Using Bathymetry Survey: Case Study Of Koga Reservoir (Upper Bluenile Basin) Ethiopia.”

Sheng, D, K Axelsson, and S Knutsson. 1995. “Frost Heave Due to Ice Lens Formation in Freezing Soils 1 . Theory and Verification.” : 125–46.

Sir, Ishraga, and Elkhatim Osman. 2015. “Impact of Improved Operation and Maintenance on Cohesive Sediment Transport in Gezira Scheme , Sudan Ishraga Sir Elkhatim Osman.”

Society, United States. 2015. *Modeling Sediment Movement in Reservoirs United States Society on Dams Modeling Sediment Movement in Reservoirs*.

Survey, U S Geological et al. 2014. “Identifying Sediment Sources in the Sediment Tmdl Process.”

Tadesse, Mesfin. 2017a. “Investigation Of Reservoir Sedimentation Using Bathymetry Survey : A Case Study Of Tebi Micro Earth Dam (Upper Beshilo River Basin).” *Thesis*.

2017b. “Investigation Of Reservoir Sedimentation Using Bathymetry Survey : A Case Study Of Tebi Micro Earth Dam (Upper Beshilo River BASIN).”

Tegegne, Enideg Diress. 2008. “Importance of Ficus Thonningii Blume in Soil Fertility Improvement and Animal Nutrition in Gondar Zuria , Ethiopia Thesis Submitted to Institute of Forest Ecology in Partial Fulfillment of the Requirements for the Degree of Master of Science in Mountain F.”

Teka, Tegegne, Alemayehu Azeze, and Ayele Gebremariam. 1999. “Cross-Border Livestock Trade and Food Security in the Southern and Southeastern Ethiopia Borderland.”

To, Contribution, Promote Conservation, O F Water, and Storage Assets. 2003. “Reservoir Conservation Volume I : The RESCON Approach.” 1.

Tommasi, Tatiana, Novi Patricia, Barbara Caputo, and Tinne Tuytelaars. 2017. “A Deeper Look at Dataset Bias.” *Advances in Computer Vision and Pattern Recognition* (9783319583464): 37–55.

Vanmaercke, M., F. Obreja, and J. Poesen. 2014. “Impact of Earthquake-Triggered Landslides on Catchment Sediment Yield.” *IAHS-AISH Proceedings*

Vito, Stijn Janssen, Lisa Blyth Vito, and Nele Veldeman Vito. 2016. “Service Contract on Improved Tools for Assessing NO2 Exposure (EU Ambient Air Quality Policy) Task 1 Interim Report : Review of Existing Methodologies Report for : European Commission Directorate-General-Environment.”

Yesuph, Asnake Yimam, and Amare Bantider Dagnew. 2019. “Soil Erosion Mapping and Severity Analysis Based on RUSLE Model and Local Perception in the Beshillo Catchment of the Blue Nile Basin ,.” *Environmental Systems Research*: 1–21. https://dYimer, Fantaw. 2007. “Soil Properties in Relation to Topographic Aspects , Vegetation Communities and Land Use in the South-Eastern Highlands of Ethiopia Fantaw Yimer.”

Zeleke, Takele, Ahmed Moustafa Moussa, and Mohamed S El-manadely. 2013. “Prediction of Sediment Inflows to Angereb Dam Reservoir Using the SRH-1D Sediment Transport Model.”

Zemen, H.G., Belete Solomon, Bekure Woldegiorgis, Alehegne Dagnew, G.A. Tigistu, And T.D. Belete. 2017. “Ethiopia’S Move To a National Integrated Land Use Policy and Land Use Plan.”

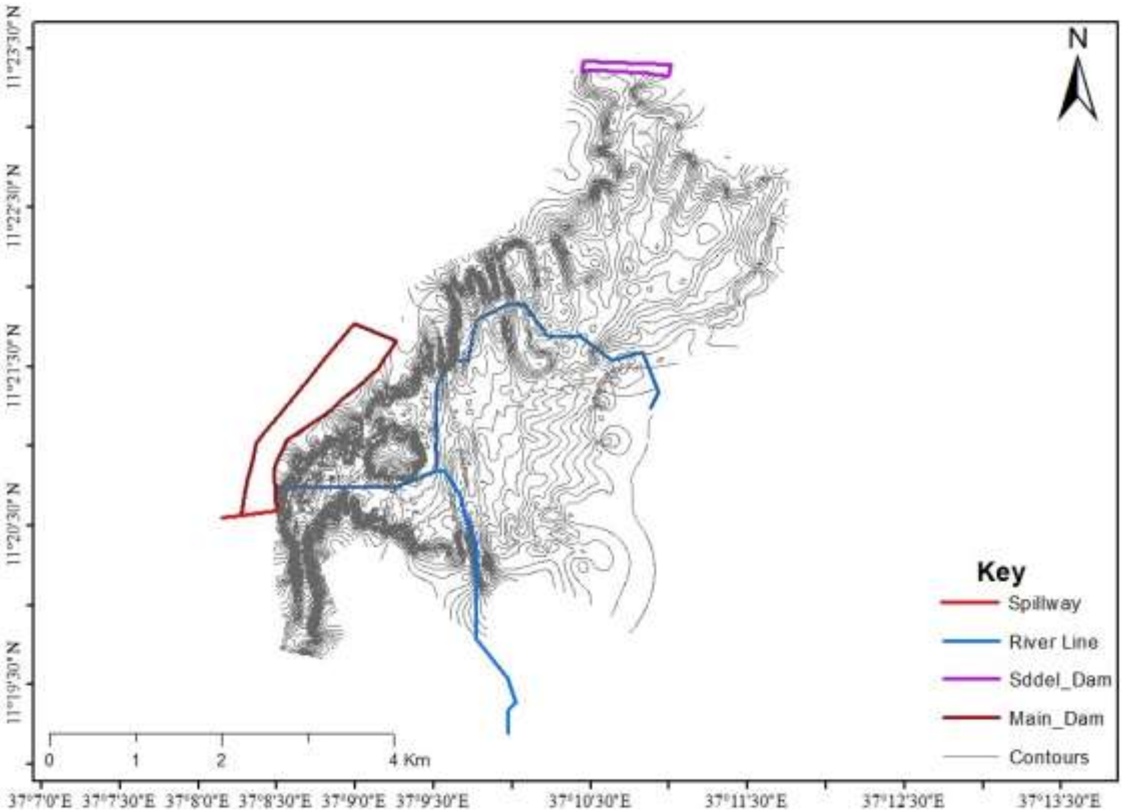
CHAPTER 7 APPENDIX

Appendix -A: some field materials used during Reservoir bathymetric survey.

Appendix- B :Table1:Measurment data quality and assurance for sonar instrument.

A NO.	B X-coordinate	C Y-coordinate	D Echo sounder	E Tape Measurement(m)	F E-D	G (E-D)2
1	300591	1259709	4.2	4.15	-0.05	0.0025
2	300896	1259841	4.3	4.31	0.01	1.00E-04
3	300932	1259853	3.9	3.41	-0.49	0.1401
4	300948	1259874	3.4	3.37	-0.03	0.0009
5	300940	1259888	2.6	2.58	-0.02	0.0004
6	300905	1259889	4.2	4.2	0	0
7	300871	1259886	4.6	4.62	0.02	0.0004
8	297657	1254269	3.2	3.22	0.02	0.0004
9	297657	1254253	2.7	2.7	0	0
10	297639	1254235	2.6	2.54	-0.06	0.0036
11	297624	1254218	2.65	2.66	0.01	0.0001
12	301802	1258688	1.3	1.23	-0.07	0.0049
13	301795	1258715	1.2	1.18	-0.02	0.0004
14	301777	1258810	1.4	1.3	-0.1	0.01
15	301763	1258857	2.2	2.3	0.1	0.01
17	301727	1258987	4.4	4.45	0.05	0.0025
18	301730	1259008	2.9	2.99	0.09	0.0081
19	301682	1259074	2	2.1	0.1	0.01
21	301653	1259090	1.8	1.7	-0.1	0.01
22	301581	1259133	1	1.2	0.2	0.04
23	299929	1254170	4.5	4.6	0.1	0.01
24	299961	1254157	3.9	3.8	-0.1	0.01
RMSE						0.13033

Appendix C



Original topography map of Koga reservoir (2006)

Appendix D

Table 2: K_factor for Koga watershed

ID	Area -ha	Soil _type	K_factor
0	5242	Eutric Vertisols	0.2
1	12272	Haplic Alisols	0.2
2	8762	Haplic Luvisols	0.2
3	7398	Haplic Nitosols	0.20
4	4572	Lithic Leptosols	0.15

Appendix E

***Table 3*- m value**

m-value	Slope (%)
0.5	>5
0.4	3-5
0.3	1-3
0.2	<1

So, in our case use m value slope >5 which is 0.5

Appendix F

Table 4 **Land covers factor evaluation method**

NO	Land Cover/Use Class	Source	C Value
1	Forest	(Hurin,1985)	0.01
2	Shrub land	(Hurin,1985)	0.02
3	Cultivated land	(Hurin,1985)	0.1
4	Grass land	(Hurin,1985)	0.05
5	Bare land	(Seleshietal.2012)	1

Appendix G

Table 5 Land management values

Land use Type	Slope %	P-Factor
Agriculture	0-5	0.1
	10-20	0.12
	20-30	0.14
	20-30	0.19
	30-50	0.25
	50-100	0.33
For all other land use	1	

Appendix H Table 6 Sediment volume b/n 2006 and 2020

Volume change 2006&2020				
FID	Shape *	Volume	S Area	Code
0	Polygon	1837729.24	6599290.551	-1
1	Polygon	405387.151	3035141.334	-1
2	Polygon	1667884.42	9586969.932	-1
3	Polygon	129740.528	1092498.509	1
4	Polygon	1969.81709	571627.7472	-1
5	Polygon	77621.3064	362860.8642	1
6	Polygon	39811.6544	204759.679	-1
7	Polygon	6071.50598	96386.55389	1
8	Polygon	54.6642613	2112.44216	-1
9	Polygon	9809.95196	56270.33866	1
10	Polygon	576.329122	11915.81359	1
11	Polygon	4060.89786	89925.96782	1
12	Polygon	413.225488	16212.52151	1
13	Polygon	678.273851	7579.478182	1
14	Polygon	217.408255	3786.008671	-1
15	Polygon	7885.67997	72502.02844	1
16	Polygon	50.8630973	5956.875931	-1
17	Polygon	6.6837136	2075.554201	1
18	Polygon	0.5893142	112.094662	1
19	Polygon	14.0557984	1912.92247	-1
20	Polygon	25.0276061	24978.58159	-1
21	Polygon	6.45790711	11621.29645	1
22	Polygon	1.326884	144.130132	1
23	Polygon	0.000648	0.312141	-1

24	Polygon	4.97.049546	6207.301614	-1
	Shape *	Volume	S Area	Code
25	Polygon	0.097051	3.755041	-1
26	Polygon	0.5266446	78.557367	-1
27	Polygon	1.1358113	243.624213	-1
28	Polygon	0	0.004403	0
29	Polygon	0.120709	13.740457	-1
	Sum	4190018.94		

Appendix I: Table 7 Sediment volume b/n 2006 and 2012

Volume change 2006&2012				
FID	Shape *	Volume	S Area	Code
0	Polygon	64693.63813	7748980.933	-1
1	Polygon	48027.8529	1516125.033	-1
2	Polygon	31672.99962	61798.19397	-1
3	Polygon	26180.08565	6873258.767	-1
4	Polygon	21412.46419	100604.8633	-1
5	Polygon	10725.59068	1055712.864	-1
6	Polygon	7685.750303	19805.21078	-1
7	Polygon	396.4736517	109257.1191	-1
8	Polygon	1146.24664	1007422.764	-1
9	Polygon	600.6103267	1570068.874	-1
10	Polygon	544.9456092	88150.09034	-1
11	Polygon	738.9203151	80110.4516	-1
12	Polygon	8549.453975	20568.75314	-1
13	Polygon	3373.157847	2944.584986	-1
14	Polygon	1757.390228	2215.064561	-1
15	Polygon	14142.92406	33766.03171	-1
16	Polygon	3666.831413	133253.8007	-1
17	Polygon	44137.11871	1178833.845	-1
18	Polygon	29.554585	606.489182	-1
19	Polygon	1024.480129	1380.062055	-1
20	Polygon	576.599478	2010.973757	-1
21	Polygon	6448.189163	22720.8561	-1
22	Polygon	992.212448	1576.335744	-1
23	Polygon	22912.34659	70063.92816	-1
24	Polygon	627.651085	2082.966748	-1
25	Polygon	3809.586891	4134.011799	-1

26	Polygon	472.985653	1858.373035	-1
27	Polygon	52.651526	1201.761558	-1
28	Polygon	24.733258	1662.600753	-1
29	Polygon	2285.750476	11646.20201	-1
30	Polygon	1103.78465	3765.040209	1
31	Polygon	416.989466	1548.447942	-1
32	Polygon	90.207924	542.534569	-1
33	Polygon	77.57617186	28243.54832	-1
34	Polygon	40.7702966	2187.079809	-1
35	Polygon	45.5828367	2561.314363	-1
36	Polygon	1256.740436	3993.06551	-1
37	Polygon	411.8681637	13555.76916	-1
38	Polygon	2635.100106	6814.560467	-1
39	Polygon	2169.867483	12816.38148	-1
40	Polygon	46.631747	905.968861	-1
41	Polygon	509.405743	7565.999283	-1
42	Polygon	90.3949867	11489.65201	-1
43	Polygon	28.818386	523.280724	-1
44	Polygon	28.5122418	1477.266727	-1
45	Polygon	26.0147273	6826.944874	-1
46	Polygon	15.296459	312.701568	-1
47	Polygon	45.140045	2401.952433	-1
48	Polygon	110.352138	2312.093076	-1
49	Polygon	263.889232	2631.02407	-1
50	Polygon	439.843974	12231.52964	-1
51	Polygon	89.633188	742.444236	1
52	Polygon	12.624105	442.693363	-1
53	Polygon	0.278658	18.25594	-1
54	Polygon	41.111066	1634.287587	-1
55	Polygon	16.625142	581.2144	-1
56	Polygon	1.448542	157.280166	-1

57	Polygon	0.000055	0.111792	1
58	Polygon	0.00203	1.348197	-1
59	Polygon	8.354578	149.006615	-1
60	Polygon	7.131052	95.66769	-1
61	Polygon	0.024866	13.002718	-1
62	Polygon	40.025138	207.779445	-1
63	Polygon	84.652727	583.355334	-1
64	Polygon	546.4247	5329.925528	-1
65	Polygon	40.78323	436.703824	-1
66	Polygon	0.05716	18.244293	-1
67	Polygon	117.738476	2485.92718	-1
Sum		339568.8975		

Appendix J; Table 8 Sediment volume b/n 2006 and 2012

Volume change 2006&2012				
FID	Shape *	Volume	S Area	Code
0	Polygon	64693.63813	7748980.933	-1
1	Polygon	48027.8529	1516125.033	-1
2	Polygon	31672.99962	61798.19397	-1
3	Polygon	26180.08565	6873258.767	-1
4	Polygon	21412.46419	100604.8633	-1
5	Polygon	10725.59068	1055712.864	-1
6	Polygon	7685.750303	19805.21078	-1
7	Polygon	396.4736517	109257.1191	-1
8	Polygon	1146.24664	1007422.764	-1
9	Polygon	600.6103267	1570068.874	-1
10	Polygon	544.9456092	88150.09034	-1
11	Polygon	738.9203151	80110.4516	-1
12	Polygon	8549.453975	20568.75314	-1
13	Polygon	3373.157847	2944.584986	-1
14	Polygon	1757.390228	2215.064561	-1
15	Polygon	14142.92406	33766.03171	-1
16	Polygon	3666.831413	133253.8007	-1
17	Polygon	44137.11871	1178833.845	-1
18	Polygon	29.554585	606.489182	-1
19	Polygon	1024.480129	1380.062055	-1
20	Polygon	576.599478	2010.973757	-1
21	Polygon	6448.189163	22720.8561	-1
22	Polygon	992.212448	1576.335744	-1
23	Polygon	22912.34659	70063.92816	-1
24	Polygon	627.651085	2082.966748	-1
25	Polygon	3809.586891	4134.011799	-1

26	Polygon	472.985653	1858.373035	-1
27	Polygon	52.651526	1201.761558	-1
28	Polygon	24.733258	1662.600753	-1
29	Polygon	2285.750476	11646.20201	-1
30	Polygon	1103.78465	3765.040209	1
31	Polygon	416.989466	1548.447942	-1
32	Polygon	90.207924	542.534569	-1
33	Polygon	77.57617186	28243.54832	-1
34	Polygon	40.7702966	2187.079809	-1
35	Polygon	45.5828367	2561.314363	-1
36	Polygon	1256.740436	3993.06551	-1
37	Polygon	411.8681637	13555.76916	-1
38	Polygon	2635.100106	6814.560467	-1
39	Polygon	2169.867483	12816.38148	-1
40	Polygon	46.631747	905.968861	-1
41	Polygon	509.405743	7565.999283	-1
42	Polygon	90.3949867	11489.65201	-1
43	Polygon	28.818386	523.280724	-1
44	Polygon	28.5122418	1477.266727	-1
45	Polygon	26.0147273	6826.944874	-1
46	Polygon	15.296459	312.701568	-1
47	Polygon	45.140045	2401.952433	-1
48	Polygon	110.352138	2312.093076	-1
49	Polygon	263.889232	2631.02407	-1
50	Polygon	439.843974	12231.52964	-1
51	Polygon	89.633188	742.444236	1
52	Polygon	12.624105	442.693363	-1
53	Polygon	0.278658	18.25594	-1
54	Polygon	41.111066	1634.287587	-1
55	Polygon	16.625142	581.2144	-1
56	Polygon	1.448542	157.280166	-1

57	Polygon	0.000055	0.111792	1
58	Polygon	0.00203	1.348197	-1
59	Polygon	8.354578	149.006615	-1
60	Polygon	7.131052	95.66769	-1
61	Polygon	0.024866	13.002718	-1
62	Polygon	40.025138	207.779445	-1
63	Polygon	84.652727	583.355334	-1
64	Polygon	546.4247	5329.925528	-1
65	Polygon	40.78323	436.703824	-1
66	Polygon	0.05716	18.244293	-1
67	Polygon	117.738476	2485.92718	-1
Sum		339568.8975		