

**ADDIS ABABA UNIVERSITY**  
**ADDIS ABABA INSTITUTE OF TECHNOLOGY**  
**SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING**



# **Assessment Of Reservoir Sedimentation Using Remotely Sensed And Ground Observation Data (The Case Of Legedadi Reservoir, Ethiopia)**

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**A Thesis in Hydraulic Engineering stream**

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**Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science**

The undersigned have examined the thesis entitled ‘**Assessment of Reservoir Sedimentation using Remotely Sensed and Ground Observation Data**’ presented by **Almaz Girma**, a candidate for the degree of **Master of Science** and hereby certify that it is worthy of acceptance.

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## DECLARATION

I confirm that research work titled “**Assessment of Reservoir Sedimentation using Remotely Sensed and Ground Observation Data**” is my work. The work has not been presented elsewhere. Where material has been used from other sources it has been properly acknowledged.

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## ABSTRACT

*Reservoir sedimentation is one of the issues that need to be addressed in water resources management. Sediment deposition in reservoirs for water system, hydroelectric power control, and urban water supply, reduces their capacity, service life, water quality and requires expensive operations for removal and treatment. Lack of normal and less cumbersome methods for assessment of sedimentation ranges and available potential poses undertaking for the sustainable administration of reservoirs. The conventional methods for quantification of sediment such as inflow- outflow and hydrographic survey methods are clumsy, expensive and time consuming. Hence, there is a need for simple methods, which requires less time and economical. The remote sensing is incredibly useful, economical and reliable tool for conducting such surveys and monitoring sedimentation in reservoir.*

*This study examines to assess Legedadi reservoir sedimentation by using remotely sensed data. Satellite imageries have been employed for the water spread area, which was used for calculating sedimentation rate. This research put together the geographical information system (GIS), Envi software, and DEM to assess the reservoir sedimentation by using remote sensing data.*

*The result indicated that the current 2019/20 capacity of the Legedadi reservoir estimated using remote sensing techniques becomes 34.87Mm<sup>3</sup> at an elevation of 2465.13m a.m.s.l and the original capacity (using hydrographic survey) was 40.8 Mm<sup>3</sup> at the same level, the loss in reservoir gross capacity due to sediment deposition for the period of 41 years of reservoir since 1979 to 2020 was determined to be 5.93 Mm<sup>3</sup> which convert to 14.53 % gross capacity loss or showing annual storage loss due to sedimentation deposition is found to be 0.35% loss between elevation 2465.13 and 2457.46 m a.m.s.l. Accordingly, the annual rate of sedimentation using remote sensing was found to be 0.145Mm<sup>3</sup>/year. Those values are found to be in close correspondence with results obtained from the hydrographic survey. LULC change and domination of cultivated land indicate a significant impact on reservoir sedimentation.*

*Keywords: Remote sensing, reservoir sedimentation rate, Storage capacity, Reservoir, hydrographic survey*

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## LIST OF ACRONYMS

|       |                                                                  |
|-------|------------------------------------------------------------------|
| AAWSA | Addis Ababa Water and Sewerage Authority                         |
| ASTER | Advanced Space borne Thermal Emission and Reflection Radiometric |
| ENVI  | Environmental Visualization Interfere                            |
| ETM+  | Enhanced Thematic mapper plus                                    |
| FRL   | Full Reservoir Level                                             |
| FCC   | False color combination                                          |
| GIS   | Geographic Information system                                    |
| LULC  | Land use/Land cover                                              |
| MDDL  | Minimum drawdown level                                           |
| MCM   | Million cubic meters                                             |
| MSS   | Multispectral Scanner                                            |
| NIR   | Near infrared Radiation                                          |
| NDWI  | Normalized difference water index                                |
| RS    | Remote Sensing                                                   |
| TM    | Thematic Mapper                                                  |
| TIRS  | Thermal infrared Sensors                                         |
| USGS  | United States Geological Survey                                  |
| UTM   | Universal Transverse Mercator                                    |

## 1. INTRODUCTION

Surface water reservoirs are created by constructing dams across rivers to meet various requirements of the community. After the dam is constructed water flows into the reservoir may cause siltation in both live storage and dead storage of the reservoir. Thus, utilizable water storage and benefits from reservoirs are reduced when the speed of sedimentation exceeds the design rate. Such issues are attributed to the fact that sediment particles originating from erosion process within the catchment are propagated together with the river flow.

Among many factors, proper water resources planning and management are the key approaches to sustain the service life of reservoir. Water resource planning involves periodic measurement of sediment flow rate, deposition pattern, and net storage availability. For appropriate distribution and controlling water of Legedadi reservoir, knowledge about the sediment deposition in various zones of reservoir is essential. Thus, assessment of reservoir sedimentation becomes vital for management and operation of reservoir. Some conventional methods, like inflow-outflow methods and hydrographic survey are used for quantification of sediment in reservoir but these methods are clumsy, expensive, and time-consuming (Dadoria, Tiwari and Jaiswal, 2017). Therefore, it is essential to develop simple methods which require less time and cost-effective. Accordingly, remote sensing-based approach has become very efficient and convenient to quantify the sedimentation in a reservoir and to assess its distribution and deposition pattern. Remote sensing knowledge offers data acquisition over a long period and broad spectral ranges which provide synoptic, repetitive, and timely information regarding sedimentation characteristics of reservoirs.

In Ethiopia, water level elevations in reservoir are likely to be near the full reservoir level (FRL) at the end of summer season (September/October), before it gradually depletes to lower levels toward the end s of the drawdown cycle (March/May). Reduction in water spread area for particular elevation indicates deposition of sediment at that level. This integrated over the range of elevations using bathymetric and satellite data enables in computing volume of storage lost due to sedimentation.

Sedimentation in a reservoir is always a tedious problem and moreover, it is very challenging to accurately measure the volume of sediments in a reservoir. Moreover, the selection of an appropriate period for analysis is an important step and it is imperative to use remote sensing data for the period when there is maximum variation in reservoir water level (Peng *et al.*, 2006a).

## 1.1. Statement of the Problem

Sedimentation is a process whereby soil particles are dissolved and transported by streaming water or other transporting media and kept as layers of strong particles in water bodies such as reservoirs and rivers. However, the major issue of sediment deposition in reservoirs for water systems, hydroelectric control supply, and urban water supply, are reduces their capacity, service life, water quality and requires expensive operations for removal and treatment. The municipal area of Addis Ababa is supplied by water from the Legedadi reservoir which is under threat of volume decrease because of sedimentation. Lack of normal and less cumbersome methods for assessment of sedimentation ranges and available potential poses undertaking for the sustainable administration of reservoirs. There are presumable reasons for such storage reduction that can be attributed to upstream land degradation and lack of frequent site sediment regulation method. However, the quantitative assessment of storage losses due to sedimentation was not properly determined. Such issues are becoming a challenge in planning their future demand for water and project planning from other sources.

According to the 1998 bathymetric survey Legedadi reservoir report the topography map of reservoir, the full capacity of the reservoir at the time of commissioning was 63.68MCM. However, in report it is commented that this volume is on the higher side and probably the capacity is 6m above the present full supply level included. In 1999, TAHAL Consulting Engineers has carried out a bathymetric survey of 1979 was reconstructed. As a result, the maximum storage capacity of the reservoir at an elevation of 2466ma.a.m.s.l for 1979 and 1998 was 45.9MCM and 43.8MCM respectively. Similarly, a 20-year bathymetric survey 1978-1998 for Legedadi reservoir indicated an average annual silt accumulation of 26,000m<sup>3</sup> (Andualem G. and Yonas m., 2008).

Thus, it is necessary to assess reservoir sedimentation with the help of remotely sensed and geographical information techniques. The aim of present study is therefore to assess the Legedadi reservoir sedimentation by using remotely sensed data and ground observation.

## 1.2. General Objective

The main objective of this study was to assess Legedadi reservoir sedimentation by using remotely sensed and ground observation data.

### 1.2.1. Specific Objective

-  To explore the capability of remotely sensed data in the assessment of reservoir sedimentation.
-  To compare original storage capacities of reservoir and capacity of reservoir from remotely sensed data.
-  To assess the impacts of land use land cover changes in the Legedadi reservoir.

### 1.3. Research Questions

- ✓ What is the relationship between capacity of reservoir from remotely sensed data and original storage capacities of the reservoir?
- ✓ What is the amount of sediment deposition in reservoir?
- ✓ How to identify the water pixels and water spread area?

### 1.4. Significance of the Study

In Ethiopia, there are reservoirs below progress for example Grand Ethiopian Renaissance Dam (GERD) and many different are being designed such as Abasamuel, Gefersa ,Arjo Didessa ,Geba and Koka reservoirs are used for the development of the country by the Federal and Regional governments. The country has experienced low reservoir sedimentation control and administration due to many reasons for many decades.

However, most of the projects have experienced sediment problem such as Gefersa and Koka reservoirs which looks up to develop or make contributions better knowledge to the efforts working towards reaching storage ability of the reservoir for which it was designed. Sediment deposition knowledge turns into essential management and operation of reservoir. In general, the study will have a significant contribution in understanding the sedimentation problem by using remotely sensed data in time and in a cost-effective way. It can also be used as the baseline records for those who are involved to conduct an assessment of reservoir sedimentation.

### 1.5. Scope of Study

This study aimed to develop and apply the methodology using remote sensing approaches and to quantify the amount of sediment deposited in the Legedadi reservoir. To achieve such targets of study: secondary input data were collected from different sources. Landsat satellite images were downloaded from USGS Website, ASTER DEM and Top map of study area (1:50000) purchased from Ethiopian mapping agency and those data was processed and analyzed by ARC GIS and Global mapper. And then the annual sediment accumulation and capacity loss of reservoir would be determined.

### 1.6. Thesis Outline

The entire thesis is divided into five chapters. The first chapter deals with introduction parts that contain background of study, statement of problem, objective of study, research questions, Significance of study and scope of study. The second chapter includes the literature review part that elaborates previous research work regarding remote sensing method applied to reservoir sedimentation. The details regarding study area description, data collection methods, and data used during study are discussed in the third chapter. The fourth chapter describes the result obtained from study and analysis of the same. The final chapter deals with conclusion and recommendation derived from remote sensing method to assess reservoir sedimentation.

## 2. LITERATURE REVIEW

### 2.1. Reservoir Sedimentation in General

Sedimentation is a filling of a reservoir or artificial lake with sediments or residues, which leads to a decrease in the capacity reservoir(Prasad, Garg and Thakur, 2018). (Shendge and Chockalingam, 2016) concluded that sedimentation was caused by things, which carried alongside with the inflow of water and typically deposited in the reservoir. It was the main issue that needed to be addressed in water resources management.

The use for which a reservoir was constructed could be sustainable only where sedimentation was controlled by adequate management for which suitable measures should be developed (Shendge and Chockalingam, 2016).

Xiaoqing, 2003, studied the effects of sedimentation on the capacity of the reservoir, and forwarded that globally, the overall annual loss rate of reservoir storage capacity was estimated at 1 to 2 percent of the total storage capacity. Sedimentation caused the loss of reservoir capacity around 0.4 to 2.0% of the world reservoir extent annually (Issa *et al.*, 2015), while sediment deposition rate varies from 0.1 to 2.3% for large dams worldwide(Rashid *et al.*, 2015). However, small reservoirs in semi-arid and arid areas experience significantly higher sediment deposition levels depending on the nature of the catchment.

### 2.2. Reservoir Sedimentation in Ethiopia

Sedimentation is a serious problem in reservoirs in the river system within Ethiopia; the existing condition of reservoirs showed that a significant portion of the storage capacities was lost due to sedimentation every year. Earlier studies on sediment yield and impacts, conducted mainly in northern parts of the country had shown that spatial variability of sediment yield in that region was generally higher. The frequent power cuts and rationing-based electric power distribution recently experienced in the country have partially attributed to storage loss due to sedimentation. Haile and Govers (2006), conducted research in Tigray, southern Ethiopia and resulted in specific sediment yield values between 237 to 1817 ton/ km<sup>2</sup>/year. Similarly, Belete, (2013), studied on the impact of sedimentation on the hydrological status of Lake Hawassa, in southern Ethiopia with hydrographic survey methods, used an echo sounder for depth measurement by 500m\*500m grid spaces. He concluded that the annual reduction in storage capacity of Lake due to sedimentation was about 0.08%.

Zeberie,( 2020), conducted study on the Upper Awash basin, with the title of assessment of sediment yield and conservation practices in Akaki watershed. His study focused on estimating the sediment yield, determining the spatial variability of sediment yield and evaluating different scenarios to reduce sediments. From the result of the study, it could be concluded that the average annual yield of sediment for all watersheds was 2.12ton/ha/year.

The Koka reservoir has been formed as a result of construction of the Koka dam in 1959 for developing hydroelectric power for Ethiopia. The inflow to the reservoir is supplied by the Awash basin and Mojo Rivers. The total sediment deposited in Koka reservoir in period 1961-1981 has been estimated at 0.34km<sup>3</sup>, yielding an average of 17Mm<sup>3</sup>yr (Shahin, 1993).

Similarly, Abdulmenan, 2014, studied, sediment yield estimation on upper Awash watershed. The objective of his study was to forecast sediment yield from watershed and to evaluate the sediment inflow into Koka reservoirs. He concluded that the forecasted and observed sediment yields matched well.

Tenaw, 2020, study on upper blue basin with title investigation of reservoir sedimentation using geographic information system and remote sensing approaches and his methodology was tested in Koga, Shina and Selamko reservoirs all in the Upper Blue Nile basin. His result indicated that Koga reservoir has reduced from 83.10 to 81.179 Mm<sup>3</sup>, showing annual storage loss of 0.33%. For Shina and Selamko reservoirs annual storage loss due to sediment deposition was found to be 1.67% and 2.29% exceeding the annual average worldwide rate for reservoir sedimentation of 1%. Consequently, the annual rate of sedimentation was found to be  $27 \times 10^4$  m<sup>3</sup>/year for Koga,  $2.1136 \times 10^4$  m<sup>3</sup>/year for Shina and  $2.3755 \times 10^4$  m<sup>3</sup>/year for Selamko reservoir.

According to (Borji, 2013) with the topic “ sedimentation and sustainability of hydropower reservoirs case in Grand Ethiopian renaissance dam in Ethiopia” and concluded that downstream inside Sudan, in rosaries reservoir, the average annual sedimentation rate at rosaries was 1.8% between 1966 and 1985. 335m<sup>3</sup> of initial capacity lost over 19 years of operation. The risk of losing storage capacity in the long term due to reservoir sedimentation is series for hydropower projects in the area and the main issue concerning sustainability of reservoir.

The Grand Ethiopian Renaissance Dam (GERD), also known as Millennium dam and locally referred to as ‘Hidase Dam’, is an under construction gravity dam. The GERD project is located approximately 750 km northwest of Addis Ababa and 40 km East of Sudan. The dam is a single purpose hydroelectric facility which controls about 177,700 km<sup>2</sup> of the Blue Nile Basin. The reservoir at 74 billion m<sup>3</sup> storage capacity will be one of the continent’s largest manmade reservoirs. The project has envisaged a power plant with an installed capacity of 6,000 MW and 15,692 GWh annual energy.

Table:2.1. Estimated sediment yield at different locations in the Blue Nile Basin (Borji, 2013)

| Station  | Area<br>(km <sup>2</sup> ) | SSL<br>(million<br>t/year) | Total load<br>(million<br>t/year) | Specific<br>Sediment<br>yield (t/km <sup>2</sup> ) | Method                                                           | Year       |
|----------|----------------------------|----------------------------|-----------------------------------|----------------------------------------------------|------------------------------------------------------------------|------------|
| Kessie   | 64,060                     | 188                        | 217                               | 3384                                               | Rating curve                                                     | 1973-2009  |
|          |                            | 143                        | 165                               | 2576                                               | Rating curve                                                     | 1973-1994  |
|          |                            | 154                        | 177                               | 2774                                               | Rating curve                                                     | 2009       |
|          |                            | 154                        | 177                               | 2774                                               | Average<br>concentration                                         | 2008-2010  |
|          |                            | 147                        | 169                               | 2640                                               | Average<br>concentration                                         | 2009       |
|          |                            | -                          | 134                               | 2100                                               | SDR (55%)                                                        |            |
| Burie    | 94,490                     | 218                        | 250                               | 2645                                               | Average<br>concentration                                         | 2008-2010  |
| Guder    | 524                        | 0.044                      | 0.05                              | 97                                                 | Rating Curve                                                     | 1960- 2001 |
| Tato     | 43                         | 0.009                      | 0.01                              | 247                                                | Rating Curve                                                     | 1996- 2004 |
| GERD     | 177,700                    | -                          | 187                               | 1052                                               | SDR (45%)                                                        |            |
| El-deim  | 178,200                    | 161                        | 187                               | 1050                                               | Average<br>concentration                                         | 1970-1994  |
|          |                            | 130                        | 150                               | 839                                                | Average<br>concentration                                         | 1993       |
| Roseires | 195,000                    | -                          | 155                               | 795                                                | Bathymetric<br>survey (deposit<br>density=1 t/m <sup>3</sup> )   | 1966-2007  |
|          |                            | -                          | 186                               | 954                                                | Bathymetric<br>survey (deposit<br>density=1.2 t/m <sup>3</sup> ) | 1966-2007  |

According to (Bui *et al.*, 2010), with title on trap efficiency of reservoirs on the Nile River that the reservoir will lose about 41% of its storage capacity due to sedimentation after 100 years with flushing schemes. Furthermore the trap efficiency and the reservoirs lifetime within the Nile River basin can be well quantified using these findings.

Haregeweyn and Tsunekawa (2011) conducted a study on Angereb reservoir for sedimentation evaluation using bathymetric surveys in 2005 and 2007. The reservoir surface area and capacity at each 1-m elevation distinction have been generated based on (x, y, z) data collected. The result showed that the annual total potential loss all through 1997-2005, 1997-2007 and 2005-2007 used to be estimated at 4.02%, 3.16% and 3.03% respectively, and the extremely reducing trend is attributed to the effect of limited soil and water conservation practices implemented in the watershed at the later stage of the dam project.

In 1980, the BCEOM investigated Legedadi and Gefersa reservoirs in different ways and generated maps for both reservoirs. A study was carried out with, bathymetric surveys, hydrologic analysis and reservoir operation. Bathymetric maps were produced for the Legedadi and Gafarsa Reservoirs. Moreover, frequency analysis of annual peak rainfall depth and inflows into the reservoirs were computed for the period 1958 to 1979. The average annual inflow into Legedadi Reservoir was estimated at 64MCM (million cubic meters). Similarly, AESL (1993) estimated the annual sediment yield of Legedadi reservoir was 4.5MCM as an average value over 13 years (1979 to 1992).

According to (Yonas, 2018), the sedimentation rate obtained using remote sensing data can be explained on the basis of accuracy in the determination of water spread area and the mixing of water pixels with the land around the periphery of the reservoir. The application of remote sensing techniques for estimating the sedimentation rate in the Gibe 1 reservoir shows that the average sedimentation rate for 27 years (1990-2017GC) is 0.675 Mm<sup>3</sup>/year, whereas ground observations through hydrographic survey provided a sedimentation rate of 0.845Mm<sup>3</sup>/ year for the period of (1990-2017GC).

The comparison of the result from the two different approach showed that the estimated deposition rate ranged 0.675-0.845Mm<sup>3</sup>/year. For the subsequent prediction of the reservoir deposition, a mean value of 0.17 taking into consideration a safety factor 0.2 for predicting the reservoir sedimentation empirical area reduction method can be used. This study is applied only once in 27 years, it should be applied with in some interval.

Sedimentation results for 2017GC from remote sensing techniques that are comparable with 1990GC hydrographic survey further confirms the applicability of remote sensing for sedimentation analysis for medium reservoirs. Reservoir play an important role for the generation of power, and should be regularly monitored for sedimentation to ensure that corrective measures are taken in time. The results also show that sedimentation rates in Gibe 1 reservoir are comparable with sedimentation rates recorded within the country and region. Corrective measures have to be put in place to ensure that the useful life of reservoir in not compromised in the near future.

In 1998, TAHAL Consulting Engineers has carried out a bathymetric survey on the reservoir and the bathymetry survey of 1979 was established. A comparison of both bathymetries resulted in an average annual sediments accumulation of 110 000 m<sup>3</sup>. This amount represented a loss of 0.25% of live storage.

A study was done by (TAYE, 2009), on impacts of land use land cover change on catchments Hydrology and water quality of Legedadi-Dire Catchment. The main objective of his study was to identify the scale of the impact of land-use change on Hydrology and water quality and suggest remedial measures by using advanced distributed parameter hydrologic model SWAT (Soil and Water Assessment Tool).SWAT calculates the soil erosion and sediment yield within each hydrologic response unit (HRU'S) Within Each Sub Basin. The output of the SWAT model has shown that there has been an increase in sediment yield of about 61.5%and 21.5% in Legedadi and Dire catchment. Sisay and Mogesie, (2014), study showed that land use land cover change on soil erosion potential in Legedadi watershed. And found that continuous and active LULC change was due to human use component rather than the natural changes in the study area. In the study area analysis of input data of LULC six Major LULC classes were identified for each study year.

In general, Sedimentation is a significant issue that reduces the storage capacity of reservoirs gradually and this in turn leads to make the shortage/scarcity of usable water body as general unless managed carefully. Particularly, Legedadi Reservoir, the sedimentation directly influences reservoirs storage capacity and satisfaction of water demand, especially, for Addis Ababa city people.

This implies that sedimentation assessment on the reservoirs and remedial measures should be performed. In other words, Sedimentation in a reservoir is always a tedious problem and it is very dangerous to accurately measure the volume of sediments in a reservoir. Traditionally assessment of reservoir sedimentation was done by hydrographic method. But, by using remote sensing techniques it becomes quite easy to compute reservoir sedimentation with less error time (Prasad and Tiwari, 2019).

### 2.3. Impact of Reservoir Sedimentation

The major impact of sedimentation was to decrease storage capacity of reservoir, which leads to a serious problem on water resources development by reducing water supply; hydropower production, the supply of irrigation water, and the effectiveness of flood manipulate schemes. Growth of the delta deposits at the upstream end of the reservoir due to deposition might cause improved flooding or possibly a rising groundwater level in the backwater upstream. Sediment trapping and flow control aggregates also have a drastic impact on the ecosystem, transparency of water, balance of sediments, nutrient budgets, and downstream river morphology of the reservoir. As such, reservoir sediment accumulation was most likely the major issue that impeded the sustainable use of surface water supplies that have already been built and will be developed in the future Wang, Wu, and Wang, (2005). Among the impacts: reduction in volume, increase in turbidity, and loss of life expectancy of reservoir were the most essential ones Issa *et al.*, (2015).

#### 2.3.1. Reduction in Volume

Sedimentation is the major factor that affects the storage capacity of reservoir by increasing the level of sediment deposit within the reservoir. The loss of storage, associated with water supply for domestic use. So that Reservoir sedimentation could be a critical issue in Legedadi reservoir. Sediment aggregation in supplies diminishes their capacity and limits their valuable life in case it isn't controlled in a few ways. When a barrier was constructed over a stream, the stream cross-area dynamically increments and the stream velocity decrease toward the dam. The velocity flow and energy of watery has condensed as the stream entered to reservoirs, most of this sediment settles to the bottom of reservoir where it becomes trapped.

Over many years without sustainable management, the sediment will gradually displace the volume that was previously used for water storage until the reservoir becomes filled with sediment (Alias and Mansor, 2017).

The water spread area of the reservoir reduced with sedimentation at a given level and those utilized for assessment of reservoir capacity (Patil, Mukhopadhyay and Kulkarni, 2018).

The reservoir capacity between two elevations was computed by Trapezoidal formula using water spread areas obtained by:

$$V_{12} = \frac{H_{12}}{3} (A_1 + A_2 + \sqrt{A_1 * A_2}).$$

Where,  $V_{1-2}$  = Volume between elevation  $E_2$  and  $E_1$  ( $E_2 > E_1$ )  $\Delta h = E_2 - E_1$

$A_1, A_2$  = Water spread areas at elevation  $E_1$  and  $E_2$

The overall reduction in capacity between the lowest and the highest observed water levels can be obtained by adding the reduced capacity at all levels.

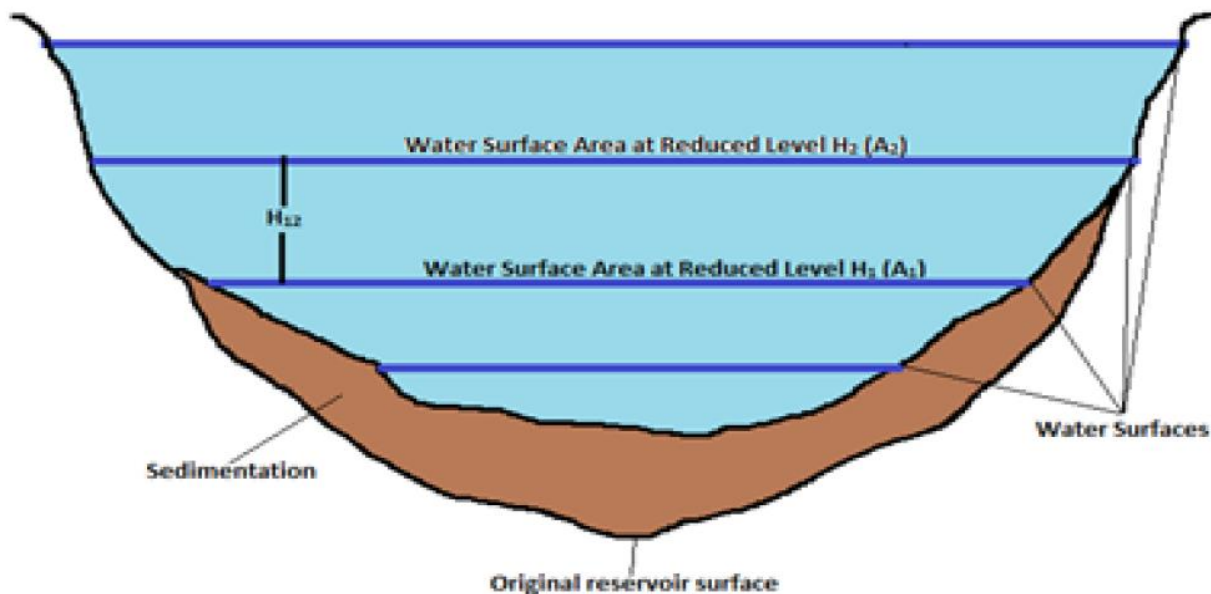


Figure: 2. 1. Reservoir sedimentation and impacts on reservoir water surface areas

(Mupfiga and Mudereri, 2016)

The volume of sediments deposited below the level cannot be determined by remote sensing knowledge. Therefore, the quantity of the reservoir below followed level is assumed to be identical before and on one occasion of sedimentation (Avinash and Chandramouli, 2018).

### 2.3.2. Increase Turbidity of Water

Turbidity is a measurement of how cloudy the water is in a lake or river. Particulate include sediment - particularly clay and silt, first-class organic and inorganic matter, solvent-colored organic compounds, green growth, and other microscopic organisms. Turbidity can also increase water temperature because suspended fragments absorb greater heat. High turbidity can reduce

the aesthetic great of lakes and streams, having a harmful impact on recreation and tourism (Quality, 2008). White, (2010), Concluded that most of the sediment that was scoured from the land surface was transported in watercourses as a suspended load. These fine sediments account for the turbidity typically determined in rivers and their fall velocity in water is therefore low that the turbulence maintains them in suspension. A tiny proportion of the sediment, maybe around 10 percent, is coarser material that is transported as bed load. Coarser sediments tend to be deposited towards the upstream finish of reservoirs whereas the finer sediments accumulate additional downstream. Throughout the early stages in the life of a reservoir, abundant the incoming sediment is cornered and forms areas of alleviation that progress downstream from the upstream finish of the reservoir.

However, as the volume of the reservoir diminishes a lot of the incoming sediment passes through the reservoir due to increasing water velocities and reducing times of residence.

### 2.3.3. Life of Expectancy of Reservoir

The life Expectancy of the reservoir is usually calculated from the ratio of storage capacity to the mean annual sediment yield trapped in the reservoir. The analysis of reservoir sedimentation requires an understanding of the physical process to predict possible changes in sediment during the lifetime of the reservoir. The life of the reservoir is reduced when the rate of sedimentation is higher than the design rate (Garg and Jothiprakash, 2008).

Reservoir shape is a vital thing in calculating the deposition profile. For example, the flow coming into a huge reservoir spreads out, accordingly lowering transport capacity, but the direction of expanding float does no longer necessarily follow the reservoir boundaries (Ezugwu, 2013)

## 2.4. Factors Affecting Sediment Yield

The amount of sediment generated within a catchment depends on several hydro-metrological topographical and land-use factors. Several factors influence the yield of sediment: the key factors are Land use, soil type, size of catchment, climate, and rainfall (Imanshoar *et al.*, 2014).

### I. Climate

The climate has continually been determined to own a powerful influence on erosion and sediment yield. Larger the raindrop size and larger the rain intensity additional the soil splash in inter-rills. The presence of land flow will increase the discharge capability and splash capability of the raindrops. The temperature plays a crucial role within the method of weathering that ends up in the disintegration of rocks. The rate of erosion and sediment yield is found to extend if the precipitation is focused throughout one season rather than being nearly uniformly distributed over the year.

## II. Topography

Catchment area, relief, and drainage density are several factors associated with construction topography that are found to influence sediment yield. Speed of land flow and hence the shear stress on the land surface and transport capability are more responsible for erosion.

## III. Land use

Effects of land use on sediment yield are closely joined to those of climate, earth science, and soil characteristics. Vegetation or plant cover reduces erosion, its effectiveness relying upon the peak and continuity of cover, the density of ground cover, and root density. Roots play a crucial role in reducing erosion rate by binding the soil mass to extend its resistance to flow. Usually, forests are simplest in reducing erosion thanks to their canopy; dense grass is equally effective.

## IV. Geology

The interdependency among climate, land use, and soil/geology makes it troublesome to find the precise role compete by soil and earth science in sediment yield production. It is understood that geological conditions indirectly influence the vegetation and thus its result is indirectly enclosed if vegetation cowl is taken joined by the factors sensitive erosion and sediment yield.

### 2.5. Method of Assessing Reservoir Sedimentation

The methods used to check sedimentation in a reservoir can be classified into three groups:

#### A. Inflow–Outflow method

In this method, water and sediment inflow into the reservoir as well as their outflow are measured at all giant factors of entry and exit. The distinction between the sediment influx and outflow offers the extent of sediment deposited in the course of the given period. Outflow from the reservoir can take place through the spillway, low-level outlets, and irrigation canals(Dadoria, Tiwari, and Jaiswal, 2017).

#### B. Capacity Survey Method

The capacity Survey methods typically remarked as a geological phenomenon or hydrographic surveys may be a direct measuring procedure, geared toward assessing the quantity and spatial distribution of the sediment deposited in an exceeding reservoir through periodic surveys. Conventionally, these surveys measure conducted victimization instrumentality like theodolites, plane tables, sextants range finders, sounding rods, echo sounders, and slow-moving boats. Reservoir surveys have many advantages: they can be less costly than continuous sediment measurements undertaken at several locations; the accuracy of these surveys is usually very high (Dadoria, Tiwari, and Jaiswal, 2017).

Yan *et al.*, (2018), concluded that a hydrographic survey is an exact method to measure the distribution pattern of sediments and volume occupied.

The whole deposit load (bed and suspended load) transported by way of the river, and the time required for a survey can be extensively reduced via the use of advanced equipment. The foremost limitations are that these surveys do not provide any statistics regarding the temporal variability of the sediment enter and only supply facts on the whole amount of sediment accumulated since the remaining survey. The survey conducted using conventional methods takes a month to collect data, during such a long time survey, the siltation pattern and bed level would also change (Goel, Jain and Agarwal, 2002).

The difference between the traditional approach and the method based on remotely sensed data is the calculation for water surface area, which is obtained by measurement of the topographic map with the electronic Plato meter for the traditional method, but calculation of the processed RS images for the latter (Peng *et al.*, 2006b).

The contour and range methods are the two basic approaches used for reservoir surveys. In some situations, a combination is used.

Moreover; the prediction of sediment deposition profiles using mathematical models requires large quantities of records that are rarely available. As a result, the potential for using remote sensing strategies has attracted considerable interest in latest years (Jain and Jain, 2011)

### C. Remote sensing method

Remote sensing is the art, science, and technology of observing an object or phenomena by instrument-based techniques. Remote” because observation is done at a distance without physical contact with the object of interest. Remote sensing-based reservoir sedimentation assessment is based on representing of water spread area at the time of satellite (Mandwar, Hajare and Gajbhiye, 2013).

Hydrographic surveys for reservoirs in a hilly region with thick vegetation within and around reservoirs pose great difficulties despite high-tech systems. Apart from the time factor, these hydrographic surveys are not cost-effective and therefore cannot be carried out regularly at shorter intervals for purpose of monitoring reservoir sedimentation.

According to (Shendge and Chockalingam, 2016), remote sensing has the capability of providing a large amount of data of the whole earth and also very frequently.

The water spread area of a reservoir at a given water stage or elevation will gradually reduce. A series of remote sensing images covering a range of reservoir water levels (over one or more water years) can, therefore, be obtained. These images are analyses to determine the floor place of the water structure at the time of the satellite overpass on special dates. The remote sensing method uses the phenomena of satellite imageries representing a two-dimensional water spread area of a reservoir that changes through the years due to sedimentation. The change in volume of a reservoir over years gives an estimate of the sedimentation rate(Publications *et al.*, 2015).

In general, for sedimentation assessment one can use the three methods described above based on situations. But for this study, the remote sensing method is used for assessing sediments of the Legedadi reservoir. Because this method has the capability of providing a large amount of data of earth and very frequent and also can be carried out regularly at a shorter interval for monitoring sedimentation accumulation. It is also a cost and time-effective tool to estimate the capacity loss of sedimentation during the assessment. Current technologies such as geographical information systems (GIS) and remote sensing make available a cost-effective and accurate to understanding countryside dynamics. Digital change detection techniques based on multi-temporal and multi-spectral remotely sensed data have established a great potential as a means to understanding landscape dynamics- detect, recognize, map, and observe differences in land use/land cover patterns over time, irrespective of the causal factors.

## 2.6. Application of remote sensing and GIS in reservoir sedimentation

Remote sensing is useful for estimating sedimentation in the reservoir where rise and fall of water level is a regular phenomenon. It is known established that sedimentation in reservoirs takes place at different levels causing shrinkage in water spread (Jaiswal *et al.*, 2017).

Remote sensing data is used to provide elevation contours and water spread region of every contour and amount of reservoir at different water levels of a reservoir (Tikal, Sorgul and Balakarzai, 2017).

Several studies have been conducted on reservoir sedimentation assessment by using remote sensing and the GIS model. GIS has huge potential as an associate degree setting for the conception of dynamic models of physical environmental processes (Irhoumah, Agarwal and Lal, 2014), (Rimal, 2011)

A study was conducted by (Vishwakarma, Tiwari and Jaiswal, 2015) on reservoir sedimentation assessment using remote sensing and GIS method and concluded that remote sensing techniques can be used as cost and time-effective tools to estimate the capacity loss.

Pandey *et al.*, (2016), concluded that from satellite remote sensing of Patraru Reservoir, the live storage capacity of reservoir was reduced to 89.96hm<sup>3</sup> from 101.95hm<sup>3</sup> showing an 11.76% loss in its original capacity. Additionally, in order to get a true picture of sediment deposition in the reservoir, an integrated survey by carrying out a hydrographic survey below MDDL and multispectral analysis from MDDL to FRL would be more appropriate.

In addition, Mupfiga and Mudereri, (2016) with the title on assessment of sedimentation in Tuli-Makwe Dam in the semi-arid Mzingwane Catchment in the Matabeleland South province of Zimbabwe using remotely sensed data. The loss of reservoir gross capability due to sediment deposition capability for forty-seven years since the development of the dam in 1966 to 2013 was resolute to be 3.371Mm<sup>3</sup> that translates to 40.84% capacity losses. The reservoir capacity is calculated to 4.883 Mm<sup>3</sup>. The annual rate of geological phenomenon was calculated to be 0.87%

once a year that interprets to  $0.0717 \text{ Mm}^3$  once a year. The precise sediment yield over Tuli-Makwe construction was calculated to be  $110.63 \text{ ton} / \text{km}^2 / \text{year}$ . The results of the geological phenomenon analysis are typical of small reservoirs in semi-arid regions in Southern Africa loss. The geological phenomenon results for Tuli-Makwe reservoir exploitation remote sensing for 2013 are comparable with geological phenomenon results from the 2012 hydrographical survey.

#### 2.6.1. Application of remote sensing data

According to Jaiswal *et al.*, (2017), the assessment of new capacity with the help of digital image analysis of remote sensing data is possible to determine current water spreads at different levels and in his study, an attempt has been made to apply remote sensing data for computation of sediment pattern in dead storage zone by extrapolated of best fit line current water spreads with reservoir levels and determine new reservoir bed and current volumes in dead storage zone which in turn gave the volume of total sediment.

The results of computed reservoir capacities were compared with the capacities obtained from remote survey to assess the use of remote sensing methodology for determination of new bed and sedimentation in dead storage zone of reservoir. Foteh *et al.*, (2018), suggest that remote sensing has become capable to compute the sedimentation in a reservoir and assessing distribution and deposition patterns.

Issa *et al.*, (2015), With a title of Monitoring and Evaluating Sedimentation in Mosul Dam Reservoir using trap efficiency, that a bathymetric survey of a reservoir was conducted in 2011 after 25 years of dam operation and results showed that  $1.143 \text{ km}^3$  of sediment has accumulated over a period of 1986-2011. this represents an annual sediment deposition rate of  $45.72 \times 10^6 \text{ m}^3 \cdot \text{yr}^{-1}$ . As a result, the reservoir lost 10.29% of its storage capacity. The survey results were used to construct area storage capacity curves. The result indicates that water depth below the normal operating level at the dam site was 83m in 1986 and current in 2011 it was about 80m due to sedimentation.

#### 2.6.2. The Component in remote sensing

- i. Platform: the vehicle which carries a sensor. Such as satellites, aircraft, balloons, etc.
- ii. Sensors: Device that receives radiation and converts it into a signal that may be recorded and displayed as either numerical knowledge or a picture. One Platform carries more than one Sensor.

#### 2.6.3. Types of Remote Sensing:

Remote sensing can be either active or passive. The active system has its source of energy such as (RADAR) whereas the passive systems depend upon an external source of illumination (such as SUN) or self-emission for remote sensing.

- I. Active Remote Sensing: instruments send out a signal of radiation at a particular length.
- II. Remote Sensing: instruments either use the sun as the source of radiation emitted by the earth's surface or atmosphere.

#### 2.6.4. Reflectance Characteristics of Earth's Cover types in Remote sensing imageries

The spectral characteristics of the three main earth surface features in the land sat imageries are:

**Vegetation:** The spectral characteristics of vegetation shift with wavelength. Plant shade in clear out called chlorophyll emphatically assimilates radiation within the ruddy and blue wavelengths but reflects green wavelength. The inside structure of the solid clears out acts as a diffuse reflector of close infrared Wavelengths. Measuring and observing the close infrared reflectance is one way that scientists Determine how sound specific vegetation may be.

**Water:** The larger part of the radiation incident upon the water isn't reflected but is either ingested or transmitted. Longer obvious wavelengths and close infrared radiation are retained more by water than by the unmistakable wavelengths. In this way, the water looks blue or blue-green due to more grounded reflectance at these shorter wavelengths and darker in the event that seen at ruddy or closes infrared wavelengths. The components that influence the inconstancy in reflectance of a water body are profundity of water, materials within water and surface harshness of water.

**Soil:** The majority of radiation occurrence on a soil surface is either reflected or ingested and small is transmitted. The characteristics of soil that decide its reflectance properties are its dampness content, natural matter substance, surface, structure and press oxide substance. The soil bend appears less top and valley varieties. The nearness of dampness in soil diminishes its reflectance. For illustration, Water and Vegetation reflect some degree so also within the obvious wavelength but not within the infrared.

#### 2.7. Landsat 8

Landsat-8 represents the most recent satellite in series of earth remote sensing tasks back to 1972. These satellites have collected and archived moderate resolution knowledge of the complete Earth's land surface long enough to be helpful for observance trends and evaluating however land use has modified. Applications of Landsat data include agriculture, land mapping and change detection to uses in fresh and coastal waters and snow and ice. According to (M. A. Ridwan *et al.*, 2018) Landsat 8 sensor is divided into Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). Data for a visible, panchromatic band, short-wave infrared spectral bands are collected by the OLI while TIRS collect images in the thermal region.

The Landsat eight mission objectives are to supply timely, top-quality visible and infrared pictures of land near-coastal areas in the world. Data input into the system is sufficiently consistent with currently archived data in terms of acquisition geometry, calibration, coverage, and spectral characteristics to allow for comparison.

As with all Landsat data, products are available at no cost to the user. Available data can be

Viewed through a number of interfaces:

 Earth Explorer

-  Global Visualization Viewer
-  Landsat Look Viewer\

According to (Program, 2013) The OLI sensing element collects image information for 9 shortwave spectral bands over a 185 km swath with a thirty m spatial resolution for all bands except the fifteen m panchromatic band. The widths of a few OLI groups are refined to maintain a strategic distance from climatic absorption features inside ETM+ groups.

OLI has exacting radiometric performance prerequisites and is required to deliver information calibrated to the instability of less than 5% in terms of absolute, at-aperture spectral radiance and to an uncertainty of less than 3% in terms of top-of-atmosphere spectral reflectance for each of the spectral groups.

#### 2.7.1. Thermal Infrared Sensor (TIRS)

TIRS is additionally a thrust broom sensor utilizing a central plane with long clusters of photosensitive finders. TIRS have a high degree long wave warm infrared vitality radiated by the Earth's surface, the intensity of which may be a work of surface temperature. The TIRS is touchy to two warm infrared wavelength groups, enabling partition of the temperature of the Earth's surface from that of the environment. The lifted electrons make an electrical flag that can be studied out, recorded, interpreted to physical units, and utilized to make a digital image.

#### 2.7.2. Applications of Landsat

Landsat data are used by government, commercial, industrial, civilian, military, and educational communities throughout the United States and worldwide. Satellite imagery is images of earth or other planets gathered by way of imaging satellites operated through governments and corporations around the world. Satellite imaging corporations promote images via licensing them to governments and corporations like Apple Maps and Google Maps (Domain et al., 2013).

Landsat is the oldest continuous earth observing satellite imaging program. Optical Landsat imagery has been collected at 30m resolution since the early 1980s. Starting with Landsat 5, thermal infrared imagery was also collected (at coarser spatial resolution than optical data). The Landsat 7 and 8 satellites are currently in orbit. Landsat 9 is planned.

According to M A Ridwan *et al.*, (2018) Landsat was earlier used particularly for remote sensing, however, it's evolved in additional numerous fields like international modification analysis, agriculture, forestry, geology, resource management, geography, mapping, water quality, and coastal studies.

#### LANDSAT 5 Thematic Mapper (TM)

The Landsat five thematic mapper (TM) was launched on March one, 1984 with 2 sensors: the Multi-Spectral Scanner (MSS) and also the Thematic Mapper(TM). The thematic device was designed to considerably improve the spatial and spectral resolutions, geometric and radiometric accuracies compared to Landsat 1-3 MS device. Extra mid-IR bands and a thermal channel were

added to attain improved spectral resolution than the MSS device. Landsat TM has multiplied spectral and spatial characteristics in contrast with MSS. Both Landsat TM and MSS are Optical-Mechanical whiskbroom sensors: they use oscillating mirrors to furnish cross-track scanning all through the ahead motion of the space platform. TM scans in both directions but MSS scans in one direction.

MSS had no shortwave infrared or thermal wavelength bands and coarser spatial, spectral and radiometric resolution compared to later Landsat sensors.

Table:2.2. MSS band Descriptions

| Landsat 1-3 spectral bands | Landsat 4,5 spectral bands | Wavelength( $\mu\text{m}$ ) | Resolution(m) |
|----------------------------|----------------------------|-----------------------------|---------------|
| Band4-green                | Band1-green                | 0.5-0.6                     | 80            |
| Band5-red                  | Band2-red                  | 0.6-0.7                     | 80            |
| Band6-NIR                  | Band3-NIR                  | 0.7-0.8                     | 80            |
| Band7-NIR                  | Band4-NIR                  | 0.8-1.1                     | 80            |

Source (Program, 2013)

#### LANDSAT 7 Enhanced Thematic Mapper Plus (ETM+)

The Landsat seven ETM+ was launched on April fifteen, 1999 following the failure of Landsat's half-dozen ETM+ to realize orbit. The world observant instrument on Landsat-7, the improved thematic mapper and (ETM+), offers an increased version of the thulium device and provides continuity of the Landsat five sensors. Compared to the thulium, the ETM+ instrument provides a full aperture five the radiometric standardization, a panchromatic band with the next abstraction resolution of fifteen meters, and a thermal IR band with sixty abstraction resolutions.

Table:2.3. Landsat 7 and 8 with their resolution and wavelength

| S. N | Landsat 7 Enhanced thematic mapper plus(ETM+) |                      |              | Band    | Landsat8 Operational Land Imager (OLI) and Thermal Infrared Sensor(TIRS) |                      |               |
|------|-----------------------------------------------|----------------------|--------------|---------|--------------------------------------------------------------------------|----------------------|---------------|
|      | Resolution(m)                                 | Wavelength( $\mu$ m) | Band Name    |         | Band Name                                                                | Wavelength( $\mu$ m) | Resolution(m) |
| 1    | 30                                            | 0.45-0.52            | Blue         | band 1  | Ultra Blue                                                               | 0.435-0.451          | 30            |
| 2    | 30                                            | 0.52-0.6             | Green        | band 2  | Blue                                                                     | 0.452-0.512          | 30            |
| 3    | 30                                            | 0.63-0.69            | Red          | band 3  | Green                                                                    | 0.533-0.590          | 30            |
| 4    | 30                                            | 0.77-0.9             | NIR          | band 4  | Red                                                                      | 0.636-0.673          | 30            |
| 5    | 30                                            | 1.55-1.75            | SWIR1        | band5   | Near Infrared                                                            | 0.851-0.879          | 30            |
| 6    | 60*30                                         | 10.4-12.5            | Thermal      | band 6  | SWIR1                                                                    | 1.566-1.651          | 30            |
| 7    | 30                                            | 2.09-2.35            | SWIR 2       | band7   | SWIR2                                                                    | 2.107-2.294          | 30            |
| 8    | 15                                            | 0.52-0.9             | Panchromatic | band8   | Panchromatic                                                             | 0.503-0.676          | 15            |
| 9    |                                               |                      |              | band9   | Cirrus                                                                   | 1.363-1.384          | 30            |
| 10   |                                               |                      |              | band 10 | TIRS1                                                                    | 10.6-11.19           | 100*30        |
| 11   |                                               |                      |              | band 11 | TIRS2                                                                    | 11.5-12.51           | 100*30        |

Source (Kshetri, 2020)

ENVI image analysis software is used by GIS experts, remote sensing researchers, and image experts to capture meaningful data from imagery to overcome well conclusions. ENVI can be organized and recovered from the computers, in the cloud, and on mobile tablets, and can be modified through an API to encounter precise scheme necessities (L3HARRISgeospatial). ENVI answers combine the newest spectral image analysis and image processing product with an in-built, accessible package help to get expressive data from imagery (whether it is panchromatic, LiDAR, SAR, multispectral or hyperspectral imagery). ENVI's algorithms have been scientifically proven, are easy to use, and are tightly integrated with the ArcGIS platform from Esri(Wikipedia/Harrisgeospatial).

### 2.7.3. Image Preprocessing

There are several types of errors that can be manifested in remotely sensed data. Among these are line dropout and striping. These mistakes can be corrected to an extent in GIS through radiometric and geometric correction. Striping or banding takes place if a detector goes out of adjustment that it gives readings persistently increased than or less than other detectors for the identical band over the same ground cover.

Preprocessing corrects or restores data before analysis so that it is close as possible to the radiant energy.

#### A. Radiometric correction

Any image involves radio metrical errors as well as geometric errors; this error should be corrected to avoid radiometric errors while geometric correction is to remove geometric distortion. Accurate geometry ensures that Land data pixels are aligned and the data can be used easily in time series analysis. Landsat Level-1 data products were georeferenced and geometrically corrected by Ground Control Point (GCP), in UTM Adindan Zone 37 N WGS 84 in the system. After the above task is done in the system, needs to carry-out layer stacking of all imageries/bands. Radiometric correction is done to calibrate the pixel values and/ correct for errors in the values. The process improves the interpretability and quality of remote sensed data. This task is done by ENVI 5.3 Software package.

#### B. Geometric correction

Each satellite image was geo-rectified employing an initial order transformation and resampled to the Universal Transverse Mercator (UTM) organization, zone 18 World geophysical sciences System (WGS 84) knowledge employing a nearest-neighbor interpolation formula. The nearest neighbor may be a resampling methodology, which preserves the first reflection factor worth of the image knowledge. Spatial resolutions of the two Landsat scenes were corrected from 28.5 to 30 m pixels.

#### C. Atmospheric correction

Is the process of removing the effects of the atmosphere on the reflectance values of images taken by satellite or airborne sensors. Atmospheric effects in optical remote sensing are significant and complex, dramatically changing the spectral nature of the radiation reaching the remote sensor. In this study atmospheric correction is done by using FLAASH method instead of DOS approach due to the accuracy of the methods.

#### 2.7.4. Digital Image Processing for Delineation of Water and Land Boundary

For delineation of the land and water pixels, the following methods were used for better accuracy.

##### 2.7.4.1. Generation of Contours

Contours of equal intensity (lines of equal digital numbers) were generated on the image. Contours that confirmed probable water-land delineation had been extracted and edited primarily based on Digital Number (DN) of more than a few bands.

The contour satisfying the condition  $DNNIR < DNR < DNG$  Infrared, R: RED, G: GREEN) at the maximum wide variety of pixels on the contour, is regarded as closing contour giving two delineations representing water unfold vicinity at that precise two elevations. This closing contour is then similarly edited for corrections.

#### 2.7.4.2. Thresholding Technique

After examining the histogram of the image, the stages of the NIR band for land/water boundary demarcation had been identified. The NIR band was once threshold into two to three ranges. The first range contained all tested water pixels and a mask was once created, second and third contained pixels at the land/water boundary and at the tail parts of the water-spread extending into river direction and masks were created accordingly.

The criterion for Thresholding the image should not provide nice results in identifying the correct water pixels due to shallow depth of water at some of the locations alongside the periphery and the tail component of the reservoir. Hence, proper water pixels in these two vary masks have been estimated by means of along with Thresholding of RED band statistics and similarly making use of the situation of reflective property of water for NIR and RED band. (The reflectivity of water in NIR band is smaller than a RED band and therefore the DN values of the NIR band will be smaller than DN values of the RED band for water). The total reservoir water spread area was estimated by adding the water spread masks under the different range masks (Narasayya *et al.*, 2002).

Accurate delineation of water and land boundary is performed by way of Thresholding Technique and the following techniques were adopted.

#### 2.7.4.3. Water Index (WI) Method

The water pixels are identified by taking a band ratio of Green/Near-Infrared. Since the maximum absorptance of Electromagnetic Radiation by water is in the Near Infrared (NIR) spectral region, the DN value of water pixel in the NIR band is appreciably less than the DN values of Green spectral region, which is having high reflectance value. This ratio separates the water body from soil/vegetation quite distinctly. (Nagar, 2005) decided that surface area of reservoir was determined by adding all pixels classified as water.

#### 2.7.4.4. Normalized Difference Water Index (NDWI) method

Normalized difference water index (NDWI) could be a new model developed to delineate open water features and to boost their presence in remotely perceived digital representational process whereas at the same time eliminating soil and terrestrial vegetation options. Fast and economical estimation of open water expanse in such digital representational process will then be created using image process software system. Also, the NDWI could convince be a great tool within the study of water quality problems, especially with relevant turbidity estimations. (Taylor and Mcfeeters, 2007)

NDWI Is Calculated By:  $\frac{Green-NIR}{Green+NIR}$

Where Green is a green band for Landsat-8 band 3, and NIR is a near-infrared band 5 for Landsat-8 and Green is a green band for Landsat-7 band 2, and NIR is a near-infrared band 4 for Landsat-7

NDWI is intended to

- Maximize reflectance of water with the aid of the usage of inexperienced wavelengths;
- Minimize the low reflectance of NIR by water features; and
- Take benefit of the high reflectivity of NIR through vegetation and soil types

NDWI greater than zero is assumed to characterize water surfaces while less than one or equal to zero is assumed to be non-water surfaces. According to (Environmental, 2019) NDWI is efficient to detect water surfaces because these surfaces have low surface reflectance in the NIR of spectral when compared to vegetation which is characterized by high surface reflectance.

#### 2.7.4.5. The Modified NDWI(MNDWI ) method

The NDWI is modified by substituting the MIR band for the NIR band to avoid the mixed up of water with buildup areas . In short, under normal conditions one finds high water content in the plant cells. This causes high inter-cellular reflection in the NIR and high absorption in the Middle Infrared Radiation (MIR)(Xu, 2006). In cases of less water content for example, in the cause of dryness; the NIR values could be expected to be slightly higher than under cold conditions and also the MIR values would clearly be higher, since less water absorption occurs. In case of frost damage, the internal cell structure of the leaves will be destroyed, resulting in a lower NIR reflection than MIR reflection. NDWI can enhance information about water bodies and restrict information about vegetation and soil features, but it cannot completely distinguish built-up features from water bodies.

MNDWI Is Calculated By:  $\frac{Green-MIR}{Green+MIR}$

Where Green is a green band for Landsat-8 band 2, and NIR is a Middle -infrared band 5.

#### 2.7.4.6.Land Use/Land Cover Classification

Various image preprocessing techniques will be practiced to increase the qualities of the image and to support the visual interpretation and classification of the satellite images. In remote sensing, image classification methods are classified into two major types, supervised (human-guided) and unsupervised (calculated by the software) classification.

Image classification is the foremost critical portion of digital image examination. The most objective of the image classification process is to classify all pixels in advanced images into one of a few land cover classes. This categorized information may at that point be used to deliver current maps of arriving cover show in image. Ordinarily, multispectral information utilized to perform the classification and, in fact, the spectral design display inside the information for each pixel is utilized as the numerical premise for categorization. Image processing takes an essential understanding of remote detecting and of advanced images through the basic stages of image preparing. It moreover gives a changed set of cases for application of picture preparing and presents a wide range of handling methods. These frame the premise for proceeded advancement to progressed level. It is the method of assigning each pixel of image to a specific group or class.

There are two primary classification strategies which are supervised classification and unsupervised Classification.

#### A. Supervised Classification

In supervised classification, the image processing software is conducted by the user to specify the land cover classes of interest. The user defines training sites, areas on the map that is known to a representative of the land cover type of interest. The software determines the spectral signature of the pixels within each training area.

The pixel in the image is then assigned based on spectral signature; to class, it most closely matches. Some of the most common algorithm for supervised classification includes: Minimum-distance to mean classifier, Parallelepiped classifier and Gaussian Maximum likelihood classifier. Supervised classification can be very effective and accurate in classifying satellite images. The supervised classification relies on the thought that a user will choose sample pixels in a picture that area unit representative of specific categories then directs the image process software package to use these training sites as references for the classification of all different pixels within the image. Unsupervised classification is wherever the outcomes (groupings of pixels with common characteristics) area unit supported the software package analysis of a picture while not the user providing sample categories (Olaode, Naghdy, and Todd, 2014).

#### B. Unsupervised Classification

Unsupervised classification could be a technique that examines an oversized range of unknown pixels and divides them into a variety of categories supported by natural groupings gift within the image values. Not like supervised classification, the unsupervised classification doesn't need analyst-specified training information. Unsupervised classification is the simplest technique. The mean digital worth for every input band may well be delineated as a spectral coefficient profile.

The cluster represents values around the mean for the land cover category. Once the category has been completed every class ought to be examined and assigned a reputation. It should even be necessary to merge a variety of categories into one class.

### C. Maximum likelihood Classification

Maximum likelihood Classification is applied statically criterion to assist in the category of overlapping signatures; pixels are assigned to the class of highest likelihood. The utmost chance classifier is taken into account to administer additional correct results than parallelepiped classification but it's a lot slower thanks to additional computations.

Maximum probability Classification could be an accurate choice model to help within the classification of covering marks; pixels are relegated to the course of most noteworthy likelihood. The most extreme probability classifier is considered to deliver more precise comes about than parallelepiped classification be that as it may it is much slower due to additional computations.

Generally, in the Literature reservoir sedimentation deposition studies are reported. A very few attempts have been made to check sediment yield and sedimentation altogether. It is well said that all reservoirs are subjected to sedimentation and the trouble of sedimentation can't be definitely stopped; however, it can be controlled by using quite several capabilities on the upstream reservoir watershed. Therefore, there is a need to recognize the behavior of the upstream catchment toward sediment yield alongside reservoir sedimentation.

### 3. METHODOLOGY

#### 3.1. Description of the study area

##### 3.1.1. Location

The Legedadi reservoir is located about 30km from Addis Ababa in the East direction. It is located in the upper north-western part of the Awash basin. Geographically, the reservoir is bounded by latitude 9 °01' N – 9°13' N and longitude 38°60' E - 39°07' E. The reservoir area covers a total area of 207 km<sup>2</sup>. The reservoir was constructed in 1970 to harvest run-off water during the rainy seasons for urban water supply, which was potable water for Addis Ababa City.

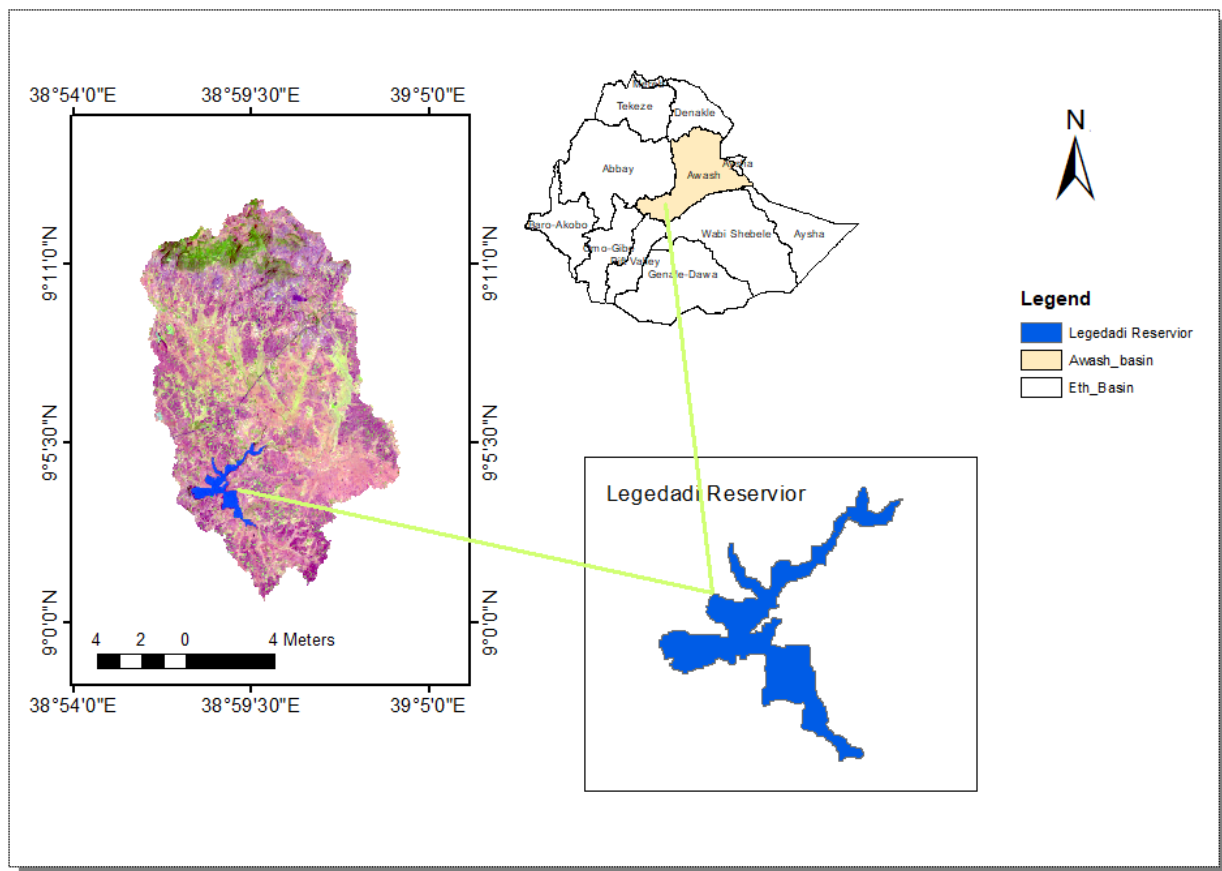


Figure: 3. 1. Map of the study area

### 3.1.2. Topography

The topography of the Legedadi reservoir is predominantly flat land constituting 70 % of all the landmass. 20 % of the land is undulating and the remaining 10 % is classified as valleys. Minimum, mean and maximum elevation of the reservoir is reported as 2,754, 2284, and 3228 mAMSL respectively.



Figure: 3. 2. Site view around Legedadi Reservoir (photo taken by Almaz in 2020)

### 3.1.3. Climate of Study Area

The climates of the project area, like any other part of Ethiopia, are characterized by four seasons. These are Bega (dry season, October-January), Kiremt (long rainy season from June to September), Belg (small rainy season from February - May) and Maker from November to December.

### 3.2. Data Sources:

For this study, secondary input data were collected from different sources. Landsat satellite images were downloaded from USGS Website, ASTER DEM and Top map of study area (1:50000) purchased from Ethiopian mapping agency. The main important part of the Landsat series data are available free of cost in public domain, efficient spatial resolution of (30m) and temporal (16days) resolution.

### 3.2.1. Satellite Data

The only useful information extracted from remote sensing data is water spread area at different dates during the data acquisition of the satellite over the reservoir area. Selection of suitable periods for analysis is a vital step in the study of reservoir sedimentation assessment using remote sensing data.

The multispectral data of satellite, Landsat sensor were available for the period of analysis and were used in this study. The data were obtained using Global Visualization Viewer interface, on the United States Geological Survey (USGS) platform. The Legedadi Reservoir water spread area was covered in one scene of Path 168 and Row 54 of the satellite this obtained (from EO-1 and Landsat archived on USGS server).

### 3.2.2. Digital Elevation Model Data (DEM)

ASTER (Advanced space borne thermal Emission and Reflection radiometric) was used for this study and this 30m by 30m spatial resolution DEM was imported to Arc GIS Environment to convert in the projected coordinate system of UTM Zone 37 N, WGS84. Each DEM grid cell contains a value corresponding to its actual elevation across the landscape in the real world. In this study, the DEM data was used to generate original reservoir area of Legedadi reservoir using global mapper 18.

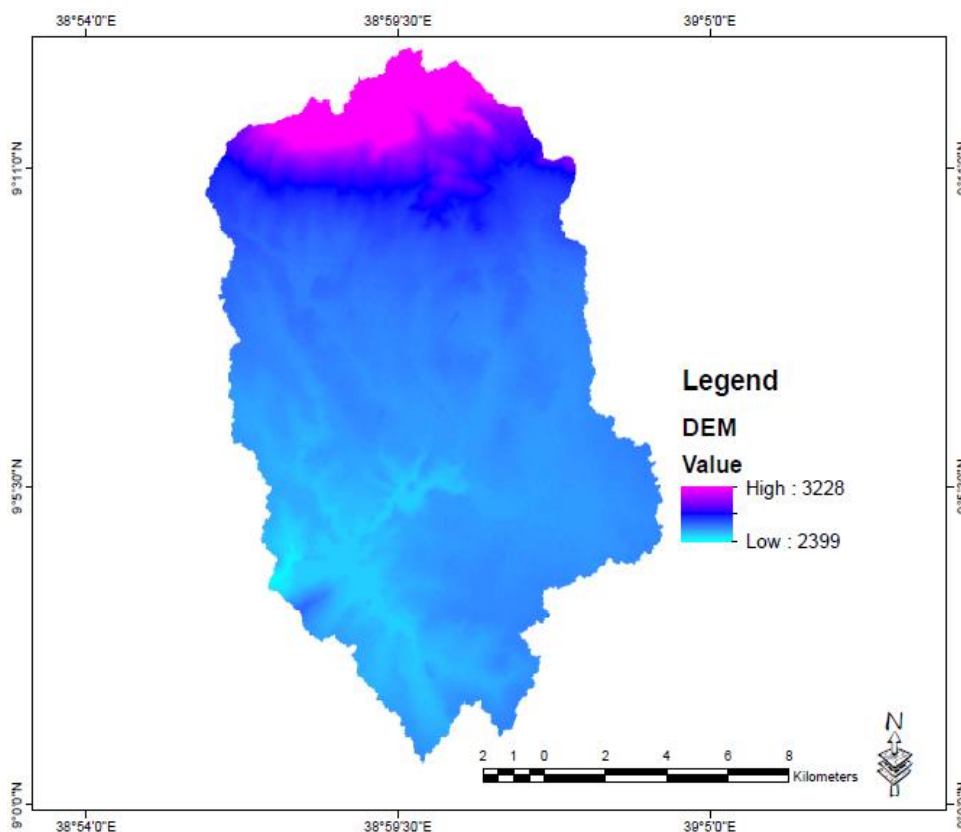


Figure: 3. 3.Digital elevation model of Legedadi reservoir

### 3.2.3. Land use /Land Cover

Multi-temporal Landsat imageries of MSS (1979), TM (1998), and ETM+ (2010) data were used to classify land use/land cover map of study area. They freely download from USGS website. Landsat images of 1979, 1998, and 2010 were collected for analysis. The reservoir is below full reservoir level during December, January, February, March and April and above full reservoir level in October and November. Landsat MSS (Multispectral scanner) images contains of 60m spatial resolution with 4 spectral bands.

Landsat Thematic Mapper (TM) images involve of seven spectral bands with a spatial resolution of 30 meters for Bands 1 to 5 and 7. Spatial resolution for Band 6 (thermal infrared) is 120 meters, but is resampled to 30-meter pixels.

Landsat 7 Enhanced Thematic Mapper Plus (ETM+) images consist of eight spectral bands with a spatial resolution of 30 meters for Bands 1 to 7. The resolution for Band 8 (panchromatic) is 15 meters. All bands can collect one of two gain settings (high or low) for increased radiometric sensitivity and dynamic range, while Band 6 collects both high and low gain for all scenes.

### 3.2.4. Topographic Maps

In order to visualize the landscape of the reservoir area, two medium-scale topographic maps have been purchased from Ethiopian mapping agency. Both topographic map at scale of 1:50,000, series(ETH4), Edition 2 EMA of sheet 0938D4 and Edition 1EMA 1986 of sheet 0939C3 were collected. These topographic maps had been color-coded for distinct land covers which include: reservoir settlement, streams, and forest area. The study about watershed boundary is additionally delineated based on these topographic maps.

## 3.3. Materials and Methods

Dadoria and Tiwari, (2017), suggest that remotely sensed data is commonly not complete for use directly but needs to undergo a series of preprocessing steps. Image process consists of processes aimed toward the geometric and radiometric correction, improvement, or standardization of images to enhance our ability to interpret qualitatively and improve our ability to interpret qualitatively and quantitatively image elements. In order to cover the intended period of study .Different types of imageries originating from different types of sensor were used. Therefore, 1979 Landsat Multispectral Scanner (MSS), 1998 Thematic mapper(TM) and Landsat Enhanced Thematic Mapper Plus (ETM+) of 2010 image over the 31 years (1979-2010) were used.

### 3.3.1. Image Pre-Processing

Digital image processing refers to manipulation and interpretation of digital images, by a computer system, to prepare an image for display and interpretation and to extract useful information from the image. Thus, Landsat satellite imagery data received from satellites need to be corrected before use. Then from the satellite image, the study area image has been extracted

by clipping the area of interest layer of the study area shape file from GIS in ARCGIS 10.4 Software. For each of them, digital image pre-processing operations such as image restoration, geo-referencing, and image enhancement have been done.

#### 3.3.1.1. Image Restoration

Prior to use and classification of any image information acquired from satellites, atmospheric effects and geometric distortions be eliminated and corrected. In order to able to work in GIS environment like overlying maps, the image must be linked to a coordinate system and projection of the globe. In this study images of MSS 1979, TM 1998, and ETM+ 2010 have been geo-referenced using topographic map UTM projection type, WGS spheroid, and in north direction 37 Zone.

#### 3.3.1.2. Image Enhancement

Image enhancement technique concerns the adjustment of an image to enhance its quality as perceived with the help of a viewer. A quantity of strategies can be applied to perform image enhancement. The most appropriate must be chosen to obtain the great color of images for visual interpretation. In order to improve the visualization of the images for the prospected classification different false and actual color composite in order of Red Blue Green (RGB) Were Produced for Different LULC elements identification and training site for supervised classification.

#### 3.3.1.3. Image Classification

The general objective of classification is to categorize all pixels in digital images into one of several land cover classes. The LULC study of the catchment was made based on 1979, 1998, 2010 satellite images and field observations. However, in this study since the data of satellite image is far from present ground observation data no need of field observations. Based on prior knowledge of study area and additional information from previous research of study area satellite image classification can be done based on two classification techniques namely supervised and unsupervised classification.

##### A. Unsupervised Image Classification

Unsupervised classification is a type of classification; the computer produces spectral classes based on the digital numbers without any course from the user. It offers preliminary records on the possible spectral clusters to be assigned to thematic classes. Therefore, subsets of the satellite data have been first categorized by the use of supervised classification. The class undertaking was carried out through evaluation of the categorized image with discipline observation.

##### B. Supervised Image Classification

This approach of classification unlike unsupervised ones needs training points and the analysis must have prior knowledge of study place in order to supply the software with special training

instructions in view that it was hard to become aware of all the land cover training only by using interpreting satellite images.

To perform the classification the maximum likelihood supervised classifier was employed. Training areas for all spectral classes were developed composing each information class to be identified by the classifier. Maximum likelihood classifiers, that measure wide used sort of supervised classification, assume the training information statics every for category in each band measure commonly distributed and calculates the chance that given pixel belongs to a specific class. In the maximum likelihood supervised classification procedure, each pixel is evaluated for its statistical probability of belonging in each category of the LULC classes and assigned to class with maximum probability.

Based on prior knowledge of study area and additional information from previous research of study area six different types of land use land cover have been identified from Legedadi Reservoir. Consequently, six classes were identified Legedadi Reservoir (water), Eucalyptus, Settlement area, Cultivation area, Grassland and Natural Vegetation.

According to Sisay and Mogesie, (2014), with title impact of land use land cover change on soil erosion in Legedadi watershed. The main objective of this study is to examine the impact of LULC change on soil erosion potential in Legedadi reservoir, and its implication on sedimentation problems. The result indicates continuous and active LULC change was observed at a variety of spatial and temporal scales due to human use component rather than the natural changes in the study area. in the study area based on analysis of input data of LULC six major LULC classes were identified for each study year.

Generally, major LULC classes in Legedadi reservoir were determined in the following table

Table:3.1 . Description of LULC types

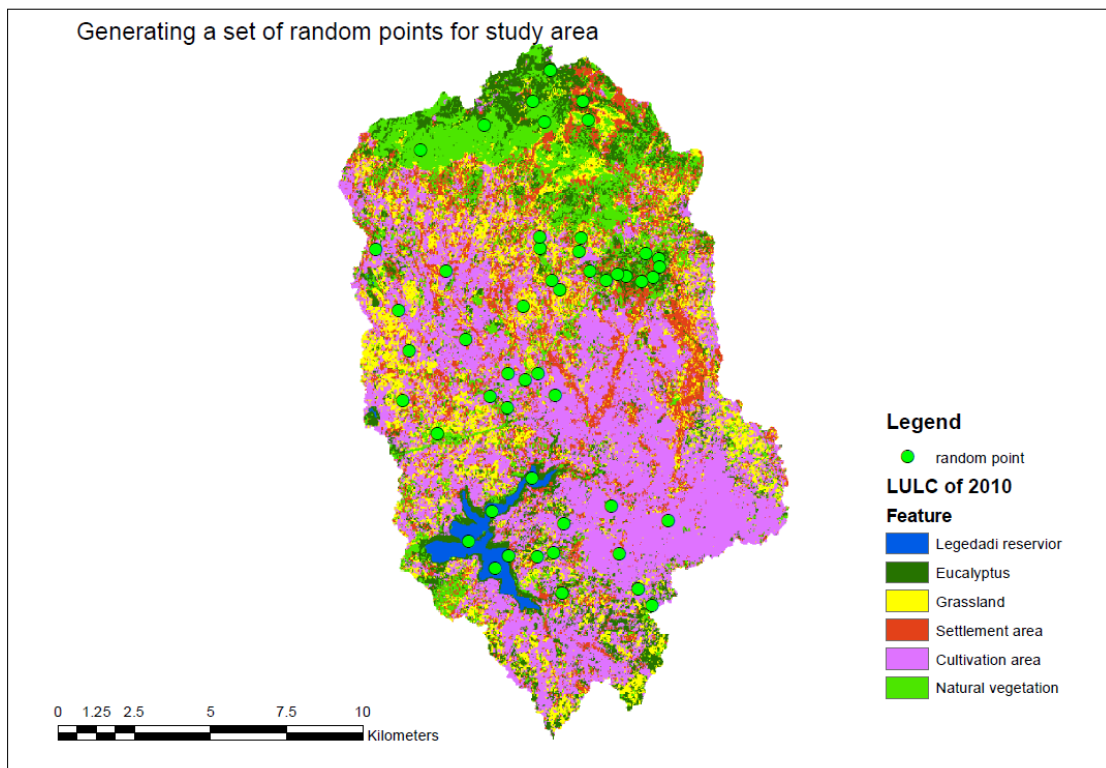
| LULC classes       | Description                                |
|--------------------|--------------------------------------------|
| Legedadi Reservoir | Water part, river and its main tributaries |
| Eucalyptus         | Land covered by eucalyptus trees           |
| Settlement area    | Urban areas or permanent residential area  |
| Cultivation area   | Areas used for crop cultivation            |
| Grassland          | Area covered with grass                    |
| Natural Vegetation | Area with plant community                  |

#### 3.3.1.4. Accuracy Assessment of Classified Image

The generated classified land use maps were verified using Google earth images of January 2010 (for 1979 and 1998, being the oldest historical images in Google earth for the area). From classifier, several reference points were generated randomly for each of image using nearest Google earth map for each of the image year as Ground Truth value, respectively. An accuracy assessment for classified image was done in ARCGIS 10.4 and converting random points to KML in order to open in Google earth. The randomly generated points were identified points on Google Earth Maps were considered as classified values used for confusion /error matrix (Tilahun, 2015).

The overall accuracy is weighted by the number of sample in each class. The sum of all samples on the diagonal divided by the total number of cells  $(4+6+7+3+4+6)/42$  which equal to 0.714 or 71.43%. The major cover classes within study area are Legedadi reservoir (water), Eucalyptus, Settlement area, cultivation area, grassland and natural vegetation. For each of the 42 random points were generated in ArcGIS 10.4.

(A)



(B)

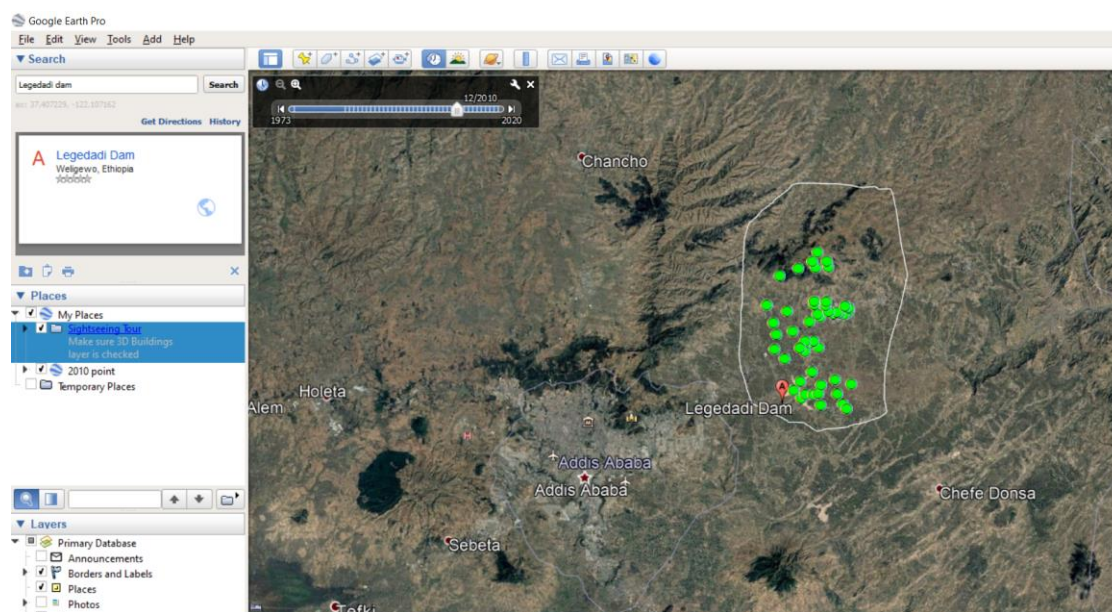


Figure:3.4. Generating random points in ARCGIS 10.4(A) and opening the points on Google Earth (B)

$$\text{Kappa coefficient} = \frac{(TS * TCS) - \Sigma(\text{Column} * \text{Row total})}{TS^2 - \Sigma(\text{Column} * \text{Row total})}$$

Where TS=Total sample, TCS=Total correctly classified sample

$$\begin{aligned} &= \frac{42 * 30 - (16 + 77 + 72 + 28 + 45 + 63)}{(42)^2 - (16 + 77 + 72 + 28 + 45 + 63)} \\ &= 0.656 \end{aligned}$$

The kappa coefficient lies typically on scale between 0 and 1, where the 1 indicates complete agreement (100%). Generally, kappa values characterized into three groups: a value greater than 0.8(80%) is strong agreement, a value between 0.4 and 0.8(40 to 80%) be situated moderate agreement, and value below 0.4(40%) is poor agreement (Rwanga and Ndambuki, 2017).

### 3.3.2. Estimation of Reservoir Capacity and Sedimentation

Normalized difference water index (NDWI) could be a new model developed to delineate open water features. NDWI was calculated with the help of satellite data using Thresholding technique to define water spread area in a reservoir for specific time intervals. In addition, using elevation and corresponding water spread area; the capacity of reservoir between two successive elevations and water level was once calculated using trapezoidal formula.

$$\text{NDWI is Calculated By: } \frac{\text{Green} - \text{NIR}}{\text{Green} + \text{NIR}}$$

Where Green is a green band for Landsat-8 band 3, and NIR is a near-infrared band 5 for Landsat-8 and Green is a green band for Landsat-7 band 2, and NIR is a near-infrared band 4 for Landsat-7

The water surfaces are assumed to be represented by normalized difference water index (NDWI) values greater than zero where as non water surfaces are assumed to be represented by NDWI values less than one or equal to zero.

By using the ENVI package, the water index method, water pixels will be identified by calculating the band ratio of Green/Near-Infrared for normalized difference water index (NDWI) and Green/Short Wave Infrared for Modified Normalized Water Index (MNDWI) to be very low compared to DN values in the Green band. MNDWI is the most appropriate for water mapping. The water body has strong absorbability and low radiation in the range from visible to infrared wavelengths. The index uses the green and short wave infrared bands of remote sensing images based on phenomena. Values of water bodies are larger than 0. vegetation has much smaller values, which results in distinguishing vegetation from water bodies easier. Built-up features have positive values between zero and 0.1. therefore, the range of MNDWI is between -1 and 1,

the water body pixel value is greater than 0.1.

MNDWI is Calculated By:  $\frac{Green - MIR}{Green + MIR}$

Rewrite as these for to put in the ENVI Software (float(b2)-float(b5))/(float(b2)+float(b5))

Where: Green is band 3 for landsat-8 and band 2 for landsat-7.

MIR is a middle infrared band for landsat-8 it is band 6 and for landsat-7 its band 5.

Bathymetric surveys were carried out for Legedadi reservoir for 1979, 1998 and 2010. The three data sets were used to estimate capacity loss due to sedimentation and consequently to compare the results with remote sensing methods. The reduction in reservoir capacity between consecutive contour levels can be computed using Trapezoidal formula. The overall reduction in capacity between the lowest and the highest observed water levels can be obtained by adding the reduced capacity at all levels. The amount of sediments deposited below the lowest observed and above the highest observed reservoir water surface elevations cannot be determined using remote sensing techniques. This is one of limitation of remote sensing method. Because remote sensing methods are applicable only when there is a variation in reservoir water surface elevations between minimum drawdown and full reservoir levels. Hence it is possible to calculate the sedimentation rate within zone of fluctuation of reservoir water surface elevations. Below minimum drawdown levels, the information on capacity of reservoirs could be taken from most recently conducted bathymetric (hydrographic) surveys. This is due to the fact that cloud-free Landsat satellite imagery can't be obtained and seen clearly in false-color composite (FCC) below minimum draw down level. The general frameworks of the study were shown in diagram depicted below in figure 3.5.

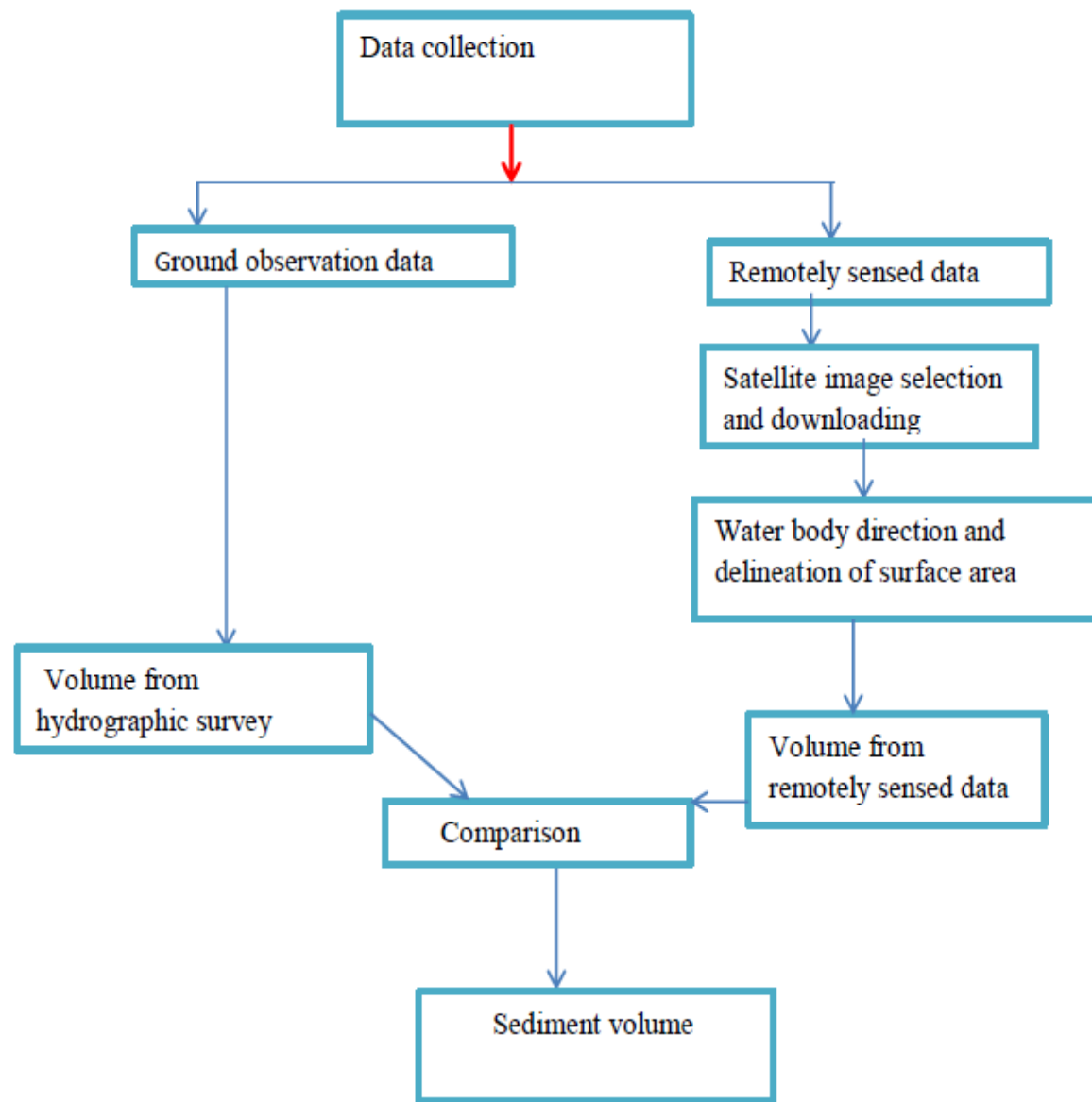


Figure: 3. 5. General framework of the study

### 3.3.3. Processing of Remote Sensing Data

In many applications, a visual interpretation of remotely sensed data may additionally be adequate. Resulting maps or comparable products can be used as a stand-alone product and as input for further evaluation in GIS.

Der and By, (2002), suggest that the maximum areas of reservoirs by means of remotely sensed data, which are represented by their largest surface area extent, the time of acquisition has to be

as close as possible to the end of the rainy season.

To assess reservoir sedimentation the data of Landsat for different years were analyzed and the capacity was estimated using Trapezoidal formula.

The water spread area in each image was calculated in ENVI 5.3 software package and GIS by multiplying the number of water pixels and one-pixel area (30×30).

The reservoir capacity between two elevations was computed by Trapezoidal formula using water spread areas obtained by:

$$V_{12} = \frac{\Delta h}{3} (A_1 + A_2 + \sqrt{A_1 * A_2}).$$

Where,  $\Delta V_{12}$  = Volume between elevation E2 and E1 ( $E_2 > E_1$ )  $\Delta h = E_2 - E_1$

$A_1, A_2$  = Water spread areas at elevation E1 and E2

The overall reduction in capacity between the lowest and the highest observed water levels can be obtained by adding the reduced capacity at all levels.

## 4. RESULT AND DISCUSSION

### 4.1. Land Use Land Cover Change

In this study, there are six major LULC classes for three periods in 1979, 1998, and 2010 which include: water (Legedadi Reservoir), eucalyptus, grassland, settlement area, cultivation area, and Natural Vegetation .

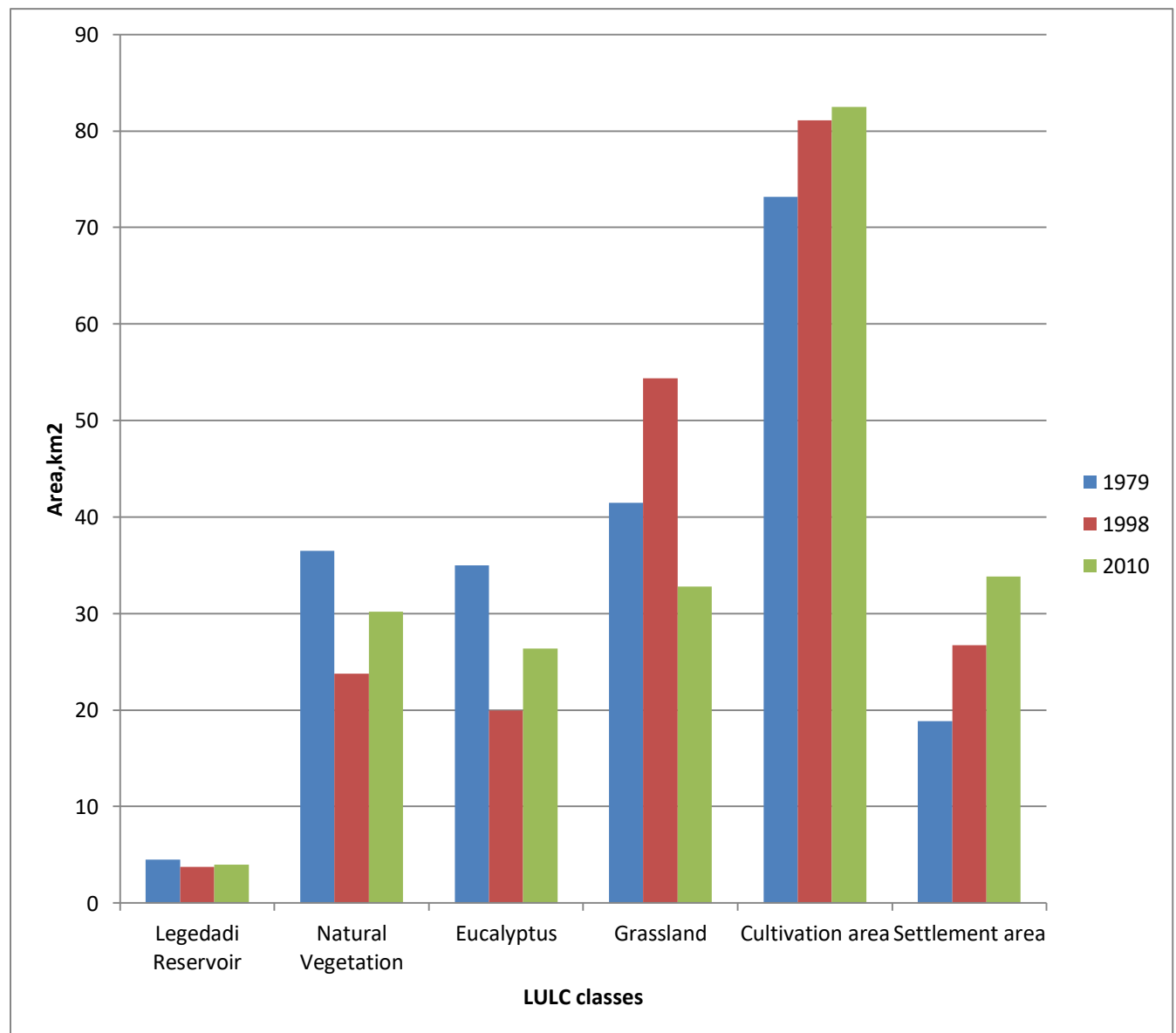


Figure: 4. 1.LULC Coverage (km<sup>2</sup>) of study area in three periods

Generally, from the result of this study, a continuous and active LULC change was found at a

range of spatial and temporal scales: exchange is the alteration of physical characteristics of the land. It could be under the impact of humans and nature, resulting in various kinds of impacts on the reservoir.

1979 LULC

For different applications, band combinations other than true or false color may be used.

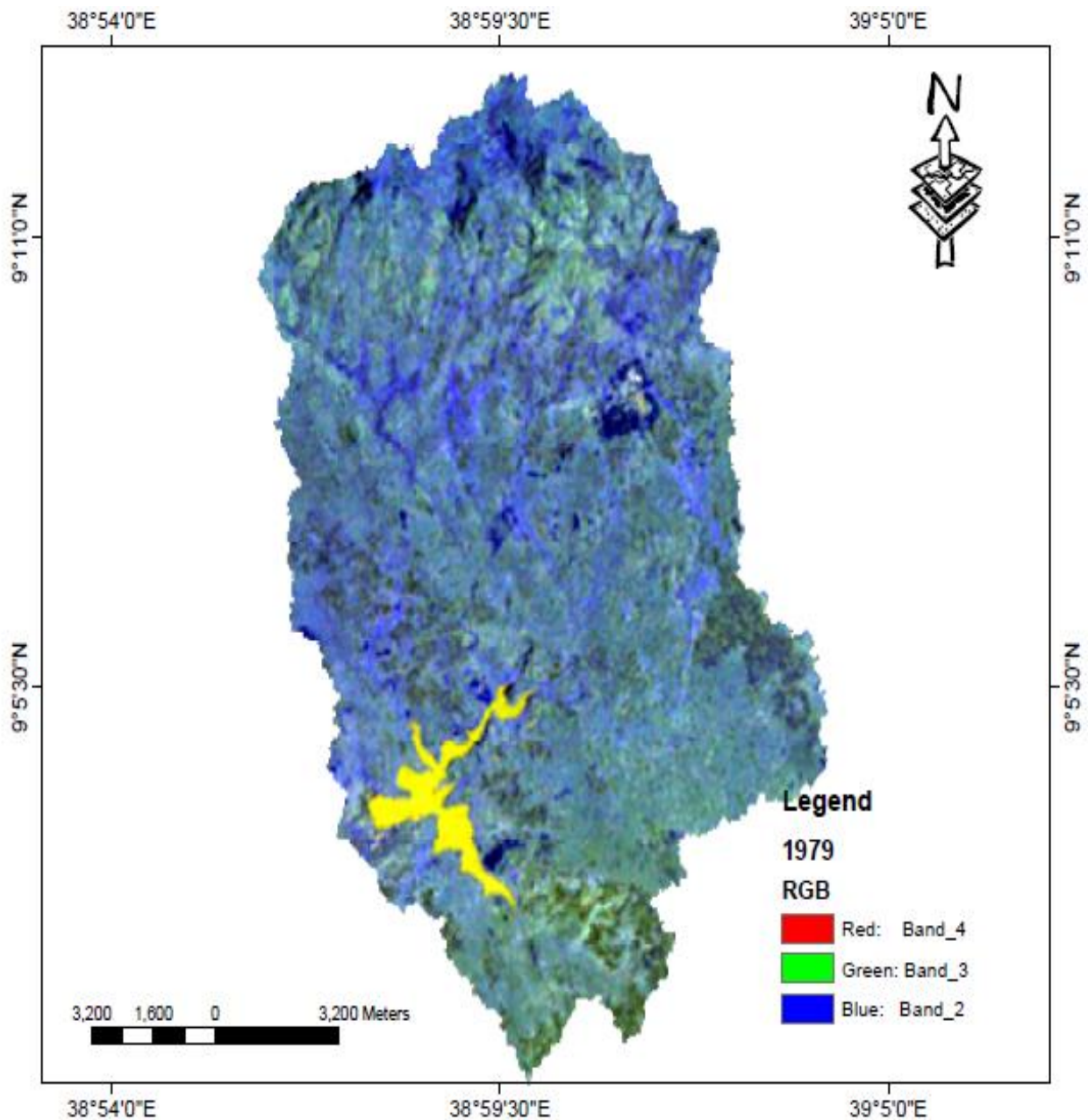


Figure: 4.2. Landsat MSS image of 1979

Source: produced based on satellite image obtained from USGS.

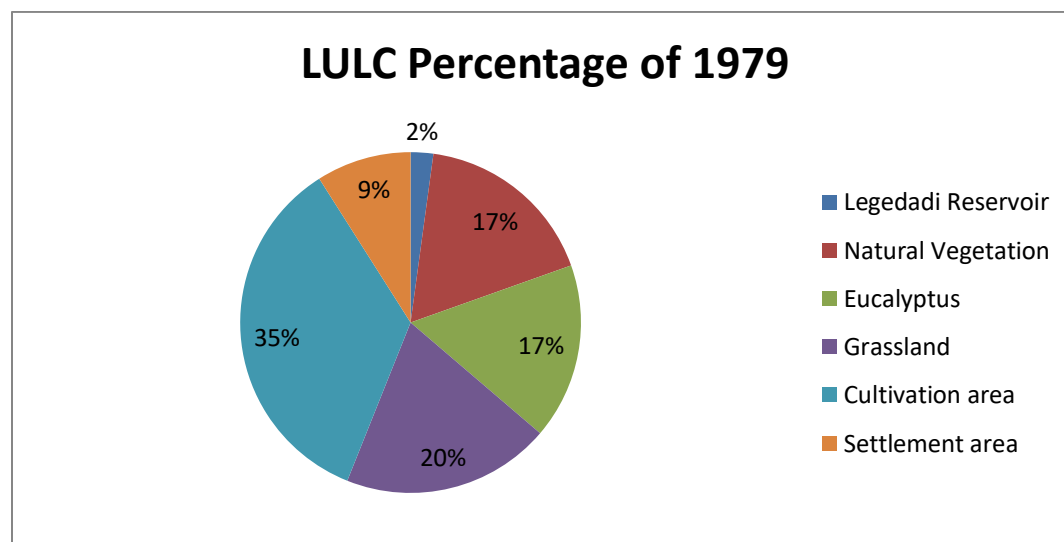
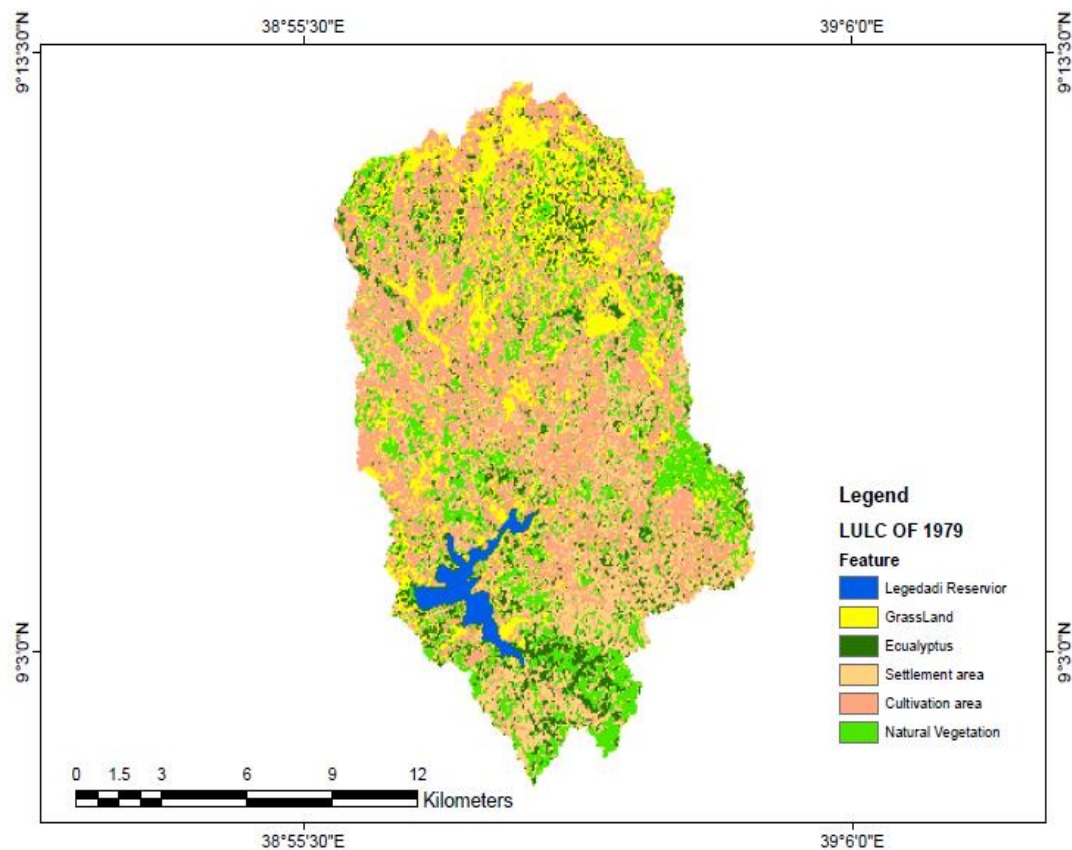


Figure: 4.3. LULC type and area coverage % of 1979

Source: based on GIS analysis result

As indicated in the table cultivation area accounts for 34.94% of total land area followed by grassland, natural vegetation, eucalyptus, settlement area and Legedadi reservoir (water).

#### 1998 LULC

The wavelength range of TM sensor images ranges from the visible to thermal infrared portion of electromagnetic spectrum and it has spatial resolution of 30m. TM of 4,3,2 was combined for false-color composite.

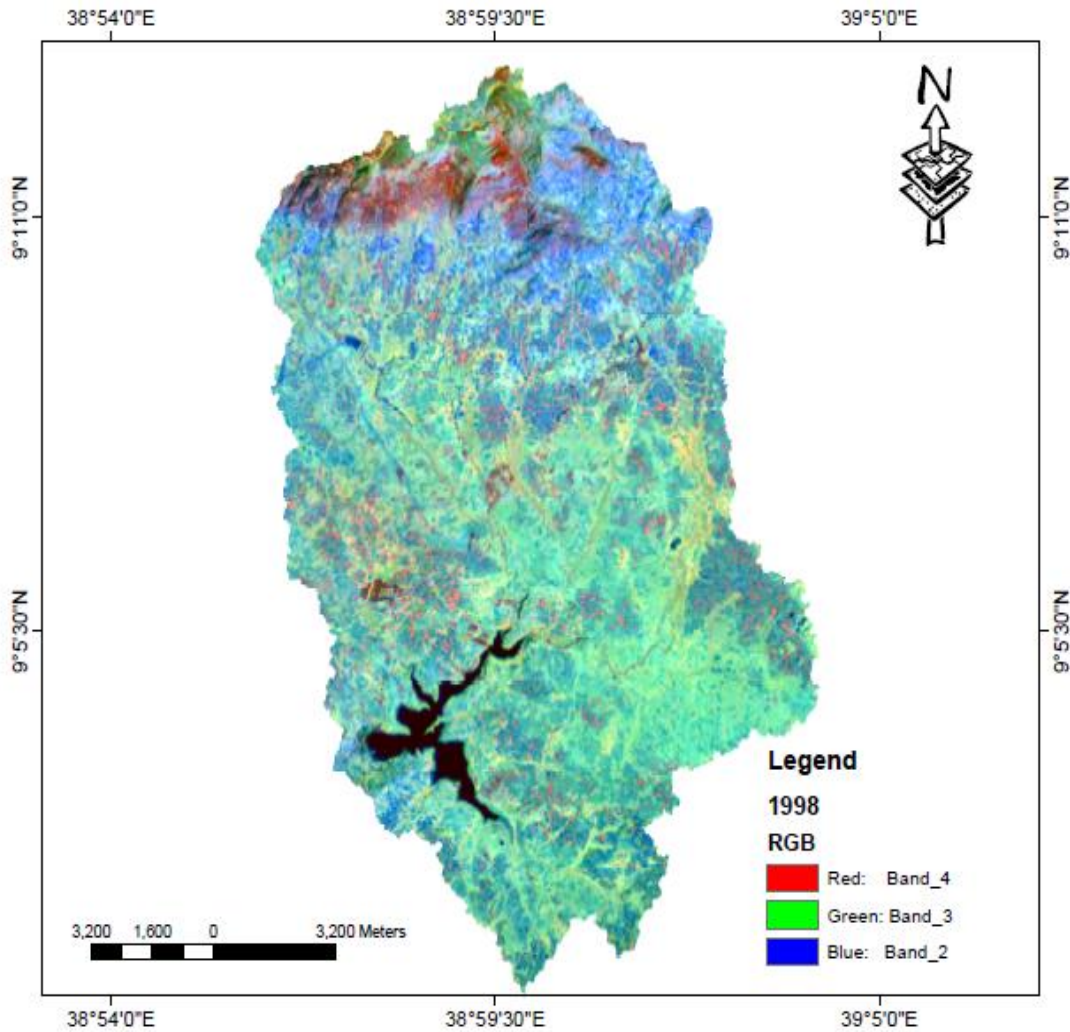
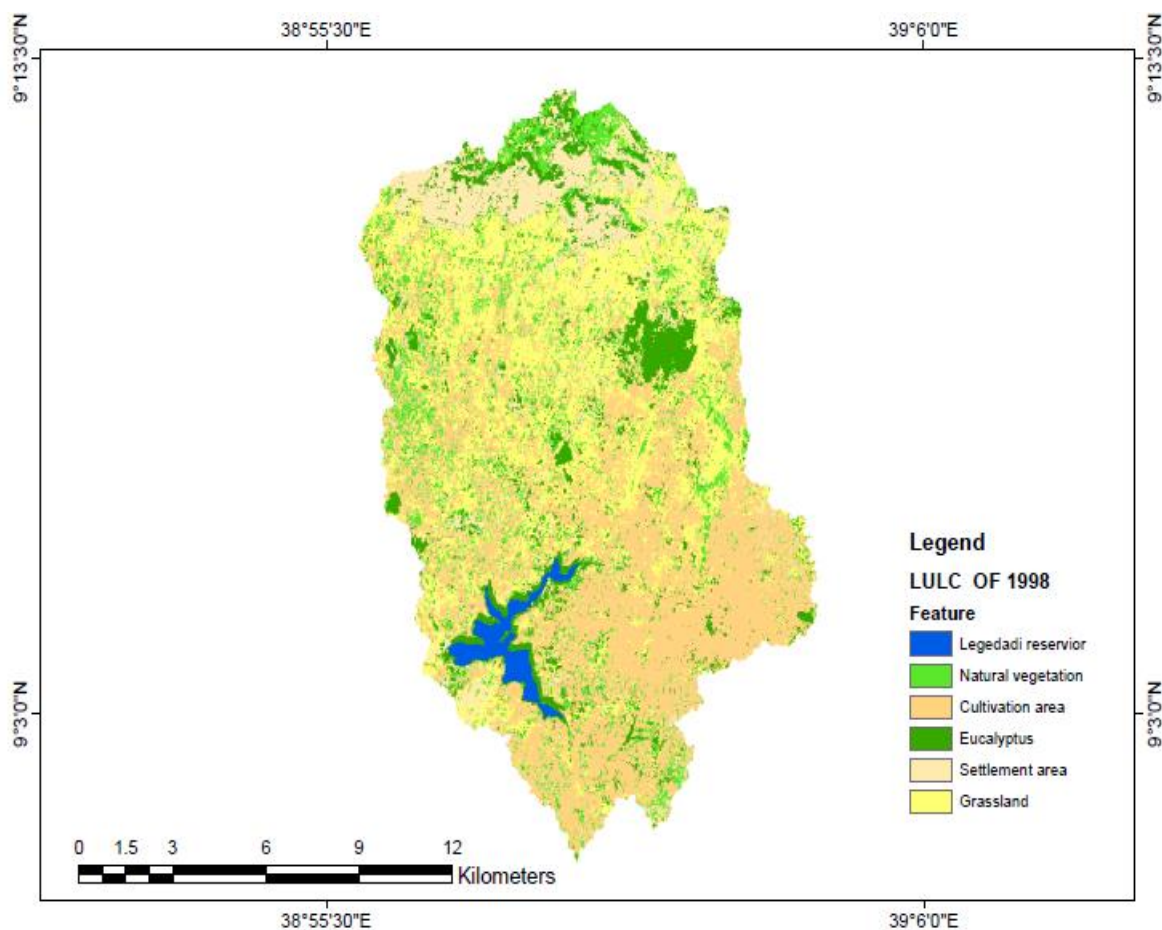


Figure: 4.4.Landsat TM image of 1998

Source: produced based on satellite image obtained from USGS.



As indicated in the table cultivation area accounts for 38.68% of total land area followed by grassland, settlement area, natural vegetation, eucalyptus and Legedadi reservoir (water).

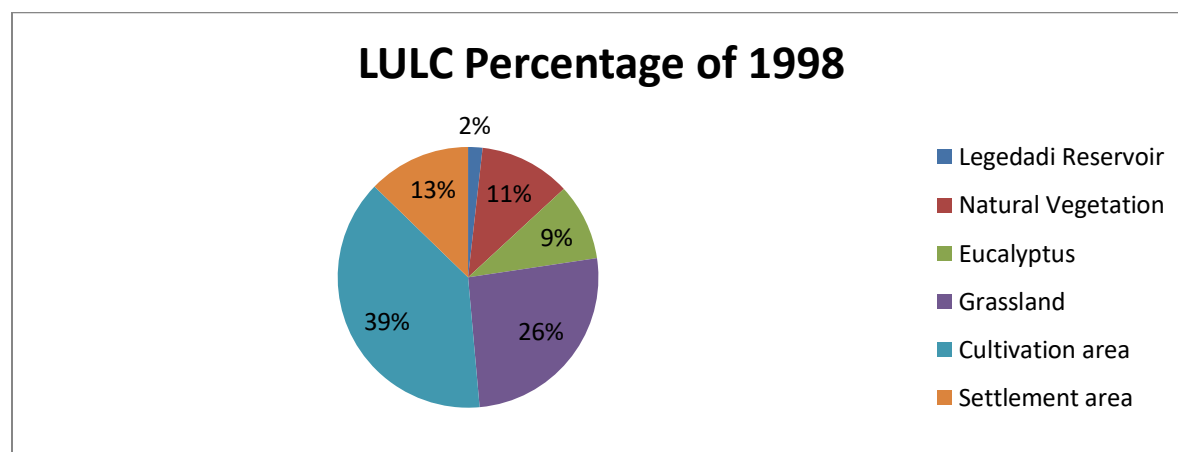


Figure: 4.5. LULC type and area coverage % of 1998

Source: based on GIS analysis result

## 2010 LULC

The Landsat ETM+ image band 5, 4 and 3 were combined to make false-color composite images with spatial resolution of 30m. (Fig.4.6)

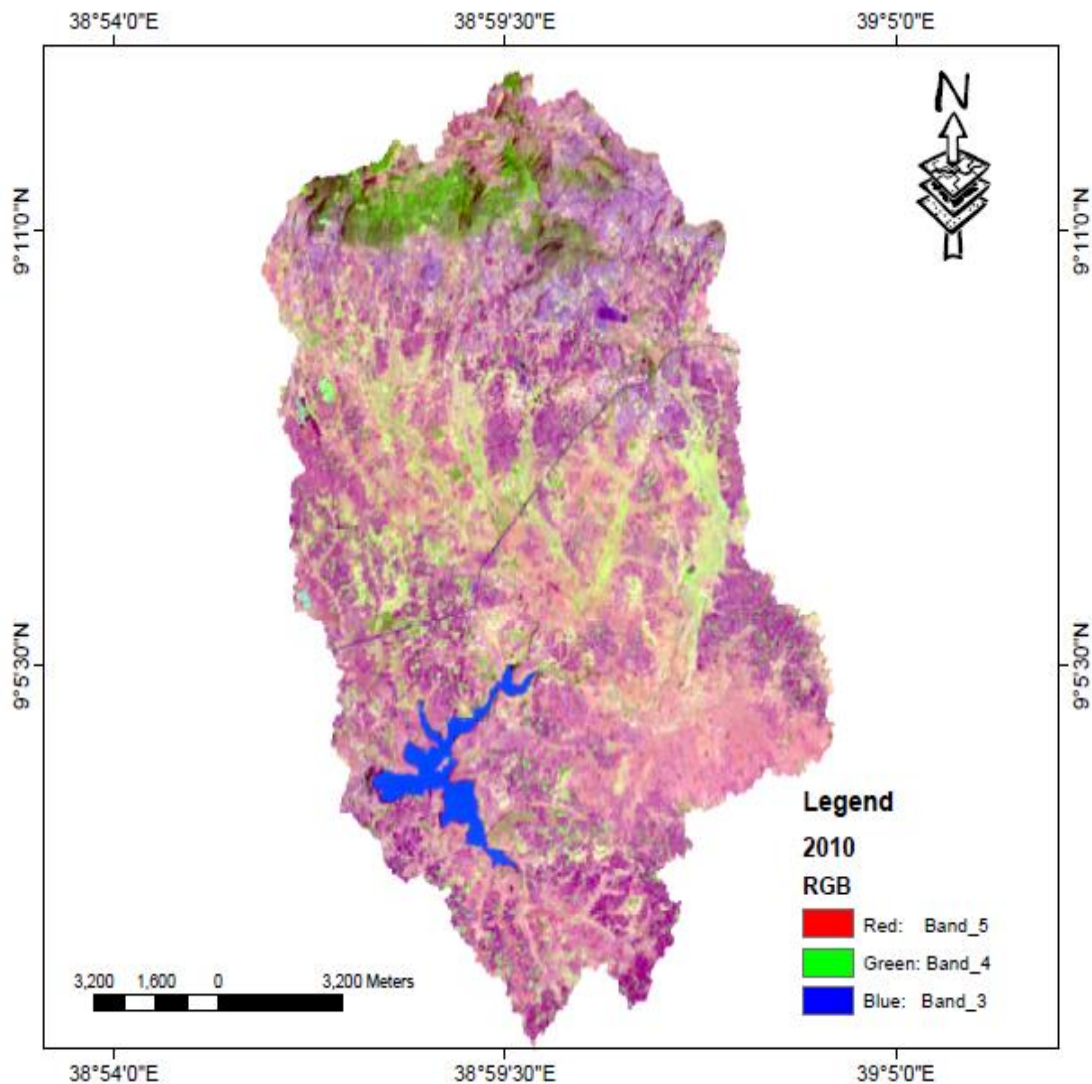


Figure: 4.6. Landsat ETM+ image of 2010

Source: produced based on satellite image obtained from USGS.

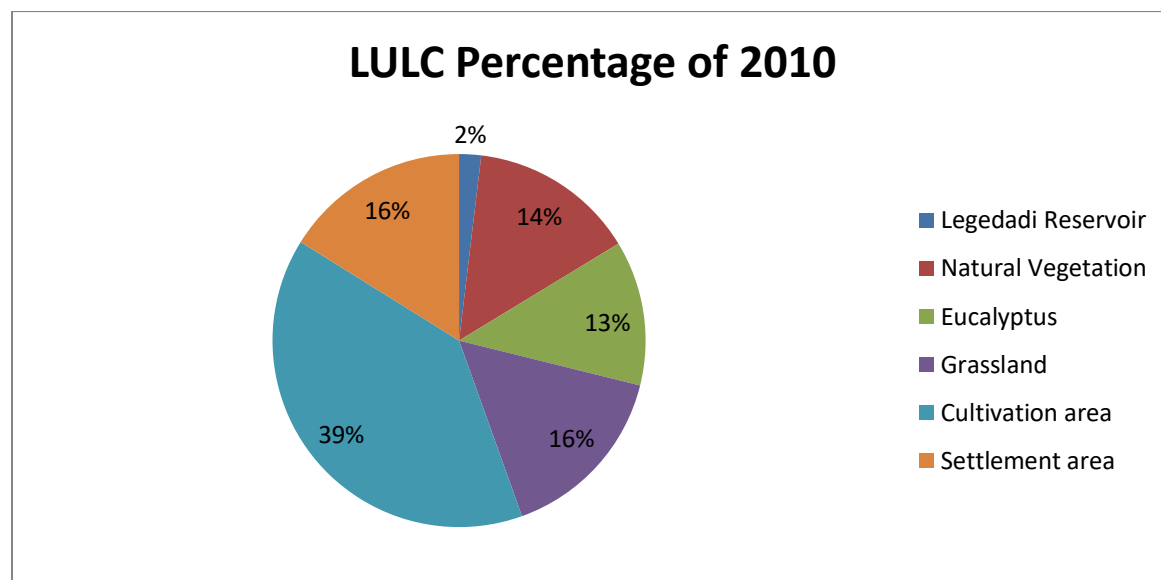
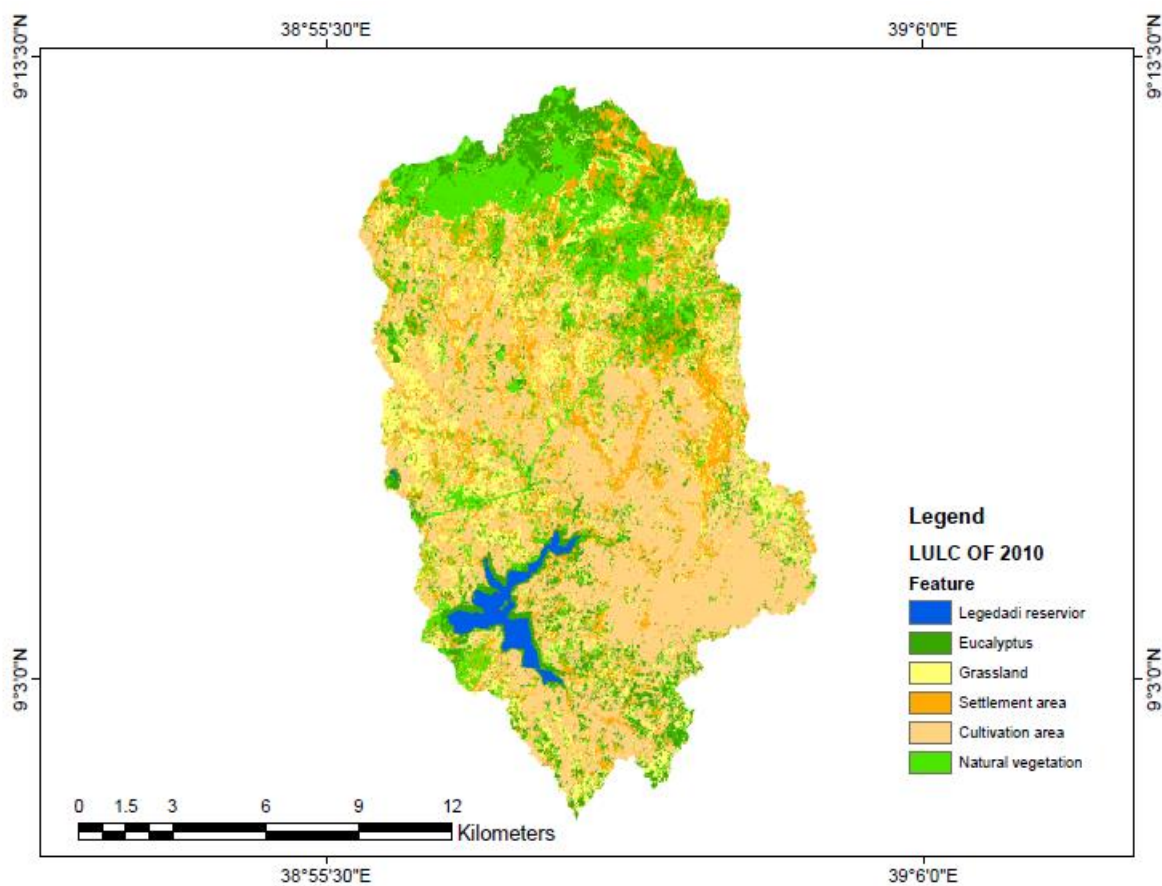


Figure: 4.7. LULC type and area coverage % of 2010

Source: based on GIS analysis result

As indicated in the table cultivation area accounts for 39.34% of the total land area followed by settlement area, grassland, natural vegetation, eucalyptus, and Legedadi reservoir (water).

### Accuracy Assessment

Accuracy assessment was the dominant and mostly used classification error matrix or confusion matrix. An accuracy assessment was performed for the 2010 because good available on Google earth image. The overall classification accuracy and an overall Kappa statistics were calculated. The Kappa coefficient implies the errors that may come with simple random classification and over all classification accuracy reveals that the amount of classification accuracy. In addition, producer and user accuracy were also be attained from the matrix created. Producer's accuracy is calculated as the total numbers of correct pixels in a category divided by the total numbers of pixels of that category as derived from the reference data (i.e. the column total). This accuracy measure indicates, the probability of a reference pixel being correctly classified. On the other hand, if the total number of correct pixels in a category is divided by the total number of pixels that will be classified in that category, it is said to be user's accuracy.

Table:4.1. Classification accuracy assessment of 2010 image using confusion matrix

| Class Name         | Legedadi reservior | Eucalyptus | Grassland | Settlement | Cultivation | Natural vegetation | Total |
|--------------------|--------------------|------------|-----------|------------|-------------|--------------------|-------|
| Legedadi reservior | 4                  | 0          | 0         | 0          | 0           | 0                  | 4     |
| Eucalyptus         | 0                  | 6          | 0         | 2          | 3           | 0                  | 11    |
| Grassland          | 0                  | 0          | 7         | 1          | 1           | 0                  | 9     |
| Settlement         | 0                  | 0          | 1         | 3          | 0           | 0                  | 4     |
| Cultivation        | 0                  | 0          | 0         | 0          | 4           | 1                  | 5     |
| Natural vegetation | 0                  | 1          | 0         | 1          | 1           | 6                  | 9     |
| Total(producer     | 4                  | 7          | 8         | 7          | 9           | 7                  | 42    |

The overall accuracy and kappa coefficient were used to perform accuracy assessment and consequently overall accuracy of data is 71.43%.The kappa coefficients indicated that the classified images showed moderate classification performance agreement which was computed at 0.656.

#### 4.2. Water Spread Area Estimation

The water spread area of the reservoir was calculated from remotely sensed data.

MNDWI is Calculated By:  $\frac{\text{band 2} - \text{band 5}}{\text{band 2} + \text{band 5}}$

The difference between elevation levels was calculated using the trapezoidal formula

Table:4.2(a) waterspread area for Oct 27/2009 GC at an elevation of 2465.16m.a.m.s.l

|   | OID | Value | Count | Area_km2 |
|---|-----|-------|-------|----------|
| ▶ | 0   | 1     | 23399 | 21.0591  |
|   | 1   | 2     | 9481  | 8.5329   |
|   | 2   | 3     | 5185  | 4.6665   |
|   | 3   | 4     | 5580  | 5.022    |

Area=No of water pixel \*one pixel area

$$=5580 \times 900\text{m}^2 / 10^6 = 5.022 \text{ km}^2$$

Table:4.2(b) waterspread area for Nov 12/2009 GC at an elevation of 2464.76m.a.m.s.l

|   | OID | Value | Count | Area_km2 |
|---|-----|-------|-------|----------|
| ▶ | 0   | 1     | 22539 | 20.2851  |
|   | 1   | 2     | 14348 | 12.9132  |
|   | 2   | 3     | 1404  | 1.2636   |
|   | 3   | 4     | 5354  | 4.8186   |

Area=No of water pixel \*one pixel area

$$=5354 \times 900\text{m}^2 / 10^6 = 4.8186 \text{ km}^2$$

Table:4.2(c) waterspread area for Jan 15/2010 GC at an elevation of 2463.3m.a.m.s.l

|   | OID | Value | Count | Area_km2 |
|---|-----|-------|-------|----------|
| ▶ | 0   | 1     | 24309 | 21.8781  |
|   | 1   | 2     | 14545 | 13.0905  |
|   | 2   | 3     | 150   | 0.135    |
|   | 3   | 4     | 4641  | 4.1769   |

Area=No of water pixel \*one pixel area

$$=4641*900\text{m}^2/106=4.1769 \text{ km}^2$$

Table:4.2(d) waterspread area for Jan 31/2010 GC at an elevation of 2462.84m.a.m.s.l

|   | OID | Value | Count | Area_km2 |
|---|-----|-------|-------|----------|
| ▶ | 0   | 1     | 22518 | 20.2662  |
|   | 1   | 2     | 16377 | 14.7393  |
|   | 2   | 3     | 175   | 0.1575   |
|   | 3   | 4     | 4575  | 4.1175   |

Area=No of water pixel \*one pixel area

$$=4575*900\text{m}^2/106=4.1769 \text{ km}^2$$

Table:4.3(a) waterspread area for Nov 21/2015 GC at an elevation of 2463.73m.a.m.s.l

|   | OID | Value | Count | Area_km2 |
|---|-----|-------|-------|----------|
| ▶ | 0   | 1     | 30894 | 27.8046  |
|   | 1   | 2     | 21537 | 19.3833  |
|   | 2   | 3     | 242   | 0.2178   |
|   | 3   | 4     | 87    | 0.0783   |
|   | 4   | 5     | 4528  | 4.0752   |

Table:4.3(b) waterspread area for Dec31/2015GC at an elevation of 2462.62m a.m.s.l

|   | OID | Value | Count | Area_km2 |
|---|-----|-------|-------|----------|
| ▶ | 0   | 1     | 33022 | 29.7198  |
|   | 1   | 2     | 29958 | 26.9622  |
|   | 2   | 3     | 263   | 0.2367   |
|   | 3   | 4     | 4213  | 3.7917   |

Table:4.3(c) waterspread area for Jan 24/2016 GC at an elevation of 2462.07m.a.m.s.l

|   | OID | Value | Count | Area_km2 |
|---|-----|-------|-------|----------|
| ▶ | 0   | 0     | 2     | 0.0018   |
|   | 1   | 1     | 33173 | 29.8557  |
|   | 2   | 2     | 20035 | 18.0315  |
|   | 3   | 3     | 170   | 0.153    |
|   | 4   | 4     | 3908  | 3.5172   |

Table:4.3(d) waterspread area for March 28/2016 at an elevation of 2460.08m.a.m.s.l

|   | OID | Value | Count | Area_km2 |
|---|-----|-------|-------|----------|
| ▶ | 0   | 0     | 1     | 0.0009   |
|   | 1   | 1     | 33347 | 30.0123  |
|   | 2   | 2     | 20557 | 18.5013  |
|   | 3   | 3     | 128   | 0.1152   |
|   | 4   | 4     | 3255  | 2.9295   |

Table:4.4(a) waterspread area for Oct 15/2019 GC at an elevation of 2465.13m.a.m.s.l

|   | OID | Value | Count | Area_km2 |
|---|-----|-------|-------|----------|
| ▶ | 0   | 1     | 29790 | 26.811   |
|   | 1   | 2     | 21109 | 18.9981  |
|   | 2   | 3     | 543   | 0.4887   |
|   | 3   | 4     | 335   | 0.3015   |
|   | 4   | 5     | 4611  | 4.1499   |

Table:4.4(b) waterspread area for Jan 19/2020GC at an elevation of 2462.78m.a.m.s.

|   | OID | Value | Count | Area_km2 |
|---|-----|-------|-------|----------|
| ▶ | 0   | 1     | 25360 | 22.824   |
|   | 1   | 2     | 26268 | 23.6412  |
|   | 2   | 3     | 459   | 0.4131   |
|   | 3   | 4     | 516   | 0.4644   |
|   | 4   | 5     | 3785  | 3.4065   |

Table:4.4(c) waterspread area for March 07/2020 GC at an elevation of 2461.38m.a.m.s.l

|   | OID | Value | Count | Area_km2 |
|---|-----|-------|-------|----------|
| ▶ | 0   | 1     | 25360 | 22.824   |
|   | 1   | 2     | 26268 | 23.6412  |
|   | 2   | 3     | 459   | 0.4131   |
|   | 3   | 4     | 1247  | 1.1223   |
|   | 4   | 5     | 3054  | 2.7486   |

Table:4.4(d) waterspread area for april 08/2020GC at an elevation of 2460.37m.a.m.s.l

|   | OID | Value | Count | Area_km2 |
|---|-----|-------|-------|----------|
| ▶ | 0   | 0     | 2     | 0.0018   |
|   | 1   | 1     | 37776 | 33.9984  |
|   | 2   | 2     | 31051 | 27.9459  |
|   | 3   | 3     | 667   | 0.6003   |
|   | 4   | 4     | 536   | 0.4824   |
|   | 5   | 5     | 2968  | 2.6712   |

Table:4.4(e) waterspread area for may 26/2020 GC at an elevation of 2457.46m.a.m.s.l

|   | OID | Value | Count | Area km2 |
|---|-----|-------|-------|----------|
| ▶ | 0   | 1     | 47819 | 43.0371  |
|   | 1   | 2     | 21779 | 19.6011  |
|   | 2   | 3     | 385   | 0.3465   |
|   | 3   | 4     | 65    | 0.0585   |
|   | 4   | 5     | 2952  | 2.6568   |

(A)

(B)

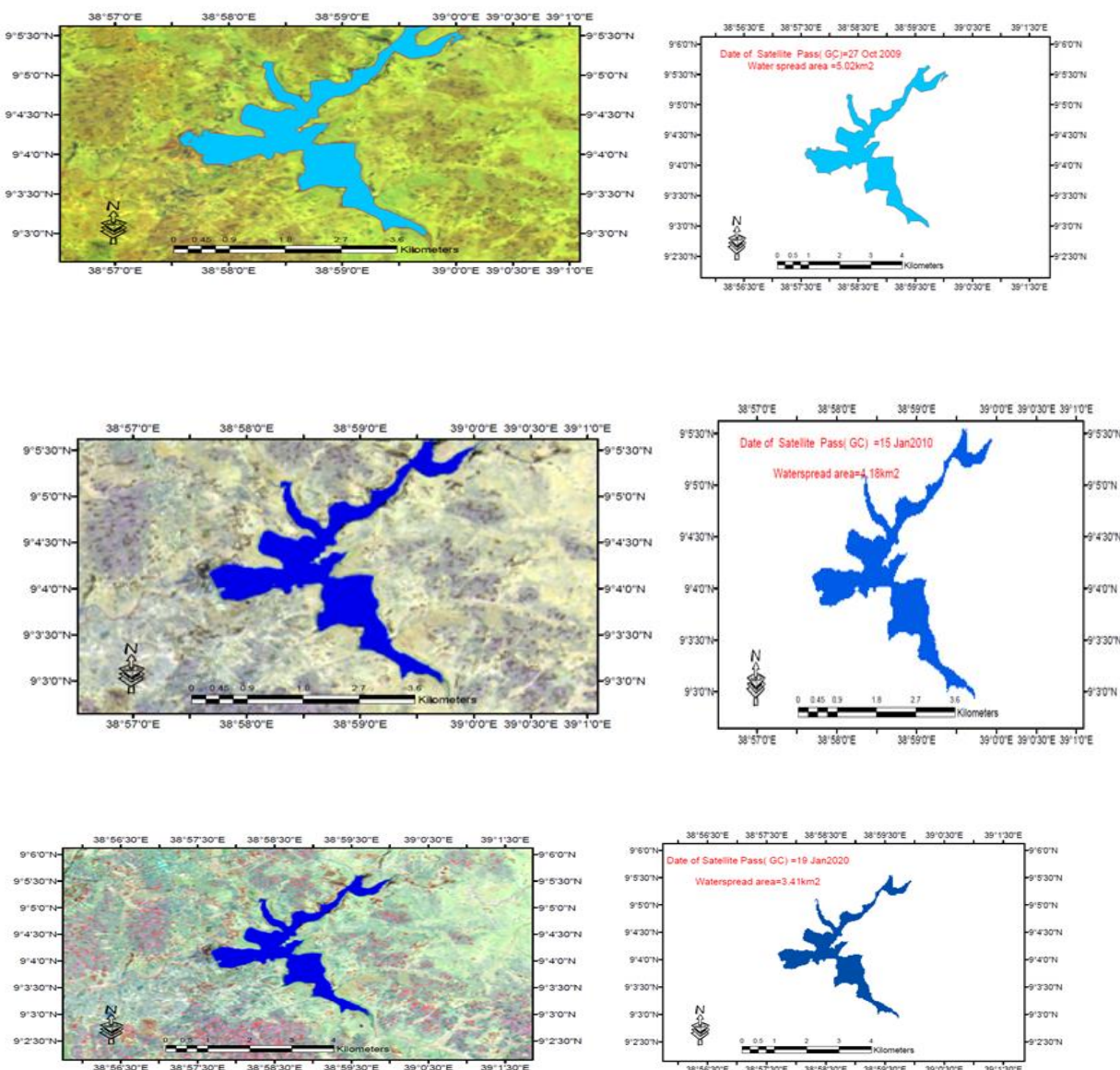


Figure:4.8. False color composite (a) and extracted water spread area (b)

### 4.3 Estimation of reservoir capacity and sedimentation

The capacity of reservoir for different periods estimated by using trapezoidal formula is calculated as shown below .

Table:4.5. sediment deposition in Legedadi reservoir using remote sensing for (2009/10 GC)

| Date of Satellite Pass( GC) | Observed WL (m,a.m.s.l) | Cumulative Capacity (Mm3) |         |             | Sediment deposition (Mm3 ) 2009/10 |
|-----------------------------|-------------------------|---------------------------|---------|-------------|------------------------------------|
|                             |                         | HS1979                    | HS 1998 | SRS 2009/10 |                                    |
| 27-Oct 2009                 | 2465.16                 | 42.56                     | 39.7    | 38.79       | 3.77                               |
| 12-Nov 2009                 | 2464.76                 | 40.62                     | 37.8    | 36.87       | 3.75                               |
| 15-Jan 2010                 | 2463.3                  | 34.0                      | 31.78   | 30.26       | 3.74                               |
| 31-Jan 2010                 | 2462.84                 | 32.11                     | 30.0    | 28.39       | 3.72                               |

To calculate the capacity elevation data corresponding to satellite passing date (cloud free) taken from AAWSA and area extracted from satellite image was used and determined by using trapezoidal formula.

$$V_{12} = \frac{H_{12}}{3} (A_1 + A_2 + \sqrt{A_1 * A_2})$$

Where,  $V_{1-2}$  = Volume between elevation  $E_2$  and  $E_1$  ( $E_2 > E_1$ )  $\Delta h = E_2 - E_1$

$A_1, A_2$  = Water spread areas at elevation  $E_1$  and  $E_2$

Sample volume calculation

$A_1 = 5.02, A_2 = 4.82, E_1 = 2465.16, E_2 = 2464.76$

$V_1 = 2465.16 - 2464.76 / 3 (5.02 + 4.82 + \sqrt{5.02 * 4.82})$

$V_1 = 0.13(9.84 + 4.92) = 1.92 \text{ MCM}$

$V_2 = 6.61 \text{ MCM}$

$V_3 = 1.87 \text{ MCM}$

According to AAWSA report from 1979 GC to 2010 GC average siltation per year is 0.12 MCM.

For the year 1979 GC to 2010 GC it becomes 31 years  $\times 0.12 = 3.72 \text{ MCM}$  Capacity loss,

Therefore the volume become  $32.11 - 3.72 = 28.39 \text{ MCM}$  in 2009/10 GC at an elevation of

2462.84 m,a.m.s.l.

28.39+V1=30.26MCM

30.26+V2=36.87MCM

36.87+V3=38.79 MCM

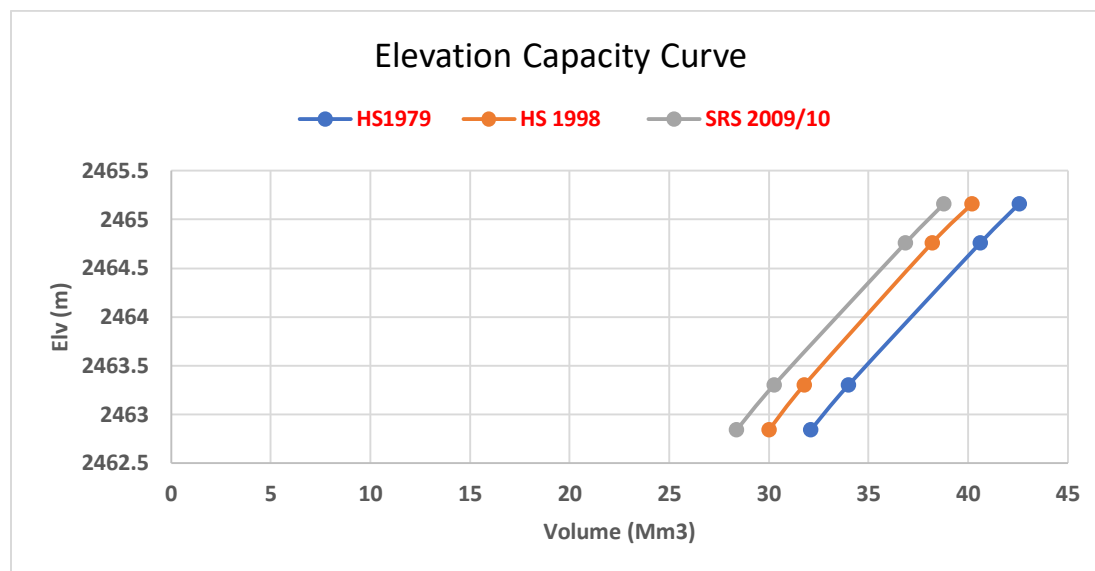


Figure:4.9. The elevation-Capacity curve of Legedadi Reservoir for the year 2009/10

Waterspread area of reservoir was calculated using satellite data and the capacity is calculated using trapezoidal formula, the revised capacity between the maximum (2465.16m a.m.s.l) and minimum (2462.84m a.m.s.l) at observed levels were obtained.

The difference between 1979 GC bathymetric survey and 2009/10 satellite remote sensing result, estimated cumulative capacity represented the loss of capacity due to sedimentation of reservoir. The 2009/10 GC capacity was estimated using trapezoidal formula is found 38.79Mm3 at an elevation of 2465.16m a.m.s.l the loss in capacity is deducted from 1979 bathymetric survey at the same level. (42.56Mm3) it becomes 3.77 Mm3 indicates that sediment deposition between an elevation 2465.16 and 2462.84m a.m.s.l from 1979 to 2009/10 GC.

Based on satellite remote sensing (SRS) the annual sediment rate for a given period is **3.7 Mm3/31 years** becomes 0.122Mm3/year.

Table:4.6. sediment deposition in Legedadi reservoir using remote sensing for (2015/16 GC)

| Date of Satellite Pass( GC) | Observed WL (m,a.m.s.l) | Cumulative Capacity (Mm3) |         |             | Sediment deposition (Mm3 ) 2015/16 |
|-----------------------------|-------------------------|---------------------------|---------|-------------|------------------------------------|
|                             |                         | HS1979                    | HS 1998 | SRS 2015/10 |                                    |
| 21-Nov2015                  | 2463.73                 | 38.6                      | 33.53   | 33.43       | 5.17                               |
| 31-Dec 2015                 | 2462.62                 | 32.02                     | 30.01   | 27.1        | 4.92                               |
| 24-Jan 2016                 | 2462.07                 | 29.8                      | 27.4    | 25.12       | 4.68                               |
| 28-March 2016               | 2460.08                 | 23.2                      | 20.8    | 18.76       | 4.44                               |

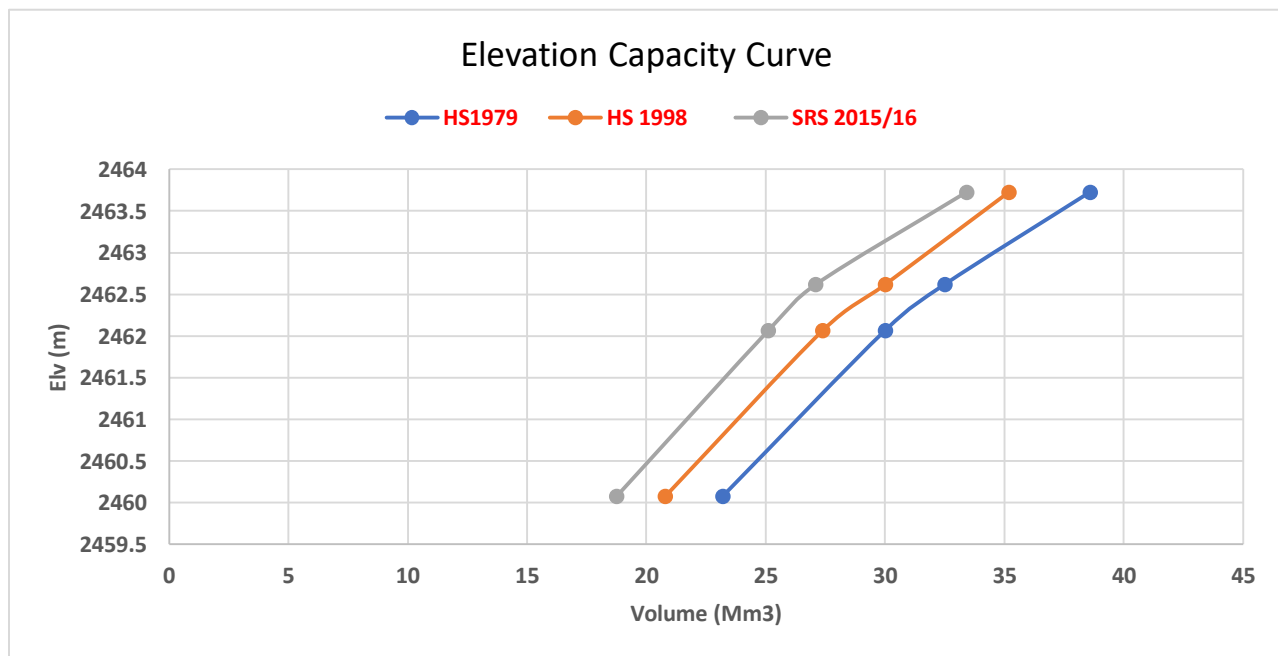


Figure:4.10. The elevation-Capacity curve of Legedadi Reservoir for the year 2015/16

Waterspread area of reservoir was calculated using satellite data and the capacity is calculated using trapezoidal formula, the revised capacity between the maximum (2463.73m a.m.s.l) and minimum (2460.08m a.m.s.l) at observed levels were obtained.

The difference between 1979 GC bathymetric survey and 2015/16 satellite remote sensing result, estimated cumulative capacity represented the loss of capacity due to sedimentation of reservoir. The 2015/16 GC capacity was estimated using trapezoidal formula is found 33.43 Mm<sup>3</sup> at an elevation of 2463.73m a.m.s.l the loss in capacity is deducted from 1979 bathymetric survey at the same level (38.6 Mm<sup>3</sup>) it becomes 5.17 Mm<sup>3</sup> indicates that sediment deposition between an elevation 2463.73 and 2460.08m a.s.l from 1979 to 2015/16 GC.

Based on satellite remote sensing (SRS) the annual sediment rate for a given period is **5.17 Mm<sup>3</sup>/37 years** becomes 0.139Mm<sup>3</sup>/year.

Table:4.7. sediment deposition in Legedadi reservoir using remote sensing for (2019/20 GC)

| Date of Satellite Pass( GC) | Observed WL (m,a.m.s.l) | Cumulative Capacity (Mm <sup>3</sup> ) |         |         |       | SRS | Sediment deposition (Mm <sup>3</sup> ) 2019/20 |
|-----------------------------|-------------------------|----------------------------------------|---------|---------|-------|-----|------------------------------------------------|
|                             |                         | HS1979                                 | HS 1998 | HS 2010 |       |     |                                                |
| 15-Oct 2019                 | 2465.13                 | 40.8                                   | 38.5    | 37.15   | 34.87 |     | 5.93                                           |
| 19-Jan 2020                 | 2462.78                 | 31.5                                   | 29.8    | 28.67   | 26.04 |     | 5.42                                           |
| 07-March2020                | 2461.38                 | 26.82                                  | 25.1    | 23.2    | 21.71 |     | 5.11                                           |
| 08-April 2020               | 2460.37                 | 23.96                                  | 21.6    | 20.1    | 19.0  |     | 4.96                                           |
| 26-May 2020                 | 2457.46                 | 16.17                                  | 14.3    | 13.01   | 11.25 |     | 4.92                                           |

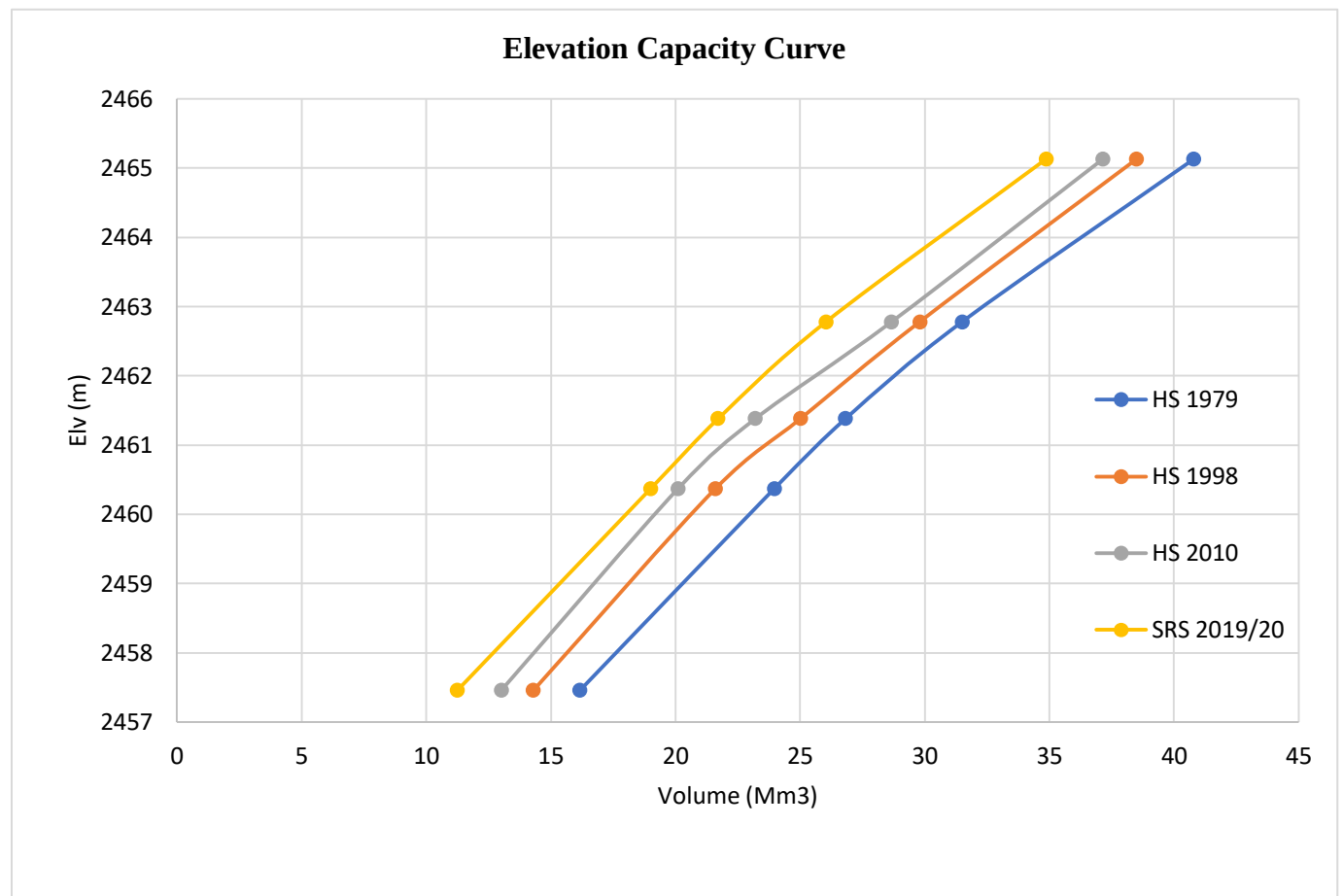


Figure:4.10. The elevation-Capacity curve of Legedadi Reservoir for the year 2019/20

Waterspread area of reservoir was calculated using satellite data and the capacity is calculated using trapezoidal formula, the revised capacity between the maximum (2465.13m a.m.s.l) and minimum (2457.46m a.m.s.l) at observed levels were obtained.

The difference between 1979 GC bathymetric survey and 2019/20 satellite remote sensing result, estimated cumulative capacity represented the loss of capacity due to sedimentation of reservoir. The 2019/20 GC capacity was estimated using trapezoidal formula is found 34.87 Mm<sup>3</sup> at an elevation of 2465.13m a.m.s.l the loss in capacity is deducted from 1979 bathymetric survey at the same level (40.8 Mm<sup>3</sup>) it becomes 5.93 Mm<sup>3</sup> indicates that sediment deposition between an elevation 2465.13 and 2457.46m a.s.l from 1979 to 2019/20 GC.

Based on satellite remote sensing (SRS) the annual sediment rate for a given period is **5.93 Mm<sup>3</sup>/41 years** becomes 0.145 Mm<sup>3</sup>/year.

Assuming sediment mix density 1.43 ton/m<sup>3</sup> and taking Legedadi reservoir area 207 km<sup>2</sup>, the annual sediment rate using remote sensing method is calculated to be 207,350 ton/year or 1002 ton/km<sup>2</sup>/year and the annual sedimentation rate was **0.35%** per year.

#### 4.4 Comparison of result with previous studies

Haile and Govers (2006), studied in Tigray (Northern Ethiopia) of which specific sediment yield value is between 237 to 1817 ton/ km<sup>2</sup>/year. The Legedadi reservoir watershed sediment yield is found between these ranges. Haregeweyn and Tsunekawa (2011) studied in north eastern Ethiopia, of which specific sediment yield for Angereb reservoir is 2927 km<sup>2</sup>/year. Bathymetric survey were conducted on Legedadi reservoir in 1979 and 1998 and showed an average silt accumulation of 110,000 m<sup>3</sup>/year and an average sediment yield deposited in reservoir 760 ton/km<sup>2</sup>/year (Master plan review of Legedadi reservoir, 2011). Similarly, study on Gefersa reservoir the average sediment yield deposited in reservoir 1200 ton/km<sup>2</sup>/year. Generally, the current study of Legedadi reservoir estimates sediment yield of (1002 ton/km<sup>2</sup>/year) and the annual sedimentation rate of 0.35% per year.

### Estimation of useful life of reservoir

The period up to which the reservoir can serve the defined purpose is called usable life.(Ezugwu et al, 2013), studied the conditions of Ikpoba reservoir and obtained the total volume of silt in the Ikpoba reservoir. The useful capacity of the reservoir lost every year by sediment deposition was estimated.

The useful capacity of the reservoir lost every year by sediment deposition is  $V_s = Q_s Te$ ,

Where  $V_s$  =volume of useful capacity of reservoir lost each year

$Q_s$ = annual sediment inflow into the reservoir

$Te$  = trap efficiency of the reservoir

$Q_s$ = capacity of reservoir calculated using trapezoidal formula/ number of years

$$Q_s = \frac{34.87 \text{ Mm}^3}{41 \text{ yrs}} = 850,488 \text{ m}^3/\text{year}$$

According to Brown, 1943  $Te$  is calculated

$$TE = 100 \left( 1 - \frac{1}{0.0021 \frac{D \times V}{W}} \right)$$

where,  $V$ = reservoir storage capacity expressed in  $\text{m}^3$ ; and  $W$  = catchment area expressed in  $\text{km}^2$ .  $D$  is a coefficient whose values range from 0.046 to 1, with a mean value of 0.1.

in our case:  $W=207 \text{ km}^2$ ,  $D=0.1$  ,  $V=34,87 \text{ Mm}^3$  by substituting into equation

$$TE = 100 \left( 1 - \frac{1}{0.0021 \frac{D \times V}{W}} \right) = 100 \left( 1 - \frac{1}{0.0021 \frac{0.1 \times 34,87 \text{ Mm}^3}{207 \text{ km}^2}} \right) = 97.17\%$$

$$V_s = Q_s * TE = 850488 \text{ m}^3/\text{year} * 0.9717 = 826,446 \text{ m}^3/\text{year}$$

Therefore, Life of reservoir = capacity of reservoir of reservoir divided by volume of useful capacity of reservoir lost each year.  $= \frac{40,8 \text{ Mm}^3}{826,446 \text{ m}^3/\text{year}} = 49 \text{ years}$

Assuming that this average rate of sedimentation will continue in future, the estimate of the life age must be about 49 years.

## 5. CONCLUSION AND RECOMMENDATION

### 5.1 Conclusion

The use of remote sensing techniques enables a fast and reasonably accurate estimation of capacity loss due to sedimentation. The water spread area of Legedadi reservoir was calculated by using satellite data and the volume is calculated using trapezoidal formula. And the revised capacity between minimum and maximum observed levels were obtained.

From the analysis of the outcome of remote sensing method from 2009/10 GC the capacity was estimated by using trapezoidal formula is 38.79Mm<sup>3</sup> at an elevation of 2465.16m a.m.s.l to found the loss in capacity subtract the 2009/10 from bathymetric survey of 1979 at the same elevation of 2465.16m a.m.s.l. 42.56Mm<sup>3</sup> it becomes 3.77Mm<sup>3</sup> the loss in live storage capacity for a given period and the annual sediment rate of 0.122Mm<sup>3</sup>/year. Similarly the 2015/16 capacity was found to be 33.43Mm<sup>3</sup> at an elevation of 2463.73m a.m.s.l then subtract the 2015/16 from bathymetric survey of 1979 at the same elevation of 2463.73m a.m.s.l. 38.6Mm<sup>3</sup> becomes 5.17Mm<sup>3</sup> the loss in live storage capacity for a given period and the annual sediment rate of 0.139Mm<sup>3</sup>/year.

The current capacity of 2019/20 of Legedadi reservoir is 34.87Mm<sup>3</sup> at an elevation of 2465.13m a.m.s.l. Then the loss of reservoir capacity due to sediment deposition for a period of 41 years since 1979 GC of bathymetric survey was determined to be 5.93Mm<sup>3</sup> which convert to 14.5% capacity loss between 2465.13 and 2457.46m a.m.s.l.

A comparison of the result showed that the rate of sedimentation assessed using a remote sensing-based approach is close to the results obtained from the hydrographic survey.

Keeping in view the time and cost involved in hydrographic surveys, it is recommended that hydrographic surveys may be conducted at longer intervals and the remote sensing-based sedimentation surveys may be carried out at shorter intervals so that both surveys complement one another. Though there are some limitations in the remote sensing data collection method. For example, remote sensing techniques give information on the capacities only in the water level fluctuation zone; the information on the capacity could be taken from the most recently conducted hydrographic survey. Generally, the current study of Legedadi reservoir estimates sediment yield of (1002 ton/km<sup>2</sup>/year) and the annual sedimentation rate of 0.35% per year below the annual average worldwide rate for reservoir sedimentation 1%.

Expansion of cultivated land and deforestation of natural vegetation and eucalyptus and increasing settlement area imposed to land degradation. Therefore, it is essential to put great concern and take remedial measures in Legedadi Reservoir to reduce silt of reservoir.

## 5.2 Recommendation

The recommendation achieved for this study relate to the assessment of sedimentation using remote sensing:

- More accurate results would be found in case of considering uncertainties such as inflow-outflow method and hydrographic survey method to assess sediment effect on the reservoir; hence, the results of this study should be taken as a reference for further studies on the impact of sediment on Legedadi reservoir.
- It is recommended that studies should be carried out on different reservoirs in our country periodically (say every ten years) to monitor their sedimentation rates.
- The major limitation of remote sensing method is that reservoir capacity below the lowest observed level and above the highest observed levels cannot be determined. It is only possible to calculate sedimentation rate within zone of fluctuation of reservoir water levels.
- Estimation of sedimentation by remote sensing techniques is highly sensitive for water-spread area determination.
- There is urgent need to commence sedimentation and general reservoir management studies in all reservoirs in our country to save them from rapid siltation and loss of benefits.
- Generally, for the future study on estimation of reservoir sedimentation using remote sensing data, it would be better to take some control points on the date of satellite pass around the boundary of the reservoir, especially around the river entrance to the reservoir.

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