2023-03

ASSESSMENT OF LAND USE LAND/ COVER AND CHANNEL MORPHOLOGY CHANGE IN THE UPPER REACHES OF ZORIT RIVER, EAST ESTIE DISTRICT, SOUTH GONDAR ADMINISTRATIVE ZONE, ETHIOPIA

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FACULTY OF CIVIL AND WATER RESOURCE ENGINEERING

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By

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Bahir-Dar, Ethiopia

March 2023

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By

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A Thesis submitted to the School of Research and Post Graduate Studies of Bahir Dar Institute of Technology Bahir Dar University in partial fulfillment of the requirements for the degree of Master of Science in Hydraulic Engine ering in the Faculty of Civil and Water Resources Engineering.

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March 2023

Declaration

This is to certify that the thesis entitled "Assessment of Land use/ Land cover and channel Morphology change in the upper reaches of Zorit River watershed**,**", submitted in partial fulfillment of the requirements for the degree of Master of Science in "**Hydraulic Engineering**" under Faculty of Civil and water Resources Engineering, Bahir Dar Institute of Technology, is a record of original work carried out by me and has never been submitted to this or any other institution to get any other degree or certificates. The assistance and help I received during the course of this investigation have been duly acknowledged.

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Approval of thesis for defense result

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ACKNOLODGMENT

First of all, I am extremely thankful to the creature of time and all things, God with His Mother. Secondly, I am humble to extend the deepest and heartfelt gratitude to Dr. Fasikaw Atanaw for his comment, support and respected suggestions. He shared with me his expensive and the innovative suggestions, a leading role which contributed to the successes of this thesis to adhere the future expectations in my life which I could likely to grasp.

I express my honest thanks to my families especially my wife, she is ever with me in every aspect of my life to reach this stage and mister Samuel Melese for his unlimittted wifi access.

I would also like to thanks Bahir Dar University, Institute of Technology for giving me a chance of my Hydraulic Engineering MSc. Degree program and the National Meteorologi cal Agency (NMA) (Bahir-Dar Branch) for their honest to give me climate data.

Finally, I am also thankful to all those who are not mentioned here but have helped and supported me in order to achieve this paper successfully

LIST OF ABBREVATIONS AND ACRONYMS

AMC	Antecedent Moisture Condition
AOI	Area of Interest
CI	Channel Index
CL	Channel Length
CN_W	Weighted Curve number
DEM	Digital Elevation Model
ENVI	Environment for Visualizing Images
GCPs	Ground Control Points
GIS	Geographic Information System
HSG	Hydrological soil group
LULCC	Land Use Land Cover Change
SCS	Soil Conservation Service
SI	Sinuosity Index
SRS	Satellite Remote Sensing
USDA	U.S Department of Agriculture
USGS	United States Geological Survey
VI	Valley Index
VL	Valley length

ABSTRACT

Zorit River is located in South West of Guna Mountain that is more of highly affected by runoff. The increase in the cultivation of the highland areas of Zorit river watershed increase degradation and erosion of upper parts of the river and also since there is different land use practice on the upper part of the watershed which causes not only degradation but also it causes shitting of river direction. The main objective of the study is assessing channel morphology changes in Zorit River by evaluating the impacts of land use land cover change (width, and channel length), identify the main cause of channel morphology change in the river reach and indicate the downstream plan form Zorit River. To see the change from the time series of the past river meanders and changes Google earth pro was used. To compare the plan forms of Zorit River Current River cross sections were taken at different intervals from Google earth and the past cross sections were developed from the old topographic map of the study area. For the data preparation Environment for Visualizing Images (ENVI 5.1) and Arc- GIS 10.8 were used. The result of land use /land cover classification indicated that the forest land, shrub land and bare land declined by 0.7 %, 7.4% and 1 % from 1990 to 2008, 2%,13.1% and 3.2% from 1990 to 2020 and 1.3%,5.7% and 2.2% from 2008 to 2020 while agricultural land and built-up area was increased by 8.8 % and 0.4 % from the year 1990 to 2008 ,17.9% and 0.4% from 1990 to 2020 and 9.1% and 0.1% from 2008 to 2020 respectively. The channel shifts its direction 136 m to the left bank (east ward direction) and to the right bank 145.27 m (westward direction). The Sinuosity index of Zorit River is 1.03, 1.02 and 1.03 in the year 1990, 2008, and 2020 between reach 1 and 2 respectively. This revealed that the three years of river center line shows straight river channel pattern downstream of the junction of the new river course to the past one. Hence, land use/ land cover change and the increase in sinuosity index could affect the channel morphology without manmade (hydraulic) structures like dams and bridge.

Key words: ‘Plan form change, GIS, watershed, Morphology, Zorit River’

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1. INTRODUCTION
1.1 Background

Land use/land cover change (LULCC) has been of great concern to many countries over the years. Some of the main reasons behind LULCC are rapid population growth, migration, and the conversion of rural to urban areas. LULC has a considerable impact on the land-atmosphere/climate interactions. Over the past two decades, numerous studies conducted in LULC have investigated various areas of the field of LULC. However, the assemblage of information is missing for some aspects(Nedd et al.,2021).

Zorit River is located in South West of Guna Mountain and which received high rainfall amount and also that facilitates a morphological change. It is the part of Guna catchment since the geographical location of the catchment is undulating from high to small mountains that facilitate the river meandering and river bank degradation. The increase in the cultivation of the highland areas of Zorit river watershed increase degradation and erosion of upper parts of the river and also since there is different land use practice on the upper part of the watershed which causes not only degradation but also it causes shitting of river direction.

The morphology of a river channel is a function of a number of different processes and environmental conditions,including the arrangement and erodibility of the bed and banks. The hydrology and geomorphology of most rivers has been fundamentally altered through a long history of human interventions including modification of river channels, floodplains, and wider changes in the landscape (Grabowski et al., 2014).

The most significant morphological property of a river is the meandering process, which is governed by hydraulic, hydrologic and topographic characteristics of the river (Laliberte et al., 2001). The morphology of natural rivers is determined by interaction of water, sediment, and riverbed conditions(Grabowski et al., 2014).besides, intensification of human activities further affects the evolution process of riverbed morphology(Grabow ski et al., 2014). The morphological studies, play an important role in planning, designi ng and maintaining river engineering structures(Manjushree et al., 2014).

1.1.1 Remote sensing and GIS

Remote sensing and Geographic Information System (GIS) techniques are common tools for time series analysis; however, in most cases satellite imagery or small-scale aerial photography is used. The increased resolution of large-scale aerial photos helps in identifying small features on the ground and is highly useful in the assessment of riparian areas(Laliberte et al., 2001). Satellite Remote Sensing (SRS) is being successfully used for various river morphological/engineering studies. The changes have been illustrated by comparing pre and post event satellite images for better understanding(Manjushree et al., 2014). Remote sensing satellites provide timely, accurate and reliable data on degraded lands at definite time intervals in a cost effective manner (Venkataratnam & Ravi Sankar, 1996). Remote Sensing Technology gives a method for obtaining regular, current data about environment for monitoring these kinds of changes(Seker et al., 2003).

1.1.2 Geographical information system (GIS)

The advancements in the field of computer technology, image processing, global position system and mathematical morphology have resulted in the development of Geographical Information System (, GIS) technology for storage, retrieval, management of spatial data (e.g., maps derived from remotely sensed data etc.), attribute data (cg. Soil properties, climatic parameters etc. and other related ancillary information more efficiently. GIS proved to be an effective tool in handling spatial data available at different scales, voluminous point data such as soil information, rainfall, temperature etc. (Venkataratnam & Ravi Sankar, 1996). There are direct and indirect methods for monitoring the river bank erosion. The direct method is taking measurements from the field in terms of linear rates of erosion, volumes of erosion and channel cross section where the indirect method applies multi temporal high-resolution satellite data, the latest river configuration, and shift in the river courses, formation of new channels can be mapped at different scales. Information derived from remote sensing can be used for other river morphological application studies like monitoring the existing flood control works and identification of vulnerable reaches, planning bank protection works, drainage improvement works (Manjusree et al., 2014).

1.2 Statement of the problem

Even though the Government is straggling to secure the land degradation on the upper part of the watershed still there is a problem of erosion and land degradation.

Because it is the common source of sediment for the grand Ethiopian renascence dam and still there is a problem of food security so, that increase in the cultivation of the high land areas that increases land clearance for agricultural practice. In addition to this an individual traditional diversion works for flood hazard protections causes of river bank migration and change in river direction at different parts of the river and that destroys the farmer's land which is their income generation. Since the geographical location on the watershed is undulating, the velocity of flow to the downstream of the watershed also increases. Spatially the traditional diversion practice leads to shifting of the river direction by making obstruction at the course of the river. There are no associated researches done in the study area and the present study attempts to show some of the problems and how to solve these problems.

. So, that this study indicated that the main cause of the river morphology changes and shifting of the river direction and what type of remedial measures are taking to alleviate the problems.

1.3 Objective

1.3.1 General objective

The main objective of the study is assessing of Land use land cover and channel morphology changes in Zorit watershed

1.3.2 Specific objective

- To assess effects of land use land cover change in view of channel characteristics
- To assess the changes in the downstream plan form (width, channel length) of Zorit River

1. 4 Research questions

When attempting to analyze the impacts of Zorit watershed on the downstream river morphology, there are fundamental questions that should be answered:

- How do these modifications occur? Does the river plan form change its course due to change in land use/cover or by other human land use activities like traditional flood protection mechanisms?

- What kind of changes would be anticipated, such as land use change, river shifts or deterioration, and by how much?

Finding the variables that affect the channel morphology and the characteristics of the river morphology that are likely to change is the first step in finding the answers to these two questions. What are the needs of the society to protect the distraction of resources?

1.5 Significance of the study

The unlimited agricultural practices and deforestation have a significant impact on changes in river plan form. As a result, the study was focused on the nature of river morphology and evaluates how river channel alterations would affect the human resource such as agricultural lands, improving community adaptability and identifying potential effectiveness of river morphology rehabilitation under the influence of manmade natural hazards preserving the environment. The Morphological Studies play an important role in knowing the nature of rivers which helps in planning, designing and maintaining of flood protection/ river training works and water resources projects. The morphological studies help in finding the vulnerable spots for bank erosion/deposition. To give early warning before the damage of the surrounding resources of the nearby rivers have been destroyed and to indicate the ways to protect river banks erosion.

1.6 Scope of the Study

The scope of the work of the study is spatially limited at Zorit watershed. The research study is enclosed to assess plan form changes of Zorit River, and identifying downstream lateral plan form changes in cross-section of Zorit River. To achieve such targets of the study field observations, collection of secondary data from the relevant organizations, and current River cross section data from Google were used. The Scope of the study of this research goes up to the extent of analyzing and detecting fluvial morphology changes of Zorit watershed starting from the most vulnerable portion of the river.

1.7 Structure of the Thesis

The first chapter explains an introduction made up of the problem statement, research questions, research objectives, general objective, and scope of the study, significance of the study and thesis structure.The literature review demonstrates the key elements that ela borate the plan form alterations, including, river course shifts, and investigations of river channels, techniques formeasuring plan form changes, measurements of sinuous meande ring,and anatomizing channels,surface morphometric measurements,cross section morph ology, related past studies, and the need for GIS and remote sensing. The third chapter in-cludes the study area location, accessibility, geography climate; a data requirement which also covers the materials and procedures employed.The fourth chapter explain the results and discussion of data analysis and current plan form attribute compare with the precedin g Landsat image output data.The final chapter which is chapter five includes overall conc lusions and recommendations.

2. LITERATURE REVIEW

2.1 Related studies for river morphology

Channel morphology changes with time is affected by water discharge and velocities; sed iment discharge and sediment characteristics; the composition of bed and bank materials apart from different geological controls such as rock type, soil type, faults. River morphol ogy describes the shapes of river channels and how they change over time(Uddin et al., 2 011).The hydrology and geomorphology of most rivers have been fundamentally alteredt hrough a long the history of human interferences, through a characterization of geomorph ologic change(Grabowski et al., 2014).The geomorphologic character of river reaches depends not only upon interactions and practices within the reach but also the upstream activities (and sometimes the downstream) in a catchment (Grabowski et al., 2014). The continuous change of river channels over time has been a major focus study in geomorphology various techniques, such as sediment logical, historical sources, plan metric resurvey, repeated cross-profiling, erosion pins and terrestrial photogrammetric, have been used to measure riverbank erosion, bank collapse, deposition, channel direction change and channel change. The variables that affect channel or river system, such as climate, geology, vegetation, valley dimensions, hydrology, channel morphology and sediment load, have different causal relationships one with another, depending upon the time scale of analysis which means spatial and temporal analysis (Asmare 2011).

2.2 Shifts in river plan form

A river is a dynamic system and tends to adjust its channel roughness, geometry, pattern and profile with time. When a river carries high sediment loads, it tends to deposit it wherever the slope is gentle. A river is a conveyor of water and sediment (Newson, 2002). Sediment is produced in spatially varied rates across the watershed and transported downstream by a spatially and temporally variable hydrograph (Gilliam, 2011).

An equilibrium condition means that the stream plan form, geometry, and slope reflect an approximate balance between the sediment load entering a reach of stream and the sediment load leaving the same reach over a period of decades(Lang bein & Leopold, 1966) in addition to the formation of multi-channels and development of meanders. An acceptable riparian zone includes a buffer strip of a minimum of 18 m from the stream on either side(Galeotti, 2022). The acceptable width of the riparian zone may also be variable depending on the size of the stream. Streams over 4 m in width may require larger riparian zones(Galeotti, 2022).

Human factors related to channel stability problems can often be considered a disruptions or disturbances to the "natural" balance between the available erosional force acting on the channel boundaries and the erosional resistance provided by those boundaries. Such disturbances can be imposed directly on the channel as in the case of dredging or channel straightening, or can be indirect as in the case of land clearing.

Researchers in fluvial geomorphology have noted that alluvial channels in different environments, destabilized by different natural and human-induced disturbances, pass through a sequence of channel forms with time(Galeotti, 2022),Simon & Rinaldi,2006). River bank erosion, deposit and lateral channel movement are important geomorphologic studies(Ibitoye, 2021).

2.3 Investigation of river channels

Any quantitative or qualitative approach to river channel analysis should be preceded by the topological classification of the plan form configuration of the river, as the type of channel is the criterion which determines the ensuing steps: the segmentation of rivers, the actual morphometric measurements and determining the plan form migration of river channels. The geomorphologic classification of channel types is relevant because it contributes to better understanding of the relationships between processes, forms and stability. The progresses made in classifying channel plan form shapes resulted in some changes in this regard compared to the earliest classifications((Kondolf et al., 2005).The extent of channel change that occurs for a given disturbance depends on the amount of work accomplished by the event (flood magnitude time duration(Buffington, 2012).

The sinuosity indexes: - The sinuosity of the channel within a given reach is described by the ratio between two lengths: the distance between the extremities of the reach measured along the axis of the main channel, and the length measured along the axis of the valley. Unlike the braiding index, which is applied in evenly distanced cross sections, sinuosity can be measured on reaches of varying lengths, according to the morphology of the channel. Cross section morphometric measurements on the bank full channel and floodplain are performed in sections perpendicular to the central axis of the floodplain and are equally distanced. The measurements for each time frame are made in the points of intersection of the respective cross sections with the river and its central axis, in accordance with the morphometric parameters considered. The measuring interval is determined according to the level of detail required and the size of the investigated river/reach. Natural channels are rarely perfectly linear and straight. While there are exceptions, and while boundary constraints may require a straight constructed channel, most natural channels exhibit at least some degree of sinuosity in their platform. It is also important to note that platform flexibility may be limited by riparian features, infrastructure, land use, or other restrictions on the right-of-way. These factors may preclude the use of meanders with the amplitudes suggested from the described analogy or hydraulic geometry methods(USDA, 2007).

The straight (R) type is extremely rare in nature. It depicts straight channels with relatively uniform widths, low sediment loads, low slope gradients and stable banks which are usually shaped in deposits with high contents of silt and clay. The sinuosity index (SI) ranges from 1 to 1.05.

The sinuous (S) type describes a channel with an SI ranging from 1.05 to 1.5 carrying a mixed solid load (suspended and dragged), which contains small bars positioned alternately in the context of a sinuous thawing, indicating the accumulation on the bank will be ensued by erosion due to the upstream migration of the bar.

The meandering (M) type describes a whole array of meandering channels (IS equal to or above 1.5) ranging between two extreme situations: a) channels with high sinuosity where the suspended solid load is prevalent, which have high dynamic stability and their typical evolution is towards meander cutoff, and b) less stable meandering channels, due to the mixed solid load with increasing dragged sediments content. The channel width is greater within the meanders. Processes such as meander migration and meander cutoff are characteristic for this subtype of channel. The channel meander length is simply the meander wavelength times the valley slope divided by the channel slope (USDA, 2007).

The sinuous type with alternating bars and the wandering (W) type are transitional from meandering to braided channels. The solid loads are carried by the channels in this class typically high, comprise mainly of sand, gravel and boulders. The channel width is relatively high in relation to the depth. Alluvial banks and bars commonly develop within the channel bed, which play an important role in localizing bank erosion.

The braided (AI) type is a category of channels commonly occurring in cases where the rivers have a significant dragged sediment load, braided channels enclosing rhomboidal bars, high slope gradients and highly unstable channel, which, in some cases, may lead to avulsion (sudden abandonment of the previous channel) (sinuosity index of >1.3).

The anastomosing (A) type includes channels comprising of branches divided by islands covered with vegetation, low slope gradients and cohesive banks, and are typically more stable due to the prevalence of suspended solid load (sinuosity index of >2).

2.4 Bank line migration

Bank line migration is a natural process associated with natural meandering channels. Meander loops tend to move downstream as river processes erode the outside of bends and deposit sediment on point bars. The ability to forecast adjustments in plan form is important to the planning and design of any project where highways or structures could be damaged. The rate of bank migration at a given site is a function of erosional forces and resisting forces. The variables affecting erosional forces include discharge, cross-sectional geometry, sediment load, bed roughness, bed forms and bars, and the geometry of the bend itself. The variables affecting resistance forces include bank geometry of the river, bank vegetation, pore water pressure, freezing and thawing, and wetting and drying. Due to the wide variability in significant variables, it is difficult to develop an algorithm that can reliably predict bank line migration rates (USDA, 2007).

2.5 Surface Morphometric Measurements

Whenever highly detailed cartographic materials in terms of the channel and floodplain morphology are available, the method of surface morphometric measurements can be applied in order to investigate the spatial and temporal behavior of several elements of interest. Depending on the nature of the investigation (i.e. the purpose), the data generated for each considered time frame can be used for: a) Characterizing the channel, the active discharge strip or the floodplain at a certain time (e.g. the percentage value of the elements of interest within the investigated area); b) Analyzing the spatial dynamics of the elements of interest (repositioning, narrowing, broadening), by overlaying /intersecting the polygons corresponding to different time frames (this type of investigation allows for prediction analyses of future trends in the spatial dynamics of the channel, such as narrowing/broadening, lateral migration, chute bar development, bar/island dynamics, changes in the riparian land cover); c) Analyzing the temporal dynamics of the elements of interest by statistical analysis of the variations in the surface values of the delineated elements (e.g. variations along the river, statistics on the variations of the mean and total values). The available historical maps have enabled to delineate the boundaries of the vegetation within the channel, as well as outside the channel (Wyzga 2023).

2.6 Cross section measurements of river channel

The morphometric variables subject to measurements are discussed below. These parameters are essential for the quantitative assessment of the platform dynamics of the channel. In the case of meandering channels, the active belt approximately equals the maximum amplitude of the meanders and includes both abandoned meanders and active ones. In braided channels, the active belt equals the width of the bank full channel, whereas in anatomizing rivers all the channels need to be taken into account in delimiting the active belt(Rădoane M., Perşoiu I., Cristea I., 2013).

2.7 Surface Morphometric Measurements

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b) Analyzing the spatial dynamics of the elements of interest (repositioning, narrowing, broadening), by overlaying /intersecting the polygons corresponding to different time frames (this type of investigation allows for prediction analyses of future trends in the spatial dynamics of the channel, such as narrowing/broadening, lateral migration, chute bar development, bar/island dynamics, changes in the riparian land cover); c) Analyzing the temporal dynamics of the elements of interest by statistical analysis of the variations in the surface values of the delineated elements (e.g. variations along the river, statistics on the variations of the mean and total values). The available historical maps have enabled to delineate the boundaries of the vegetation within the channel, as well as outside the channel (marginal vegetation, (Qiu 2022)

2.8 Trends of land-use and land cover change

Land use/cover (LULC) change is a dynamic and complex process that can be caused by many interacting processes ranging from various natural factors to socioeconomic dynamics. It exerts a strong influence on the structure, functions and dynamics of most landscapes. Monitoring and mapping of LULC dynamics are crucial as changes observed reflect the status of the environment and provide input parameters for optimum natural resources management and utilization and also LULC transitions that seems to be continu ed in the future due to eternal anthropogenic activities and natural factors(Yesuph & Dagnew, 2019). The complexities of land-use/cover change and propose a framework for a more general understanding of the issue and is driven by synergetic factor combinati ons of resource scarcity leading to an increase in the pressure of production on resources (Lambin et al., 2003). Land use and land cover change (LULCC) are the result of different interacting socio-economic and environmental causes and consequences that have been known since the beginning of agriculture(Hassen et al., 2021).The Ethiopian Land tenure system has shown drastic change from a tenant-landlord system to private ownership in the Imperial regime and public land ownership during the Dergue and EPRDF periods (Getahun, 2019). Land use and land cover (LULC) change through inappropriate agricultural practices and high human and livestock population pressure have led to severe land degradation in the Ethiopian highlands. This has led to further degradation such as biodiversity loss, deforestation, and soil erosion (Tesfaye et al., 2014). The effects of the land cover changes have impacted on the stream flow of the watershed by changing the magnitude of surface runoff and ground water flow (Geremew, 2013).

2.9 Land use and land cover change studies in Ethiopia

Land use/cover (LULC) change is a dynamic and complex process that can be caused by many interacting processes ranging from various natural factors to socioeconomic dynamics. It exerts a strong influence on the hydraulic structure, functions and dynamics of most landscapes Land use/cover (LULC) exerts a strong influence on the structure, functions and dynamics of most landscapes. Monitoring and mapping of LULC dynamics are crucial for the environment and provide input parameters in natural resources manage ment and utilization.(Yesuph & Dagnew,2019),(Gessesse & Bewket, 2014) explores the major drivers of Land use/Land cover (LULC) dynamics and the observed environment al degradation in the Mojo watershed central Ethiopia.

LULC changes are driven by a combination of proximate and underlying drivers such as economic, demographic, biophysical and institutional factors. The study intended to explore the implications and drivers of LULCC in the Ethiopian rift valley region (Hassen et al., 2021).

2.10 Remote sensing and GIS for river morphological studies

There are direct and indirect methods for monitoring the river bank erosion. The direct method is taking measurements from the field in terms of linear rates of erosion, volumes of erosion and channel cross section. The indirect method is by analyzing the archival sources that exist at various timescales with the sediment records. The archive sources can be conventional survey maps, aerial photos or satellite images. In the recent years, Satellite Remote Sensing (SRS) and GIS technology have been successfully proven itself as a valuable information generator for carrying out river morphological/engineering studies and creating geospatial database for analysis (Manjusree et al., 2014).Land use/ land cover (LU/LC) changes were determined in an urban area by using Geographical Information Systems (GISs) and remote sensing technology(Mallupattu & Sreenivasula Reddy, 2013)

Remote Sensing (RS) is defined as the science of obtaining information about an object, area, or phenomenon through the analysis of data acquiring by a device that is not contact with the object, area, or phenomenon under investigation (Bawah Idi, 2005). Remote sensing and Geographic Information System (GIS) techniques are common tools for time change analysis; however, in most cases satellite imagery or small-scale aerial photography is used. The increased resolution of large-scale aerial photos helps in identifying small features on the ground and is highly useful in the assessment of riparian areas (Laliberte et al., 2001).

With the increasing availability of big geospatial data (e.g., multi-spectral satellite imagery) and access to platforms that support multi-temporal analyses (e.g., cloud-based computing, Geographical Information Systems, GIS), the use of remotely sensed information for monitoring riverine hydro-morpho-biodynamic is growing (Boothroyd et al., 2021).

Severe land degradation occurred in northern highlands of Ethiopia due to its complex topography, rainfall, and various anthropogenic activities. Substantial soil erosion occurs from degraded lands and decreased vegetative covers. (Balabathina et al., 2019).There is continuous changes upon earth surface by a variety of natural and anthropological agent’s activities. These agents cut, carry, away and deposit the materials from land surface. Running water has higher capacity of erosion than the other geomorphologic agents (Aher et al., 2012).Remote sensing satellites provide timely, accurate and reliable data on degraded lands at definite time intervals in a cost effective manner (Venkataratnam & Ravi Sankar, 1996).

3. MATERIALS AND METHODES.

3.1 Description of the Study Area

3.1.1 Location

Zorit River is located in Guna Mountain sub-catchment Easting. Zorit River is located in Guna sub catchment Woreda district in Amhara Region with latitude 1273230.28 m Nort hing and longitude of 409455.14m Easting. It is far from 121.5 kilometers from Bahir Dar 66.5 km from Debere Tabore town, and 17.5km from Mekane-Eyesus Town in the southern direction. Zorit River is the primary source of water for drinking for animals in the watershed for the society and also sometimes serves drinking for the community during the dry season. Zorit River flows from Guna Mountain sub-micro watershed through a course of 19.2 km, with a number of tributaries along the way to join Yiba River and then to Abay River. However, having 19.2 km long the study began in the upper course of the river; roughly 4.5 km from where the river changes its direction and more human intervention were practiced. The total length of the watershed is 8.93 km from the remote area to the outlet where my study ends up. Since the source of drinking water is surface water so, Zorit River is the main source of drinking water for the livestock and sometimes for the dwellers.

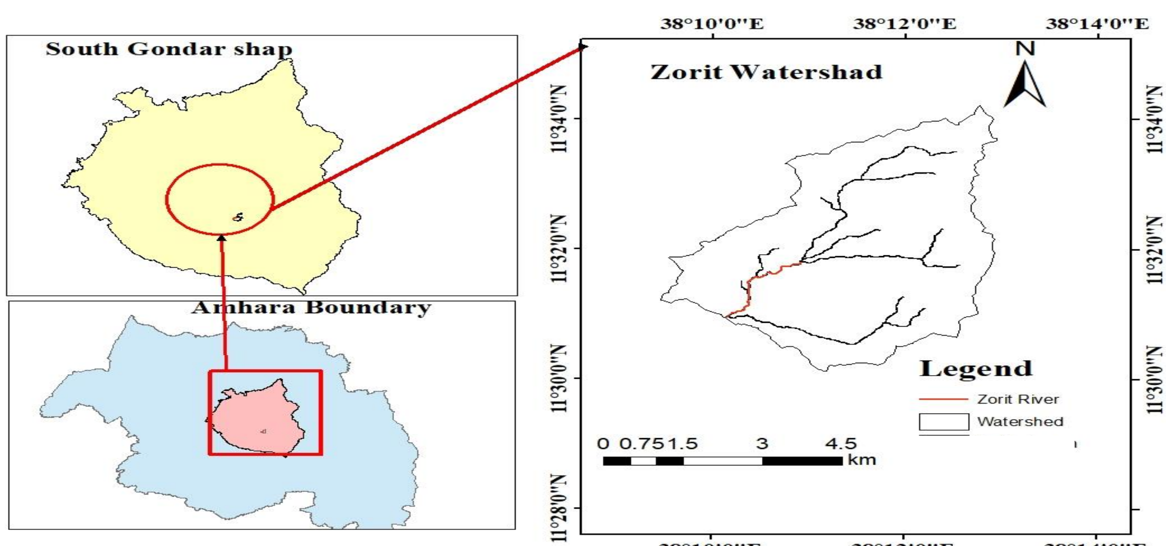

Figure3.1 Location of Map the Study area

3.1.2 Climate

According to the traditional climate classification of Ethiopia, most of the study area falls in Dega and wiona Dega zone (2429–3214 m altitude). The climate data was collected from Mekane-Eyesus station. Based on the 31 years 1990-2020 rainfall and temperature data of this station, the area receives peak rainfall in July and August with average 1540 mm of precipitation annually. The amount of rainfall varies from year to year and within months of the year in the study area and ranges from 759.8 to 1675.80 mm. The rainfall is highly seasonal with more than 80% of the rainfall occurring in the Kiremt season. With the mean annual temperature ranges between 15.6°C and 18.7°C.

The study area has an average annual maximum temperature of 33.80 °C and an average annual minimum temperature of 2.90°C in the years 2007, with a yearly temperature variation.The years 2004 and 2005 are the hottest years, with yearly annual high temperat ures of 32.80°C and 32.30°C and yearly average low and high temperatures of 22.60°Ca nd 23.0°C, respectively.

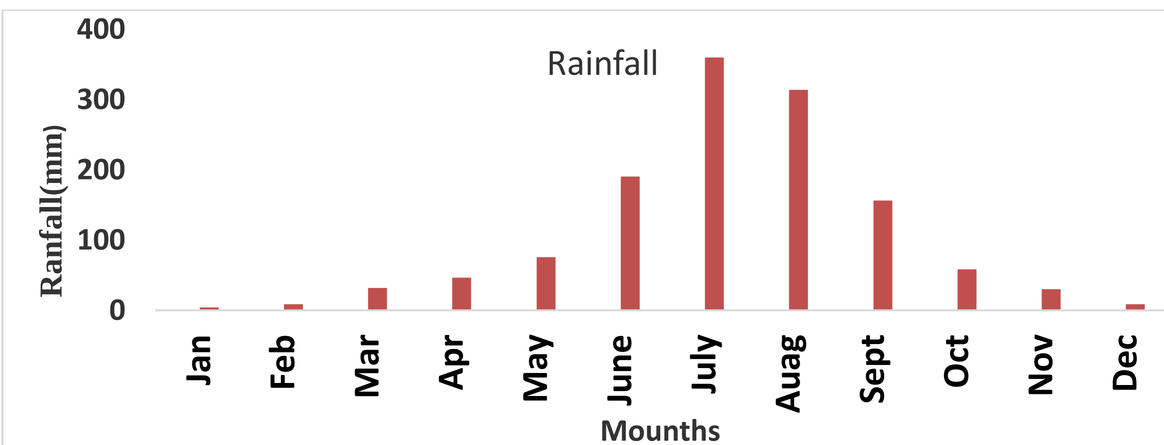

Figure 3.2 Mekane-Eyesus average monthly rainfalls

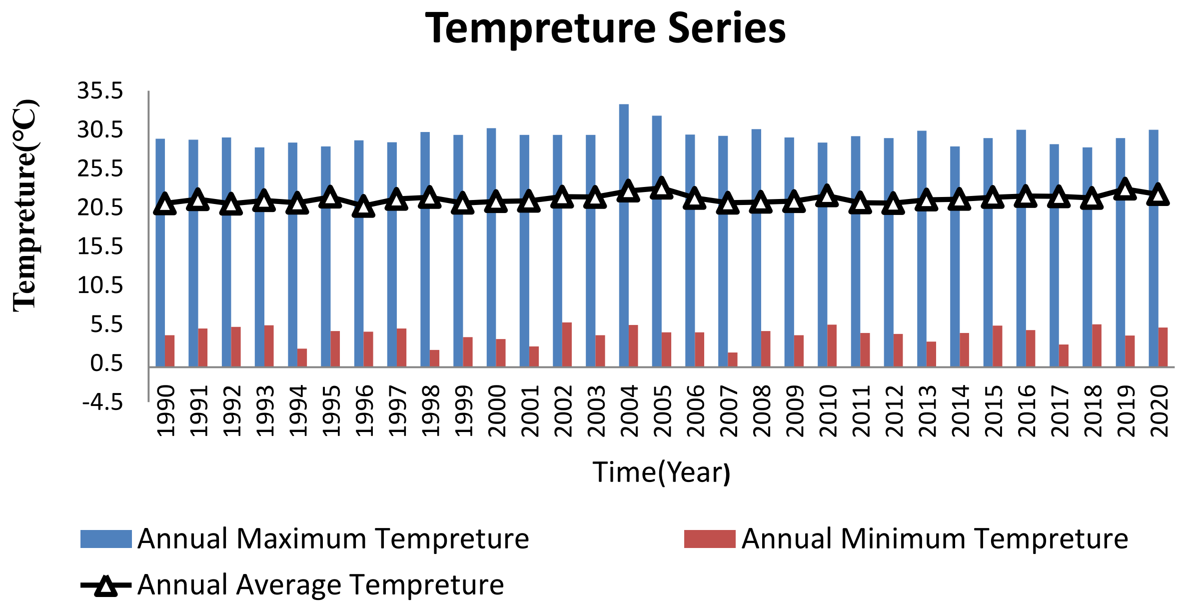

Figure 3.3 Temperature (℃) series of recorded in 31 years

3.1.5 Land use of the study area

Land use refers to the actual economic activity for which the land is used whereas land cover refers to the cover of the earth's surface. The land use of the study area can be categorized mainly as agricultural, forest, bush, built-up area and bare land. From land use/ land cover types have been identified as Such land use/ land cover types comprise 82 % cultivated land (agricultural area); 12.2% shrubs and bush land; 3.1% forest land; 1.6%, bare land and 1.1% built up area in the year 2020.The information contained in the land use map tells how the different resources were distributed on the surface under the study area. It can be seen from land use map later, from figure 1 to 3 that the watershed is mainly occupied by agricultural land.

3.1.6 Population characteristics the of district

Based on figures published by the Central Statistical Agency in 2005, this Woreda has an estimated total population of 403,956, of whom 199,325 are men and 204,631 are women; 16,014 or 3.96% of its population are urban dwellers, which is less than the Zone average of 8.3%. With an estimated area of 2,368.13 square kilometers, Este has an estimated population density of 170.6 people per square kilometer, which is greater than the Zone average of 169.21.This shows that the populations of the study area are high.

3.1.7 Geology, hydrogeology and soil

The geology of the watershed is basalt shield volcanoes' with minor trachyte. The soil in the Zorit watershed is the clay, clay to clay loam and sandy loam for which sandy loam soil is dominant texture which comprises 75.67% and covers 2125.23 ha and followed by sandy loam which comprises 24.13 % of the total area.

3.1.8 Topography

Since slope is the most important terrain characteristic and plays a vital role for soil erosion, it is very important to have an understanding of its spatial distribution in the study area. Therefore, the slope map of the study area was prepared from DEM processing using Arc GIS. The watershed is characterized by a slope ranging from 0-69.82%.

3.2 Methodology

Secondary data such as multi-temporal Landsat imageries of 30 m resolution obtaining from the United States Geological Survey (USGS) Agency (https: //www.usgs.Gov.) and Digital elevation models 12.5m resolution were used. The data which include Landsat images corresponding to the dry season of the year was collected (Figure 3.6). The dry season image data for Landsat imageries were downloaded from the library of the United State Geological Survey (USGS.gov).

3.2.1 General work flow for the methodology of LULCC and River center line mapping

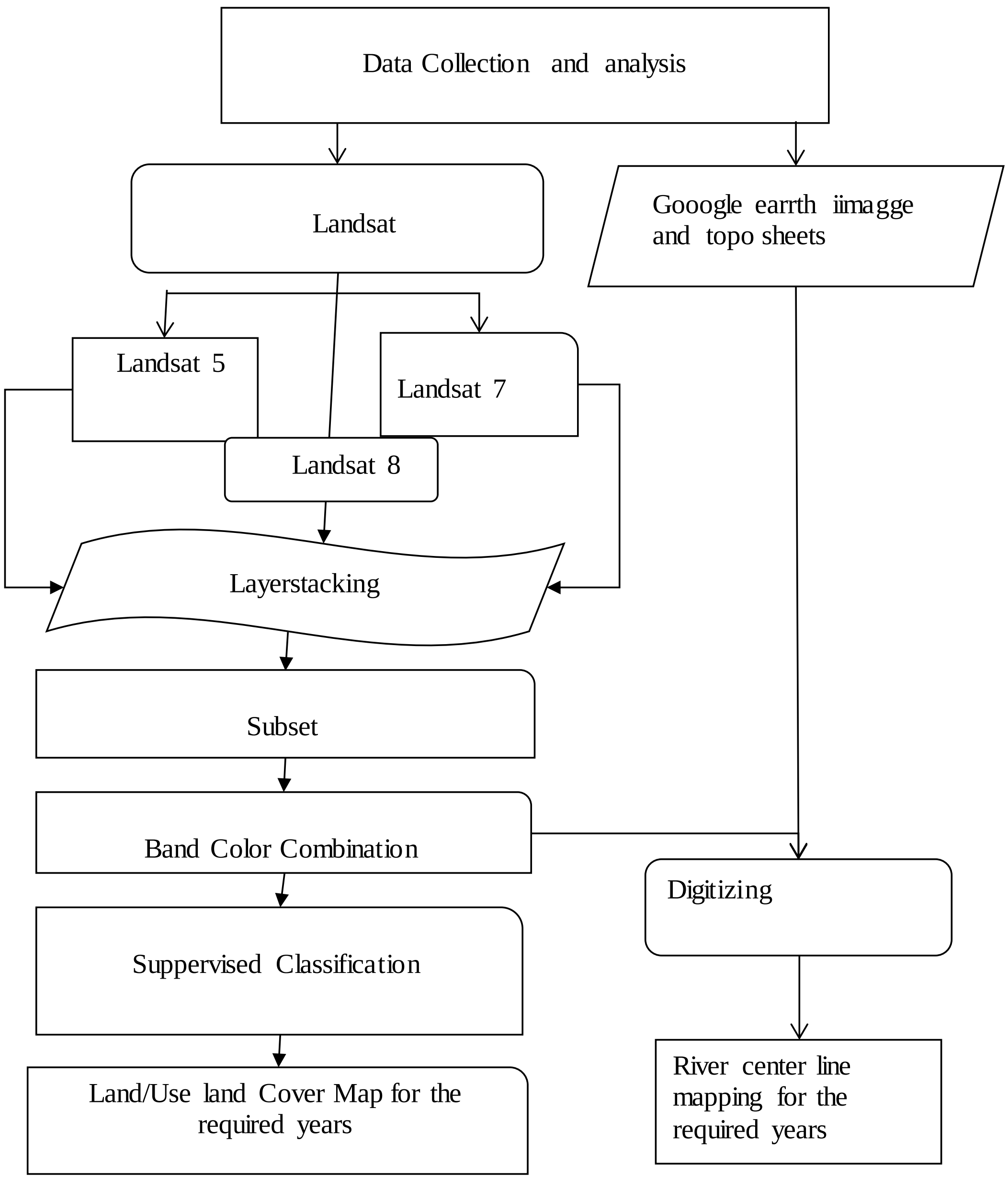

Figure 3.4 Steps followed for land use land cover map preparation

Table 3.1 Satellite image data for the study year

Satellite	Path/Row	Aquision Date
Landsat8	159/52	2/12/20220
Landsat 7	159/52	1/2/2008
Landsat 5	159/52	1/1/1990

3.3 Methods

Field equipment such as hand-held GPS with horizontal accuracy ±3m; Meter**,** and Camera were used in my field work. ARC GIS 10.8, Google earth pro and ENVI 5.1 imagine software was used for my study. In addition to office work and field surveys, it involved the use of GIS and RS analysis. These techniques are to identify land cover changes and their effects on the hydrological response to the river morphology. The following materials and software will also use in the study's implementation: Arc GIS, ENVI 5.1 and satellite images of the different years. The main data that require for my study are: - Assessing annual average surface runoff depth between 1990, 2008 and 2020 and estimating the hydrological response to land cover changes and projections were carry out in the watershed. Fieldwork included watershed visualization and well investigation of the area and collecting necessary data for helping me for my thesis which is the assessment of land use land cover and channel morphology change at the upper reaches of Zorit watershed. Land cover mapping and change detection analysis was performed by classifying cloud free Landsat images.

Table 3.2: Software used for data analysis

Software Name	Purpose
GIS 10.8	Preparation of land use maps river center line overlay
XLSTAT2015	Filling missing rainfall data
ENVI 5.1	Layer stacking and subset
Mendeley	Citation and References

In order to assess channel response to altered flow and sediment discharge, multiple analyses across a range of spatial and temporal scales and surveys of channel cross sections and longitudinal profiles were used. Clear methodology is crucial for the effectiveness of the study; not only from time and budget point of view, but also from the quality of the research result. Pre field work, and post field work phases were followed to attain the objectives of this study. The pre-field work phase of the study included the selection of suitable research methodology to carry out the study, searching literatures related to the topic from different sources, gathering the available data from different sources, collection of materials for field data. Data collected during field and pre-field work was processed during post field work.

3.3.1 Data requirement and sources

Data required for the river plan form alteration investigation are spatial in nature. Major parts of the collected data were; Land sat image, DEM, climate data and River cross section survey data. After collecting the required data, spatial analysis was made to prepare different raster and vector maps. Zorit River plan form change analysis was done from satellite images of 1990, 2008 and 2020. Digitizing and overlaying techniques in Arc GIS 10.8 environment were used. The years were selected in such a way that it is possible to capture the occurrence of major changes. Three periods were assessed through this change detection: between 1990 and 2008, the year 2008 and 2020 and 1990 and 2020.

Table 3.3 available data from different data source

SN	Types of data	Data type	Resolution(m)	year
1	DEM (Digital Elevation model)	Raster	12.5	2008
2	Landsat images	Raster	30	1990,2008 and2020
3	Rainfall Data	Raster	-	1990-2020
4	Max and Min Temperature	Raster	-	1990-2020

3.3.2 Data Analysis

The collected data were analyzed with the help of known computer software including:

- Microsoft excels: to calculate the runoff on the excel spreadsheet and prepare a comparison graph between the capacity of the existing drainage system and the proposed runoff as well as the comparison graph of the land use land cover.
- Google Earth: to visualize the study area and digitizing river shift behavior
- Arc GIS: to analyze the spatial data and delineate the Catchment area

3.3.3 Cross section and longitudinal profile surveys

For surveying works, Ground Control points (GCPs) is identified from the Google earth image and the corresponding points were found on the existing natural features. These points used as benchmarks for farther extraction of cross section points from satellite images and topo sheets. Cross section of the river was extracted in 2008 and 2020 Google earth image and 1989 topo sheet (from Amhara Region Land Bureau). For this study a total of twenty-four cross sections were conducted for a total length of 4.5km just below the main tributaries join and above the most problem exposed areas.

3.3.4 Digital elevation model

Topography is defined by a Digital Elevation Model (DEM), which describes a bare earth raster grid, which filters out vegetation and manmade features (Figure 3.4). It is frequentl y used and simplest form of digital representation of topography (elevation, slope, and as pect(Yarwood, 2020). Digital elevation model is one of the essential inputs required by Arc GIS to delineate the watershed. DEM is also used to analyze the drainage pattern of the watershed.

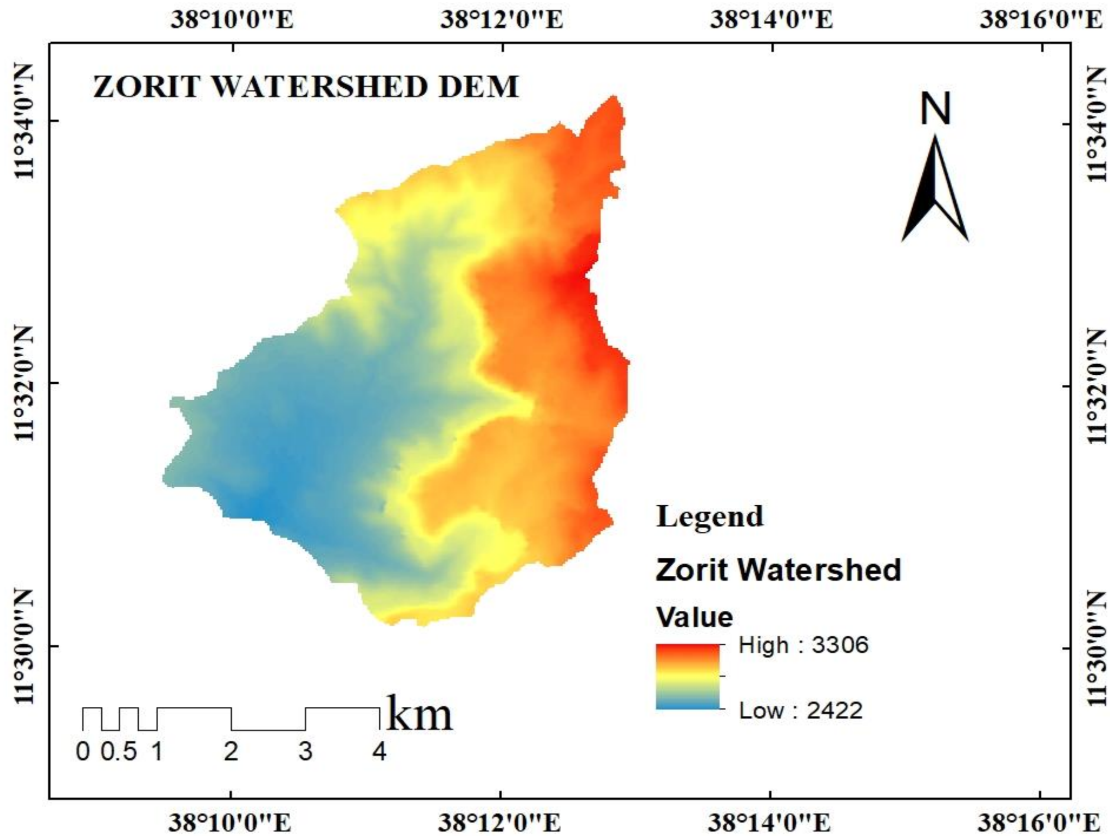

Figure 3.5 DEM of Zorit watersheds

General work flow for the methodology of LULCC and River center line mapping

3.3.5 Land cover and land use Assessment

3.3.5.1 Land cover descriptions

A total of five land cover/land use classes are may be considered by using the following definition.

1. Urban or built-up land

Built-up land includes areas that have developed intensely. These areas include cities, towns, villages, residential areas, transportation developments, power and facilities, industrial and commercial complexes and other built structures. Urban or Built-up Land is comprised of areas of intensive use with much of the land covered by structures (Gashawt 2017).

2. Agricultural land

Agricultural Land may be defined broadly as land used primarily for production of food and fiber. On high-altitude imagery, the chief indications of agricultural activity will be distinctive geometric field and road patterns on the landscape and the traces produced by livestock or mechanized equipment. However, pasture and other lands where such equipment is used infrequently may not show as well-defined shapes as other areas (Gashawt 2017)**.**

3. Bush and shrubs

Bush land comprises areas where the potential natural vegetation is predominantly grasses, grass like plants. These areas are generally unaltered, but may be seeded to encourage plant species growth. (Gashawt 2017)

4. Forest land

Forest Lands have a tree-crown areal density (crown closure percentage) of 10 percent or more, are stocked with trees capable of producing timber or other wood products, and exert an influence on the climate or water regime. Forest Land generally can be identified rather easily on high-altitude imagery, although the boundary between it and other categories of land may be difficult to delineate precisely (Gashawt 2017).

5. Bare land

Barren Land is land of limited ability to support the and in which less than one -third of the area has vegetation or other cover. In general, it is an area of thin soil, sand, or rocks. Vegetation, if present, is more widely spaced and scrubby than that in the Shrub and Brush category of Rangeland. When neither the former for the future use can be described the area is obviously in a state of land use transition, it is considered to be bare land (Gashawt 2017).

3.3.6 Land cover classification and accuracy assessment

The land cover classification was made by using ENVI 5.1 software. Because of the existence of field data of the study area the image classification may be classified using a supervised classification algorithm. The supervised classification involved the selection of a number of known training samples for each class throughout each image. Once these training samples were identified maximum likelihood supervised classification may take in ENVI 5.1 image analysis software (Approach, 2018).

Accuracy assessment was done to understand the representation of the classified images on the ground(Gashaw et al., 2017)

Among the various accuracy assessment mechanisms overall accuracy and kappa coefficient was done through the following formulas (You tube; https://www.google.com /search).

$$\text{Overall Accuracy} = \frac{\text{Total Number Of Correctly Classified Pixels (Diagonal)}}{\text{Total Number Of Refference Pixels}}$$

$$\text{Kappa Coefficient} = \frac{(\text{TS} * \text{TCS}) - \sum(\text{Column Total} * \text{Row Total})}{(\text{TS})^2 - \sum(\text{Column Total} * \text{Row Total})}$$

Where: - TS=Total Sample

TCS=Total Correctly classified Sample

3.3.7 Methods determining river plan form changes

Rivers can respond in a variety of ways to shifting inputs of water, sediment, and vegetation over the course of human interventions. Channel response may range from small-scale adjustment of channel characteristics (grain size, width) to large-scale alteration of reach morphology and plan form pattern. Several methods are currently used to investigate the spatial behavior of the channel during a given time frame or in successi ve time frames, by manually or automatically (using GIS applications) determining the morphometric parameters of the river. Below briefly present three of the methods used to investigate plan form changes. These are successive cross section measurements of the floodplain; measurements along the central axis of the channel (single channel or main drainage channel) and surface morphometric measurements. One of the most determining of river plan form changes is calculating sinuosity index in a river at different reaches with in a selected river or imaginary reach that can be easily quantified. Mueller's sinuosity indexes are briefly described(Ghosh & Mistri, 2012).

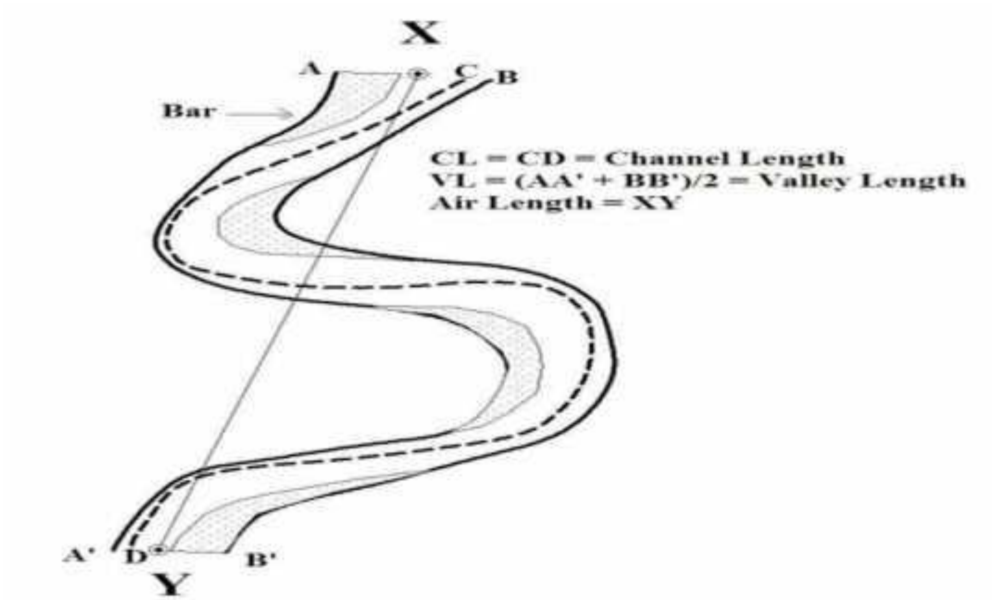

Figure 3.6 Parameters Taken for Muller's Sinuosity Index

Sinuosity index (SI) = $\frac{\text{Length of the water course}}{\text{Straight length of the river}} = \frac{CL}{VL}$................. (1)

CL= the length of the channel (thawing) in the stream under study

VL= the valley length along a stream, the length of a line which is everywhere midway between the base of the valley walls (in this case one half of total length of right and left banks of a reach)

Air= the shortest air distance between the source and mouth of the stream (in this case shortest air length of a reach)

CI (Channel Index) = $\frac{\text{CL}}{\text{Air}}$.. (2)

VI (Valley Index) = $\frac{\text{VL}}{\text{Air}}$

HSI (Hydraulic Sinuosity Index) = % equivalent of $\frac{(\text{CI}-\text{VI})}{(\text{CI}-1)}$............ (3)

TSI (Topographic Sinuosity Index) = % equivalent of $\frac{(\text{VI}-1}{(\text{CI}-1)}$........... (4)

SSI (Standard Sinuosity Index) = $\frac{\text{CI}}{\text{VI}}$.................................... (5)

Type	Sinuosity
Straight	< 1.05
Sinuous	>1.05
Meandering	>1.5
Braided	>1.3
Anastomosing	>2.0
Source: Morisawa, 1985, p.91	

3.3.8 Analysis of channel plan form change within the GIS

(a) Vector overlay within a GIS may be thought of as a similar procedure to a manual overlay. Any number of overlays may be undertaken and information on river center may be displayed in different color or line styles to differentiate between the dates that the vectors represent. The magnitude of plan form migration at any location can be directly measured so that a variety of analyses can be supported.

(b) Area Map Overlay combines any two raster maps for the same location but at different dates by employing a classification matrix. Each grid cell has a unique spatial location, so the same landscape element may be compared between different map dates and represented as reclassified map showing the locations of net erosion, deposition and no change between the two chosen dates

3.3.9 Processing of Remote Sensing data

3.3.9.1 Import and Visualization of Remote Sensing Data

ENVI software (the Environment for Visualizing Images) is a revolutionary image processing system. From its inception, ENVI was designed to address the numerous and specific needs of those who regularly use satellite and aircraft remote sensing data. ENVI provides comprehensive data visualization and analysis for images of any size and any type, all from within an innovative and user-friendly environment.

3.3.9.2 Selection of Area of Interest (AOI)

The sizes of the full scenes of the satellite remote sensing data will download if it is large in comparison to the study area then the study area will separate from the full image using a utility in the ENVI imagine software, namely, area of interest (AOI). A polygon will digitize which covers the entire study area and some portions surrounding it. The data corresponding to the AOI will save in a new shape file.

3.4 Hydrologic analysis

3.4.1 Filling missing data

Due to the absence of observer or instrumental failure rainfall data record occasionally may be incomplete. In such a case one can estimate the missing data by using the nearest station rainfall data. There are different approaches for estimating missing rainfall data varying with and based on the effect of distance between the rainfall stations and the variation of rainfall amount recorded on the stations. Even though there are different methods of filling missing data of the rainfall in this study XLSTA2015 Software is compatible with Microsoft excel and automatically filled the missing rainfall data.

3.4.2 Catchment area

A catchment is a basin shaped area of land, bounded by natural features such as hills or mountains from which surface and sub-surface water flows into streams, rivers. In general, the catchment area can be determined from the DEM data of the study area. However, for large catchment areas, it is necessary to divide the area into sub-catchment areas to account for major land use changes.

3.4.3 Soil conservation services (SCS) method

This method is developed by the U. S. Soil Conservation Service for calculating rates of runoff and requires the same basic data as the Rational Method: catchment area, a runoff factor, time of concentration, and rainfall. The SCS approach, however, is more sophistic ated in that it considers also the time distribution of the rainfall, the initial rainfall losses to interception and depression storage, and an infiltration rate that decreases during the course of a storm. With the SCS method, the direct runoff can be calculated for any storm, either real or fabricated, by subtracting infiltration and other losses from the rainfall to obtain the precipitation excess. It is therefore, potentially more accurate than the rational method and is applicable when the catchment area is larger than 50 hectares (Bekele & Sahadeva, 2018).

3.4.4 Curve numbers

In hydrograph applications, runoff is often referred to as rainfall excess or effective rainfall and defined as the amount by which rainfall exceeds the capability of the land to be infiltrate or otherwise retain the rain water.

The principal physical watershed characteristics affecting the relationship between rainfall and runoff rates are: - land use, land treatment, soil types, and slope. Land use is the watershed cover, and it includes both agricultural and nonagricultural uses. Items such as type of vegetation, water surfaces, roads, roofs, etc. are all part of the land use. Land treatment applies mainly to agricultural land use, and it includes mechanical practices such as contouring or terracing and management practices such as rotation of crops. The SCS uses a combination of soil conditions and land use (ground cover) to assign a runoff factor to an area. These runoff factors, called runoff curve numbers (CN), indicate the runoff potential of an area when the soil is not frozen.

The higher the CN, the higher is the runoff potential. Soil properties influence the relationship between rainfall and runoff by affecting the rate of infiltration.

The SCS has divided soils into four hydrologic soil groups based on infiltration rates (Groups A, B, C and D). Soil type A has the highest infiltration and soil type D has the least amount of infiltration. If heavy equipment can be expected to compact the soil during construction or if grading will mix the surface and subsurface soils, appropriate changes should be made in the soil group selected. The SCS CN method (SCS 1985) is one of the most popular methods for computing the volume of surface runoff in catchments for a given rainfall event. This approach involves the use of a simple empirical formula and readily available tables and curves. Also, runoff curve numbers vary with the antecedent soil moisture conditions, defined as the amount of rainfall occurring in a selected period preceding a given storm. In general, the greater the antecedent moisture, the more direct runoff from a given storm (Shaheed & Almasri, 2010).

The weighted curve number (CN_W) is estimated by using the formula

$$\mathrm{CN_{WII}} = \frac{\sum \mathrm{A_i} * \mathrm{CN_i}}{\sum \mathrm{A_T}} \qquad (6)$$

Where: -CN_i=Curve number from 1 to 100

$A_i = Area\ with\ curve\ number\ C_i$

A_T= The total area of the sub-watershed

$$CN_{WI} = \frac{CN_{WII}}{2.281-0.01281CN_{WII}} \ldots\ldots (7)$$

$$CN_{WIII} = \frac{CN_{WII}}{0.427-0.00573CN_{WII}} \ldots\ldots (8)$$

Where, CN_{WI}=Weighted curve number one

CN_{WII} =Weighted curve number two

CN_{WIII}= Weighted curve number three

The calculated weighted curve number is used for the calculation of recharge capacity of study area.

3.4.5 Rainfall-runoff Relationship

A relationship between accumulated rainfall and accumulated runoff will derived from SCS from experimental plots for numerous soils and vegetative cover conditions. Data for land treatment measures, such as contouring and terracing. The equation will develop mainly for small watersheds for which only daily rainfall and watershed data are ordinarily available. It will develop from recorded storm data that included the total amount of rainfall in a calendar day but not its distribution with respect to time.

The SCS runoff equation is therefore a method of estimating direct runoff from 24-hour or 1-day storm rainfall. The curve number can be determined from empirical information. The SCS has developed standard tables of curve number values as functions of catchment land use/cover conditions and HSG.

The basic rainfall-runoff relationship in the SCS methodology is equated as**:**

$$Q = \frac{(P-I_a)^2}{(P-I_a)+S} \text{------} (9)$$

For P>0.2S

Q =0 for $P \leq 0.2S$………………………………… (10)

Where:-

Q = accumulated direct runoff, mm

P = accumulated rainfall, mm

I_a = The water losses before surface runoff begins are termed as initial abstraction. Water retained in surface depressions, infiltration and intercepted by vegetation are included in initial abstraction), mm

S = potential maximum retention after runoff begins, mm

S is a site index defined as the maximum possible difference between P and Q as P⇒∞, P-I_a is called "effective rainfall". It is related to the soil and cover conditions of the catchment area through the curve numbers.

$$S = \frac{25400}{CN} - 254 \quad (11)$$

Where:

S= potential maximum retention, mm

CN = SCS runoff curve number

The relationship between I_a and S will found to be;

$$I_a = 0.2S \quad (12)$$

The initial abstraction consists of interception, infiltration and surface storage, all of which occur before runoff begins.

4. RESULTS AND DISCUSSION

4.1 Land use land covers classification and accuracy assessment

.For first LULC map (1990) 77 sample pixels were taken for the determination land use / land cover accuracy assessment. For perfect classification the land cover would result if all 77 sample pixels assigned to a particular land cover were found to actually have the land cover they were assigned. But the number of sample pixels misclassified is display ed in each matrix along with the number of accurately classified sample pixels for each year of classified imagery that was systematically studied.

Table 4.1 1990 Classification error matrix

	Cclassification						
	Built Up	Agricultural	Forest	Shrub	Bare	Total	User Accuracy
Built Up Area	15	4	0	0	0	19	79
Agricultural Land	4	23	3	0	0	31	74
Forest Lanad	0	0	6	2	0	8	75
Shrub Land	0	2	3	14	0	19	74
Bare Land	1	2	0	0	5	8	63
Total	20	31	12	16	5	85	
Producer Accuracy	75	74	50	88	100	Overall Accuracy	75

The error matrix for 1990 indicates the built up area was accurately classified in that year of imagery followed by, forest land, agricultural land, shrub land and bare land respectively. Some areas covered by built up area were mistaken for agricultural land. The area was also covered by shrub land also commonly mistaken for forest land and agricultural land was mistaken for shrub land.

The confusion between built up and agricultural land, shrub land and forest land were an incomprehensible since these land covers share similar spectral characteristics for the year 1990.

Table 4.2 2008 Classification error matrix

	Cclassification						
	Built Up	Agricultural	Forest	Shrub	Bare	Total	User Accuracy
Built Up Area	12	3	0	1	0	16	75
Agricultural Land	3	30	0	5	0	37	81
Forest Lanad	0	1	7	2	0	10	70
Shrub Land	0	0	5	15	0	20	75
Bare Land	1	0	1	0	8	10	80
Total	16	34	13	23	8	93	
Producer Accuracy	75	88	54	65	100	Overall Accuracy	77

The error matrix for 2008 indicates that agricultural land was most often accurately classified in that year of imagery followed by bare land, shrub land, built up, and forest land. Some areas covered by built up area were mistaken for agricultural land. The area was also covered by shrub land also commonly mistaken for forest land and agricultural land was mistaken for shrub land.

The confusion between shrub land and agricultural land, shrub land and forest were understandable since these land covers share similar spectral characteristics.

Table 4.3 2020 Classification error matrix

		Cclassification						
		Built Up	Agricultural	Forest	Shrub	Bare	Total	User Accuracy
	Built Up Area	20	2	1	2	1	25	80
Reference	Agricultural Land	4	38	2	1	2	45	84
	Forest Lanad	0	0	5	1	0	6	83
	Shrub Land	0	1	2	11	0	13	85
	Bare Land	1	0	0	0	6	7	86
	Total	25	41	10	15	9	93	
	Producer Accuracy	80	93	50	73	67	Overall Accuracy	83

The 2020 classification error matrix shown in table 4.3 above reveals that bare land was accurately classified, followed by shrub land, agricultural land, and forest and built up area. In the 2020 classification, agricultural land was commonly mistaken for built up area, agricultural land and shrub land and built up area were sometimes mistaken as bare land and forest land. The confusion between forest and shrub land, agricultural land and built-up area are understandable because these land covers share similar spectral characteristics.

The overall efficiency of classification is 75% in the year 1990, 77% in the year 2008 and 83% in the year 2020, whereas the kappa coefficient is 0.72, 0.75 and 0.83 in the year 1990, 2008 and 2020 respectively.

4.2 Land use land cover map of 1990

The Land cover map was developed for the year 1990, this indicates that 64.1% agricultural land, 25.2% shrub land, 5.2% forest land,0.6% built up area and 4.8% bare land. The distribution in the Figure 4.1 shows that most of the watershed is covered by agricultural land.

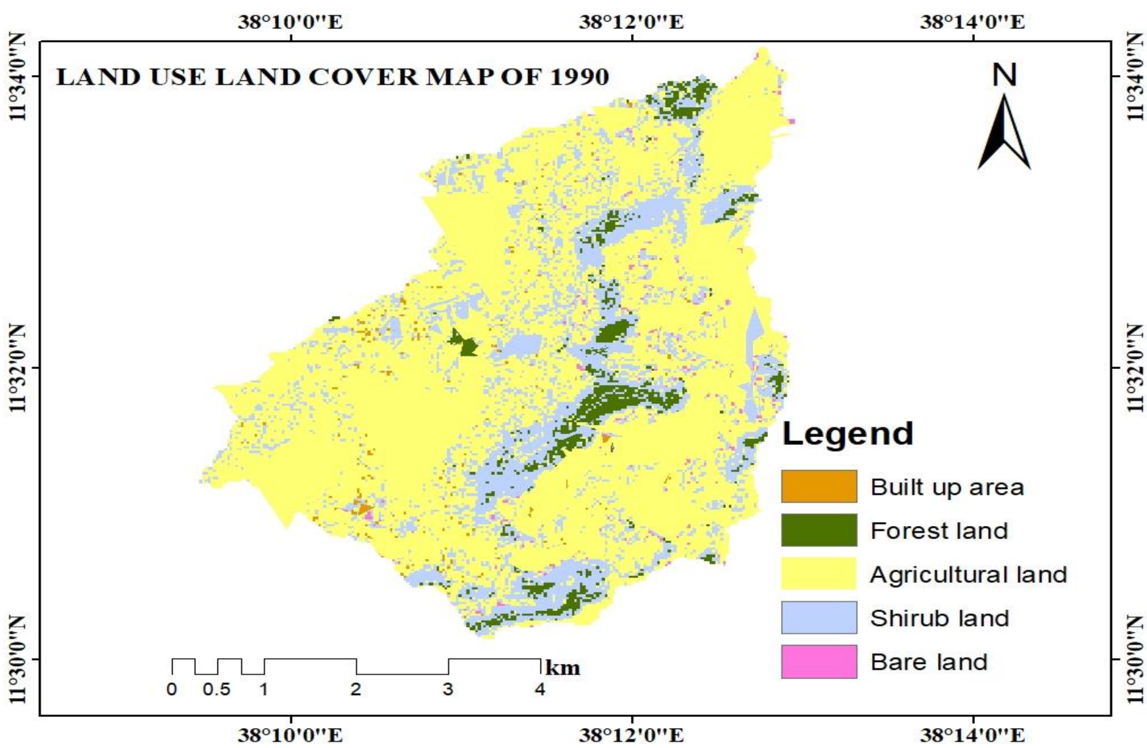

Figure 4.1 Land Use Land Cover Map of 1990

4.3 Land use land cover map of 2008

Land cover map was developed for the year 2008 and this shows that agricultural land, comprises of 72.93%; shrub land;17.8% forest land 4.46%, built up 0.97% and bare land 3.79%. The distribution in the Figure 4.3 shows that most of the watershed is covered by bush and shrub land.

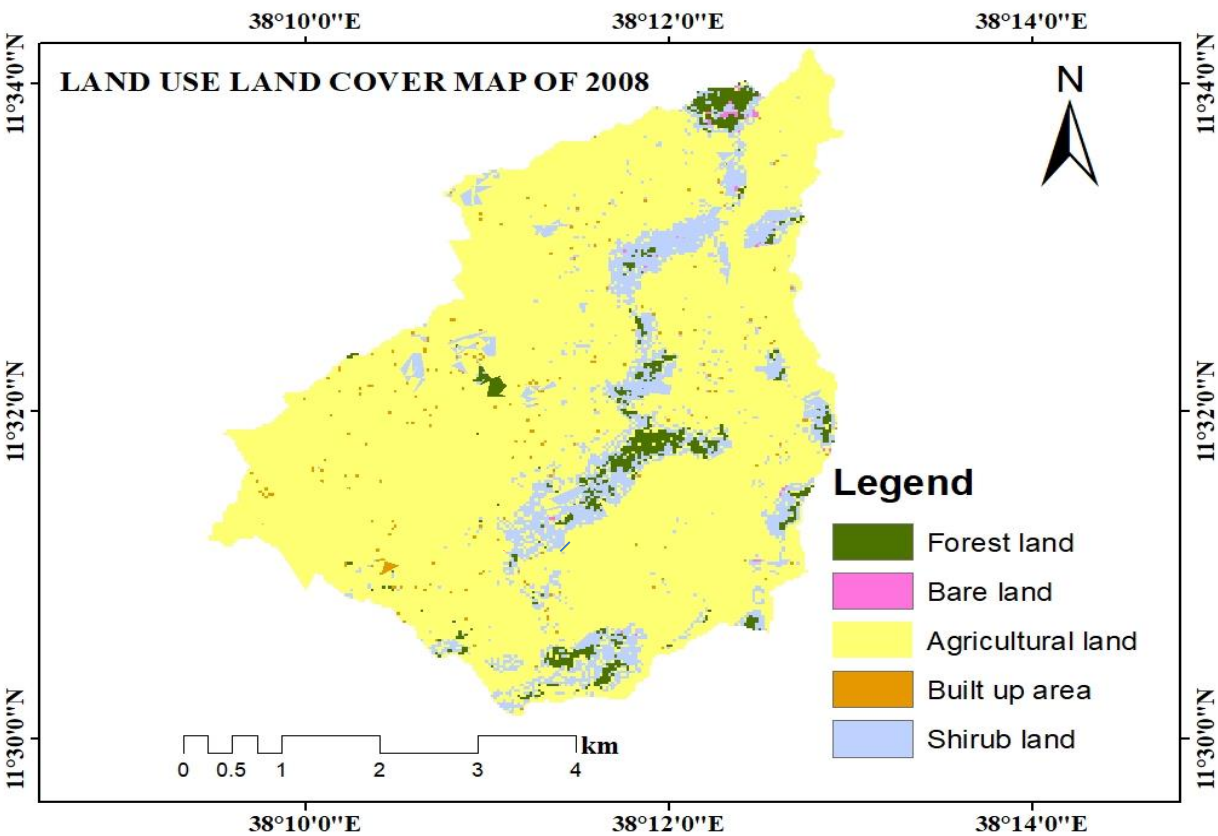

Figure 4.2 Land Use Land Cover Map of 2008

4.4 Land use land cover map of 2020

A land cover map was created for the year 2020, and it reveals that there are 82% of agricultural lands, 12.2% of shrub lands, 3.1% of forests, 1.1% of built-up areas, and 1.6% of bare ground. The distribution in Figure 4.3 demonstrates that agricultural land makes up the majority of the watershed.

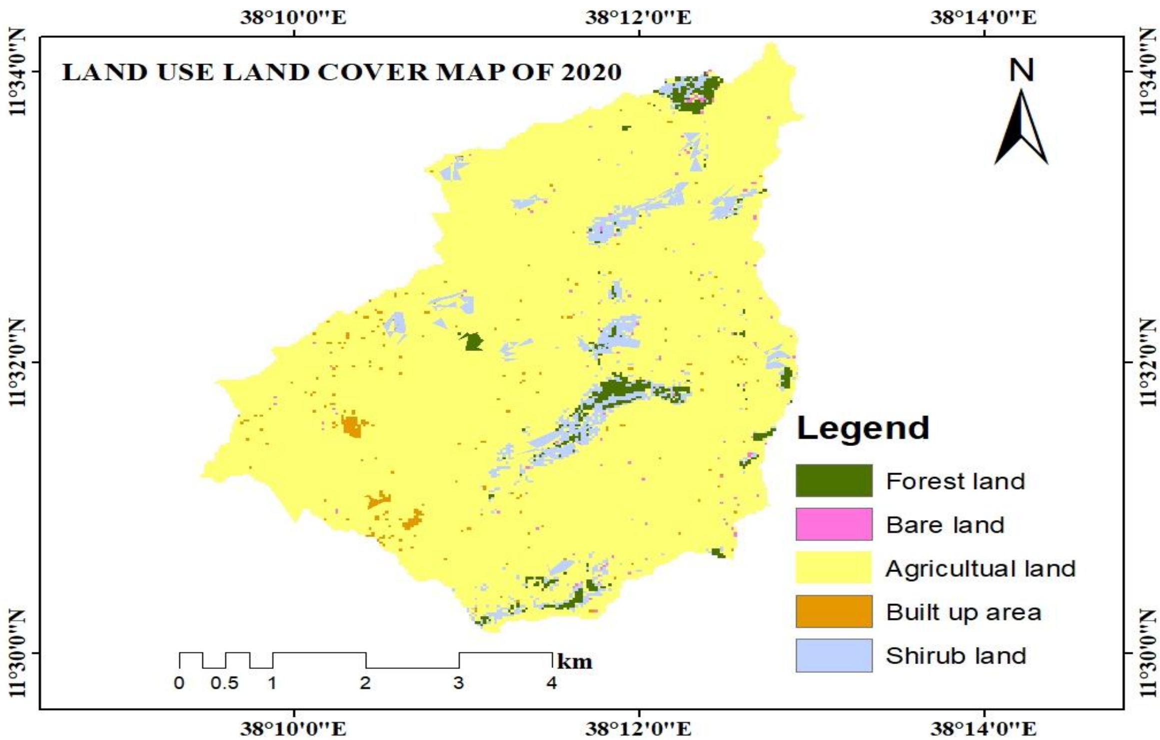

Figure 4.3 Land Use Land Cover Map of 2020

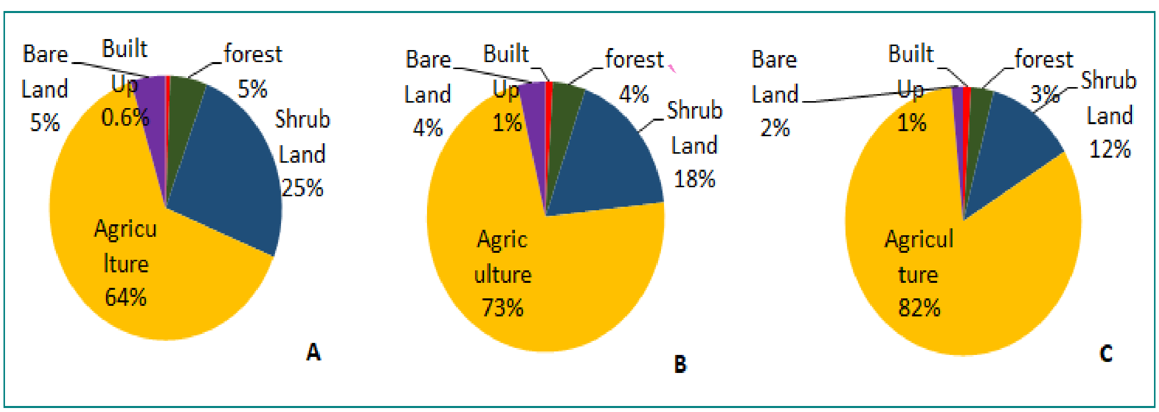

Figure 4.4 pie chart (A) land use /cover for 1990(B) land use /cover for 2008 and (C) Land use /cover for 2020

4.5 Areal and percentage change from 1990 to 2020

Table 4.4 Area and Percentage change in land use/ land cover from 1990 -2020

Land use	1990 area(ha)	Area (%)	2008 area(ha)	Area (%)	2020 area(ha)	Area (%)	%change (1990-2008)	(1990-2020)	(2008-2020)
Built Up	17.43	0.6	27.36	1.0	29.75	1.1	0.4	0.4	0.1
forest	145.00	5.2	125.40	4.5	87.84	3.1	-0.7	-2.0	-1.3
Shrub	709.00	25.2	501.05	17.8	341.53	12.2	-7.4	-13.1	-5.7
Agriculture	1801.61	64.1	2048.30	72.9	2304.22	82.0	8.8	17.9	9.1
Bare Land	135.50	4.8	106.43	3.8	45.20	1.6	-1.0	-3.2	-2.2

The total change is summarized as in the Table 4.4 above and Figure 4.7 below.

* The minus sign indicates that the decline in land use land cover from one land use type to another land use type

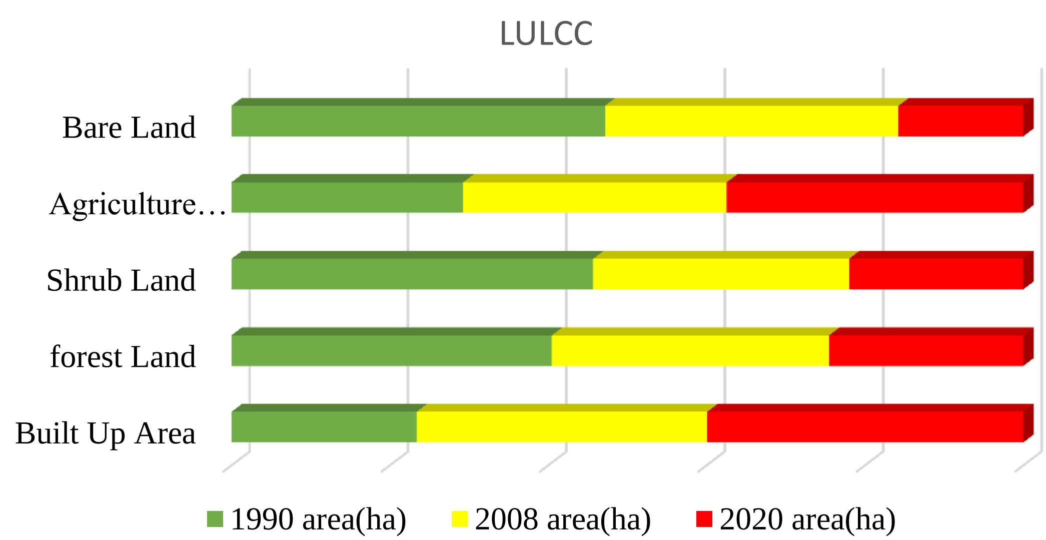

Figure 4.5 Areas and Percent Coverage of Land Use Land Cover Change

4.6 Land use/land cover changes from 1990 to 2020

Results of land use and land cover analysis of the watershed are presented in Table 4.1 to 4.3 as five land use cover types were identified namely, Agricultural land, Shrub land, Forest land, Built Up area and bare land.

From the 1990 land use and land cover map the areal and percentage coverage of forest was accounted for 145.00 ha (5.8 %) from the total study area. The bare land, agricultural land, shrub land and built up area covered about 72.5ha (2.9%), 1801.61ha (61.4%), 556. 00ha (22.3%) and 17.43 ha (0.6 %) respectively. In 2008 agricultural land accounted approximately 2048.30 (72.9%) ,built-up area, bare land, forest land and shrub land took the share of 27.36 ha (1.0 %,) 53.50ha (2.1 %), 93.15(3.7%) and 301.05(12.1%) respectively and at 2020 the forest were accounted about 60.0 ha (2.4%) of the total area of shrub land accounted about 197.0 ha (7.9 %) and the agricultural land, bare land and built-up area accounted around 2304.22 (82%), 34.3 ha (1.4%) and 45.2(1.6%) ha 29.75 (1.1%) respectively. Hence, it was indicated that the forest land, shrub land and bare land declined with the percent of 0.7 %, 7.4% and 1 % from 1990 to 2008, 2%,13.1% ;3.2% from 1990 to 2020 ;1.3%,5.7% and 2.2% from 2008 to 2020 while agricultural land and built-up area was increased by 8.8 % and 0.4 % from the year 1990 to 2008 ;17.9% ;0.4% from 1990 to 2020 and 9.1% and 0.1% from 2008 to 2020 respectively (Table 4.4 Figure 4.5). Agricultural land was the dominant land use and covers classification in the study area according to the above-mentioned consecutive decadal land use and cover classification and due of the growth in food production. Therefore, many people depend on the selling of firewood, while some others use forest resources to support their income generation. Locals claim that natural vegetation cover has been decreasing over the past 31 years, mostly due to the growth of agricultural land and there are still factors such as wood cutting for household energy, charcoal production (fuel wood), building, wood sale s, furniture making, and that contributed to the degradation of forests and shrub land. According to (Gashaw et al., 2017), population growth and a decline in land productivity are the main drivers of land use and land cover change.

4.7 Change detection between 1990 and 2020

Change detection involves quantitatively identifying the differences between multi temporal data sets (Francisco et al., 2019). In order to demonstrate how each LULC class changed over the course of 31 years, to show the change in from one land use to another land use was done by a change detection analysis.

Table 4.5 Land Use Land Cover Change Detection

SN	Class Name	Area change 1990-2008	Area change 2008-2020	Area change 1990-2020	Remark
1	forest land - bare land	29.13	24.01	14.56	
2	forest land - agricultural	13.41	1.17	0.31	
3	forest land - built up area	5.01	0.95	0.34	
4	forest land - shrub land	97.45	99.27	72.63	
5	bare land - forest land	0.45	0.87	1.35	
6	bare land - bare land	65.28	35.85	13.14	No Change
7	bare land - agricultural	62.09	67.26	6.65	
8	bare land - shrub land	7.68	2.45	24.06	
9	agricultural land-forest	0.13	1.21	0.21	
10	agricultural land - bare	0.13	0.25	0.23	
11	Agricultural - agricultural	1800.02	2045.03	2302.03	No Change
12	agricultural land - built up	0.93	0.73	0.13	
13	agricultural land - shrub	0.41	1.08	1.82	
14	built up area - forest land	0.2	0.09	1.03	
15	built up area - bare land	0.38	1.54	1	
16	built up area - agricultural	0.26	1.65	2.26	
17	built up area - built up area	16.37	23.65	23.38	No Change
18	built up area - shrub land	0.12	0.43	0.92	
19	shrub land - forest land	0.8	10.54	5.81	
20	shrub land -bare land	206.83	141.05	103.32	
21	shrub land - agricultural	417.3	327.73	135	
22	shrub land - built up area	5.07	3.6	43.7	
23	shrub land - shrub land	79	18.13	145	No Change

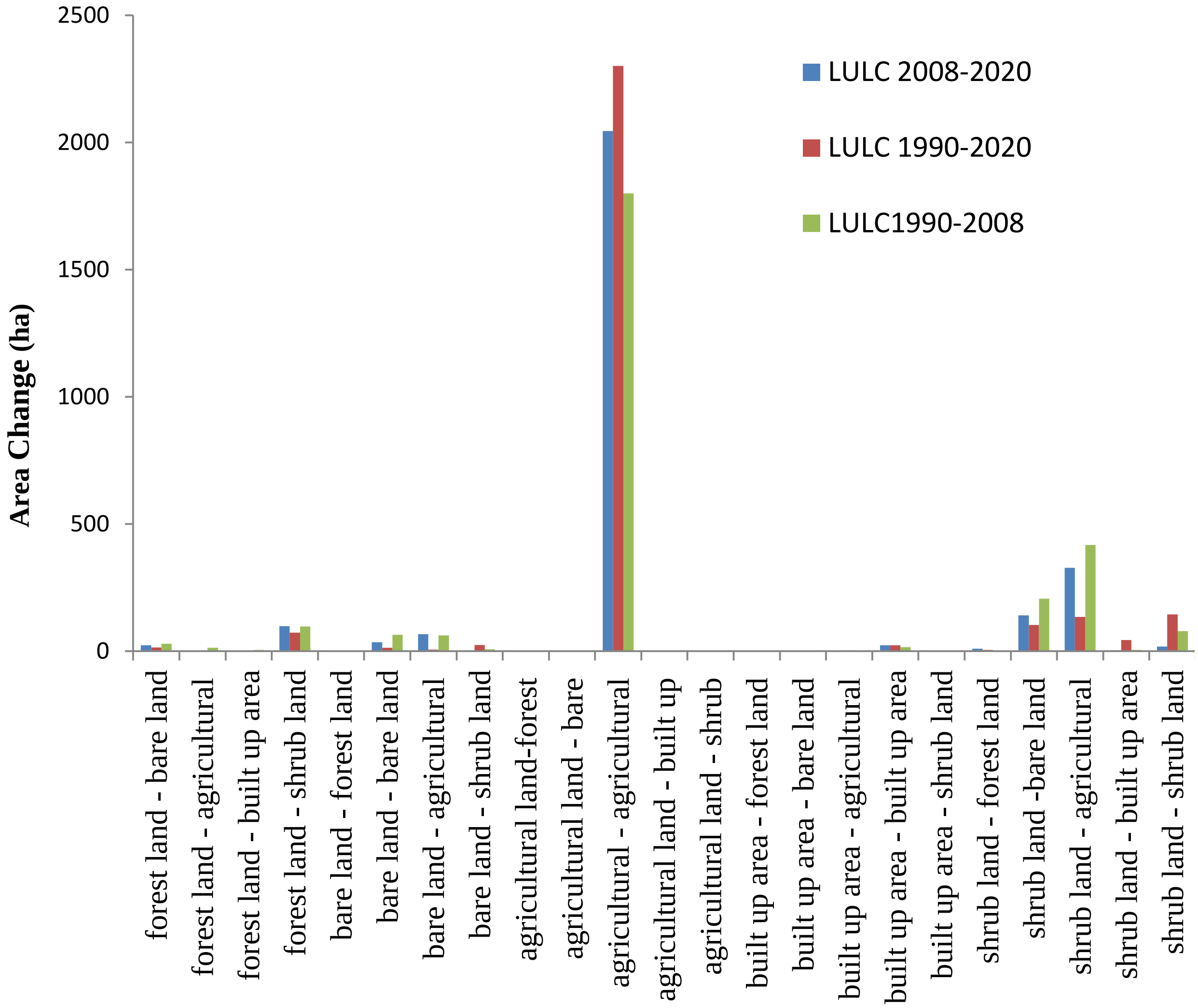

Figure 4.6 land use land cover change detection

Change detection table 4.5and figure 4.6 i realized that shrub land to agricultural land is the prevailing land use land cover change 417.3 ha, 327.7ha and 135 ha from 1990 2008,2008-2020 and 1900 -2020 respectively.And from the column chart agricultural lan d to agricultural land i.e.2302.03ha is highest value of the change is observed during 199 0-2020 at no change value and least value change is observed in bare land to bare land 13.14 ha from the study years of 1990-2020 and (Table 4.5 and Figure 4.6). From table 4.5 and figure 4.6, it has been seen that the catchment land use was changed. As shown from table 4.5 the agricultural land increases and shrub land decreases by 8.8, 17.9 and 9.1; 7.4, 13.1 and 5.7 percent respectively in the study year of 1990-2008, 1990-2020 and 2008-2020.

From change detection the areal coverage were also 417.3 ha, 327.7ha and 135 ha) from 1990-2008, 2008-2020 and 1900-2020 respectively (Figure 4.6 and Table 4.5). So the effect of this change in relation to the river characteristics also changed like plan form and river direction. In the last 31 years (1990-2020) almost all LULC class experienced some degree of change in the study area. As an increase in deforestation for agricultural purpose on the upper part of the watershed which affects the downstream part in different ways like flooding, farm land declining and totally it shows plan form changes. The morphology of the river may have changed as a result of LULC modifications(Kang & Kanniah,2022);rapid settlement,agricultural practice and reforesting significantly migrate the rapid rates of LULCC(Nath & Ghosh,2022). Increased soil degradation is a result of the agricultural intensification brought on by deforestation and land clearing. Changes in land use have an indirect impact on discharge and sediment supply, often by raising peak flows, increasing the amounts of sediment, and increasing the direct impact on river systems (Abate 2019), In general the land use land cover change of the watershed was greatly affected the river morphology directly due to different land use practices.

According to local interviews now a day the decrease in the forest and shrub land in Zorit watershed were wood cutting for domestic energy, charcoal production, building, and wood selling. From (Gessesse & Bewket, 2014) inappropriate agricultural techniques ,high human and livestock population pressure have caused significant changes in land use and land cover (LULC), which have resulted in severe ; (Jiang et al.,2021) LULC is the result of human activities. In the study area sub catchment the majority of the populati on depends on mixed subsistence crop livestock farming systems supplement by saling wood products; drainage systems downstream often display remarkable responses to chan ges in LU/LC(James & Lecce, 2013).The increase in agricultural land and built up area, and the decrease in the forest land and shrub land from (table 4.5 and figure 4.6) shows that the watershed is the most fertile portion and this reveals that the channel also is fertile and suitable for farming.

This generally affects the river bank line that it was either migrated or deposited; in cause of Zorit river bank line migration is likely to be happened.

Since slope is also the most important terrain characteristic and plays a vital role for soil erosion, it is very important to have an understanding of its spatial distribution in the study area. Therefore, the slope map of the study area was prepared from DEM processio ning using Arc-GIS. Soil erosion is accelerated by (Clark 2000), (Abate2 2019) increasing runoff on steep, cultivated slopes, a lack of persistent plant cover, and a lack of soil conservation techniques;Any element impacting a catchment's hydrological response , sediment delivery, discharge, and sediment yields will have an impact on the geomorphological characteristics of the channel. As shown from table 4.4 and 4.5 the lan d use cover was highly varied in the study yerars. Caltivated land were increasing and the slope of the watershed is sloppy (the watershed is characterized by a slope ranging from 0-69.82%) this accelerates the runoff in the study area. The diversified land use land cover can impact on the basic watershed process (Melsse 2022).When the agricultural land increase which decreases the infiltration capacity by compacting the soil particles; this increases the surface runoff in the watershed and which intensely increase erosion and sediment supply in the stream. So I conclude that one or in other case LULCC is the primary driving factor for channel morphology change in Zorit River.

4.8 Runoff volume determination and rainfall time Series

The runoff parameters were established as a complement to the analysis of land use cover change and river morphology. The river is ungagged river, so that direct runoff is calculated by using SCS-CN approach. In the hydrologic analysis for drainage patterns, there are many variable factors that affect floods such as, rainfall amount and storm distribution, catchment area, shape, location, ground cover, type of soil and slopes of the terrain.

4.8.1 Rainfall (Climate) Data

From 2000-2010 the mean annual and maximum annual rainfall distribution was shown some variations especially the mean annual at the year 2008 and the annual maximum from the year 2004 to 2008 (Figure 4.7, 4.8 and 4.9). So that the annual rainfall of the watershed shows that rainfall is distributed temporally (means that rainfall is time dependent). The maximum annual rainfall was recorded 1995, 2009 and 2019 for the first ,second and third decade respectively and the annual minimum rainfall was recorded fro m 2001 to 2004 for the second decade and the rest of the year's record were null except 1995 and 2014 for the first and the third decade respectively (Figure; 4.7, 4.8 and 4.9)

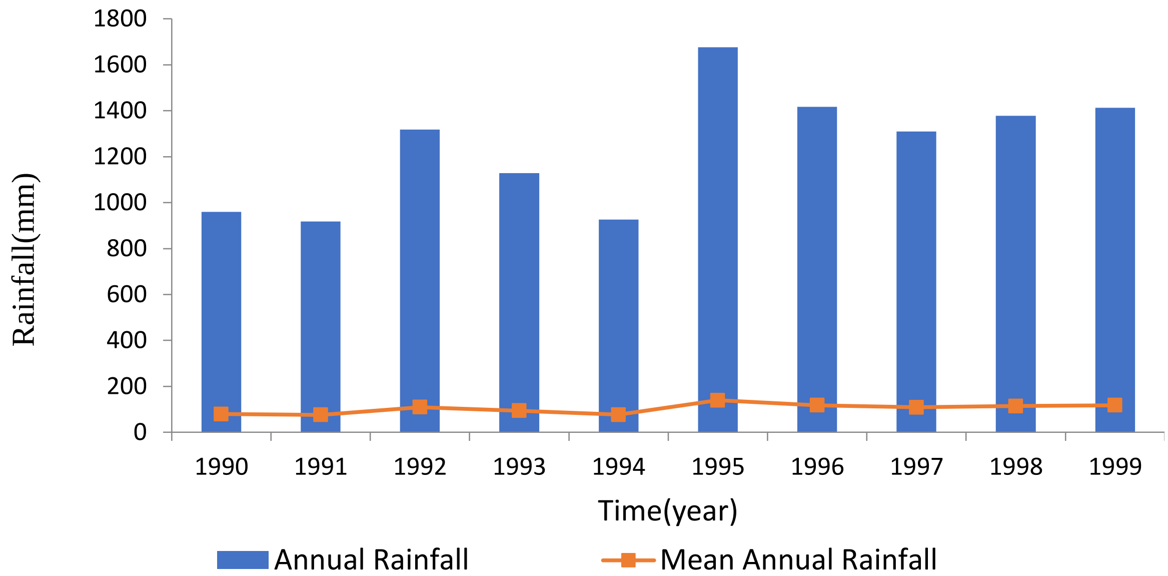

Figure 4.7 Rainfall distributions from 1990-1999

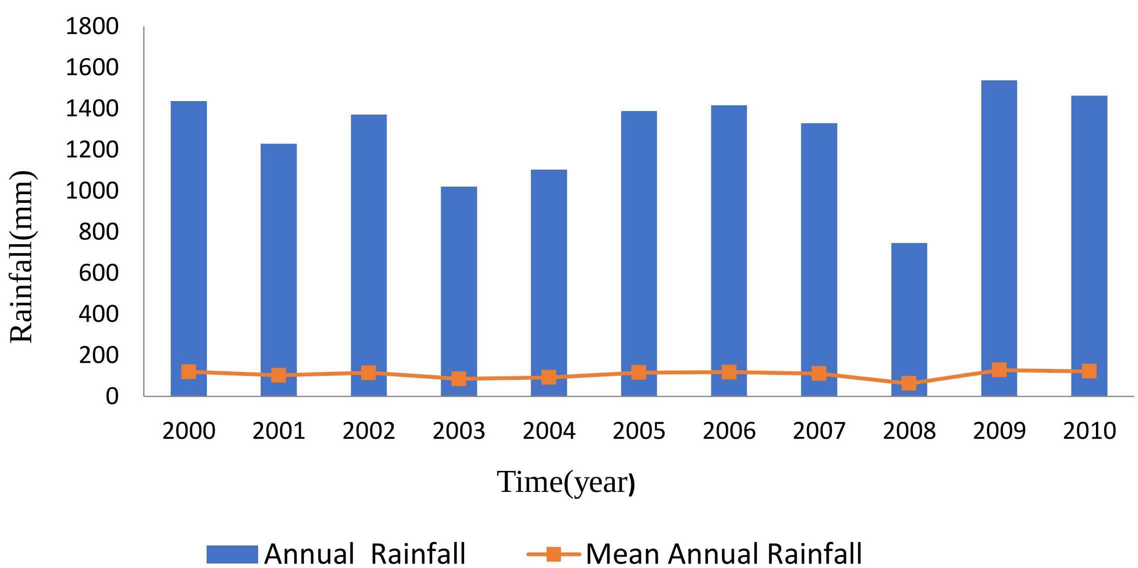

Figure 4.8 l Rainfall distributions from 2000-2010

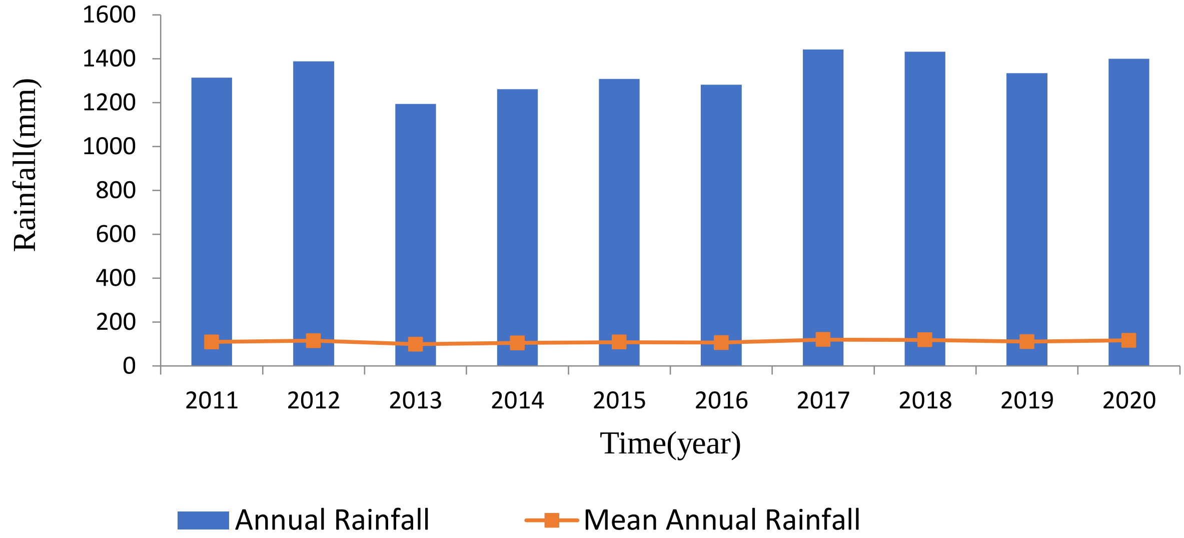

Figure 4.9 Rainfall distributions from 2011-2020

4.8.2 Watershed curve numbers

The curve number was determined based on land use/cover from classified Land sat images, soil texture, and hydrological soil group. As can be seen from Table 4.6 above, the distinct soil texture classes, land use, land cover, and hydrological soil groups are used to calculate the weighted curve number. Due to the variations in land use, land cover, and hydrological soil group values, the watershed has variable weighted curve number values.

Therefore, the average value of the curve number for an the antecedent moisture condition (AMC II) is CN II, and the other curve numbers are determined using the suggested formulas from equations 1 through 3. CN I and CN III were calculated as functions of CN II at the antecedent moisture condition (AMC I) and (AMC III), so, the curve numbers are 86, 73, and 93, CN II, CN I and CN III respectively(Table 4.6) below.

Table 4.6 determination of curve numbers

S N	Soil Texture	Land Use Type	hydrologic condition	Area coverage in %(area ratio)	HSG	Curve No. “CN”	Weighted “CN” Area*CN	SumWeighted “CN”	
1	Clay	Agricultural	Poor	0.181	D	90	16.3	AMC	CN
2	Clay	Shrub Land	Good	4.008	D	62	2.5	II	86
3	Clay	Built Up	Good	0.431	D	86	0.4		
4	Clay	Forest Land	Good	0.136	D	83	0.1	III	93
5	Clay	Bare Land	Poor	0.419	D	89	0.4	I	73
6	Clay to Clay loam	Agricultural	Poor	0.714	D	81	0.6		
7	Clay to Clay loam	Shrub Land	Good	1.533	D	62	1.0		
8	Clay to Clay loam	Built Up	Good	0.008	D	86	0.0		
9	Clay to Clay loam	Forest Land	Good	0.031	D	83	0.0		
10	Clay to Clay loam	Bare Land	Poor	0.592	D	89	0.5		
11	Sandy clay loam	Agricultural	Poor	63.173	C	88	55.6		
12	Sandy clay loam	Shrub Land	Good	6.619	C	74	4.9		
13	Sandy clay loam	Built Up	Good	0.620	C	81	0.5		
14	Sandy clay loam	Forest Land	Good	2.960	C	77	2.3		
15	Sandy clay loam	Bare land	poor	0.598	C	86	0.5		

The hydrological soil condition shows the lower infiltration rates because the HSG D having the capability of lower infiltration and this indicates that runoff in watershed is high.

4.8.3 Direct runoff analysis by soil conservation service curve number method when the rate of water application to the ground surface exceeds the rate of infiltration, a flow known as direct runoff or overland flow occurs along the slope. It is a significant part of the hydrologic cycle. By using SCS-CN method, direct runoff is determined (The United States Soil Conservation Service). This technique is more extensively used and more accurate for estimating floods. The method takes into account watershed data such as the watersheds land use and land cover, hydrological Soil Group, type of soil texture, and curve number (Shaheed & Almasri, 2010).

The direct runoff for the study years of 1990, 2008 and 2020 were determined by using the SCS- CN method and the annual runoff for each year were 171.97mm, 162.58mm an d 186.47mm for 1990, 2008 and 2020 respectively And also the maximum daily runoffs were 19.03mm, 18.67mm and 19.76mm for 1990, 2008 and 2020 respectively. Runoff of a watershed depends on rainfall intensity and typically it varies seasonally.

As a result, the impact of watershed runoff might not be the same throughout the year. This indicated that the annual and daily runoff for the years 2008 has lower value compared to that of the 1990 and 2020.But the annual runoff for the years between 1990 and 2020 were show almost similar value. From Figure 4.10 and Table 4.7 in case runoff in this watershed shows variations in between 1990 and 2008 as well as in between 2008 and 2020 in daily and annually. The annual and maximum daily runoff in the watershed is higher and this affects the morphology (river plan form) by increasing erosion of the bank lines. Here the annual and daily maximum runoff in the watershed in three consecutive decadal years became high and that has been impacts on the channel morphology changes.

Table 4.7 Annual and daily runoff for 1990, 2008 and 2020

year	annual runoff (mm)	maximum daily runoff (mm)
1990	172.0	19.0
2008	162.6	18.7
2020	186.5	19.8

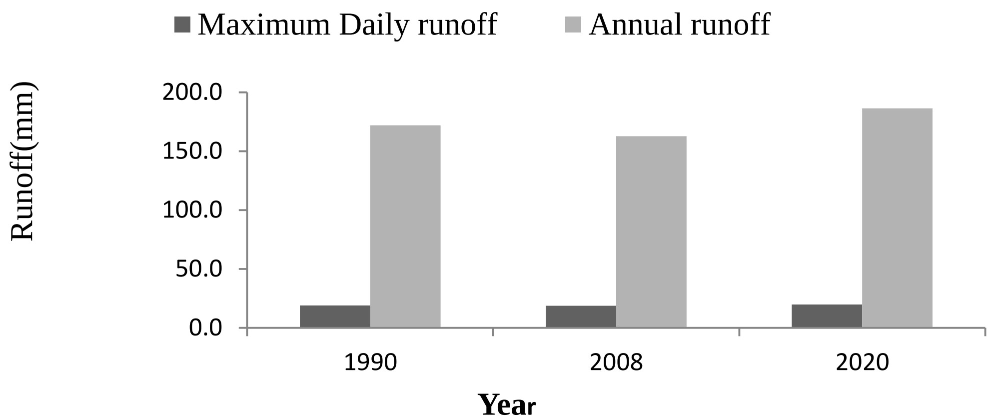

Figure 4.10 Annual and daily runoff for 1990, 2008 and 2020

4.9 Human Activities on river morphology

Human activity-related changes to the river's morphology in terms of plan form and the area's hydrological response to changes in land cover brought on by human activity was more evident. In the watershed the majority of households use forest trees and shrubs that have been planted on farmland as their supply of firewood and these activities include farming for food security, resettling, and deforestation to meet daily requirements. As a result, the community's present sole reliance on these energy sources is detrimental to the river morphology was affected that has been observed during field observations.Therefor e, the concerned body should given consideration for organizing and implementing conservation measures for sustainable development at Zorit watershed to reduce soil erosi on. Human alteration of the landscape can also significantly change watershed conditions (Hogan & Luzi, 2010). The noticeable and visible impact of human activities just below and at the area of these different land use practice changes the magnitude and pattern of runoff rate. This generally affects the fluvial morphology as well as channel morphology in the study area. Anthropogenic influences that alter the shape of the Zorit River have made the current situations of channel erosion worse spatially agricultural activities.

4.10 River Plan form Analysis

The plan form analysis was done the most human interactions were undertaken in Zorit river.The river center lines were digitized from Google earth images of 2008, 2020 and 1990 satellite image and 1989 top sheet (from Amhara Region Land Bureau).The river center line in Figure4.12 illustrates, the river center shape file has altered to varied degree s a particular area of the research area between the years 2008 and 2020.

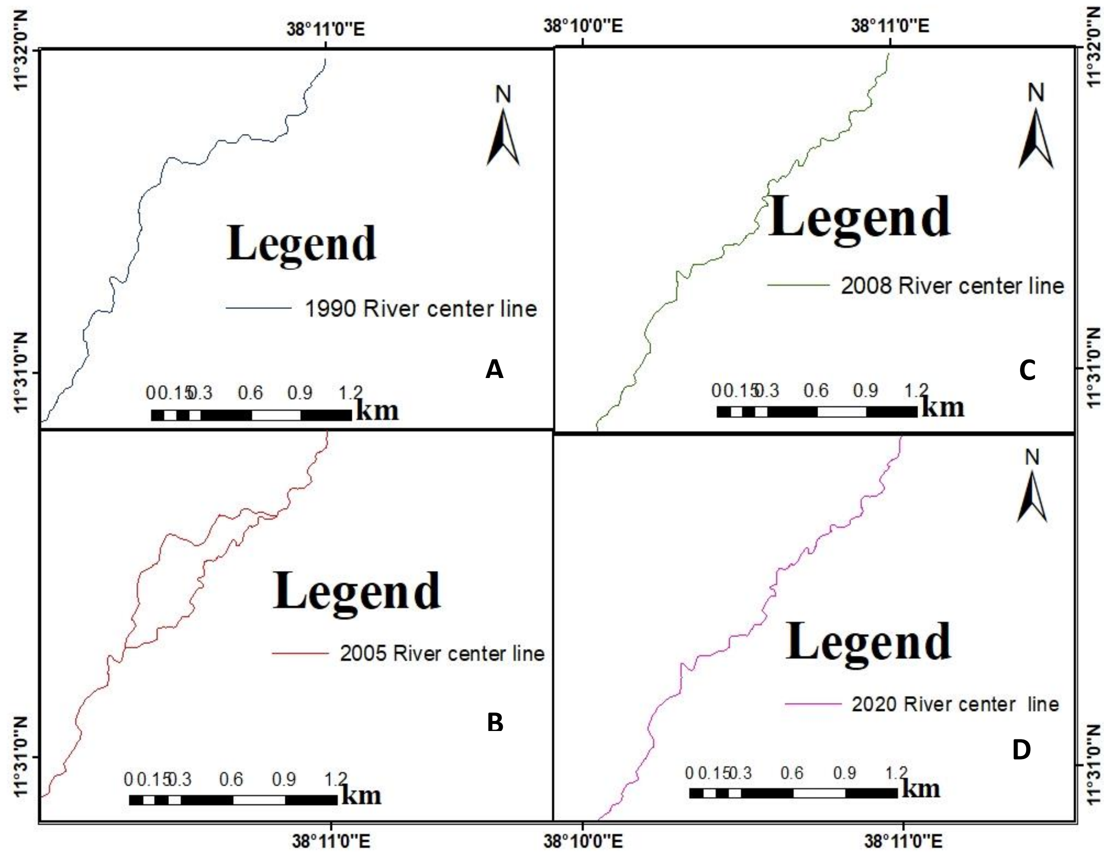

Figure 4.11; River center line from 1990- 2020
(A) 1990 River center line; (B) 2005 River center line and (C) 2008 River center line (D) 2020 River center line

The causes of river course change in direction were assessed through the local dwellers interview and from satellite images, Google earth images `and topo sheets; the river was changed its direction in 2005 towards the present direction due to the traditional river bank line protection works such as dry stone masonry and plantation of eucalypts tree at the riparian zones of the river. This indicates that between the years 2008 and 2020 the river was shown major changes in width (figure 4.14 and appendix 7, table 4.7).

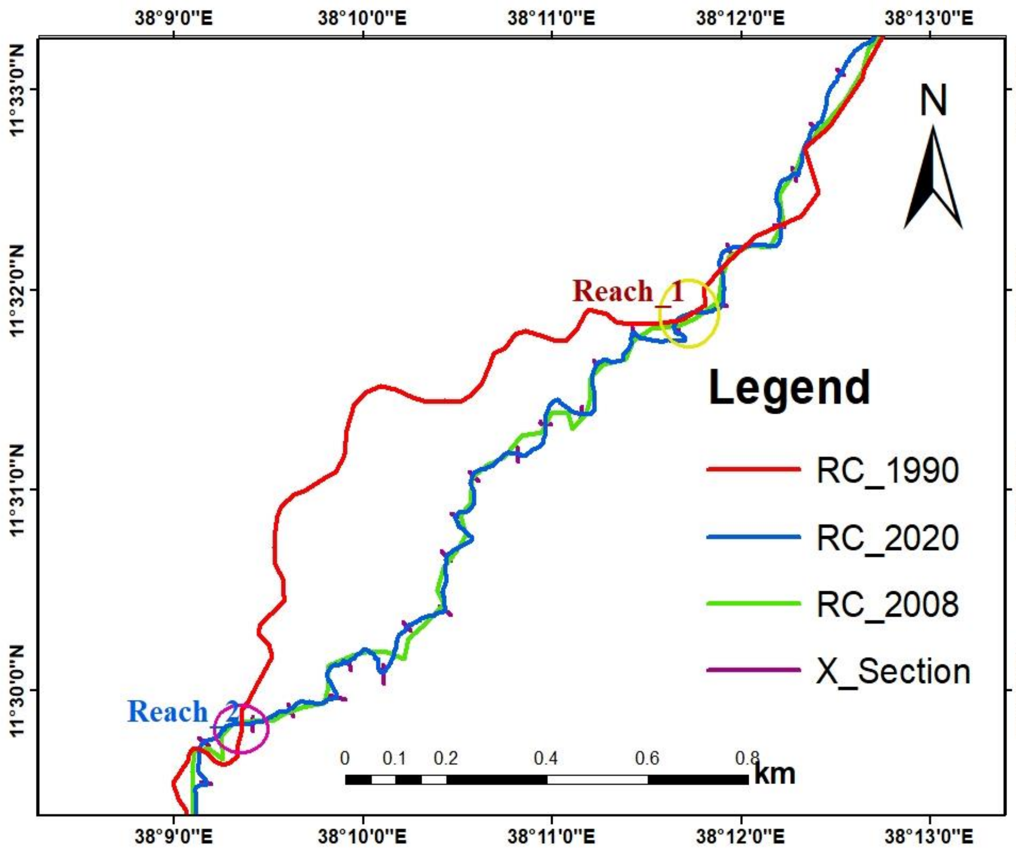

Figure 4.12 Overlapped River Center lines at cross-section for selected years

4.10.1 River Cross Section and channel width Analysis

Cross sections between the mouth and reach 1 that is at cross section 1, 2, 3, 4 and 5 at these cross sections the channel center line shifts towards both the left and right direction of the river bank in the years between 2008 and 2020 (Appendix 7,Table 4.7 and Figure.4 .14).At cross section 6, 8 and 22 both the left and the right bank line were shift towards east direction and at cross section 9,13,14,16 and 18 the river bank shifts towards the west ward. Therefore, because of the high human interface such as deforestation for agricultural practice the river course diverted its direction which affects the downstream river morphology.

At reach 1 there is flood protection mechanisms which is dry stone masonry this facilitat es river courses in the today's river direction. In general, the river lines were shifted later ally to the right and left direction with varying degrees for example, the left bank was shifted towards the downward direction(east) with a maximum value of 15.07m at cross section (11) and a minimum of 0.17m cross section (18) a total shift of 136 m (Appendix7 table,4.7) as well as the right bank was shifted towards upward direction(wes tward) a maximum of 14.14m at cross section (10) and with a minimum of 0.36m cross section (5)a total distance of 145.27m. Both the right and the left bank were shifted; the left bank was dominated to east ward direction 136m and the right bank was to the west ward direction of 145.27m (Appendix7, table 4.7).At cross section (11) there is slightly little deep cut off cross sections this is because of human activities like agricultural farmi ng causes severe erosion to the watershed resulting change in river plan form and which affects the surrounding farm lands in Zorit watershed.

So as to maintain river bank line stability from (*Galeotti, 2022*); minimum of18 m-wide buffer strip on either side of the stream defines an appropriate riparian zone; larger riparia n zones may be necessary for streams wider than 4m. Due to the river's lack of sediment variations in the river are indicators of sediment decline and migration. Since the watersh ed having undulating topography and is no riparian vegetation around the river so that, there is high runoff rate and which directly affects the river morphology.

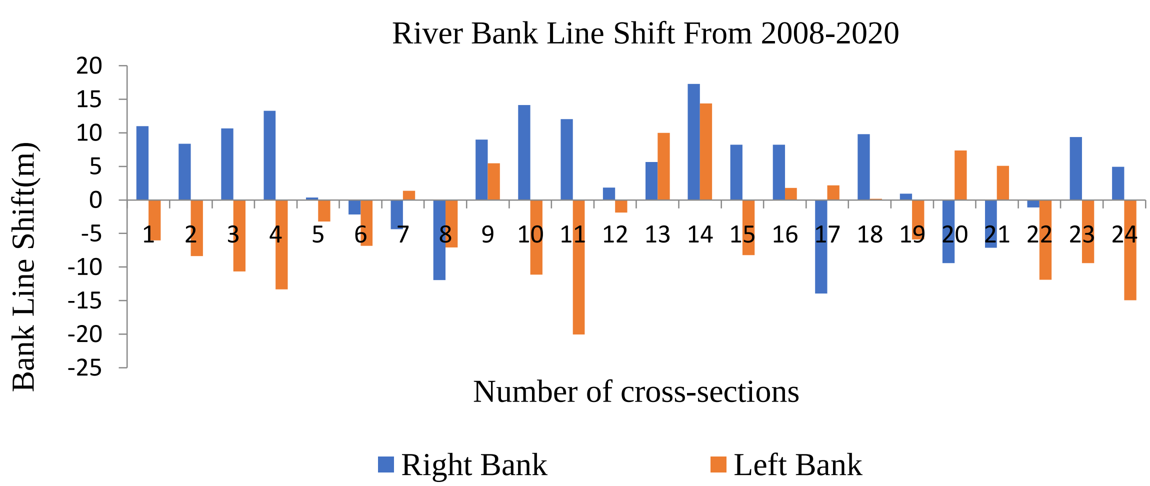

Figure 4.13 Bank line shift analysis

*In the figure 4.14 above the downward gradient means shifting to east and upward gradient means shifting toward west. The numbers indicate the cross section.

4.10.2 Sinuosity index analysis

For simplicity the stream is divided in to three reaches using Arc GIS 10.8 and sinuosity metrics for each reach including channel length,valley length, and air length, was measured using Google earth image and topo sheets. The overlay analysis showed that for the considered reach covered 4.5km length which is dived into three separate reaches starting at a distance above 1.2km from the river course changes its direction ends up somewhere 1km below the present river direction was joined to1990.

The hydraulic sinuosity index (HSI), topographic sinuosity index (TSI) standard sinuosity index (SSI).parameters were assessed.The use of HSI and TSI is recognizing the hydrolo gical and topological feature of a watershed.From (Khan et al,2018) rivers depending on how it flows might be straight, sinuous, meandering, or braided.Tables 4.8 provide the SS I characteristics and indices for the three years. Channels are classified as straight (SSI <1 .05), curved (SSI >1.05), meandering (SSI >1.5), braided SSI >1.3 and anastomosing SSI >2.

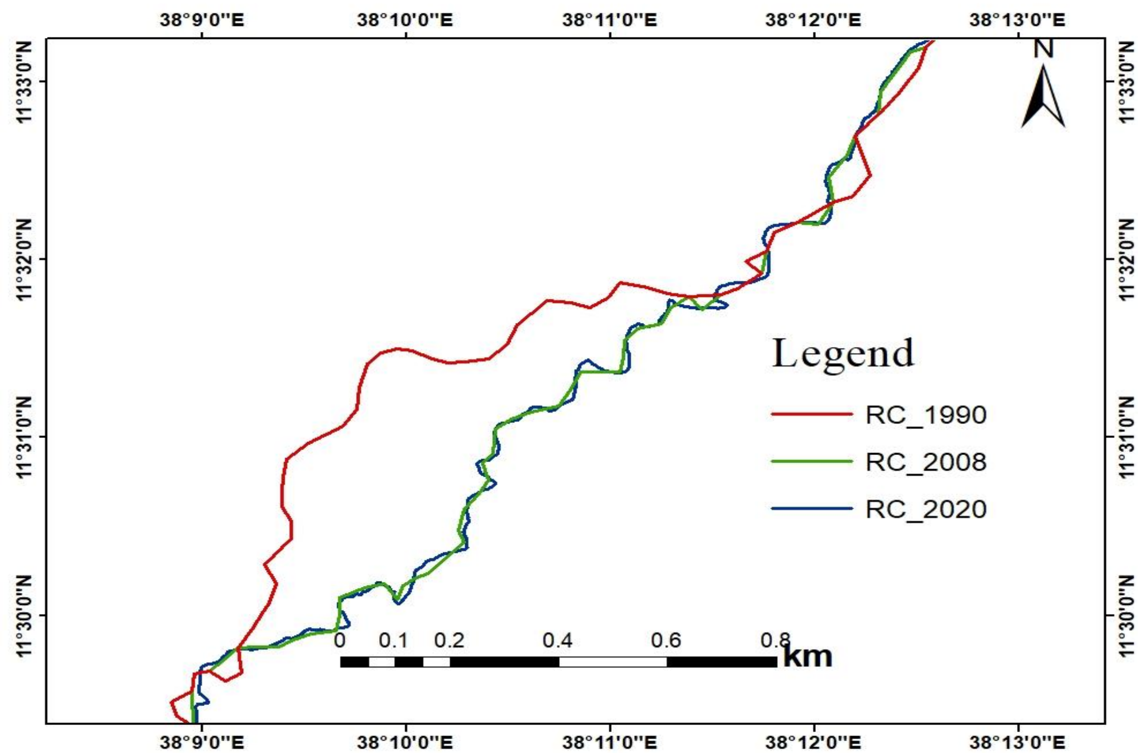

Figure 4.14 Overlapped digital central flow lines of Zorit River

Table 4.8 Sinuosity index

	year	CL	VL	AL	CI	VI	HSI	TSI	SSI
A	1990	2.70	2.62	1.87	1.44	1.40	10	90	1.03
	2008	2.54	2.48	2.02	1.26	1.23	12	88	1.02
	2020	2.60	2.53	2.02	1.29	1.25	12	88	1.03
B	1990	0.92	0.84	0.56	1.64	1.50	22	78	1.03
	2008	0.97	0.88	0.67	1.45	1.31	30	70	1.04
	2020	1.00	0.96	0.75	1.33	1.28	16	84	1.04
C	1990	1.13	1.08	0.98	1.2	1.10	35	65	1.02
	2008	1.17	1.11	0.87	1.3	1.28	20	80	1.03
	2020	1.20	1.12	0.89	1.3	1.26	26	74	1.04

(A) Between reach 1 and 2 (B) between reach 1 and the outlet (C) sinuosity between reach 2 and the mouth

CL: Channel length

AL: Air length

CI: Channel Index

VL: Valley length

VI: Valley Index

HSI: hydraulic sinuosity index

TSI: Topographic sinuosity Index SSI: standard sinuosity index

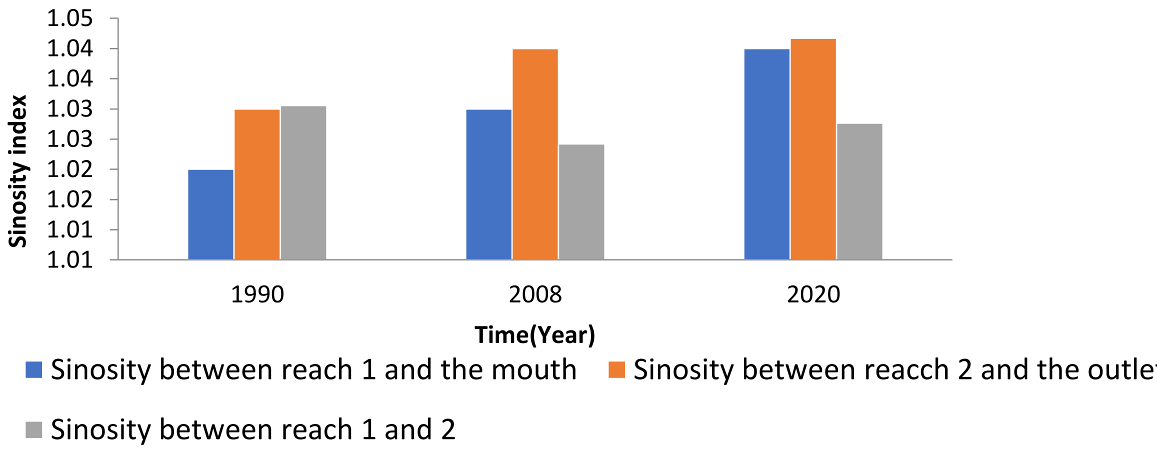

Figure 4.15 sinuosity index from 1990-2020

The standard sinuosity index of the river is less than 1.05 from (Ghosh & Mistri, 2012) and thus a straight river type.

Channel index for the main channel in1990, 2008 and 2020 rivers are low (CI < 1.05). The analysis showed that the difference between channel index and valley index is considerable approximately similar for channels indicating the main channels in the channels have not fully developed valleys. The HSI values for the three years are low which indicates that hydraulic factors such as, infiltration capacity, didn't show major impact on the river morphology. If HSI decreases for the channel, TSI must increase proportionately (Table 4.8). Since the land use land cover are the dominant factor for the plan form changes without the presence of the manmade structures like dam, bridges etc. As shown Figure 4.15 the 1990 channel was developed out of 2008 and 2020 river direction in between reach 1 and reach 2. The sinuosity index of above reach 1 and the mouth are almost similar in the year 2008 to 2020 except in the year 1990 and sinuosity between reach 1& 2 and the outlet are increased from the study years of 2008 to 2020 that is in the SSI was increased from 1.02 to 1.03 between reach 1 and 2 in 2008 to 2020 where as in reaches between reach 2 and the outlet was increased by1.03 to 1.04 in 2008 to 2020 (Table 4.8 and Figure 4.16).

The topographic and hydraulic sinuosity indices are sinuosity-controlling factors which initiates the channel development stage. In Table 4.9 the range of TSI was increasing between reach 2 and the mouth but TSI down to reach 2 is decreasing this shows that the topography becomes to gentile in slope. Here, TSI values are maxim for the three years compared from HIS; hence topographic considerations are more important than hydraulic factors.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this thesis, satellite images and Google earth image were used to evaluate the impacts of land use/ land cover and channel morphology change of Zorit River, For the data preparation and analysis image processing software (ENVI5.1),Arc GIS 10.8 and Google earth pro were used. The result of land use /land cover classification; there is a decrease in forest land, the shrubs and bare land accompanied by increase in agriculture land and built up area.

From change detection analysis the land use/cover change from shrub land to agricultural land is the dominant land use land cover change (417.3 ha, 327.7 ha and 135 ha) from 1990- 2008, 20082020 and 1900 -2020 respectively. The anthropogenic effects such as fa rming, deforestation, resettlement and animal free grazing have also aggravated the change of the plan form in the downstream part of the river. Anthropogenic influences that alter the shape of the Zorit River have made the current conditions of channel erosion worse.

The overlay analysis showed that for the considered reach 4.5 km length which dived into three separate reaches starting at a distance above 1.2km from the river course changes its direction ends up somewhere 1km below the 1990 river direction was joined. The general trend of the river banks was shifted to right and after that the river banks shifts left. The Sinuosity index of Zorit River is 1.03, 1.02 and 1.03 in the year 1990, 2008, and 2020 respectively between reach 1 and 2. The result of plan form change the left bank was shifted towards the upward direction (west) with a maximum value of 20.07 m and a minimum of 0.17 m a total shift of 136 m as well as the right bank was shifted a maximum of 14.14 m, with a minimum of 0.36 m and a total distance of 145.27 m.

Totally both the right and the left bank were shifted at the middle of the channel and the left bank was dominated to east ward direction 136 m and the right bank was dominated to the westward direction of 145.27 m. So in the study year from 2008 to 2020 the bank line was shifted towards the west direction.

5.2 Recommendation

The study only trid to address the river planfom change due to LULCC so, that the watershed has been experienced some degree of change in its physical aspect due to the impacts of land use /land cover change. Therefore land use/land cover change should be controlled in the watershed and some measures should be taken for the stabilization of the land cover change and downstream river restoration should be done. As a result of increasing deforestation of the upper watershed areas. So, as to treat the river bank line shift taking area closure from grazing and plaughing as well as improving re-afforestation program in the watershed is mandatory and to protect river bank erosion providing a buffering zone between the river bank and farmlands is mandatory. It is also recommended that there should be farthe studies to be conducted in the study area because of shortage of budget and time my study didn't include all of causes of morphology changes in the study area.

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APPENDEX

Appendix 1, Table 1, Temperature of Mekane -Eyesus station (1990 to 2020)

Year	Annual Temperature	Annual Maximum Temperature	Annual Minimum Temperature
1990	21	29.4	4.1
1991	21.6	29.2	5
1992	21	29.5	5.2
1993	21.4	28.3	5.4
1994	21.1	28.9	2.4
1995	21.9	28.4	4.7
1996	20.7	29.1	4.5
1997	21.6	28.9	5
1998	21.8	30.2	2.2
1999	21.1	29.9	3.9
2000	21.3	30.7	3.6
2001	21.4	29.9	2.7
2002	21.9	29.9	5.8
2003	21.9	29.8	4.1
2004	22.8	33.4	5.4
2005	23	32.3	4.5
2006	21.7	29.9	4.5
2007	21.1	29.7	1.9
2008	21.2	30.6	4.7
2009	21.3	29.5	4.1
2010	22.1	28.9	5.5
2011	21.1	29.7	4.4
2012	21.1	29.4	4.3
2013	21.5	30.4	3.3
2014	21.6	28.4	4.4
2015	21.8	29.4	5.3
2016	22	30.5	4.7
2017	21.9	28.7	2.9
2018	21.7	28.2	5.5
2019	22.9	29.4	4
2020	22.2	30.5	5.1

Appendix 2, Table 2, Rainfall of Mekane -Eyesus station from 1990-2020

Year	Max	Min	Mean	STD	Sleekness
1990	337.5	0	80	122	1.7
1991	295.3	0	76.5	95.7	1.4
1992	437.7	0	109.9	141.7	1.4
1993	358.6	0	94	132.9	1.3
1994	296.5	0	77.2	96.4	1.3
1995	511.5	5.4	139.7	158.9	1.3
1996	363.3	0	118.1	121.6	1.1
1997	301.1	0	109.2	123	0.5
1998	365	0	114.8	132.1	0.9
1999	426.7	0	117.7	128.6	1.4
2000	452.2	0	119.6	155.2	1.3
2001	362.8	1.2	102.5	137.4	1
2002	392.4	5.5	114.3	134.6	1.2
2003	415.1	2.4	85	119.9	2.1
2004	330.2	3.6	91.9	104.3	1.4
2005	310.8	0	115.6	117.6	0.6
2006	355.4	0	118.1	133.5	0.9
2007	332.6	0	110.8	119.2	0.7
2008	258.1	0	62.2	75.6	1.7
2009	515.6	0	128.2	159.7	1.5
2010	398.5	0	121.9	138.4	1.1
2011	317	0	109.5	123.2	0.6
2012	456.5	0	115.7	142.1	1.4
2013	305.1	0	99.5	99.1	1
2014	353.4	4.2	105.1	121.6	1.2
2015	418.3	0	109.1	140	1.1
2016	349.6	0	106.8	114.6	1.2
2017	403.2	0	120.2	145.2	1
2018	410.8	0	119.3	148.2	0.9
2019	515.5	0	111.2	179.4	1.6
2020	419.5	0	116.6	143.2	1

Where, Max=maximum rainfall Min=minimum rainfall, STD= Standard Deviation

Appendix 3, Table 3 Meta data for 1990

Field	Value
Landsat Scene Identifier	LE71690521990296EDC00
Landsat Product Identifier	LE07_L1TD_169052_19901023_20170216_01_T1
Acquisition Date	1/1/1990
Spacecraft Identifier	Landsat_5
Collection Category	T1
Collection Number	1
Sensor Mode	SAM
WRS Path	169
WRS Row	52

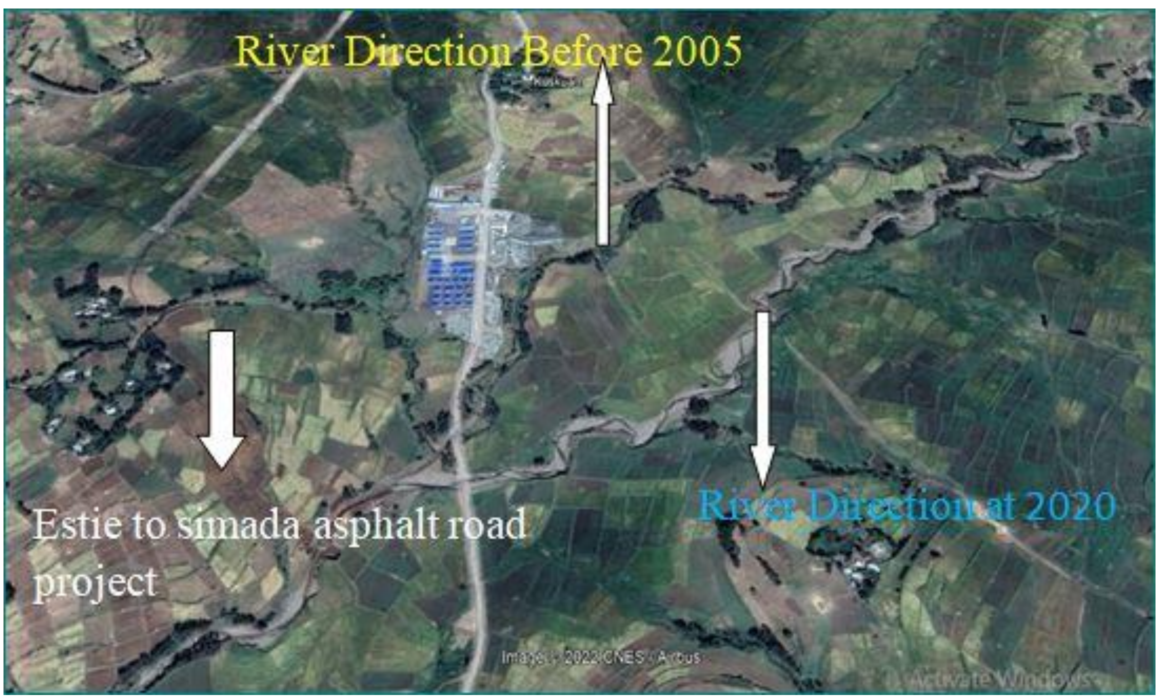
Appendix 4, Table 4 Meta data 2008

Field	Value
Landsat Scene Identifier	LE71690522008296EDC00
Landsat Product Identifier	LE07_L1TD_169052_20081023_20170216_01_T1
Acquisition Date	1/2/2008
Spacecraft Identifier	Landsat_7
Collection Category	T1
Collection Number	1
Sensor Identifier	ETM
Sensor Mode	SAM
WRS Path	169
WRS Row	52

Appendix 5, Table 5 Meta data 2020

Field	Value
Landsat Scene Identifier	LC81690522019359LGN00
Landsat Product Identifier	LC08_L1TP_169052_20191225_2020110_01_T1
Acquisition Date	12/25/2019
Spacecraft Identifier	LANDSAT_8
Collection Category	T1
Collection Number	1
Sensor Mode	SAM
WRS Path	169
WRS Row	52

Appendix 6, Figure 1 river directions before and after change its curse



Source: - Google earth pro

Appendix 7 Table 6 the right and left bank shift between 2008 and 2020

SN	Northing	Easting 2008 Right Bank	Easting 2008 Left Bank	Easting 2020 Left Bank	Easting 2020 Right bank	2008-2020 Left Bank	2008-2020 Right Bank
1	1274615.79	410809.3	410803.2	410809.3	410798.3	-6.03	10.99
2	1274712.43	410723.8	410715.5	410723.8	410715.5	-8.37	8.37
3	1274621.2	410708.9	410698.2	410708.9	410698.2	-10.67	12.67
4	1274582.38	410629.4	410626.1	410639.4	410616.1	-13.31	11.31
5	1274548.48	410578.3	410578.5	410578.3	410588.3	-3.19	0.36
6	1274517.37	410505.9	410519.1	410525.9	410508.1	-6.82	-2.18
7	1274459.21	410438.1	410459.5	410458.1	410442.5	1.38	-4.38
8	1274310.23	410217.4	410227.9	410235.6	410229.3	-7.07	-11.96
9	1274317.43	410245.6	410228.6	410223.1	410236.6	5.49	8.99
10	1274230.02	410210.3	410199.2	410210.3	410196.2	-11.14	14.14
11	1274177.17	410203.7	410199.6	410219.7	410191.6	-20.07	12.07
12	1274094.71	410170.1	410168.3	410170.1	410168.3	-1.86	1.86
13	1273996.97	410049.1	410043.1	410033.1	410043.5	10.01	5.64
14	1273977.15	410009.1	410068.8	410054.4	409991.8	14.41	17.3
15	1273941.35	409953.3	409945.1	409953.3	409945.1	-8.24	8.24
16	1273856.89	409851.4	409852.8	409851.2	409842.8	1.78	8.22
17	1273719.92	409695.8	409774.2	409772.5	409709.7	2.19	-13.96
18	1273716.18	409678.4	409678.6	409678.4	409668.6	0.17	9.83
19	1273596.91	409599.1	409598.1	409604.3	409598.1	-5.88	0.94
20	1273530.54	409544.3	409524.8	409517.4	409553.4	7.38	-9.42
21	1273452.84	409492.7	409484.8	409479.7	409499.8	5.1	-7.1
22	1273384.94	409524.8	409512.9	409524.8	409525.9	-11.9	-1.1
23	1273312.52	409502.9	409493.5	409502.9	409493.5	-9.4	9.4
24	1273216.66	409441.4	409426.5	409441.4	409436.5	-14.94	4.94
						$\sum +47.91$	$\sum +145.27$
						$\sum -136.06$	$\sum -50.1$