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MODELLING ENCROACHMENT ON GENDAGENDA FOREST RESERVE BY USING GIS AND REMOTE SENSING

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MODELLING ENCROACHMENT ON GENDAGENDA FOREST RESEVE BY USING GIS AND REMOTE SENSING TECHNIQUES

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A Dissertation Submitted to the Department of Geospatial Sciences and Technology in Partially Fulfilment of the Requirements for the Award of a Bachelor Of Science in Geoinformatics (BSc. GI) of Ardhi University

CERTIFICATION

The undersigned certify that they have proof read and hereby recommend for acceptance of a dissertation entitled "**Modelling Encroachment on Gendagenda Forest Reserve by Using GIS and Remote Sensing Techniques"** in partial fulfillment of the requirements for the award of degree of Bachelor of Science in Geoinformatics at Ardhi University.

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(Main supervisor)

Dr. Atupelye Komba

Date ………………………

DECLARATION AND COPYRIGHT

EVAREST, WILSON M I hereby declare that, the contents of this dissertation are the results of my own findings through my study and investigation, and to the best of my knowledge they have not been presented anywhere else as a dissertation for diploma, degree or any similar academic award in any institution of higher learning.

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EVAREST, WILSON M

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DEDICATION AND COPYRIGHT

I dedicate this dissertation to my beloved family. I extend my heartfelt gratitude to my father Martin Evarest, my dear mother Beatha Paschal, my brother Passian Martin and my sister Ruth Martin for their unwavering attention and support throughout my academic success through the financial assistance, encouragement and other necessary resources within four years of my studies.

ABSTRACT

The Gendagenda Forest Reserve, a crucial ecological and biodiversity hotspot is confronting escalating challenges from encroachment and human activities. This study aims to construct a comprehensive predictive model for analyzing encroachment dynamics in the Gendagenda Forest. By utilizing advanced remote sensing techniques and geographic information systems (GIS), it seeks to quantify encroachment extent and spatial patterns over a specific period. The model intends to offer actionable insights for forest management and conservation, aiding in resource allocation for effective monitoring and enforcement.

The primary objective of this research is to develop and accurate modelling framework for assessing spatial and temporal encroachment on Gendagenda forest reserve through GIS and remote sensing techniques over time using these multidimensional datasets. To assess encroachment within the Gendagenda Forest Reserve, this study perform an analysis of Landsat images from 2014, 2018 and 2022. The analysis of Landsat images generate Land Use, Land Cover (LULC) maps for each respective image. The research incorporates Google Earth images for detailed visual data, population data to explore socio-economic influences on encroachment.

In 2014, the Built-up area covered 4.32 hectares, and Bareland accounted for 313.47 hectares. By 2018, the Built-up area expanded to 7.38 hectares, while Bareland increased to 479.16 hectares. The trend continued into 2022, with the Built-up area further growing to 8.1 hectares, and Bareland expanded substantially to 749.07 hectares. These changes signify a steady increase in built-up infrastructure and the expansion of bareland within the forest reserve. Such alterations underscore the evolving land use dynamics and highlight the need for thoughtful conservation and sustainable land management strategies to safeguard the integrity of the Gendagenda Forest Reserve's ecosystem, the expansion of built-up areas poses a substantial risk of loss forest reserve that as a major impact on the integrity of the forest reserve.

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LIST OF ACRONMYS AND ABBREVIATIONS

DMS	Degree Minutes Second
ESA	European Space Agency
GIS	Geographic Information Systems
GSME	Government Subject Matter Expert
GST	Geospatial Science and Technology
LTEM	Long Term Ecological Monitoring
LULC	Land Cover Map, Land Use
MCE	Multi-Criteria Evaluation
NBS	National Bureau Statistic
RS	Remote Sensing
SNPA	Serengeti National Park Authority
TANAPA	Tanzania National Park
TAWIRI	Tanzania Wildlife Research
TFSA	Tanzania Forest Agency
USGS	United State Geological Survey

CHAPTER ONE

INTRODUCTION

1.1 Background information

Gendagenda forest reserve is significant natural habitant located in Handeni-Tanga region that cover vast area of 3184.76 Hectares that take vital natural resource with significant ecological value, serving as a critical habitat for numerous species and also essential for conserving watersheds and mitigating climate changes. The encroachment refer to the unauthorized and unsuitable exploitation of forest resource such as land conversation for agriculture, timber extraction and settlement expansion. Effectively address encroachment issues and develop appropriate conservation strategies it is crucial to assess extend and impact of encroachment. The encroachment on the Gendagenda forest reserve has become a critical environmental issue that play role in maintaining ecology balance, providing ecosystem services and conserving biodiversity. The most important concern on forest reserve is the changes in the eco-environment (Halmilton & Smith, 1989)

The keeping people out of an area to protect biodiversity is not enough. We need to integrate human activities and conservation outside the reserves as well as stressing the interdependences of the land both inside and outside the protected areas. The encroachment on the Gendagenda forest reserve has emerged as a critical environmental issues that play vital role in maintaining ecological balance, providing ecosystem services and conserving biodiversity. Tanzania plans to take vital steps to address boundary challenges on forest reserve and claim the challenges due to the increase of human activities around the most iconic ecosystem that support the wildlife. One of the most important concerns of the world nowadays is the change in eco-environment forest reserved areas are protected areas that importance for wildlife it has numerous vegetation cover distributed along the diverse landscape. The protected areas support the live and habitant for flora and fauna, features of geological and other special interest that managed for purpose of conservation and provide special opportunities for a research or studies (Baldus, 2004).

1.2 Statement of the research problem

Tanzania Forest Service plans to take vital steps to address boundary challenges and impact of human activities such as agricultural activities, timber extraction and settlement expansion around the most iconic ecosystem. Encroachment poses a significant threat to the Gendagenda forest reserve that extends beyond designated boundary that as a result of human activities. An encroachment is an unauthorized intrusion onto a neighboring properties through the creation or extension of a physical structure on the surface of land and also term as the gradually taking away someone else's rights. The encroachment on the reserved area interfered with the wildlife habitats and essential ecological functions. The increase demand for resource contributes much impact on wildlife and ecological system at all, due to the human and settlement activities lead to the conflict between the forest reserve authority and people living in the edges of the protected areas. Therefore this study is help to assess and quantify the human encroachment and rate of encroachment in forest reserve.

1.3 Research objectives

1.3.1 Main objectives

- To develop a comprehensive and accurate modelling framework for assessing spatial and temporal of encroachment on Gendagenda forest reserve through GIS and Remote Sensing techniques.

1.3.2 Specific objectives

- To detect and quantify the spatial analysis and temporal trend on Gendagenda forest reserve from 2014 to 2022.
- To determine trend of encroachment and predict future the Land Use/Land Cover (LULC) 2026.

1.4 Significance

The research data and results will be used for policy formulation and decision making, model can be aid in evidence considering during policy formulation, land use and zoning regulations for social, economic and political matter. The research data and results can be used for suitable forest management and conservation on forest reserve in accuracy for proper planning and prioritize in resource protection.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The review focus on forest reserve area in Tanzania and the factors that be considered on management of natural resources. The forest reserve faced by many challenges due to due to the human activities around or within the forest reserve, encroachment as the result of human activities impact on the forest reserve. The review describe the methods that used to management of Gendagenda forest reserve due to the encroachment of human activities. The methods used to perform modelling of human encroachment on the forest reserve are remote sensing and Geographic Information System (GIS) techniques. (Halmilton & Smith, 1989)

Forest reserves are portions of state lands where commercial harvesting of wood products is excluded in order to capture elements of biodiversity that can be missing from sustainably harvested sites. Small (patch) reserves will conserve sensitive, localized resources such as steep slopes, fragile soils, and habitat for certain rare species that benefit from intact forest canopies. Large (matrix) reserves will represent the diversity of relatively un-fragmented forest landscapes remaining in Massachusetts today. Matrix reserves will ultimately support a wider diversity of tree sizes and ages than typically occurs on sustainably harvested sites, and will also support structures and processes associated with extensive accumulations of large woody debris that are typically absent from harvested sites. (Kamangadazi & Mwabumba, 2016)

2.2 Introduction of research

Research is an academic activity and as such the term should be used in a technical sense. According to Clifford Woody research comprises defining and redefining problems, formulating hypothesis or suggested solutions; collecting, organizing and evaluating data; making deductions and reaching conclusions; and at last carefully testing the conclusions to determine whether they fit the formulating hypothesis (C.Kohari, 2004). The systematic approach concerning generalization and the formulation of a theory that involve the investigation into and study of materials and source in order to establish facts and reach new conclusions.

2.3 Type of research based on our knowledge

- Applied vs Fundamental: Applied research aims at finding a solution for an immediate problem facing a society or an industrial/business organization, whereas fundamental research is mainly concerned with generalizations and with the formulation of a theory. "Gathering knowledge for knowledge's sake is termed 'pure' or 'basic' research."4 Research concerning some natural phenomenon or relating to pure mathematics are examples of fundamental research (C.Kohari, 2004).
- Descriptive vs Analytical: Descriptive research includes surveys and fact-finding enquiries of different kinds. The major purpose of descriptive research is description of the state of affairs as it exists at present. Analytical research, on the other hand, the researcher has to use facts or information already available, and analyze these to make a critical evaluation of the material. The analytical research the data is already available that may be able to processed while the descriptive research need to collect the data by using different method of data collection.
- Conceptual vs Empirical: Conceptual research is that related to some abstract idea(s) or theory. It is generally used by philosophers and thinkers to develop new concepts or to reinterpret existing ones while s. Empirical research is appropriate when proof is sought that certain variables affect other variables in some way. Evidence gathered through experiments or empirical studies is today considered to be the most powerful support possible for a given hypothesis (C.Kohari, 2004).
- Quantitative vs Qualitative: Quantitative research is based on the measurement of quantity or amount. It is applicable to phenomena that can be expressed in terms of quantity. Qualitative research, on the other hand, is concerned with qualitative phenomenon, i.e., phenomena relating to or involving quality or kind. For instance, when we are interested in investigating the reasons for human behavior.

2.4 Need for forest reserve

The protected area is precisely described boundary and managed by the regulation or guide under the government institutions or non-government institutions. A protected area is geographical space, recognized, dedicated and managed trough legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural value.

The increase of human population around the forest reserve increase the destruction and rate of encroachment, forest is most important factor in climate for cooling the air temperature and balance the oxygen and carbon dioxide so that those human activities should be controlled in order to overcome the effects. The human activities affect the protected area through the global warming which has increased the occurrence of droughts and floods (Kirby & Usher, 2015).

Natural disturbance processes will, to a large degree, determine the structure and composition of the forest ecosystem in reserves. Reserves will provide valuable late-seral forest habitat for wildlife that may ultimately support species assemblages and abundances that do not occur on the sustainably harvested sites. Long term ecological monitoring (LTEM) is planned on reserve sites to document the composition of plant and animal communities over time. EOEA has contracted with researchers at the University Of Massachusetts Department Of Natural Resource Conservation to design and implement comprehensive LTEM in reserves. The results of LTEM may eventually aid in refining management practices on harvested sites to enhance conservation of biodiversity across all forestlands.

Forest reserves provide reference sites for objective assessment of the sustainability of forest management practices and are essential for practicing adaptive resource management. Reserves create opportunities for connectivity within the landscape, conservation of species and processes, buffering against future uncertainty, and other hard to measure but valuable functions. While no forestland in Massachusetts is free of human impact from ubiquitous influences such as air pollution and invasive, exotic organisms introduced by people, forest reserves can still help ensure that representative examples of biodiversity indigenous to an area are more likely to be conserved since wood fiber is not extracted and invasive plant species are less likely to be introduced in reserves (Merlin & Noba, 2019).

2.5 Activities occur on forest reserve

The each forest reserve will have an operational plan established with opportunities for public input to clearly define what activities will and will not occur. Determine in advance how managers will coordinates with local official in response to events like wildfire, pest and pathogen outbreaks, extensive blow downs and other natural disturbance events. Plan should be review all known disturbance events that have occurred in the vicinity of the forest reserve over the past few hundred years and also should be anticipate both natural and human caused events that may occur in the future. Monitoring of the species, communities and processes will be fundamental component of planning for all forest reserve (Yu-fang, 2011)

The primary difference in activities between reserves and other state-owned forestlands will be the exclusion of commercial timber harvesting. Recreational use of rubber-tired motorized vehicles such as dirt bikes, ATV's, and four-wheel drive trucks are already excluded from the great majority of state lands and will also be excluded from reserves. Recreational use of snowmobiles during the winter season may continue under existing permits and on designated trails depending on Agency policy. However, snowmobile use during the winter season will not be expanded on any reserve site beyond what is currently allowed. Foot-pedaled mountain biking and horseback riding will be determined on a case by case basis for each reserve according to Agency policy. Camping will typically be restricted to existing recreational sites, and will not be expanded in reserve sites. Activities such as hiking, hunting, fishing, trapping, birding and other forms of wildlife observation are currently allowed on most state-owned forestlands and will continue in reserves (Mabula & Shangali, 1998).

For planning purposes, a natural disturbance will be defined as an event that would be expected to occur absent direct human actions on the landscape. Natural disturbances include windstorms, lightning-caused wildfire, and outbreaks of native insect pests such as hemlock looped and forest tent caterpillar that have occurred historically in Massachusetts. For each natural disturbance that occurs within a given reserve, a decision must be made as to whether or not the disturbance can be allowed to proceed to any degree without threatening human life and property outside the reserve. Disturbances such as natural wildfires which can clearly threaten human life and property must either be immediately extinguished within a reserve, or to whatever degree possible, be allowed to "let burn" within portions of the reserve if state and local officials feel this can be done without impairing public health and safety. In a fire-adapted forest ecosystem like the pitch pine/scrub oak type found in southeastern Massachusetts, wildfire can be extremely difficult to contain, and prescribed burning may be appropriate to emulate natural processes while insuring public health and safety (Yanda & Eludoini, 2019).

2.6 Remote Sensing

Remote Sensing is the science and the expression of acquiring information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with an object, area, or phenomenon under investigation. The definition of Remote Sensing (RS) is as follows: "Remote sensing is the science and art of obtaining information about the Earth's surface through the analysis of data acquired by a device which is at a distance from the surface". Remote sensing is an essential tool of land change science because it facilitates observations across larger extents of Earth's surface than is possible by ground-based observations by using cameras, multispectral scanners provide a large variety and amount of data about the earth's surface for detailed analysis and dynamic with the help of various ground-based, space borne and airborne sensors (Adam, 2019).

It is occurring now with powerful capabilities to understand something and managing earth resources. Remote Sensing has been proven a very useful tool for Land-use land-cover dynamic. It is the process of obtaining information about an object or phenomenon without making physical contact with it, typically gathered by sensing devices that are mounted on aircraft or satellites, which collect data in the form of images or other measurements. Remote sensing has been widely used in various fields such as geology, agriculture, forestry, meteorology, oceanography and many more (Bathata, 2011).

2.7 Geographical Information System

A geographical Information System (GIS) consists integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS also allows the integration of these data sets for driving meaningful information and outputting the information derivatives in map format or tabular format. Also GIS system designed to capture, store, manipulate, analyses, manage and present all type of geographical data. Geographical data can be analyze to determine the location of features and relationship to other features, where the most or least feature exists. GIS can be used as the tool in both problem solving and decision making processes as well as for visualization of data in a spatial environment and also used to extract useful information from image and to produce final map output for those forest reserve area. (Howari & Girefati, 2021).

2.8 Land use, land cover

Land cover refers to the physical and biological characteristics of the Earth's surface, including the natural and human-made features that cover the land. It describes the composition and arrangement of different types of surfaces, such as forests, grasslands, wetlands, croplands, urban areas, water bodies, and barren or bare land. Land cover provides information about the types and extent of vegetation, land use activities, and the presence of natural or artificial features on the Earth's surface. It is an essential component for understanding and managing ecosystems, monitoring environmental changes, and studying the interactions between humans and the environment (Fonte & Patriarca, 2017).

2.9 Type of image classification

Land-cover maps are commonly created from remotely sensed data through unsupervised or supervised classification techniques. Image classification refers to the extraction of differentiated classes or themes, usually, land cover and land-use categories, from raw remotely sensed digital satellite data. Image classification using remote sensing techniques has attracted the attention of the research community, as the results of classification are the backbone of environmental, social, and economic applications. Because image classification is generated using remotely sensed data, many factors cause difficulty to achieve a more accurate result. Some of the factors include the characteristics of a study area, availability of high resolution remotely sensed data, ancillary and ground reference data, suitable classification algorithms, and the analyst's experience and time constraints (Halmilton & Smith, 1989).

These factors highly determine the type of classification algorithm used for image classification. Various image classification methods are applied to extract land-cover information from remotely sensed images. There are several classification methods and each method is specific to the data and the locations because in each location land categories are varies and have different values in the image. For instance, the image value of agricultural land is dependent on the type of crop that grows on that land. Even the same crop in different climates can have different colors, which changes the color of the image. Moreover, the seasons also affect the color of land-covers (Masore, 2013).

2.10 Supervise classification

Handing larger than incredible the image analyst supervises the pixel categorization process by specifying, to the computer algorithm, numerical descriptors of various land-cover change recognition current in the representation of land-use change clearly shows that area. Training samples that express the typical spectral pattern of land-use and land-cover classes are defined. Pixels in the image are similar numerically to the training samples and are labeled to land-cover classes that have a similar integral part of a logarithm. All the classification techniques like the maximum likelihood classification (MLC), parallelepiped and minimum distance to mean classification may be applied to get the best classification technique (AL-doski & Mansorl, 2013).

The maximum likelihood classification assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Each pixel is assigned to the class that has the highest probability (that is, the maximum likelihood). Maximum Likelihood is among commonly used supervised classification methods used with remote sensing image data. The Maximum Likelihood classification method is well known for the analysis of satellite images. So far, satellite image interpretation using the maximum likelihood approach was mostly applied for land-cover classification and monitoring of land-use changes.

CHAPTER THREE
METHODOLOGY

3.1 Study area

3.1.1 Gendagenda Forest reserve

Gendagenda Forest Reserve is a forest reserve located 5°34'0" S, 38°37'59"E at Mgambo ward in Handeni-Tanga that bordered with Mgambo JKT (835 KJ) and villages including; Komsanga, Gendagenda, Kwedihwahwala and Kwabojo village, also the reserve area covered 3139Ha with the length 34.5km. Gendagenda forest reserve managed by the Tanzania Forest Reserve (TFS) Agency in Handeni district-Tanga The forest reserve faced the many challenges due to the human activities evolved around it and people around the Gendagenda forest reserve high demand resource on reserve area, the human activities that much involve in reserve area are settlement, crop cultivation, livestock keeping and cutting down of tree.

An encroachment is major problem with the villages around the reserve area especially the Kwabojo village that highly rate that led the loss of species both fauna and flora. The Gendagenda forest reserve also the support the tourism activities in Tanga region due to the unique trees, many number of birds, monkeys and others species that make attractive for tourists. The Tanzania Reserve Service Agency was responsible both management and guide in order for conserve the natural resources for economic and development aspect. The forest reserve is one among reserve that important in region due the forest support the wildlife habitat, weather forecasting and tourism activities.

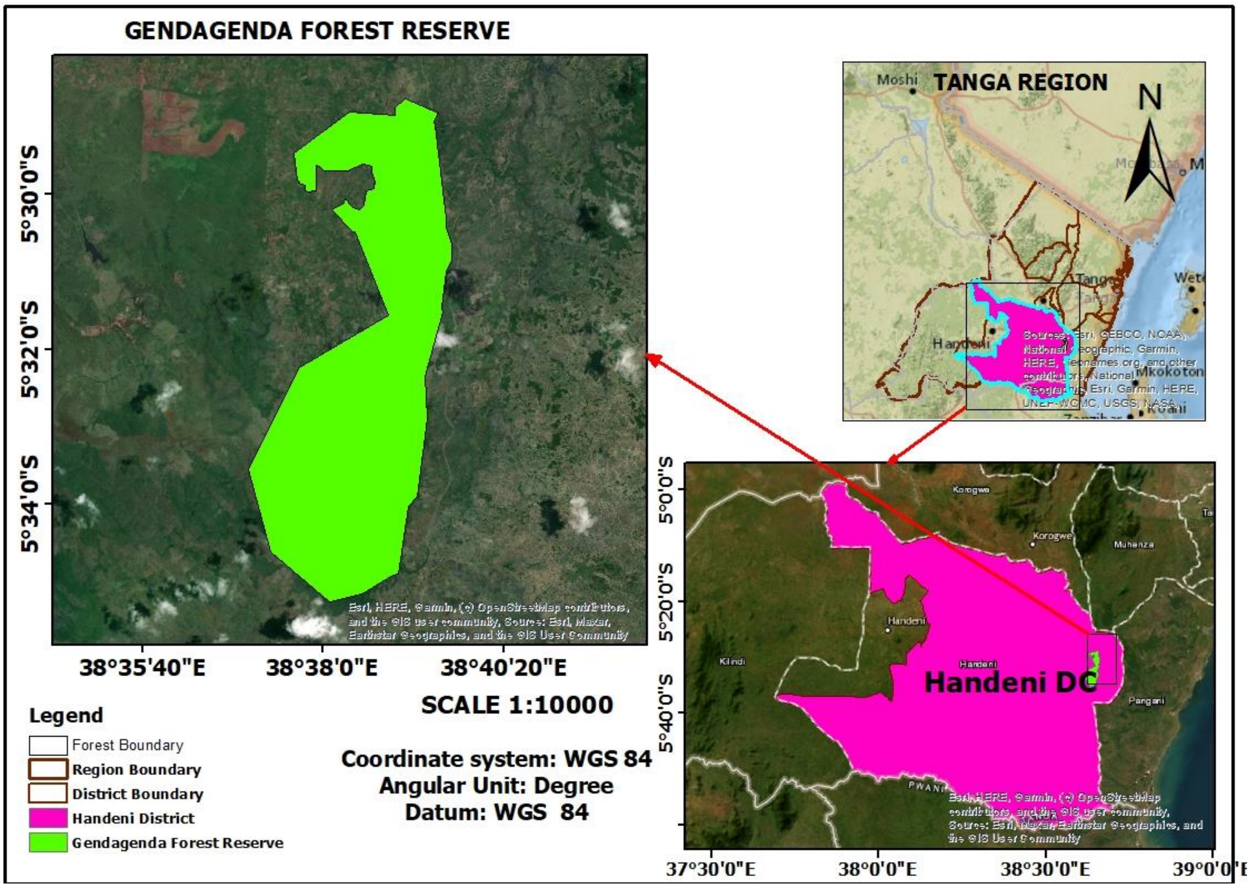

Figure 3.1: Location map of Gendagenda Forest reserve

3.2 Methods and analysis

3.2.1 Data requirement and availability

Downloading Landsat Satellite images from United State Geological Survey (USGS). The downloaded images from the United State Geological Survey (USGS) websites used for classification by use the Erdas Imagine 2014 as the software used to identified the detect changes analysis, the also determine the changes occurred within the period of time. The land cover maps of different epochs (2012-2017 and 2017-2022).

Shape files of the existing features obtained from reserved area. The data contain the information of the features like road, border and water bodies. The boundary of Gendagenda Forest Reserve and Villages used to show the exact locality and prove the interaction involve around the border area and the road and water bodies the searching and downloading the required data that categorized on the three part, which are images data, shape files and population statistical data.

An images data 2012, 2017 and 2022 downloaded on United State Geological Survey (USGS) website that cover the interest area and the shape files and population data are obtained at National Bureau Statistic (NBS) and other obtained from forest reserve.

3.2.2: Data collection

Secondary data; Landsat satellite image 2012, 2017 and 2022, existing maps and shape file data for roads, boundary, rivers and etc. Also the statistical data of National Bureau of statistics for population of human being, livestock and wildlife. The satellite images there used to produce the Land Use Land Cover (LULC) at different duration of time, also the shape files and maps are used on overlay to observe the changes and development within the area of a park. The population data are used to determine the growth of the population around the boundary of the forest reserve showed by Table 3.1 below.

Table 3.1: Downloaded Landsat images

S/N	SCENE ID	DATE	LOCATION
1	LC08_L2SP_167064_20140316_20200911_02_T1	2014	Tanga Region
2	LC08_L2SP_167064_20180207_20200902_02_T1	2018	Tanga Region
3	LC08_L2SP_167064_20220218_20220302_02_T1	2022	Tanga Region

3.3 Material and Software

Based on my research, different material and software were used to manipulate and analysis the collocated to get the expected result about the forest reserve in Tanga region-Tanzania. The analysis modeling of land use and land cover on forest reserve due to the human encroachment. The following are the software used on my research;

- Arc GIS (10.8)

ArcGIS is a family of client, server and online Geographic Information System (GIS) software developed and maintained by Environment System Research Institute (ESRI) that was released in 1999 and originally line based GIS system for manipulating data. Also, ArcGIS is proprietary software perform different task that include are data acquisition, editing, manipulation, analysis, visualization and display of spatial data.

- ERDAS IMAGINE 2014

This proprietary software that Geographic imaging professionals need to process vast amounts of geospatial data every day that often relying on software designed for other purposes and add-on applications create almost as many problem as they solve. Save both time and money, leverage existing data investments and improve your image analysis capabilities. Also that software very useful in leading geospatial data authoring system, supplies tools for all your remote sensing, photogrammetry and geospatial analysis needs.

- Google Earth pro

Google Earth pro is a free geospatial desktop application that allows you to see the world and create highly detailed maps. Aim at users with advanced features needs and allow to view the earth in three dimension that including the height from the mean sea level. This software also used for capture geospatial data and allow to import and export the GIS data of different format, both shape files, kml, csv and other GIS data format. Also used in visualization of geospatial data.

- Microsoft office (2016)

This is a version of the Microsoft office productivity suite that released on July 9, 2015 that applicable in different platform and operating system like window 7 up to 11 and the more than 100 language. All traditional editions of Microsoft office 2016 contain word, excel, PowerPoint and OneNote licensed for use one computer. In modeling of the forest reserve based on human encroachment is useful in report writing, chart preparing, graph and statistical analysis.

- Terrset 2020 and IDRISI Selva

Terrset is an integrated Geographic Information System (GIS) and Remote Sensing software developed by Clark labs at Clark University for the analysis and display of digital spatial information. Terrset is gridded based system that offers tools engaged in analyzing earth system dynamic for effective and responsible decision making for environmental management, sustainable resource development and equitable resource allocation. It essential for create the model that predict the future LULC 2026 of Gendagenda forest reserve.

- QGIS (3.20.2)

Quantum GIS is a free and open source software that allows users to create, edit, visualize, analyze and manage geospatial data through the provided tools and capabilities for working with maps, spatial data and related attributes. User friendly, interoperability, data visualization and supportive software that help for analysis remote sensing data, such as Landsat images and shape files for existing features on forest reserve, also used for create the layout maps.

3.4 Method and data analysis

I started with data collection from various sources that including primary and secondary data that analyzed by applying Multi-Criteria Evaluation (MCE) to integrating with different software. In images analysis used ERDAS Imagine for layer stacking of bands, radiometric calibration in term of atmospheric correction, haze and noise reduction. Also processed with pre-processing that including projection of an images with coordinate system and create mosaic of the area of interest but all those processing performed before the actual classification analysis. ArcGIS used for analysis of shape files of features that includes road, boundary, water bodies and other that support modelling and complete the display of visualized features and maps.

3.5 Data analysis

- Image pre-processing

Image pre-processing is done by using the Erdas Imagine 2014 software to combine the band with stack by using the layer stack process on images of 2012, 2017 and 2022. After layer stacking process there re-projection images (2012, 2017 and 2022) that help to get the exactly study area and continues with image classification.

- Classification of an image and accuracy assessment

The output obtain after pre-processing can be used in classification, the supervised classification with use the maximum likelihood as the classifier in study to separate land use land cover classes on interested area. An algorithm was used to classified the three epoch's imagery separately, then conduct the accuracy assessment of the classification that help to determine the accuracy of overall accuracy shown by Figure 3.2 below.

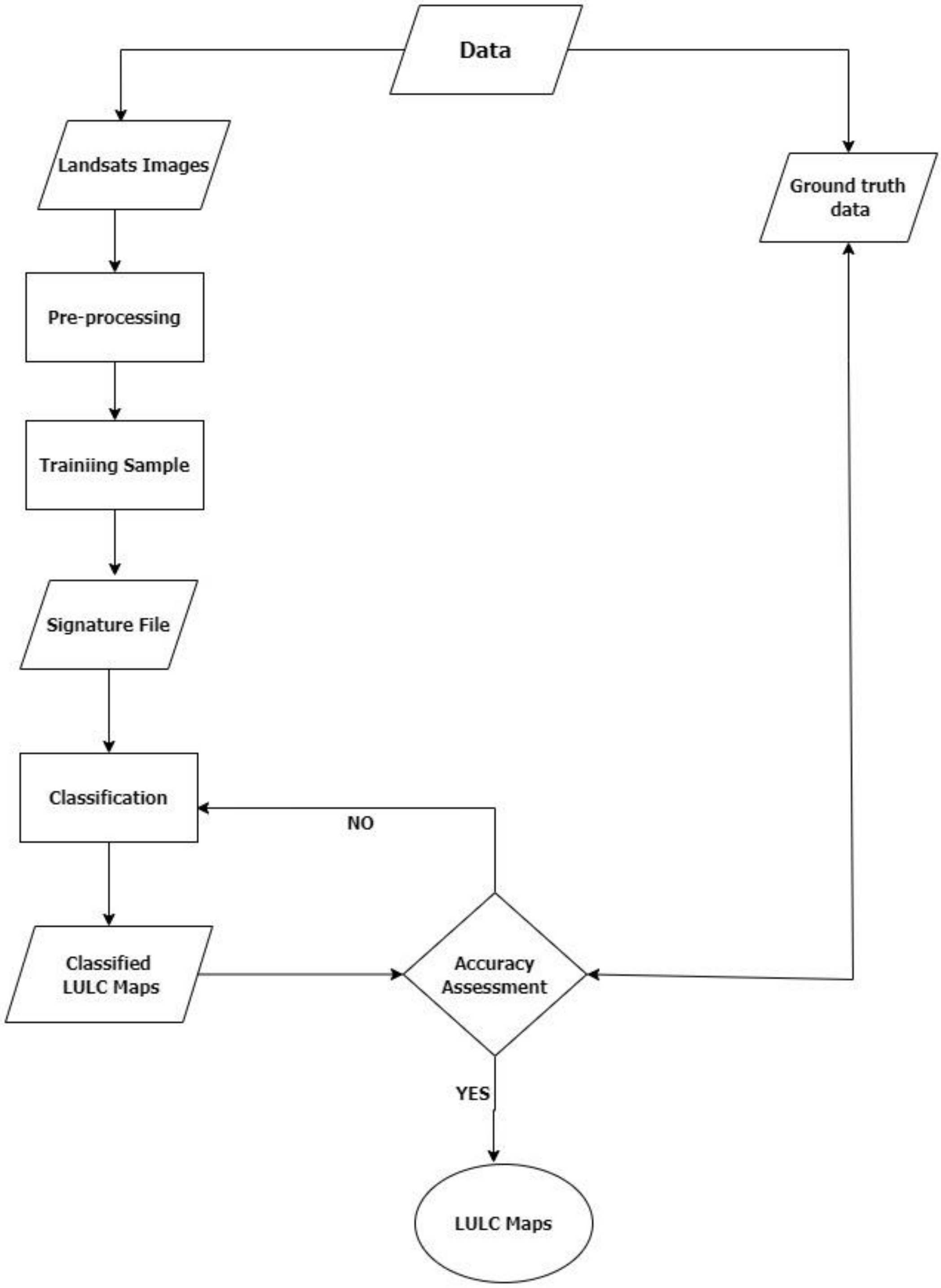

Figure 3.2: Classification work chart

3.6 Land Use Land Cover (LULC)

Land Use Land Cover (LULC) refer to the classification and distribution of various material cover the surface of earth and activities or use of land that represented trough maps or datasets categorized into classes. LULC are provide the information that help to understand the current landscape in monitoring the dynamic changes on forest reserve. The LULC map contained the key element that describe the LULC, such as legend, scale, north arrow and title on the top of map. Land cover describe the what material cover the landscape like forest, building, bare land or water bodies but the Land Use describe the purpose the land serve for example wildlife habitat, agriculture and commercial purpose. Based on my research the land use is multiple use for conservation and use for different aspect and the land cover by forest, vegetation, bare land and built-up area for monitoring of resource and planning the activities.

3.7 Future LULC map

Using Land Change Modeler, GEOMOD, Markov chain analysis, and cellular Automata, it is possible to determine the future Land-use and cover project maps. Using this neural network analysis, it is possible to determine the weights of the transitions that will be included in the matrix of probabilities of the Markov Chain for future prediction. The future Land-use and cover project maps of (2026) may be hard classifiers (Traditional classifiers) since they yield a hard decision about the identity of each pixel and soft classifiers express the degree to which a pixel belongs to each of the classes being considered. For this research, a hard classification of the Future predicted map is generated. Figure 3.3 below shown procedure followed to predict future LULC map.

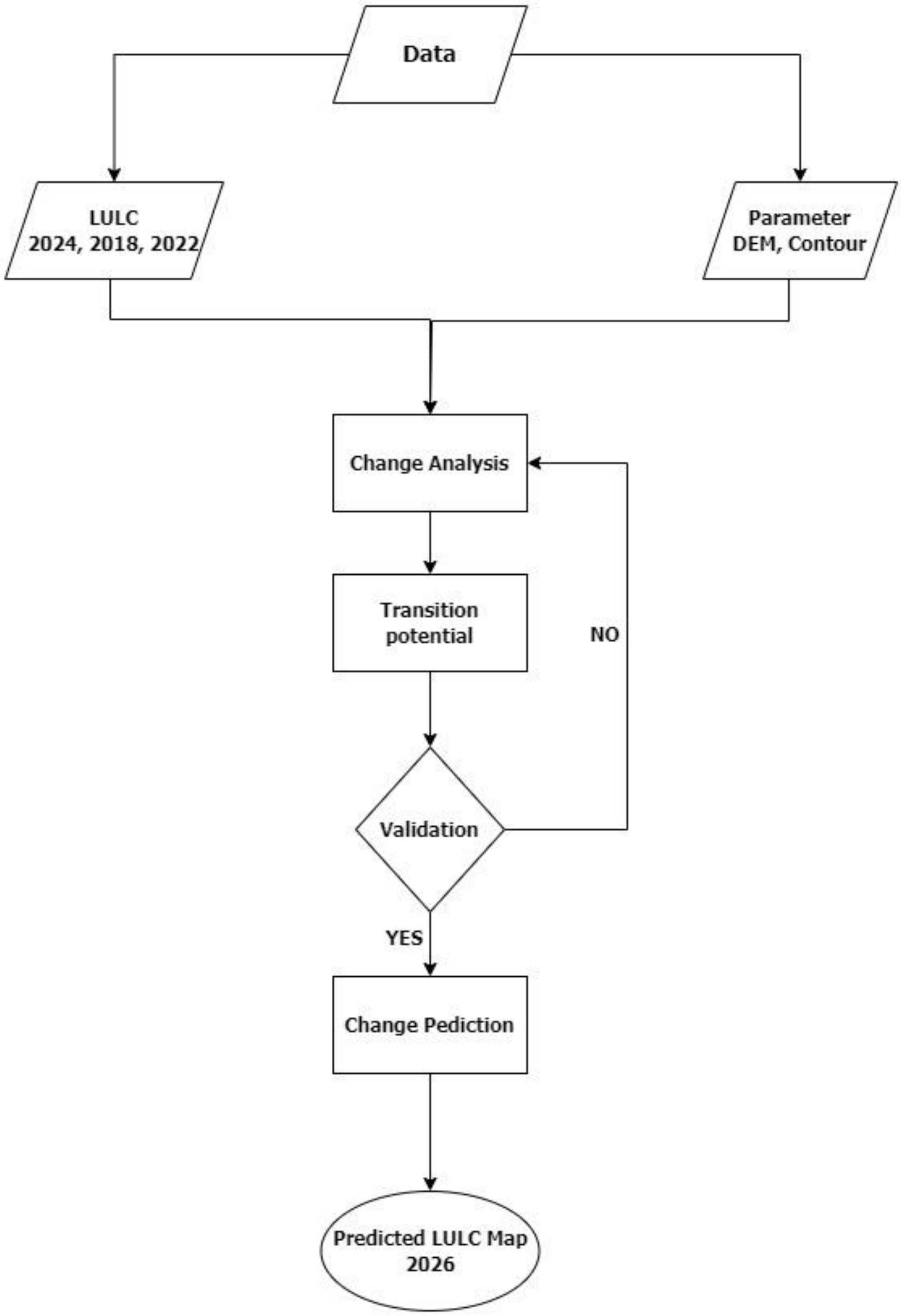

Figure 3.3: Prediction of LULC map work chart

3.8 Change detection

The classified image help to detect the changes on reserved area from 2012-2017 and 2017-2022. By using the Remote Sensing techniques perform the changes detection with satellite imagery have becomes numerous as a result to obtain the area of different land cover and observe the changes that taking place in the span of the data. List four aspects of changes detection which are important when monitoring natural resource; detecting the changes that have occurred, identifying the nature of changes, measuring the area extent of the changes and assessing the spatial pattern of the changes.

3.9 Dynamic process

After classification of an images the remote sensing data were converted into thematic maps that assess the temporal and spatial land of dynamic in the forest reserve. The land-cover and land-use of consecutively of dataset of remote sensed Landsat imageries through two analyzed of 2014, 2018 and 2022 images.

3.10 Parameters using for the creation of the future and monitoring model

The parameters varies from the most influences on the land use and land cover prediction results to least one. The variation due to the sensitivity on prediction land use and land cover LULC 2026 for the classes that includes dense vegetation, sparse vegetation, bare land area and built-up area on classification of the Landsat images 2014, 2018 and 2022 years. Most influences parameters for prediction of model are aspect, slope and contour for the terrain analysis and also the shape files of roads, railways and other features of interest so that perform the analysis for land use and land cover as the input data.

3.10.1 Contour Map

A contour line as the line drawn to indicate the ground elevation or depression of land surface that connects points of equal value or elevation, in cartography the contour line represented as specific elevation above or below reference points such as mean sea level. The contour is very potential in terrain analysis, often Digital Elevation Model (DEM) to understand the shape and the characteristics of the land. In order to create lines connecting locations with similar value in a raster dataset that shows continuous phenomena, the raster analyst tool first formed the elevation from the Digital Terrain Model (DTM). The contour lines had 25m intervals and covered a distance between 1000 and 1600 meters from the mean sea level.

3.10.2 Slope for terrain analysis

Slope as the ratio of the vertical changes in elevation to the horizontal distance between two points on the land surface in term of percentages (%) or degree (°). In terrain analysis slope measure the steepness on the ground surface and fundamental parameter used to topography of area of interest and various fields including geography, geology, hydrology and environmental sciences. By using the ArcGIS as the software that produced from Digital Elevation Model (DEM). ArcGIS is a software that used to extract the slope from Digital Elevation Model through essential 3D analyst tool. Slope analysis is essential for understanding and modelling surface water flow, erosion pattern and land stability.

3.10.3 Aspect for orientation of slope

Aspect define as the intricate function in GIS terrain analysis and modelling through define the orientation of the slope describe the steepness of the terrain. Aspect define in terms of degree start from zero degree up to the three hundred and sixty (360) degree so that flat areas with no downslope direction are given a value of -1 by using Digital Terrain Model (DTM) produced the elevation where the aspect was computed by the raster surface tool in 3D analyst tool which examined the downslope direction clockwise in degrees from 0 (due north) to 360 (due north).

3.11 Model selection and criteria

In modelling the human encroachment on forest reserve the model that would use is Cellular Automata Markov chain modeling to monitor and predict the future land use land cover 2026. Markov chain analysis is a convenient tool for modeling land use and land cover change (LULC). A model process is simply one in which the future state of a system can be modeled purely on the basis of the immediately preceding state. Markov chain analysis will describe LULC from one period to another and will use this as the basis to project future changes. This is accomplished by developing a transition probability matrix of land use and land cover change from time one to time two, which will be the basis for projecting to a later time periods. The probability function can be static over time or can be adjusted at specific intervals to account for changes in the stationary of the processes controlling the transition sequences. The probability function and transition sequences can be derived from direct observations using satellite data.

3.12 Relevance, linkage potential, transferability and data requirements

Sensitivity analysis can identify the parameter(s), which have most to least influences on land use and land cover prediction results. Sensitivity analysis was performed on the differences between the predicted LULC of 2026 by using 2014, 2018 & 2022 LULC images that LULC was obtaining from the Landsat images downloaded from USGS website.

3.13 Modelling LULC dynamic

The transition probability matrix has been calculated for the time period of 2014 to 2022 for the prediction LULC of 2026. The expected probability of transition of LULC category and parameter sensitivity of different parameters and transition probability matrix is the cross tabulation of the three images (2014, 2018 and 2022), that each LULC category will change to every other category. The transition probability areas matrix records the number of pixels that are expected to change over the specified of time.

3.14 Modelling LULC change and model calibration of CA-Markov

CA operates on grid-based cells and transition rules are applied to determine the state of a cell. Markov Chain Analysis, on the other hand, is a system in which the future state of a system is modeled based on the immediate proceeding state. The simulation refers to the process of land-use change between two points in time and extrapolating this change into the future (Roy, 2015). It can predict transition among any number of classes and transition rules were based on the factors that have impacts on LULC change. These factors include slope, proximity to the road, growing population, and land use.

3.15 Change analysis and predicting modelling

Land-use and land-cover change modeling is a rapidly growing scientific field because land-use change is one of the most important ways that humans influence the environment. Knowing the changes that have occurred in the past can use to predict future changes. Land-use change prediction in Land Change Modeler (LCM) is an empirically driven process that moves in a stepwise fashion from Change Analysis to Transition Potential Modeling and from transition modeling to Change Prediction. The Change Prediction (simulation) modeling for 2026 was based on the Cellular Automata. The validation of the model accuracy is needed, to achieve acceptable accuracy, this study had employed an approach to simulate LULC of 2020 from the previous LULC such as 2014 and 2018 LULC.

3.16 Trend analysis

The terrain analysis is the process studying and clearly interpreting the physical characteristics and landscapes behaviors of the earth's surface. Landscape analysis of various terrain features such as aspect, slope, elevation, contour, hill shades and DEM are most important part in asses the encroachment. The terrain influence the encroachment on forest reserve through accessibility on terrain features, gentle slope, flat plains and transportation networks can be easy and more accessible and proximity to resource, the forest reserve have are rich in valuable resource such as timber, mineral and water sources.

Land suitability, the human activities especial agriculture the terrain analysis helps to determine the suitability on land based on different aspects such as soil fertility, drainage pattern and elevation are most factors influence on encroachment and other activities like settlement and transportation infrastructure. protective barrier, the potentials in terrain features analysis through the terrain features also term as the natural barrier and discourse encroachment, example steep slopes, dense vegetation and landscapes can make difficult to access or navigate hence reduce the rate of human encroachment.

Vulnerability to environmental risk, the natural hazards such as landslides, flooding and erosion are high risk area so that the terrain analysis can be help to identify areas with high risks. Conservation value also factor to be considered that includes the features like unique landforms, biodiversity hotspots and other related can enhance the conservation value on the reserve area.

3.17 Population density

The population density considering as the total number of people that live within the bounded area. The population density is a factor that influences the encroachment on Gendagenda Forest reserve, the high population density around the forest reserve influence the increases of encroachment due to the human activities. The increase demand for resource contributes much impact on wildlife and ecological system at all, due to the human and settlement activities led the conflict between the forest reserve and bordered area. Table 3.1 above shown

Table 3.2: Population of ward around the Gendagenda Forest reserve

Ward	**Population**	
	2012	2022
Mgambo	11317	14821
Kwedizinga	6319	8168
Kwamgwe	7970	10531
Kabuku ndani	15551	16575

3.18 Google Earth image digitization process

By use the Google Earth digitizing the settlement and agricultural activities around the national park border conducted within specific time, which includes an images of 2014, 2018 and 2022. The digitized polygons should converted into the shape files there be used in ArcGIS software for further process of analysis and map production. The farms and house that existing within or around forest reserve boundary to digitize in different perspectives and years for determine the encroached area and rate that vary from 2014 to 2022 through the increase the population growth. By using ArcGIS imported shape files create the map the show the encroached area from 2014 to 2018 and from 2018 to 2022.

CHAPTER FOUR

RESULT, ANALYSIS AND DISCUSSION

This chapter includes the output for those step involve during creation the model of encroachment on the forest reserves and precise explanations in details. The final output based on my research is prediction model for LULC 2026 by using the LULC 2014, 2018 and 2022 but there many intermediate output that support for the creation of the model that include the LULC 2014, 2018 and 2022. Also the output for the parameters the useful in the prediction such as aspect, contour, slope, road, population and other parameters for monitoring and prediction.

Before the creation prediction of future model there many product obtained through processed data from different software such as Erdas imagine 2014, ArcGIS, QGIS, Microsoft office and Google earth pro.

4.1 Creation of the controlled mosaic

The created controlled mosaic from the Landsat images and shape file to locate the area of interest by using Erdas Imagine 2014 as the software. The bands combine and create the layer stack from the band one up to the seven then imported the shape file that used to crop the specific area (Gendagenda forest reserve) at the Tanga region of 2014, 2018 and 2022 years. The mosaic are often used for further analysis, interpretation and visualization through create the composite images that can easy for extraction of basic information, measurement, clearly identification of feature and leverage the strengths of multiple images. Figure 4.1 below showing mosaic of forest reserve.

The color presentation system that can display a wide range of color and shades that standard color model used in most modern digital devices for each pixel. The representation based on a combination of three primary colors such as red, green and blue that worth noting in term true color through the red, green and blue band are display on red, green and blue color respectively. The true color can be benefic for the user for data visualization for map data values to specific color that help the researcher in data analysis and interpretation.

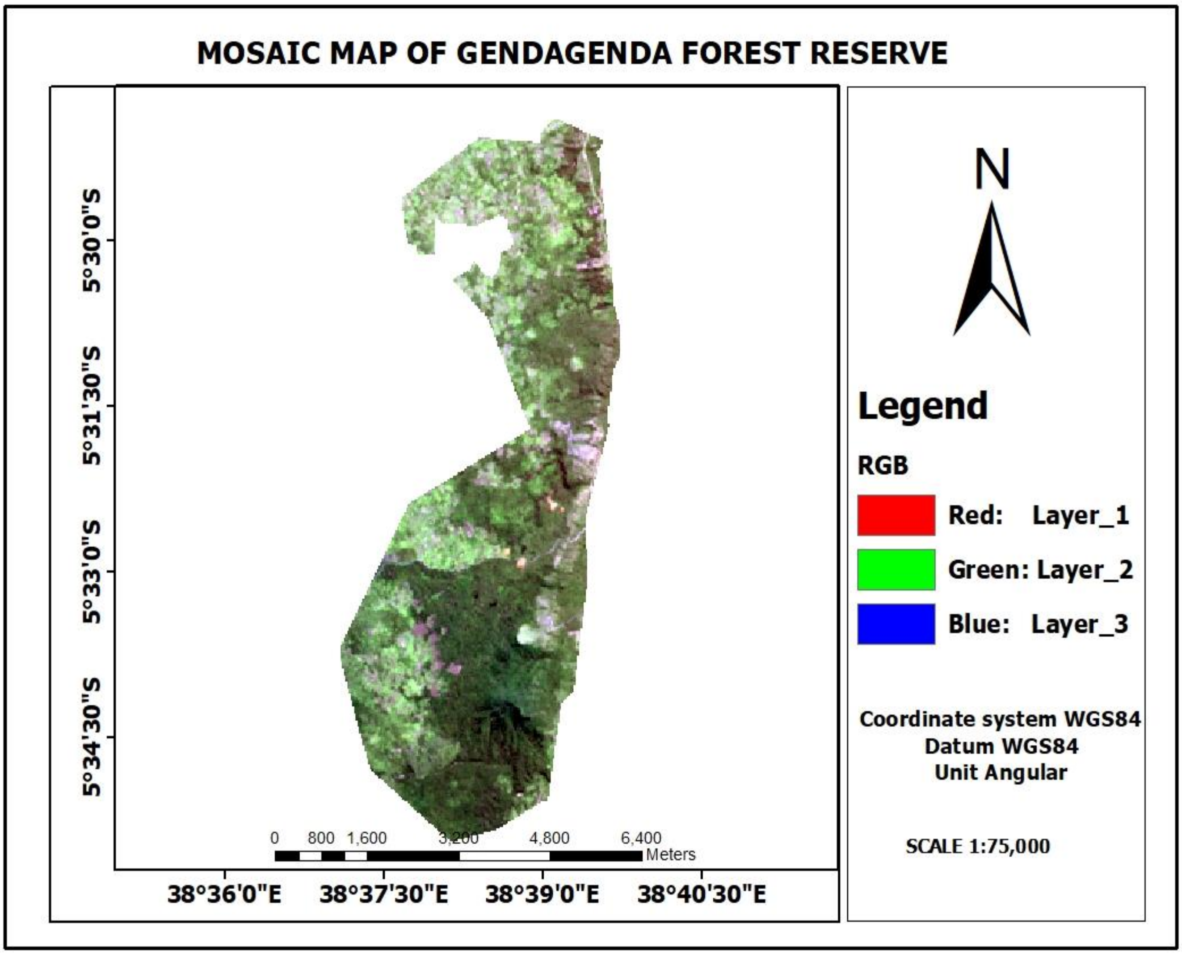

Figure 4.1: Controlled mosaic map of Gendagenda forest reserve

4.2 Land Use Land Cover Map

From the classification of the Landsat images of the years 2014, 2018 and 2022, three land cover maps were obtained comprising of the four land cover types basing on the Collin's classification scheme such as dense vegetation (forest and vegetation that is very compact to each other), sparse vegetation (sparse tree and savanna that area of transition from forested to non-forest landscape), Bare land area (area that there no dominant vegetation cover, no building, agriculture activities evolve and contain at least 90% of area covered by lichens or moss) and built-up area (area that includes the man-made features like building).

4.2.1 LULC MAP 2014

From Figure 4.2 and 4.3 below show Land cover map 2014 and distribution for each land cover type, most area cover by the dense vegetation (forest, vegetation that is very compact to each other and dense trees), sparse vegetation (savanna and vegetation does not compact to each other), followed by bare land area (cultivated area and area that not no dominant for forest) and lastly the built-up area (area that include the building and other man-made features).

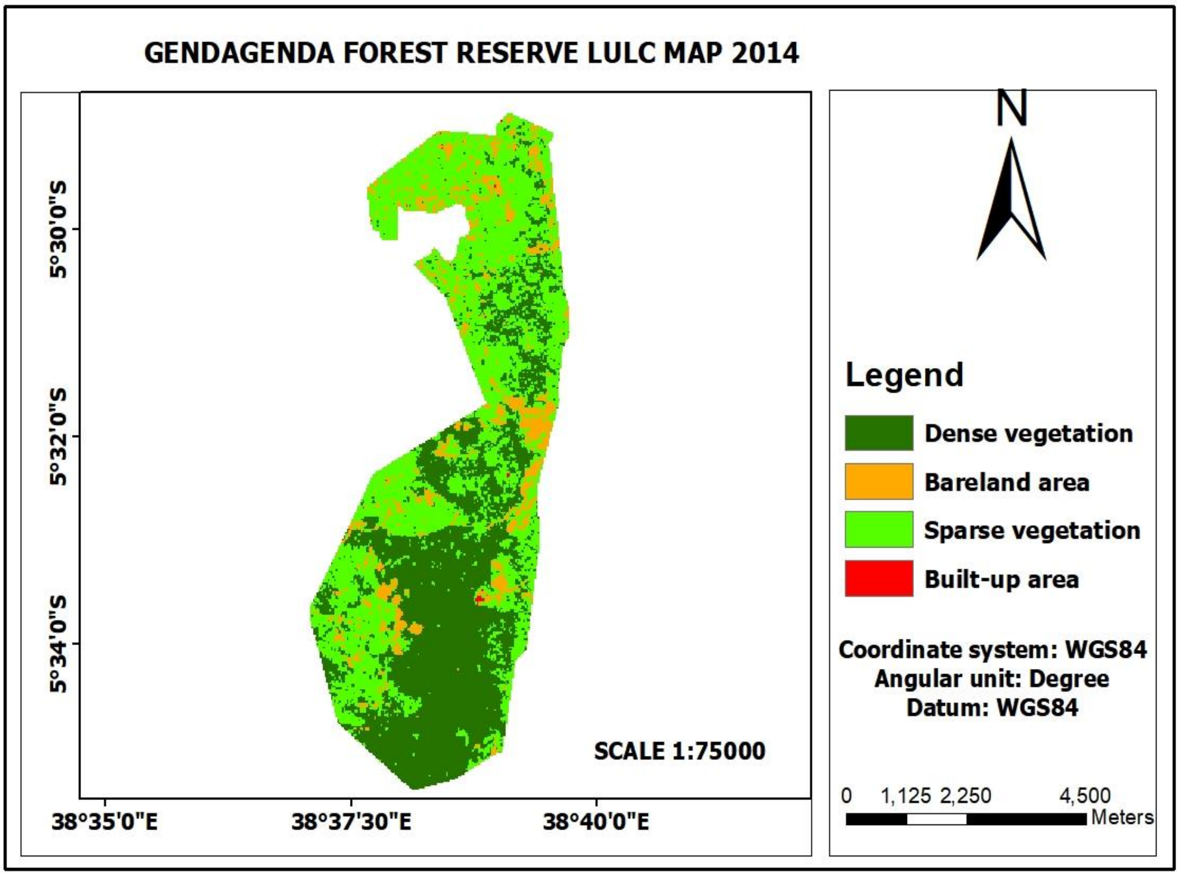

Figure 4.2: LULC map of Gendagenda forest reserve 2014

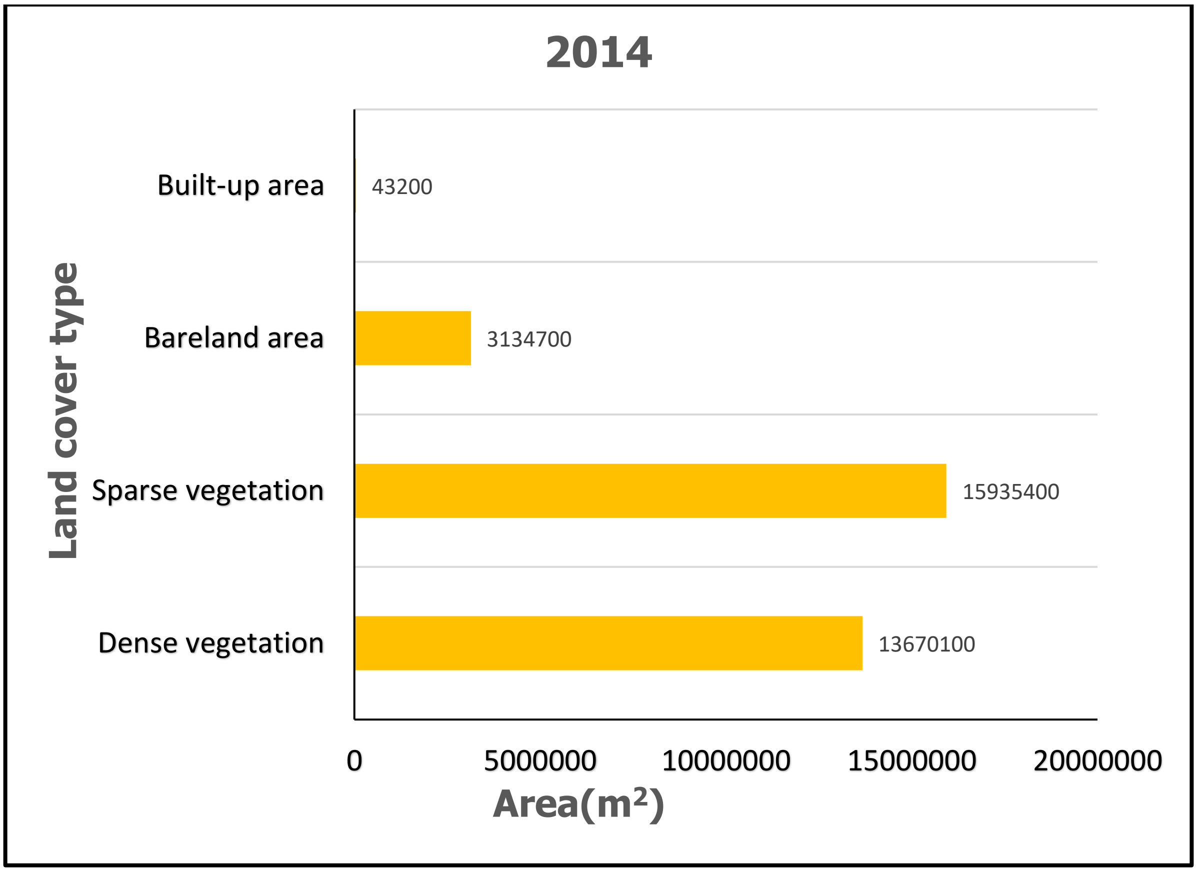

Figure 4.3: Histogram showing distribution land cover type 2014

4.2.2 LULC MAP 2018

The impact of human on forest reserve are increased led the change of land cover from one to another and some area remain past landscape properties. The statistical data for classes as the follows, 61.72% sparse vegetation, 23.44% dense vegetation, followed by 14.62% bare land area and lastly built-up area approximately 0.22% of total area of interest. The bare land area was increased by 5.06%, sparse vegetation increased by13.11%, built-up area also increased by 0.09% but the dense vegetation was decreased by 18.26% within the only four years. The statistical data proved that the rate of encroachment takes as the major factor of land cover change shown by Figure 4.4 and 4.5 below.

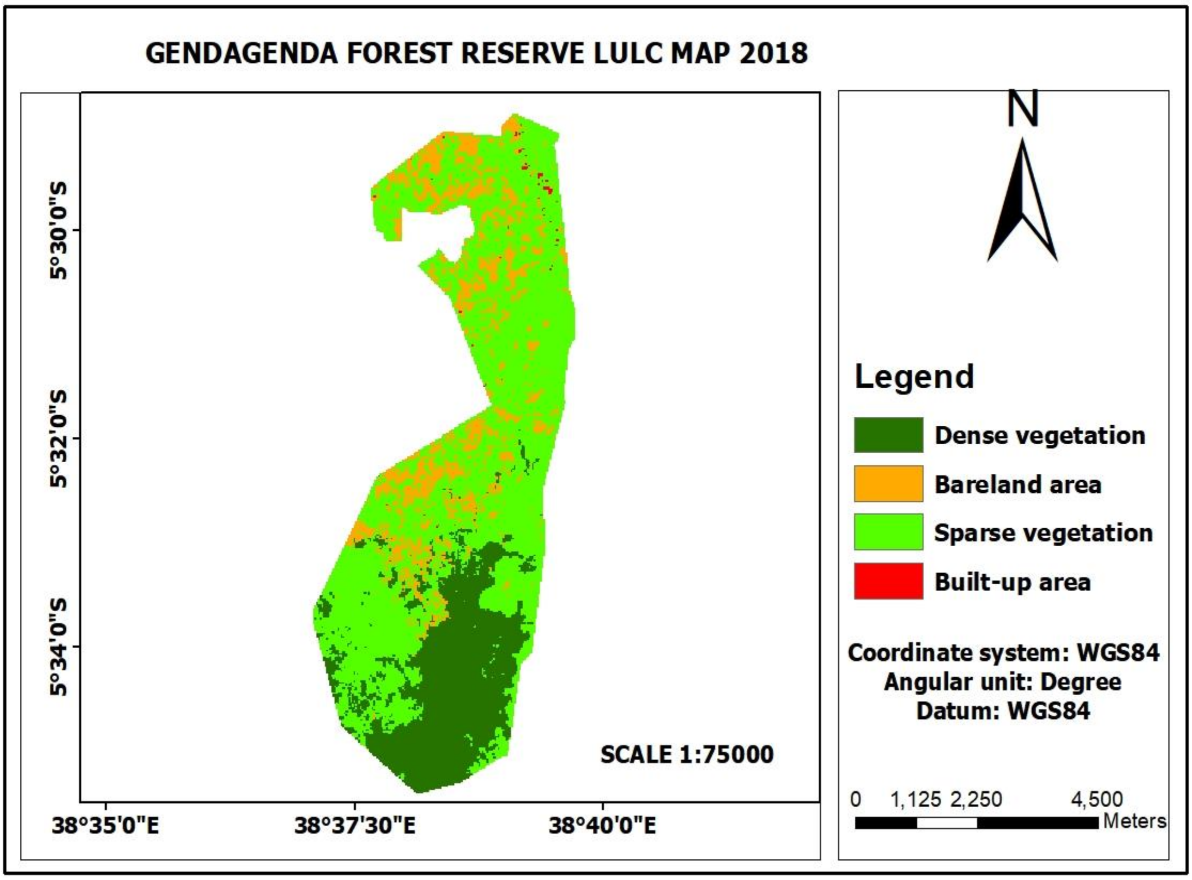

Figure 4.4: LULC map of Gendagenda forest reserve 2018

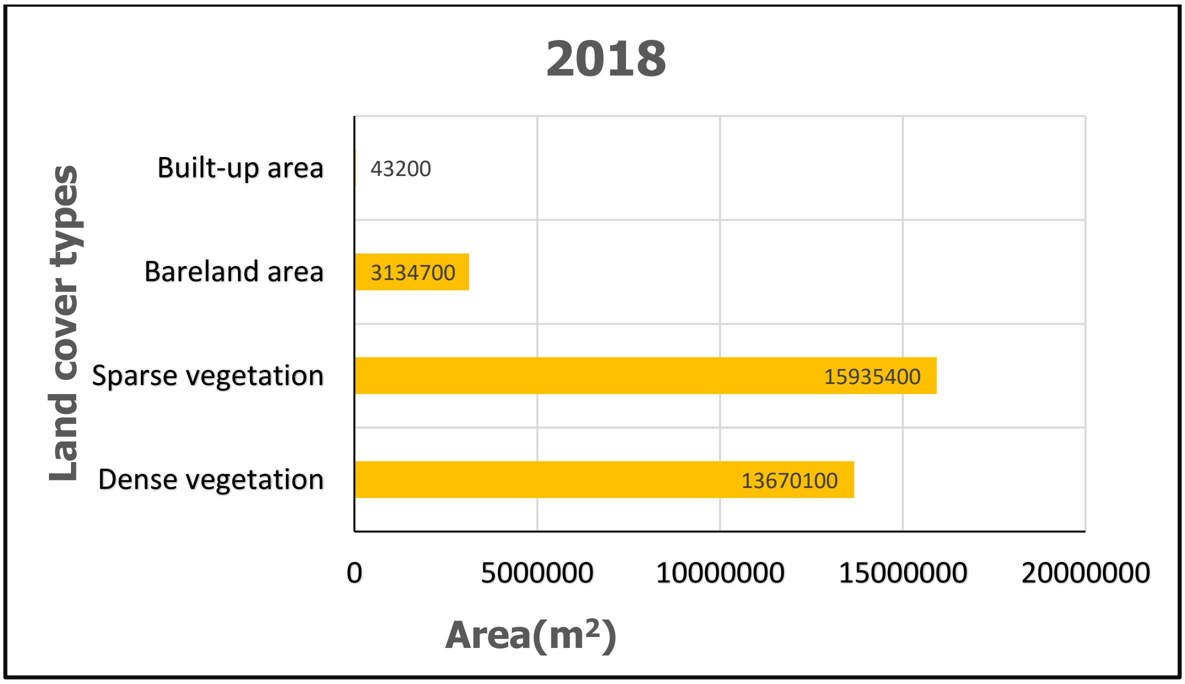

Figure 4.5: Histogram showing distribution of land cover type 2018

4.2.3 LULC MAP 2022

The LULC changes through the high rate of an encroachment on forest reserve considering four land cover types of total area for interest. The classification of LULC vary from the previous by considering the sums of pixels and area as the follow; the bare land area increased by 8.23%, dense vegetation increased by 7.08% and built-up area also increased by 0.03% but sparse vegetation decreased by 15.33% . The result show that within the four years the high variation and changes on land cover, especially the bare land area high increased from 2014 to 2022 by 13.29%, built-up area increased by 0.12%, also sparse vegetation and dense vegetation decreased randomly due to the human activities show by Figure 4.6 and Figure 4.7 show distribution for each land cover type.

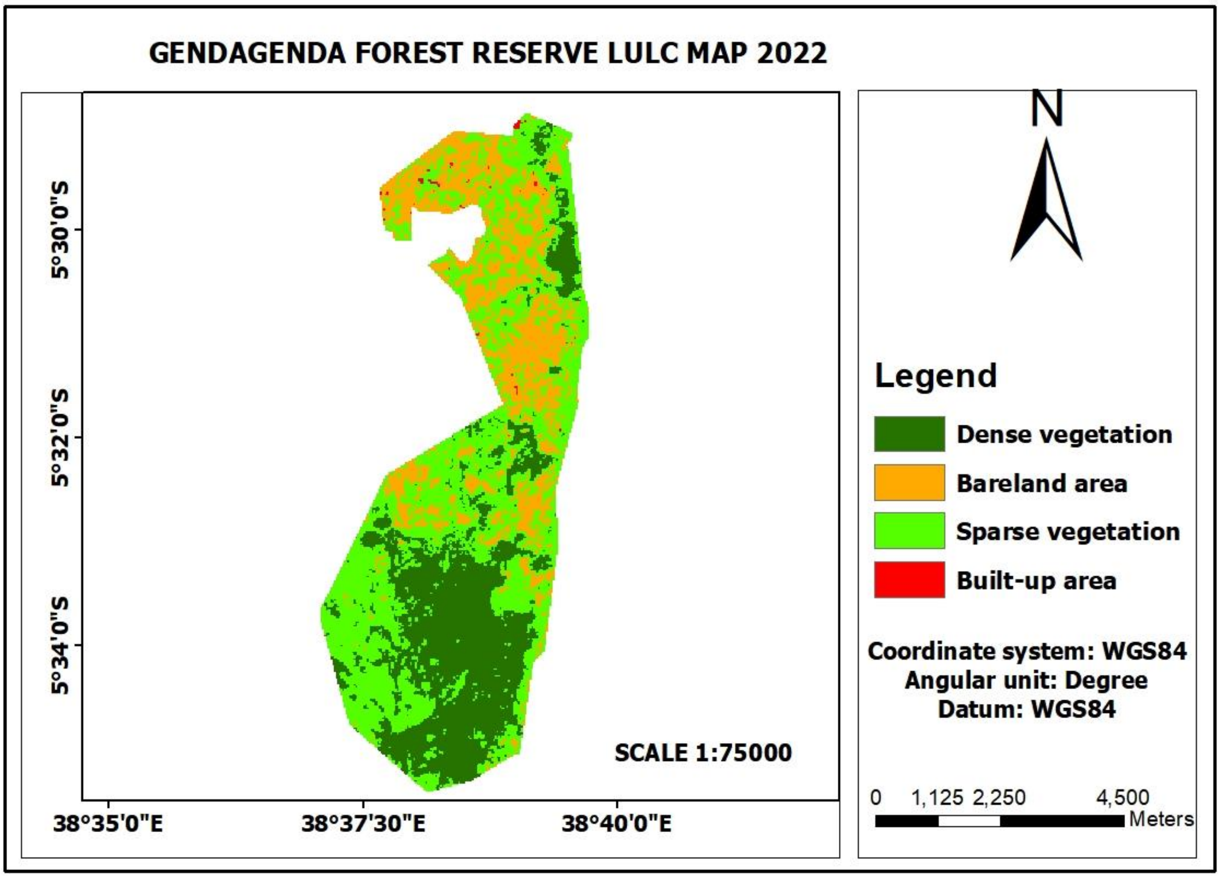

Figure 4.6: LULC map of Gendagenda forest reserve 2022

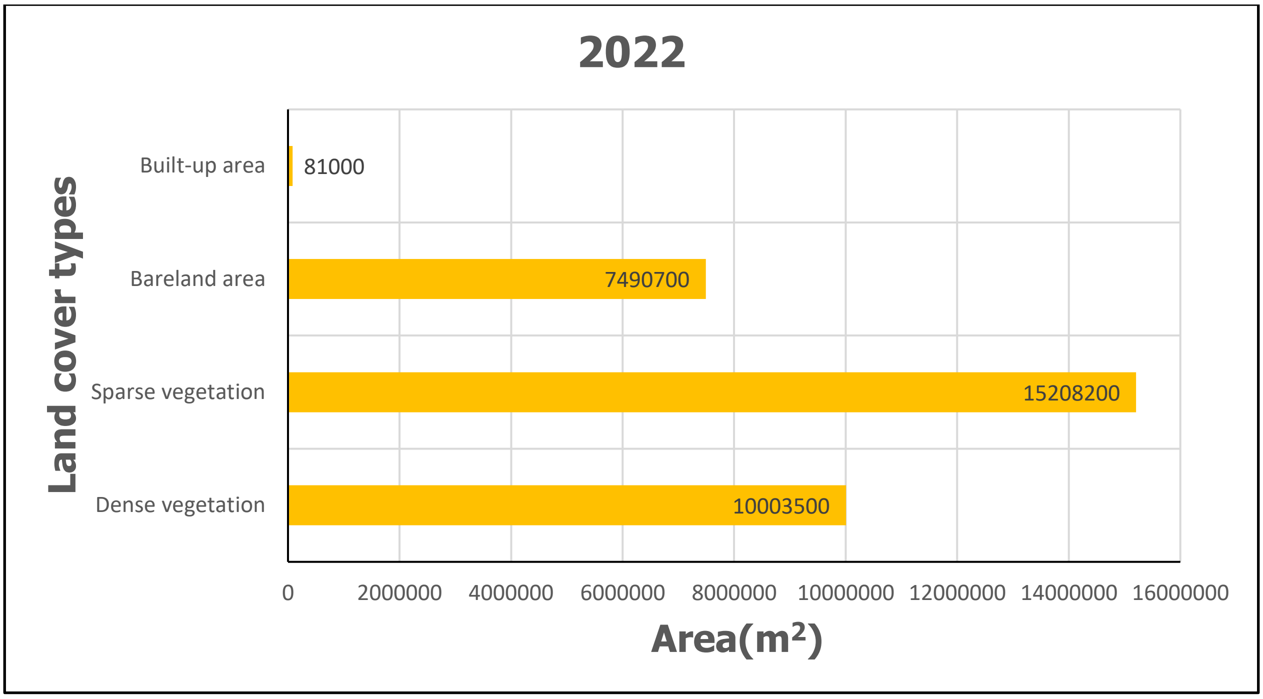

Figure 4.7: Histogram showing distribution of land cover type 2022

4.3 Change detection

Change detection of Land Use, Land Cover (LULC) maps for the Gendagenda forest reserve from 2014 to 2022 reveals the transformation of land cover types. The gradual expansion of human activities into the forest reserve boundary, encroachment on forest reserve can pose significant danger in ecological and environment impact. Within eight year the bare land area increase, information is crucial for making informed decision and implementing strategies to manage and protect the forest reserve, mitigate risk and promote its long-term conservation show by Figure 4.8 below.

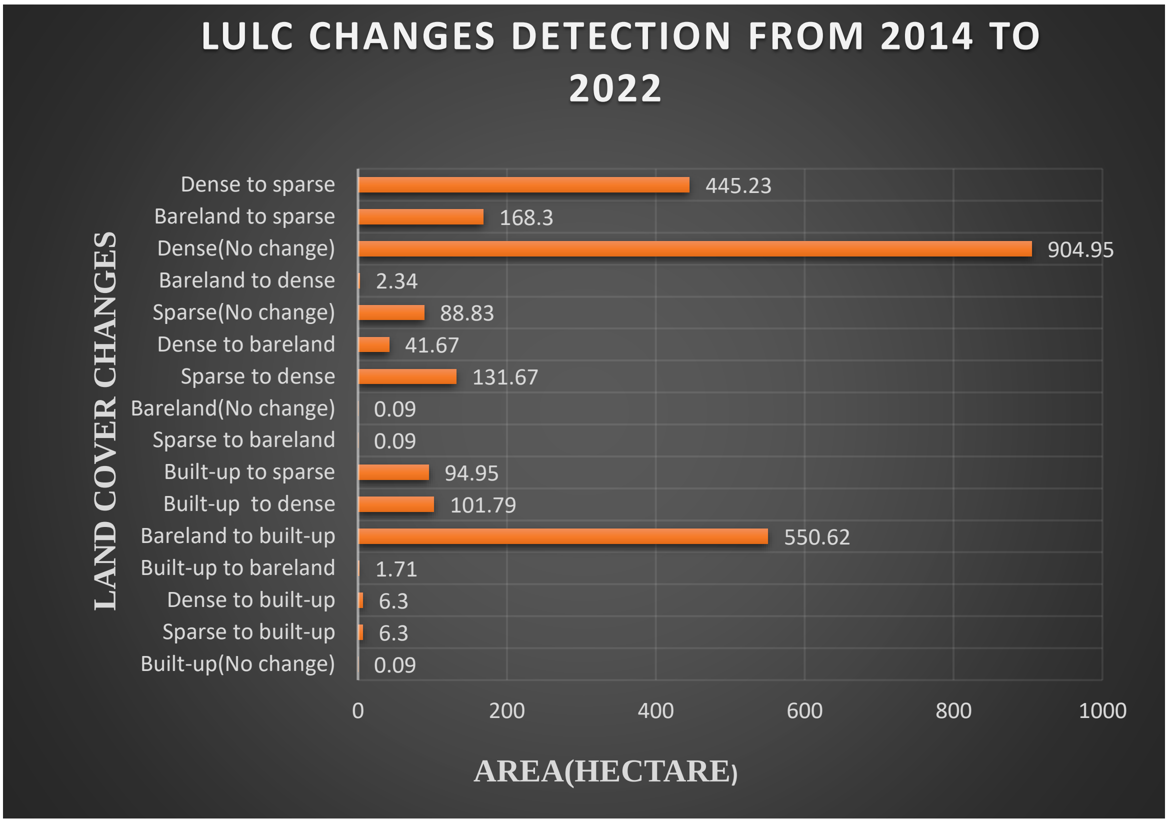

Figure 4.8: Chart showing change detection

4.4 Future Prediction LULC map

Terrset and IDRISI Selva are the essential software that used on prediction of LULC 2026 for monitoring and management of forest reserve. The previous 2014, 2018 and 2022 LULC as the imported data and most sensitive parameters such as contour, aspect, slope and DEM. The statistical data, 30.26% for dense vegetation, 23.65% for sparse vegetation, 45.65% for bareland area and followed by o.44% for built-up area, the land cover changes compared with previous LULC map. When compare with LULC 2022 prove that the land cover change due to the change land cover types from one to another by considering the increased and decreases of percentages on total area of interest. Bareland area increased by 21.80% and built-up area increases by 0.22% but dense vegetation decreased by 0.26% and sparse vegetation decreased by 22.74%, statistic shows that bareland area and built-up area increases rapid every four years and dense vegetation and sparse vegetation decreases led high risk of drought on forest reserve. The Figure 4.9 and 4.10 show predicted LULC (2026) and Table 4.1 showing distribution of land cover type.

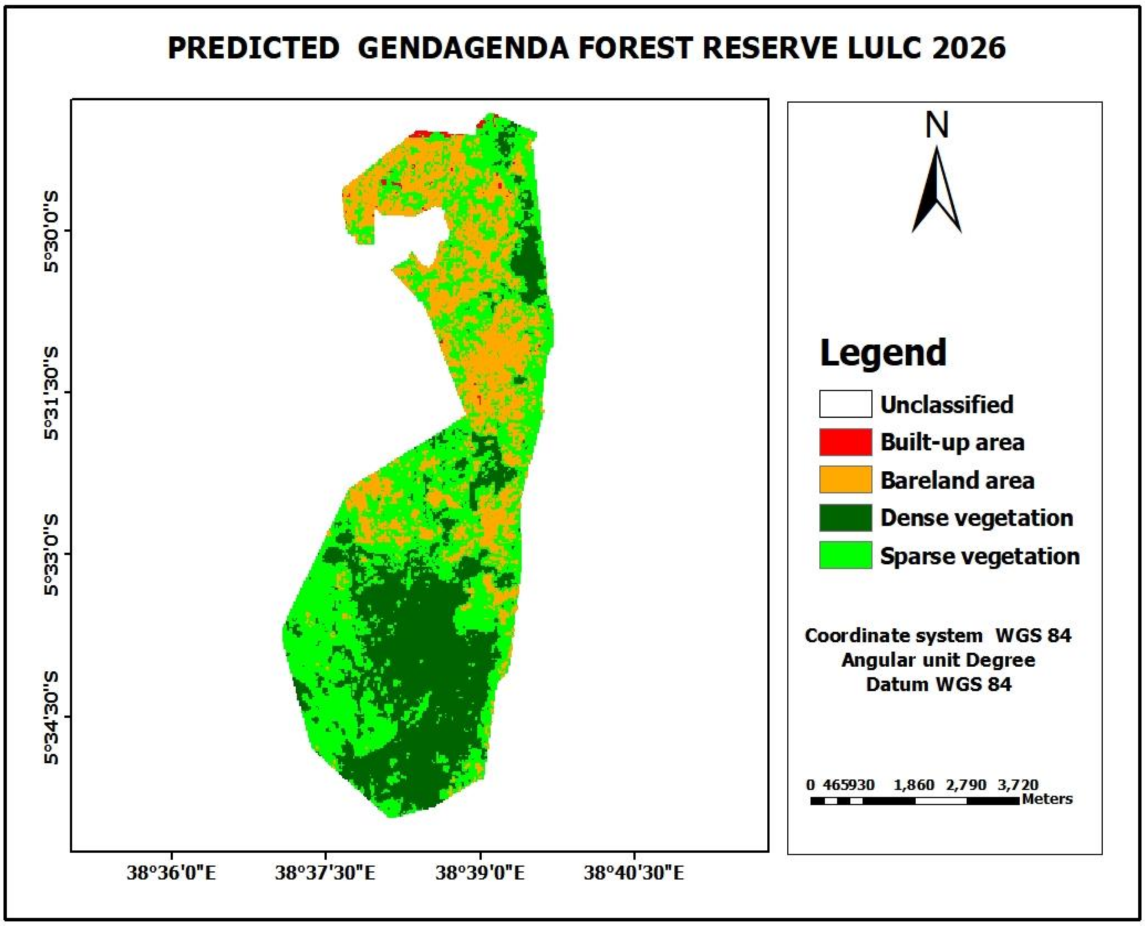

Figure 4.9: Future predicted LULC map of Gendagenda forest reserve 2026

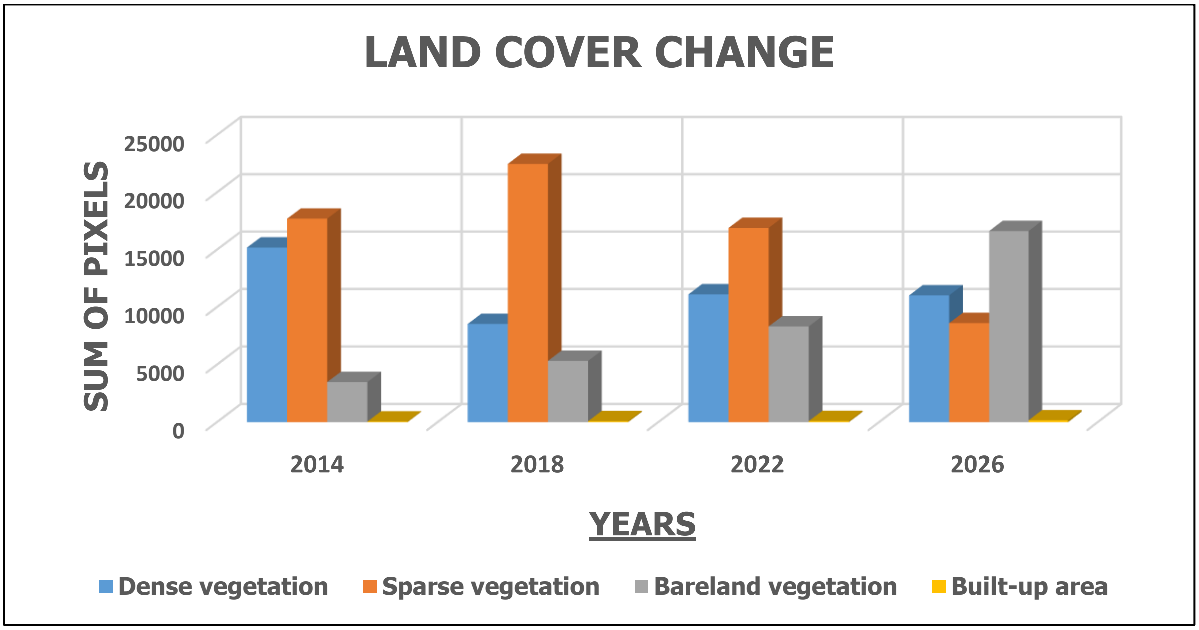

Figure 4.10: Histogram showing the trend LULC from 2014 to 2026

Table 4.1: Trend and LULC changes

LULC	AREA (Ha)				PERCENTAGE (%)			
	2014	2018	2022	2026	2014	2018	2022	2026
Dense vegetation	1367.01	768.51	1000.35	992.25	41.7	23.44	30.52	30.26
Sparse vegetation	1593.54	2023.29	1520.82	775.35	48.61	61.72	46.39	23.65
Bareland area	313.47	479.16	749.07	1496.43	9.56	14.62	22.85	45.65
Built-up area	4.32	7.38	8.1	14.31	0.13	0.22	0.25	0.44

4.5 Accuracy Assessment

Accuracy assessment is an important part after classification that compares the classified images to the data source and determine the quality of the information delivered from the remote sensing data by using the confusion matrices. The overall accuracy it help to tell us out of all of the reference data and probability that correctly classified through test the quality. Overall accuracy was obtained through the sum of correctly values divide by total number of values. The following as the accuracy assessment of Gendagenda forest reserve showing below.

Table 4.2: Accuracy assessment of classification 2014

Class Name	Reference Totals	Classification Totals	Numbers Correct	Producer's Accuracy	User's Accuracy
Dense vegetation	18	17	13	72.00%	76.47%
Sparse vegetation	19	18	15	78.95%	83.00%
Bare land Area	14	13	12	85.71%	92.31%
Built-up Area	12	15	10	83.00%	60.00%
Overall Classification Accuracy		=**79.37%**			

Table 4.3: Kappa Statistics 2014

Class Name	Kappa
Dense vegetation	0.6935
Sparse vegetation	0.7541
Bare land Area	0.8372
Built-up Area	0.7319
Overall Kappa Statistics	**=0.7518**

Table 4.4: Accuracy assessment of classification 2018

Class Name	Reference Totals	Classification Totals	Numbers Correct	Producer's Accuracy	User's Accuracy
Dense vegetation	14	13	12	85.71%	92.31%
Sparse vegetation	18	17	14	70%	82.35%
Bare land Area	15	15	13	86.00%	86.00%
Built-up Area	11	12	9	81.00%	75.00%
Overall Classification Accuracy		=**82.77%**			

Table 4.5: Kappa Statistics 2018

Class Name	Kappa
Dense vegetation	0.8591
Sparse vegetation	0.8154
Bare land Area	0.7637
Built-up Area	0.7719
Overall Kappa Statistics	**=0.8025**

Table 4.6: Accuracy assessment of classification 2022

Class Name	Reference Totals	Classification Totals	Numbers Correct	Producer's Accuracy	User's Accuracy
Dense Vegetation	13	12	11	78.57%	84.62%
Sparse Vegetation	9	8	7	87.50%	70.00%
Bare land Area	14	15	12	85.71%	86.00%
Built-up Area	13	14	10	76.92%	71.43%
Overall Classification Accuracy		=**81.63%**			

Table 4.7: Kappa Statistics 2022

Class Name	Kappa
Dense vegetation	0.7806
Sparse vegetation	0.7293
Bare land Area	0.8148
Built-up Area	0.7368
Overall Kappa Statistics	**=0.7654**

4.6 Trend analysis of land cover change

The table presents data related to the Gendagenda forest reserve, specifically focusing on the areas of built-up land and bare land for the years 2014, 2018, and 2022. The areas are measured in hectares (a unit of land area). The purpose of this data is to assess changes in land use and habitat within the forest reserve, particularly in relation to human encroachment and potential environmental impacts.

Table 4.8: The distribution of built-up area and bare land area on LULC map

Year	AREA(HECTARES)	
	Built-up	Bare land
2014	4.32	313.47
2018	7.38	479.16
2022	8.1	749.07

4.6.1 Trend analysis of bare land area

Bare land refers to areas within the forest reserve that do not have significant vegetation cover. It can result from activities such as logging, agriculture, or natural causes like wildfires. The increase in bare land might also indicate degradation of the forest ecosystem. The data indicates an increase in bare land from 313.47 hectares in 2014 to 479.16 hectares in 2018 and a further increase to 749.07 hectares in 2022. This indicates a notable rise in the area of land without significant vegetation cover, which could be due to human activities or other factors.

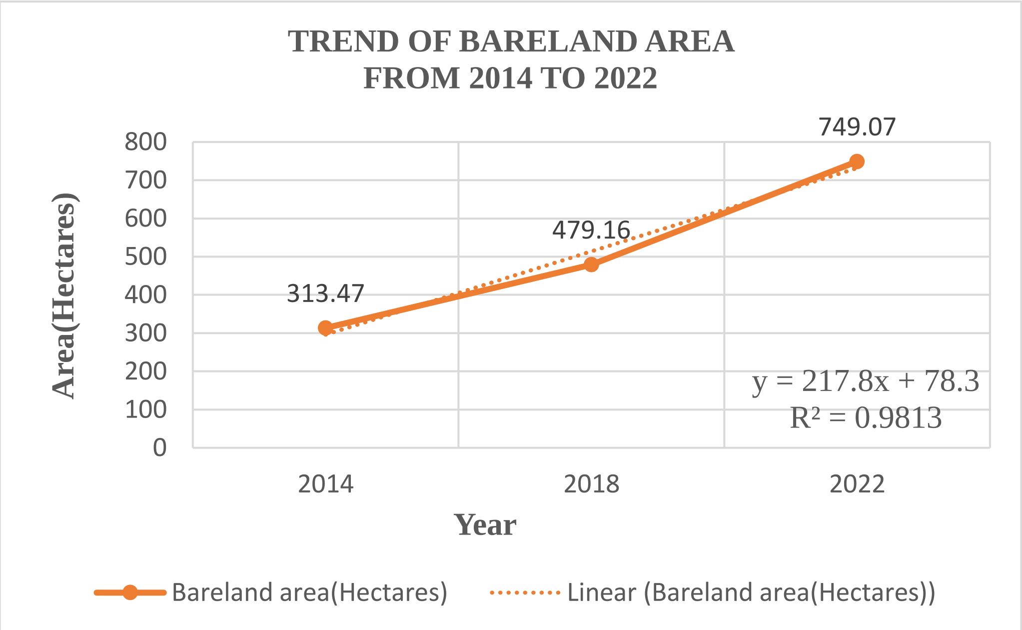

Figure 4.11: Trend analysis of bare land area

4.6.2 Trend analysis of built-up area

The expansion of settlements can significantly influence encroachment on the Gendagenda forest reserve. This refers to the land that has been developed with structures such as buildings, roads, and other infrastructure. An increase in the built-up area within the forest reserve indicates human encroachment and potential degradation of the natural habitat. The data shows that the built-up area has increased from 4.32 hectares in 2014 to 7.38 hectares in 2018 and further to 8.1 hectares in 2022. This trend suggests a gradual expansion of human settlements and infrastructure within the forest reserve.

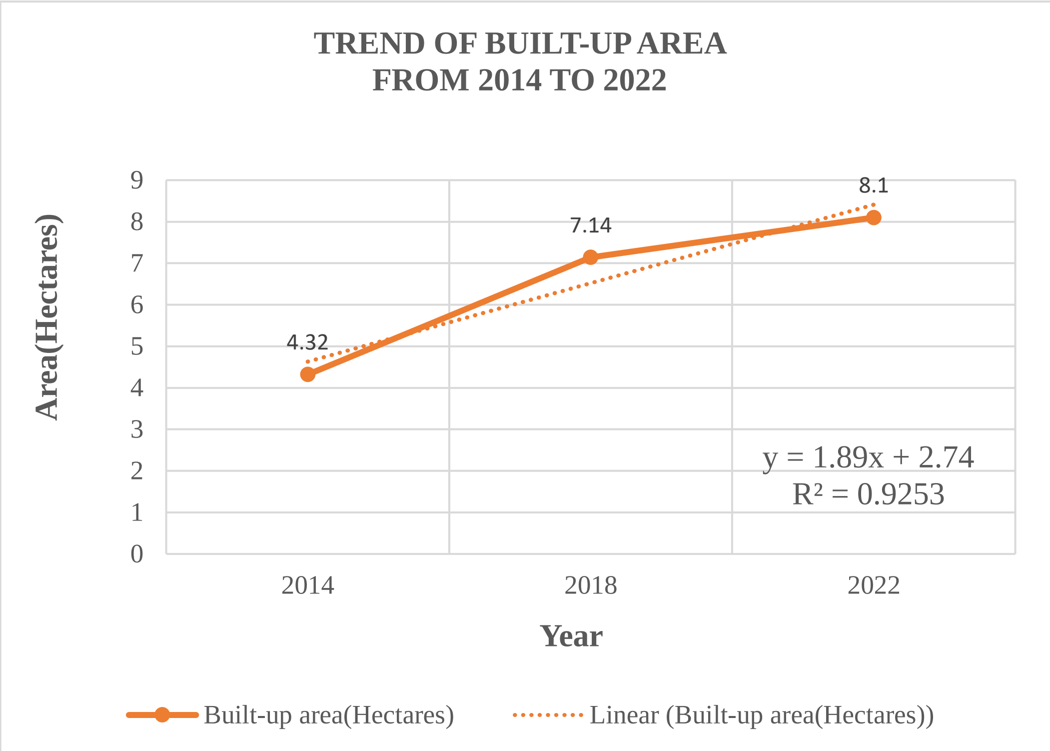

Figure 4.12: Trend of built-up area from 2014 to 2022

4.7 Trend line prediction of built up area

Table 4.9: Built-up area prediction from 2014 to 2026

Year	**Built-up area(Hectares)**
2014	4.32
2016	5.11
2018	5.9
2020	6.69
2022	7.48
2024	8.27
2026	9.06

From Table 4.9 above presents the progressive increase in the built-up area (measured in hectares) within the Gendagenda forest reserve over a period of twelve years, from 2014 to 2026. The data reveals a concerning trend of encroachment onto the forest reserve, with the built-up area consistently expanding. Starting at 4.32 hectares in 2014, the built-up area has grown steadily, reaching 9.06 hectares in 2026. This pattern highlights the ongoing and escalating encroachment on the Gendagenda forest reserve, indicating the urgency for effective conservation measures and sustainable land management practices to mitigate the loss of vital forest habitat and biodiversity.

CHAPTER FIVE
CONCUSION AND RECOMMENDATION

5.1 Conclusion

The objective of this research is to assess encroachment within the Gendagenda forest reserve. The study was conducted between 2014 and 2022, employing Geographic Information Systems (GIS) and remote sensing techniques. Through the utilization of Landsat images, Google Earth imagery and shape files. The research strives to sustainably preserve the Gendagenda Forest and set a precedent for safeguarding threatened forest ecosystems globally. If current trends persist, the built-up area is expanded to 8.27 hectares by 2024 and 9.06 hectares by 2026, emphasizing the urgency of countering encroachment to prevent habitat loss. Table 4.9 illustrates a consistent, alarming rise in built-up area, underscoring the need for conservation, policy, and sustainable land-use planning. Encroachment threatens biodiversity, worsens climate change, erodes ecosystem services and impacts local culture. Swift, comprehensive conservation is essential to mitigate these perils and preserve this invaluable asset for present and future generations.

The evident that the built-up area consistently increased at an average rate of approximately 0.395 hectares per year throughout the entire period from 2014 to 2026. This steady rise in the built-up area raises concerns about potential encroachment on the Gendagenda forest reserve and underscores the need for effective conservation and management strategies to ensure the sustainable preservation of this vital ecosystem. The results reveal a significant influence of agricultural activities, contributing to a high proportion of bare land areas within the forest reserve. Furthermore, the expansion of built-up areas poses a substantial risk of loss forest reserve that as a major impact on the integrity of the forest reserve.

5.2 Recommendation

- The asses the encroachment on forest reserve by using sentinel -2 images, there satellites capture high resolution optical imagery of the earth’s land and coastal areas. The images have a spatial resolution of 10 meters for most of the multispectral lands which allows for details land surface analysis.
- Enhance community participation, Foster active participation of local communities in decision-making processes related to forest management. Involve communities in the development of policies, plans, and initiatives to ensure their perspectives and

knowledge are considered, thereby promoting a sense of ownership and responsibility towards forest conservation

- The respective authorities, Tanzania Forest Services (TFS) should take the responsibility efficiency and effectiveness before the problem not exceed that help to reduce and control the encroachment on forest reserve. The TFS is entrusted with the management, conservation and suitable utilization of forest resources and also share experience with other institute includes TANAPA to ensure for find the solution about the problems.

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