MAPPING AND ASSESSING POTENTIAL HABITAT ZONES FOR RARE MONKEY SPECIES (IRINGA RED COLOBUS)

Case Study: Udzungwa Mountains National Park

REHEMA PETER SENDEU.

A dissertation submitted the department of Geospatial Science and Technology in partial fulfilment of the requirements for the award of Bachelor of Science degree in Geographical Information System and Remote Sensing (BSc. GIS&RS) at Ardhi University.

CERTIFICATION

The undersigned certify that they have proof read and hereby recommend for acceptance by the Ardhi University dissertation entitled "**Mapping and Assessing Potential Habitat Zones for rare Monkey Species (Iringa red colobus**)" in partial fulfillment of the requirements for the award of degree for Bachelor of Science in Geographical Information System and Remote Sensing at Ardhi University.

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Dr. Zakaria Ngereja	Mr. Michael Mavura
(Main Supervisor)	(Second Supervisor)
Date ……………………..	Date …………………

DECLARATION AND COPYRIGHT

I, Rehema Peter Sendeu hereby declare that, this dissertation is my own original work and that to the best of my knowledge, it has not been presented to any other University for a similar or any other degree award except where due acknowledgements have been made in the text.

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Rehema Peter Sendeu.

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Date

ACKNOWLEDGEMENT

I would like to extend my sincere gratitude to the Almighty God upon every step in my dissertation. My heartfelt appreciation goes to my supervisors, Dr Zakaria Ngereja and Mr. Michael Mavura for their guidance, expertise, insight and unending support that have been a significant help in directing completing this dissertation. I would like to send my gratitude to all staff members of Geospatial Science and Technology Department for supporting me throughout my journey at Ardhi University. Also, my warm gratitude to Tanzania National Parks (TANAPA) headquarters, Arusha and Udzungwa Ecological Monitoring Centre (UEMC) which enabled me to get the data for this research.

Lastly, I am deeply grateful to colleagues, Hemedy Lungo, Thereza Mavindi, Godwonder Bwemero, Rehemarose Singo and Asedi Niwagila for the physical and mental support that enriched the research's outcomes. Their contributions are unmeasurable. Lastly, I would like to convey my sincere gratitude to everyone whose support and encouragement helped this research come to the end. Your assistance has been the key to its success.

DEDICATION

I dedicate this dissertation to my beloved Family, my father Mr. Peter Sendeu, my late dearest mother Mrs. Miriam Sendeu and my sisters Ms. Rahel Sendeu and Ms. Rosemary Sendeu.

ABSTRACT

Iringa red colobus (Genus and specie name: *Procolobus gordonorum*), are the primate forest-dependent species occurring in the highest densities found only in the Udzungwa Mountains of Tanzania. Loss of habitation for Iringa red colobus has been a great problem, due to the species' unpredictable life span and breeding patterns make it difficult to monitor their existence for years. This study aimed to assess and map the potential habitat zones for Iringa red colobus specie by looking on the relationships found between vegetation and bare land or water land covers for the year 2018, 2020 and 2022 then, for the coming 50 years. Vegetation cover mostly young leaves and trees that bears fruits with seeds that constitute 60.7% and 31.7% of the species' diet, represents the habitational areas of the specie. The data used were sentinel 2B images for the year 2018, 2020 and 2022, the shapefiles for forests and the Digital Elevation Model (DEM) of Udzungwa Mountains national park which used in indicating the elevation information of the study for the areas that the species are found and one of the variables in the prediction process. The supervised classification was applied in mapping the land cover by using the random forest method where, three classes, water, vegetation and bare land for all sentinel 2B images were obtained with the overall accuracies of 92%, 86% and 94% to produce the landcover maps followed by the change detection analysis by using the Pearson's correlation method to observe the land cover change occurred from 2018-2020 and 2018-2022. The changes obtained showed the bare land cover was rapidly increasing with time while the vegetation decreased to 89% and 79% for year 2020 and 2022. From the change maps the transitions were modeled by using Artificial Neural Networks Method (ANN) with 1000 random samples followed by simulation under the Cellular Automata method for 50 years from 2022 to obtain the habitat status map as a land cover of the year 2072. The simulated model showed habitat degradation due to an intensive increase of bare land cover and a decrease of vegetation and water land covers that highly supported the existence of the species. There should be a comprehensive strategy in environmental conservation in land cover changes problems caused by climate change also, prior knowledge should be provided to all citizens on forest conservation significance together with all species living in the forest to avoid poaching and hunting the species found in it for future benefits.

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ACRONYMS AND ABBREVIATIONS

ANN	Artificial Neural Network
DEM	Digital Elevation Model.
GIS	Geographical Information System.
ICUN	International Union of Conservation of Nature
MOLUSCE	Modules for land use change evaluation
TANAPA	Tanzania National Parks.
TIFF	Tag Image File Format.
UEMC	Udzungwa Ecological Monitoring Centre
USGS	United States Geological Survey.

CHAPTER ONE

INTRODUCTION

1.1 Background:

Iringa red colobus (Genus and species name: *Procolobus gordonorum*), are the primate forest-dependent species occurring in highest densities found only in the Udzungwa Mountains of Tanzania. International Union of Conservation of Nature (1992) clarifies that, Iringa red colobus was first discovered and described in 1992 and it is classified as critically endangered species. This monkey is just one of many species' endemic to the isolated mountain range, which is covered by a rich tropical rainforest, rivers and bordering grasslands habitats, the forest composition of their habitat depends on the kind of diet they find in the trees they habit. Iringa red colobus monkeys live in the distribution groups of 20 to 40 individuals. (Starr, 2019).

Geographical Information System (GIS) and Remote sensing provides the tools, instruments and reliable data for the analysis, monitoring, protection and modelling the distribution of Iringa red colobus. Example, there are tools used to collect some useful raw data of red colobus species, camera traps for the canopy and the location in which the species are found (Alessandro Alivernini, 2018). The tools enable the visualization of data in different environment according to highlighted contributing factors for the species occurrence, tools for planning the patrol allocations in the park to cover the areas in which the specie can be protected and tools that enables the law enhancement in case of any poaching inside the park that threat the presence of the species (Linder, 2021). GIS and Remote sensing also, used in assessing the ecological relationship of red colobus species to the environment they live on and other species they relate with in ecological terms like habitats and food (Rovero, 2007). Also, GIS and remote sensing enables the access of satellite images data that derive the potential outputs that reflects the real activities that occurs in real situations such as, land changes, elevations and many natural phenomena in relation to the specie. However, with recent developments in spatial and spectral resolutions, and more advanced data processing techniques, detailed classification maps for vegetation communities and individual species can be produced to provide a better source of information for a variety of management decisions and ecological applications (Arenas-Castro, 2013).

There are several studies that have been conducted regarding the Iringa red colobus species such as Cavada (2019) on Iringa red colobus habitat by forest fragmentation conditions and breeding patterns with relation to climate change. The feeding ecology of monkeys in general is highlighted (Mtsuda, 2009). Also, Udzungwa Ecological Monitoring Centre (UEMC, 2008) in their annual report, highlighted on the effects of human disturbance on the species habitats and suggest that there must be some efforts in helping the community to become self-sufficient for energy sources if the negative effects of collecting firewood in the National Park are to be deceased and eventually stopped. Apart from that, there are several websites that provide useful information specifically regarding Iringa red colobus species, researches and innovations of the species, example of International union for conservation of nature which highlight the red lists of endangered primates including Iringa red colobus (www.icunredlist.org), the Udzungwa ecological monitoring center (UEMC) website (www.udzungwacentre.org), which promote and facilitate biological research of the species found in Udzungwa National Park including Red Colobus and, red colobus action plan website (www.pilocolobus.org) that brought many red colobus researchers together to promote more research on conservation and saving red colobus species all over Africa. This study entails in mapping the potential zone for Udzungwa red colobus habitation and predicting the eligibility of the species' habitat for the coming 10 years considering the factors like climate factors and elevation information of the area which will be one of the applicable variables for the various algorithms on the modeling process.

1.2 Problem Statement.

Encroachment of human activities such as hunting, agriculture activities, charcoal and firewood collection contribute more to habitational degradation of Iringa red colobus and their existence however, the specie's unpredictable life span and breeding patterns makes it hard to monitor the existence of Iringa Red Colobus specie for years (New primate conservancy 2013). Loss of habitation for Iringa red colobus species have been a major problem. In other ways, indication for the distribution of Iringa red colobus species over time to time will enable the decision makers to pose better ways for monitoring the possible and suitable habitational areas for Iringa red colobus species from habitat loss.

1.3 Objectives

1.3.1 Main objective

To map and assess the possible potential habitat zones for Iringa red colobus.

1.3.2 Specific objectives

i. To indicate the distribution of Iringa red colobus in different areas within the study area.
ii. To assess and map the habitats from 2018, 2020 to 2022.
iii. To predict the land cover of Iringa red colobus for the coming 10 years.

1.4 Research Questions

In this study the following questions will be answered;

i. What are the distribution patterns of habitats for the Iringa red colobus?
ii. What are the changes of Iringa red colobus habitat with time?
iii. How the habitational status is for the coming 10 years?

1.5 Scope and Limitations

The evaluation of prediction model is based on the areal amount of vegetation cover to the bare land cover. The model is limited being used by the conservation authority and related sectors in posing the better ways to solve the related problems in monitoring Iringa red colobus and associate species in the study area in which will provide possible measures of dealing with the expected circumstances in monitoring the species and their habitation.

1.6 Significance of the study

The study can enable the conservation authorities in posing the reliable ways in monitoring the Iringa red colobus species by looking at their distribution. Also, it can enable the authority to pose some decision alternatives for analysis, management and monitoring the species according to their ecological factor patterns.

The study can allow and assist the tourism sector in decision making according to the status of the species based on the inside and outside tourism market in our country considering the investors and investments to the sector regarding the species.

1.7 Beneficiaries

i. The government. Since the Udzungwa red colobus is the big source of revenue from tourism sector as it attracts more tourist and investors from inside and outside the country.
ii. Conservation Authorities. The authorities will benefit on the alternative ways possible for managing and monitoring Iringa red colobus since the species is delicate to disturbed environments.
iii. Tourism Sectors. The sectors will be able to identify the actual distribution and occurrence places for Iringa red colobus for tourist sites allocation.

1.8 Dissertation Structure and Organization

This dissertation is comprised of five chapters that explains in details about the data used, methods and the results produced in assessing and mapping potential habitats for rare monkey specie (Iringa red colobus).

Chapter 1, Explain the background of the study with the research problem, objectives, research questions, significance of the study, scope and limitation and the beneficiaries of this study.

Chapter 2 highlight the reviews based on different literatures on the study and how they applied to the study.

Chapter 3 shows all data, methods and algorithms used to integrate the data in processing steps to produce the outputs of this study.

Chapter 4 entails on providing the discussion of the results on course of this study and lastly, Chapter 5 provides the conclusion and recommendation for the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This chapter will give the understanding of the studies through various previous studies. It set the codes and techniques applied by previous researchers and establish a gap. The literature review will base on the concepts regarding the habitational zones and all related techniques and the modelling of habitat areas from the previous researches and a link to the gap to be solved in this study.

2.2 Geographical Information System (GIS)

GIS is a system that creates, manages, analyzes, and map all types of data (Esri, 2011). Also, GIS is a computer system for capturing, storing, checking and displaying data related to positions on earth's surface (Geographic, 2019). It connects and integrate location data with all type of descriptive information showing what things are like and this serve as a good foundation for mapping and most analysis used almost in every industry.

Based on this study, GIS has a major role in wildlife conservation and monitoring. Maps and the analysis of data can help in understanding when and where the preservation and protection of animals, plants and their habitats are required (Benny-Dumont, 2021). The following are the ways that GIS is used in the field of Wildlife conservation:

i. Tracking animals to understand their migration patterns (Sibley, 2023).
ii. Map biodiversity to gain a deeper understanding of where the ecosystems are located in the world (Serve, 2021).
iii. Habitat suitability modeling that guides the conservationists when, where and how to set up the protective measures and restorations.
iv. Manage species inventories and support researchers with their projects.
v. Raise awareness of the importance of conservation that will reach decision-making bodies through the use of maps.
vi. Advance science and the understanding of how conservation impacts the environment.

2.3 Modules for land use change evaluation (MOLUSCE)

MOLUSCE is a user-friendly plugin for QuantumGIS 2.0 and above where it is designed to analyze models and simulate land use/ land cover changes (NextGIS, 2013). It well suited to analyze land use and forest cover changes between different time period, model the land use/cover transition potential or area with risk deforestation and to simulate future land use and forest cover change. It contains the specific functions and with specific module, as follows;

i. Input module. Here the land cover/use maps from different years are entered
ii. Area Changes Analysis. This module calculates the changes occurred between two time periods to produce the land cover change map.
iii. Modelling methods. There are four modelling methods in this module namely, Artificial Neural Networks (ANN), Logistic Regression (LG), Multi-criteria Evaluation (MCE) and Weights of Evidence (WoE) which, all used in modelling the land use/cover change transition potentials.
iv. Simulation. Displays the transitional results and produce the simulation results as a full model like prediction model.
v. Validation. This module uses to measure the accuracy found in the model formed if it sustained the input variables and the reference inputs.

2.4 Prediction model

This is the statistical model that forecast the future event or outcome from the historical data patterns to describe and estimate the likelihood of a specific outcome to occur (Jerome H. Friedman, 2008). There are various techniques depending on nature of the data available. Some of the commonly used techniques are:

i. Regression analysis: this looks upon the relationship between a dependent and two or more independent data values based on how the changes of dependent values with respect to independent values.
ii. Classification Models: these models achieved when the outcome contains categories and a goal is to assign the new values to the predefined categories (Chapman&Hall, 2015).
iii. Neural Network: This is a two-stage regression or classification model. Both Regression and classification is included together with deep learning models that are used for complex predictions where, the relationship between variables is highly nonlinear such

that, it learns the dependencies found between the data that most of the traditional linear model being insufficient with. (Christopher, 2006)

There are several significances of this technique including;

i. Feature learning; the model discovers the meaningful representation by eliminating the need for manual feature engineering.
ii. Generalization; the neural networks are trained and designed to generalize the information from trained data to those hidden data that, they can capture the underlying patterns and trends, allowing them to make prediction on new from previously hidden examples.
iii. Flexibility; the neural network is flexible that, they can be adaptive to various types of prediction types such as regression and classification.

2.5 Pearson's Correlation

Also known as Pearson correlation coefficient, is a statistical measure that quantifies the strength of linear relationship between two continuous variables (Richard A. Johnson, 2007).it is the measure of linear correlation between two sets of data. It is used when the two statistics wants to be analyzed are both quantitative. It is denoted by a symbol "r" as shown in the formular;

$$r = \frac{\sum(x_{\bar{i}}\bar{x}) \cdot (y_i - \bar{y})}{\sqrt{\Sigma}((x_i - \bar{x})^2(y_i - \bar{y})^2)}$$

As the formular shows, to calculate r, there must be a set of paired observations of the two variables, if it the numbers or any other observations, calculating the difference between each pair of observation and correspond means of each variable, multiply the difference for each pair and sum up the products, calculating the standard deviation for each variable and multiply them. The sum of mean product and the product of standard deviation are divided, the resulting value is correlation coefficient (r).

It ranges with values between -1 and +1 meaning, when the coefficient (r) is close to +1 indicates the strong relationship, implying that one variable increase also, the other variable tends to increase. While, when r is close to -1 indicates the strong negative linear relationship, implying that, the one variable increase and the other variable tend to decrease and when r is close to 0 suggest a weak or no linear relationship between the variables. (Richard A. Johnson, 2007).

2.6 Remote Sensing

Remote Sensing technology including Satellite, Aerial and Unmannered Aerial Vehicles (UAV) technology can support conservationists to identify, track, monitor and assess wildlife in most remote areas around the world also, utilizing these technologies to protect wildlife and aid in improving the way endangered wildlife are being monitored in their natura environment (SIC, Satellite Imaging Coorporation, 2022).

Satellite Imagery as one of the Remote Sensing technologies can be used in habitat mapping of the wildlife species including Iringa red colobus where, high resolution sensors can be used to monitor the species, the changes in forest cover and all activities in relation to human intervention (SIC, Satellite Imaging Coorporation, 2022).

2.7 Random Forest Algorithm

A random forest is a classifier consisting of a collection of tree-structured classifiers $\{h(x,\Theta k),$ $k=1, ...\}$ where the $\{\Theta k\}$ are independent identically distributed random vectors and each tree casts a unit vote for the most popular class at input x (Breiman, 2001). the algorithm gets its name from the fact that it creates an assemble of a decision tree and each tree is built using random subset of date hence, random forest. It is used for both classification and regression tasks and is known for its robustness and accuracy.

To make predictions with a trained Random Forest model, the input sample is passed through each decision tree in the ensemble. For classification tasks, the class predicted by the majority of the trees is considered as the final prediction. To improve accuracy, the randomness is injected to minimize the correlation ρ while maintaining the strength (Max Kuhn, 2013).

Random Forest has several advantages, including:

i. Robustness: Random Forest is less prone to overfitting compared to individual decision trees. It can handle noisy and complex datasets effectively.
ii. Feature Importance: Random Forest provides a measure of feature importance, indicating which features have the most influence on the predictions. This information can be useful for feature selection or understanding the underlying data.
iii. Handling of Missing Data: Random Forest can handle missing values in the dataset without requiring imputation or preprocessing.

iv. Parallelization: The training and prediction processes in Random Forest can be parallelized, allowing for faster computation, especially on systems with multiple processors or cores.

2.6 Zone mapping

Zone mapping include all processes for creating a visual representation of different zones within a certain region. Zone mapping including dividing the area into different ecological zones based on the various factors (Boyce, 2002). In Iringa red colobus zone mapping, the factor considered in the zoning including the food and associate specie found in that zone. Zone mapping can be used in conservation planning and in identification of areas with high biodiversity (Ramirez-Gomez, 2016). In dividing a region or area into zone, the decision maker analyzes the factors, characteristics, resources and activities found in each zone in those areas in order to effectively divide the area into zones.

CHAPTER THREE
METHODOLOGY

3.1 Overview

This explains about overall methods used in zone mapping process and prediction modelling from data collection to output creation together with all requirements in the processes regarding techniques applied and all data inputs utilized to produce the outputs for this project.

3.2 Description of Study Area

Udzungwa Mountains National Park in the national park in Tanzania located in Iringa and Morogoro region with a size of 1,990 Kilometer squares, coordinated at -7.79, 36.68 and -7^{0}47’S, 36^{0}41’E . Being Part of the Eastern Arc Mountains, Udzungwa Mountains National Park is home for fascinating diversity of life. Eastern Arc Mountain’ that are famous for its high concentration of endemic species of animals and plants is important biodiversity hotspot on earth. The Park has variety of landforms including rolling hills, mountains, valleys, and waterfalls that makes the park outstanding scenic. Nature Lovers can explore mountain forests for a number of rare, endemic and endangered species of flora and fauna including endemic species of Sanje mangabey, Iringa red colobus and endemic Udzungwa Forest Partridge and Rufous wing sunbird. The Park offers a number of spectacular waterfalls including the biggest waterfall in National Park system in Tanzania, The Sanje waterfalls.

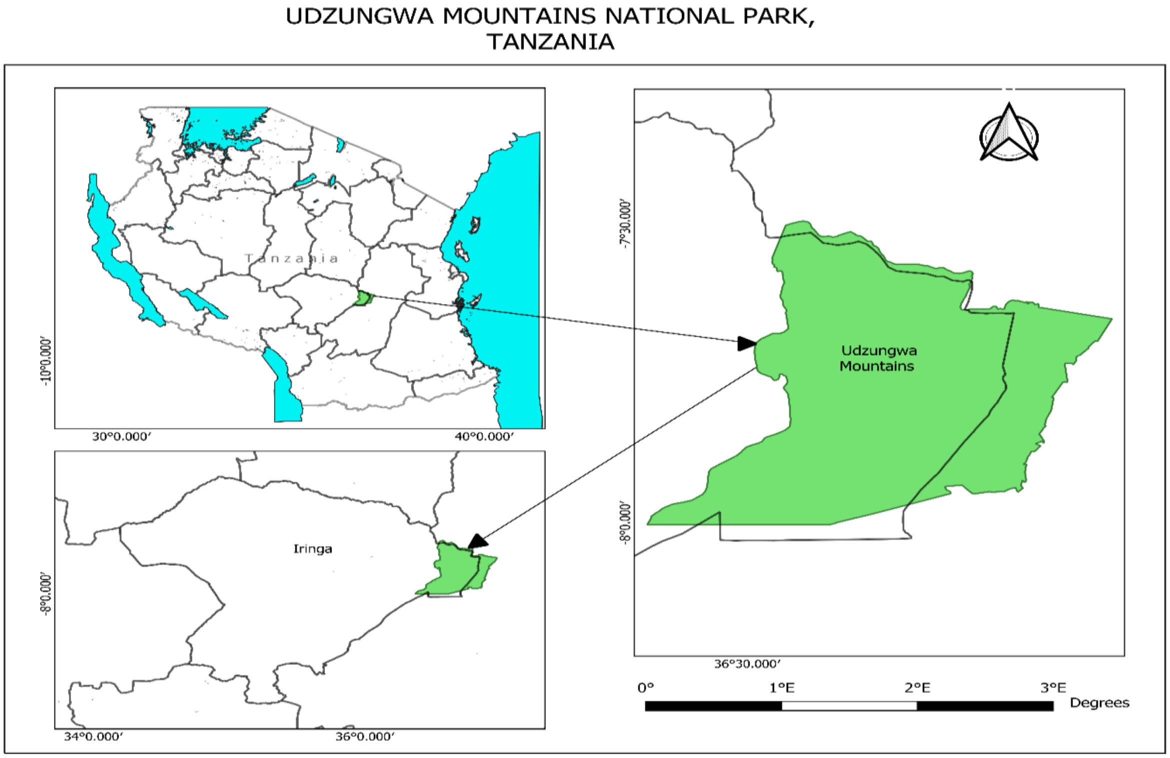

Figure 3.1 Udzungwa mountains national park, Tanzania

3.3 Zone Mapping

The mapping is based on the areas that are likely to be the specie's habitats in Udzungwa mountains national park categorized as forests inside the park such that, Mwanihana forest zone, Matundu forest zone and Luhomelo forest zone contain all requirements for the specie to occupy in term of food, shelter and friendly or associate species around them that makes them suitable for habitation. The whole process, step by step can be summarized in figure 3.2.

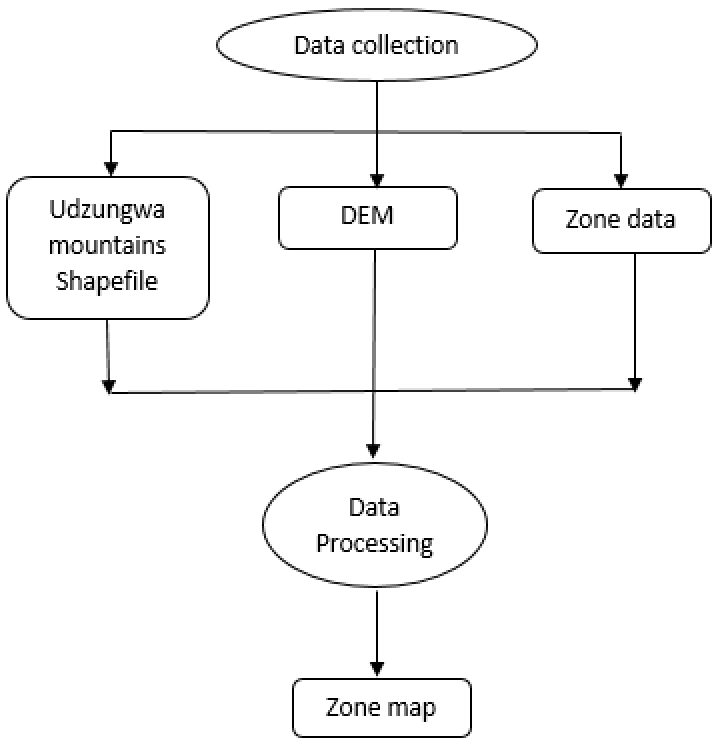

Figure 3.2 Zone mapping workflow

3.3.1 Data collection

The data collected are summarized in table 3.1

Table 3.1 The data acquired

DATA	SOURCE	DATA TYPE	USE
Zone data: -Tanzania national park's shapefile	TANAPA http://www.landscapesportal.org	Vector	For boundary indication of the study area
-Tanzania forest's data	http://www.icunredlist.org	Vector	For naming the indicated zones
Digital Elevation Model	http://earthengine.google.com	Raster	Relief visualization in 3D

3.3.2 Data processing

The data were pre-processed and processed in the QuantumGIS software where the zones were clipped with extent with Udzungwa national park's shapefile together with the DEM in display, the layout was formed and saved as a picture file (.PNG) directly to Blender GIS software where the 3D zone map was formed.

3.4 Predictive Modelling

The whole process is summarized in figure 3.3:

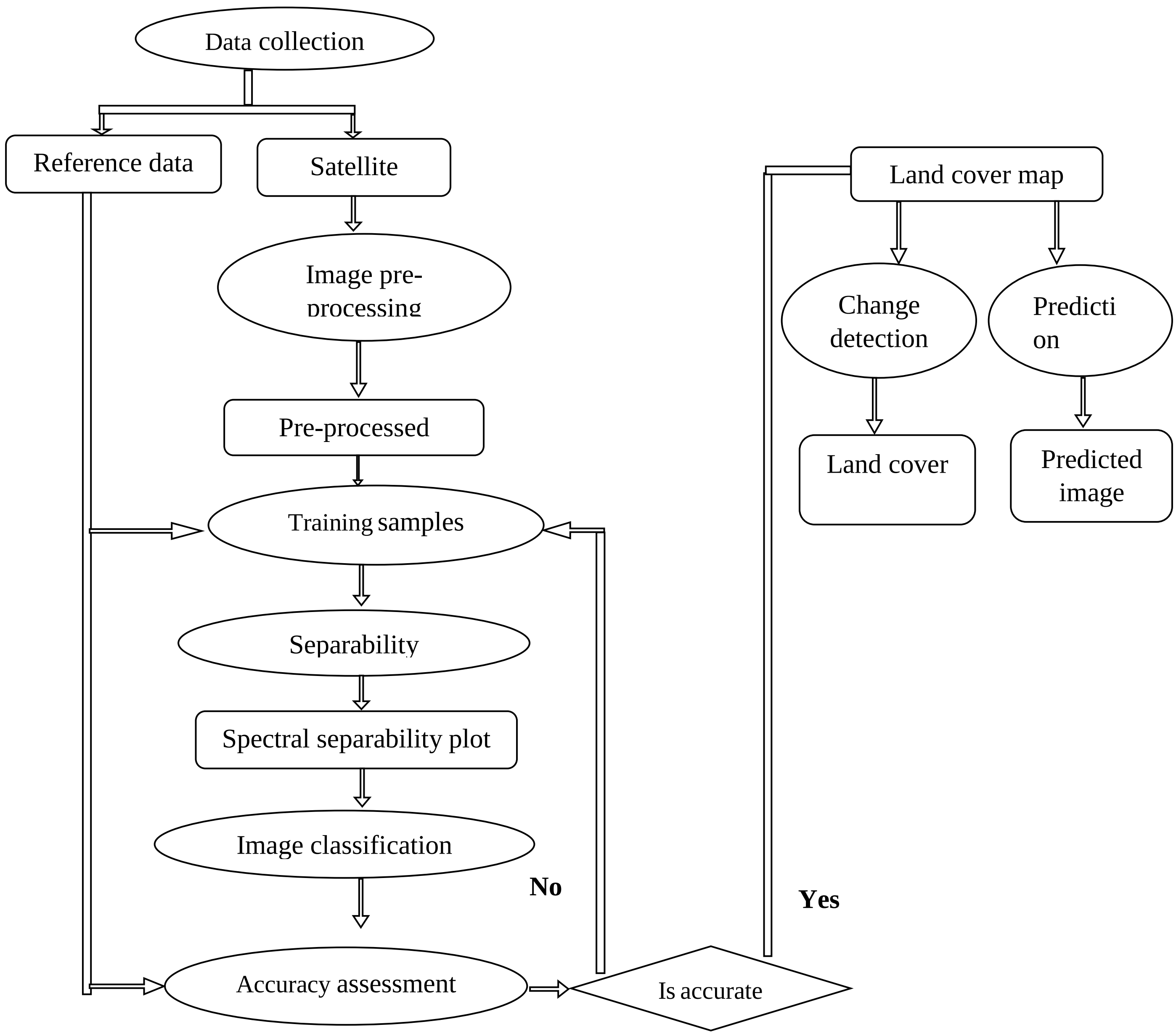

Figure 3.3 The methodology workflow

3.4.1 Data collection

The data that were collected were Sentinel 2 data, DEM for prediction analysis and the reference data for remote sensing activity that will be used in the following processes and activities in the project. Sentinel 2 data were collected from the Copernicus open source, DEM data was collected from Open topography open source and the reference data were collected from google earth pro.

3.4.2 Data preprocessing

The process was done using the Semi-automatic classification plugin (SCP) in the part of pre-processing of sentinel 2 data where, the atmospheric corrections were done under the process to obtain pre-processed sentinel 2 images for other processes to continue

3.4.3 Class separability Analysis

The analysis was done to evaluate on how the land cover classes were separate or different from one another where the training samples were set and the data of different land cover types were selected and labeled to represent different classes or categories of interest for training the classification model to be worked with in the classification process and feature extraction. The analysis helped in identifying the most effective variables for discriminating between classes (Jia, 2017).

The separability statistical measures such as mean and standard deviations were calculated based on their digital number values using the transformed divergence method (Gu, 2007) where, the measures used to quantify the separability between the classes using the input statistics values as the mean and standard deviation of the pixels' digital number and the number of classes to be associated in the analysis. The visualization was done by using scatter plot technique to assess the degree of overlap or distinctiveness between classes and, the high separability indicates that, the classes are effectively differentiated on other hand the classes with small separability indicates the potential mislead or misclassification when used in the classification process (Foody, 2002). The separability plot is presented in figure 3.4.

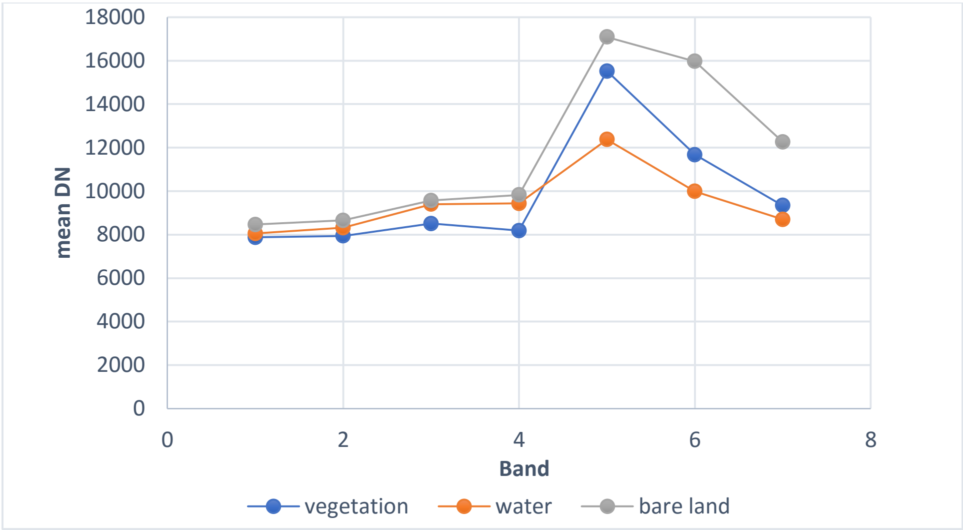

Figure 3.4 Class separability plot

3.4.4 Image classification

Based on the separability of the classes, features with high separability used as classification inputs to a classification algorithm namely random forest. the classification scheme based on the supervised classification to produce the land cover maps for the year 2018,2020 and 2022 as the habitational status map for the Iringa red colobus specie.

3.4.5 Accuracy Assessment

The performance and reliability of each image classification was assessed by comparing the classified results and the reference data only if the outputs of classification are correct. The validation samples were obtained from google satellite image from HCMGIS plugin each class with total of 15 samples. The classification error matrix was calculated and presented in the contingency table where the summary of number for each class's pixels indicated the agreement between classification results and the reference data that were summarized and quantified by the error matrix coding.

3.4.6 Land cover change

The land cover obtained from the classification process were related to each other in the MOLUSCE plugin within QuantumGIS. The change detection was conducted to obtain the class's area changes from one year to another either in decreasing or increasing of the area changing from one class to another and, the transitions were tabulated for more observation.

3.4.7 Predictive Modelling and Validation

The modelling was done after change detection by using Artificial Neural Networks (ANN) method or multi-layer perceptron where the inputs were the land cover images and change statistics of year 2018, 2020 and 2022 and Digital Elevation Model as one of the variables then, the model was trained randomly where the random sampling of pixel was done in sample size of 500 contain the known pixels and the hidden pixels. Thereafter, the model undergone the simulation for 10 years to come.

The validation was based on a simulated map and reference maps to show how the model is accurately made by looking in the percentage accuracy putting into account on interaction factors such as human interaction and climate change influences.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Overview

All results obtained from data processing are presented and described in this chapter in form of maps, graphs and tables representing the variables and their relationship to the output.

4.2 Zone Mapping

The final output consists of indicated habitat zones of Iringa red colobus specie as potential areas for habitation containing all possible requirement to sustain the specie in term of food and shelter. The Zones divides into three different forests which have protected status as forest reserves within the park covering the eastern, western and southern part of Udzungwa National Park as, Mwanihana forest, West Kilombero forest and Matundu forest as shown in figure 4.1

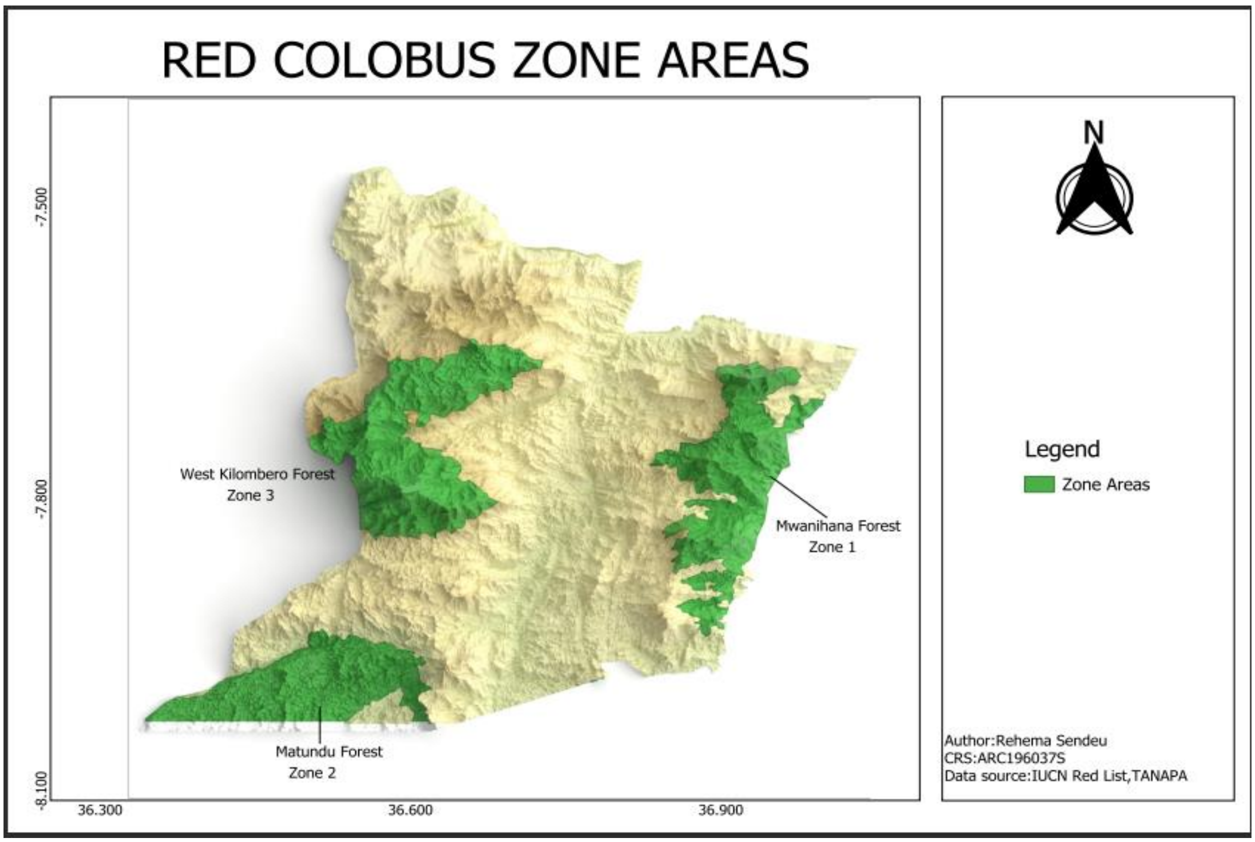

Figure 4.1 Habitation Zone map of Iringa Red colobus specie

The indicated zones (green highlighted areas) illustrate the areas where, large number of Iringa red colobus are found compare to the unindicated areas (pale-brown highlighted areas) within the park. In the zone areas, Iringa red colobus are found mostly due to several factors such as the type of vegetation as the diet of the specie (such as, young leaves and trees that bears fruits with seeds), the low level of human disturbance, altitude range of 250-2,200 metre with density being lowest at higher elevations (Cavada, 2016).

4.3 Land cover mapping

The land cover maps were obtained from image classification for year 2018, 2020 and 2022 and the area cover statistics that show the area in square metre as the coverage for each class relative to another as shown in table 4.1 with their graphical representations shown in figures 4.2 and 4.3. The statistics enables the close observation on the patterns' increase or decrease of each land cover class for a respected year.

Table 4.1 Area coverage statistics of 2018 and 2022

class	2018	2022
water	7.58 km^2	8.51 km^2
vegetation	1713.28 km^2	1608.36 km^2
bare land	200.95 km^2	304.93 km^2

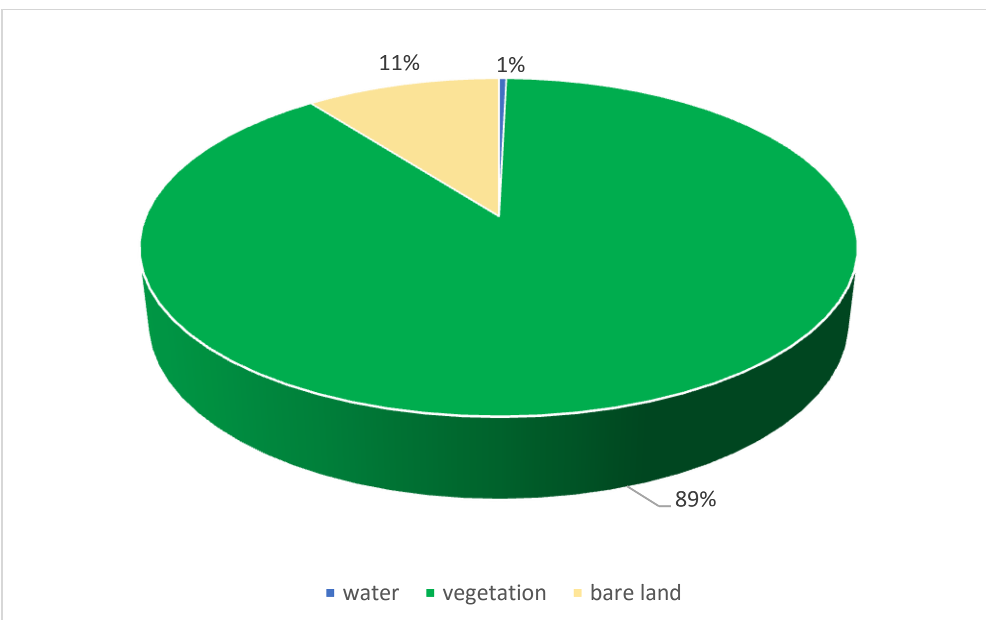

Figure 4.2 The pie chart indicating area coverage statistics of 2018

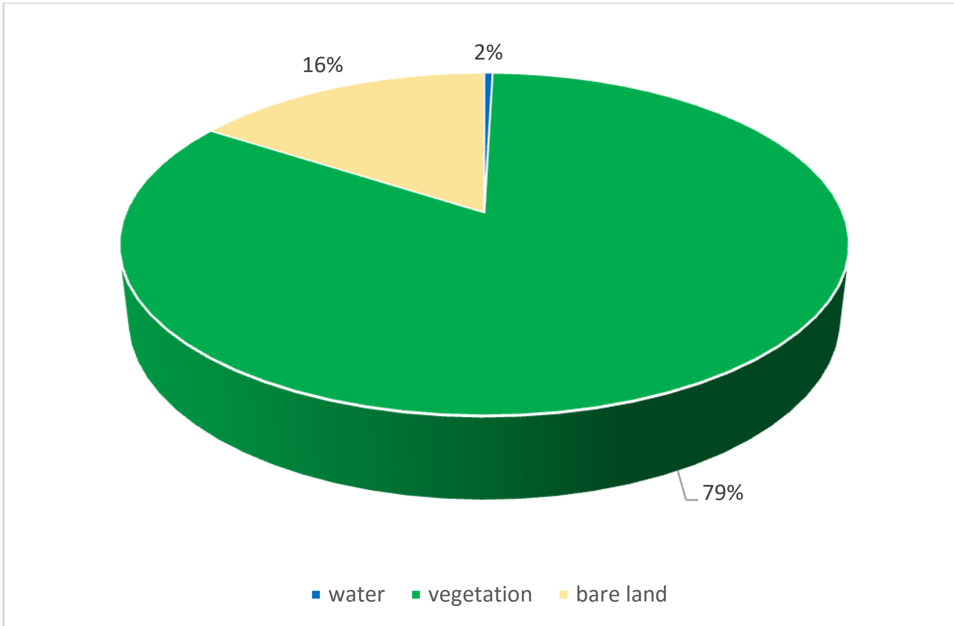

Figure 4.3 The pie chart indicating area coverage statistics of 2022

Udzungwa Mountains national park land cover for year 2018, 2020 and 2022 indicating the land cover with three classes, water, vegetation and bare land as shown in figure 4.4, 4.5 and 4.6. The landcover contain the vegetational area, depict the habitats of the specie for a given year meaning, as all places covered with vegetation represent the areas for habitation of the specie.

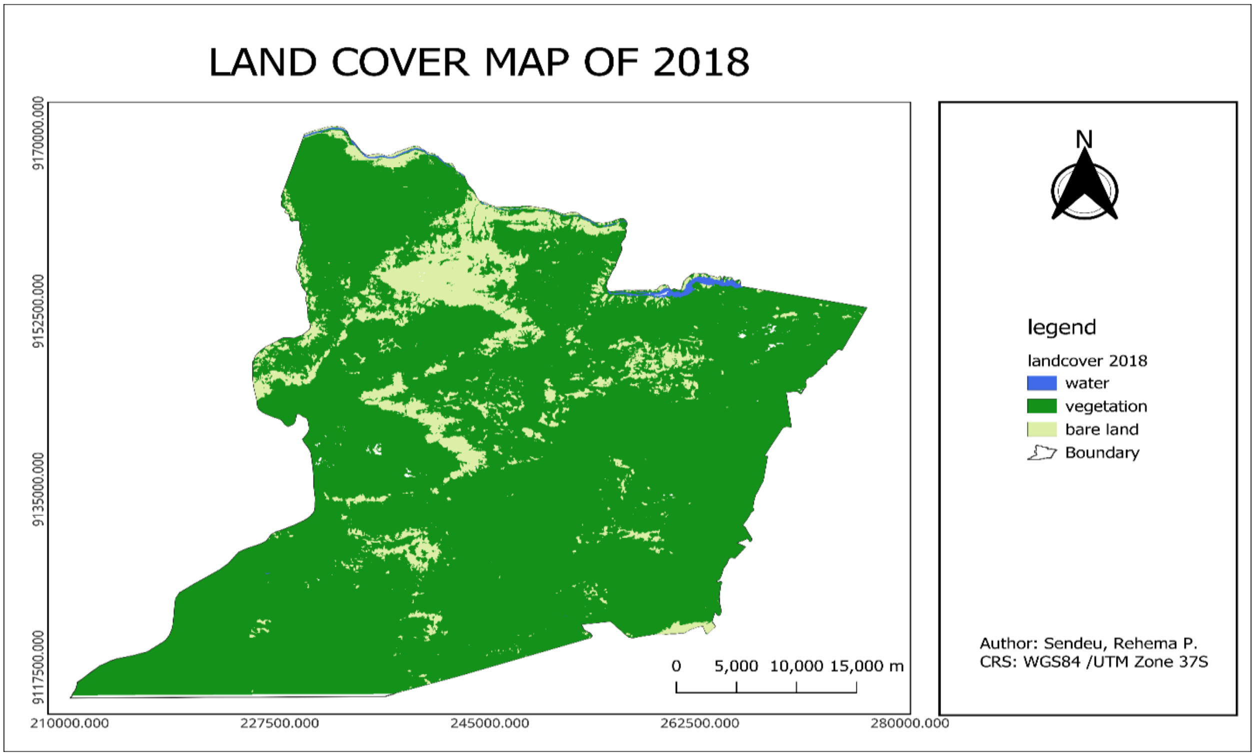

Figure 4.4 Udzungwa mountains land cover map of 2018

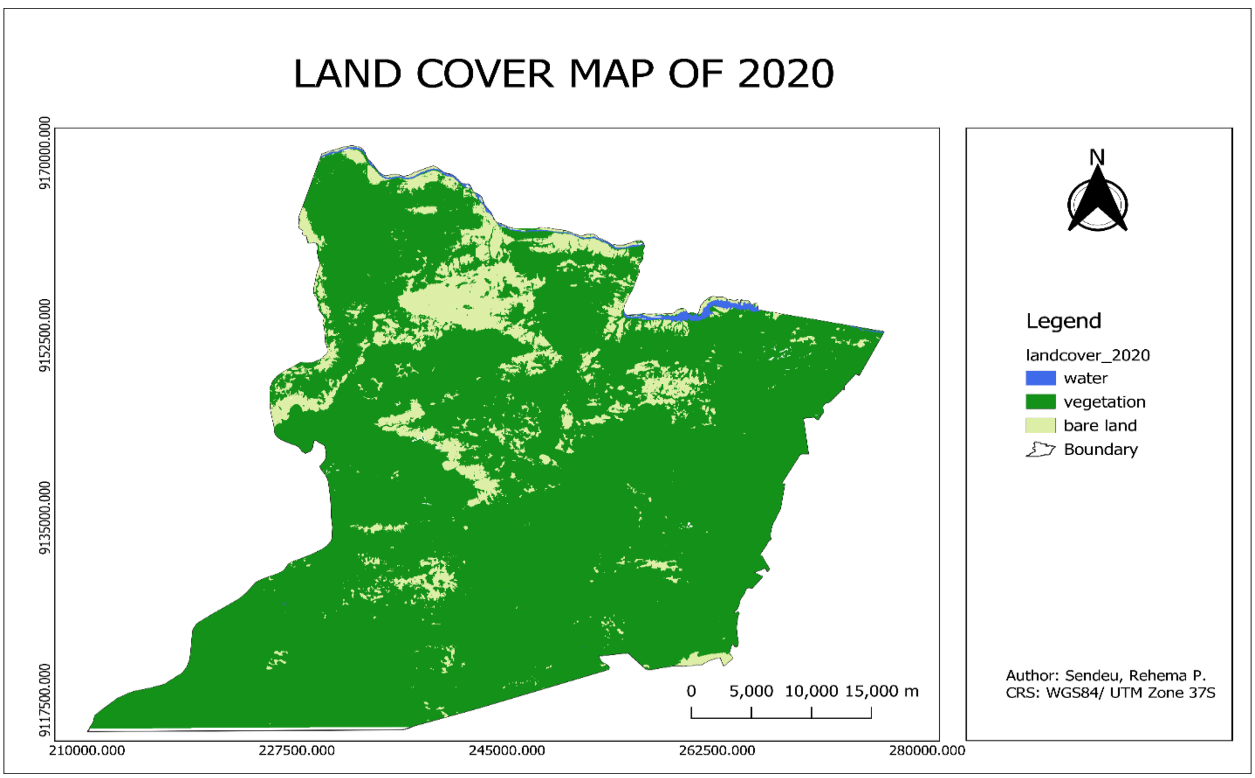

Figure 4.5 Udzungwa mountains land cover map of 2020

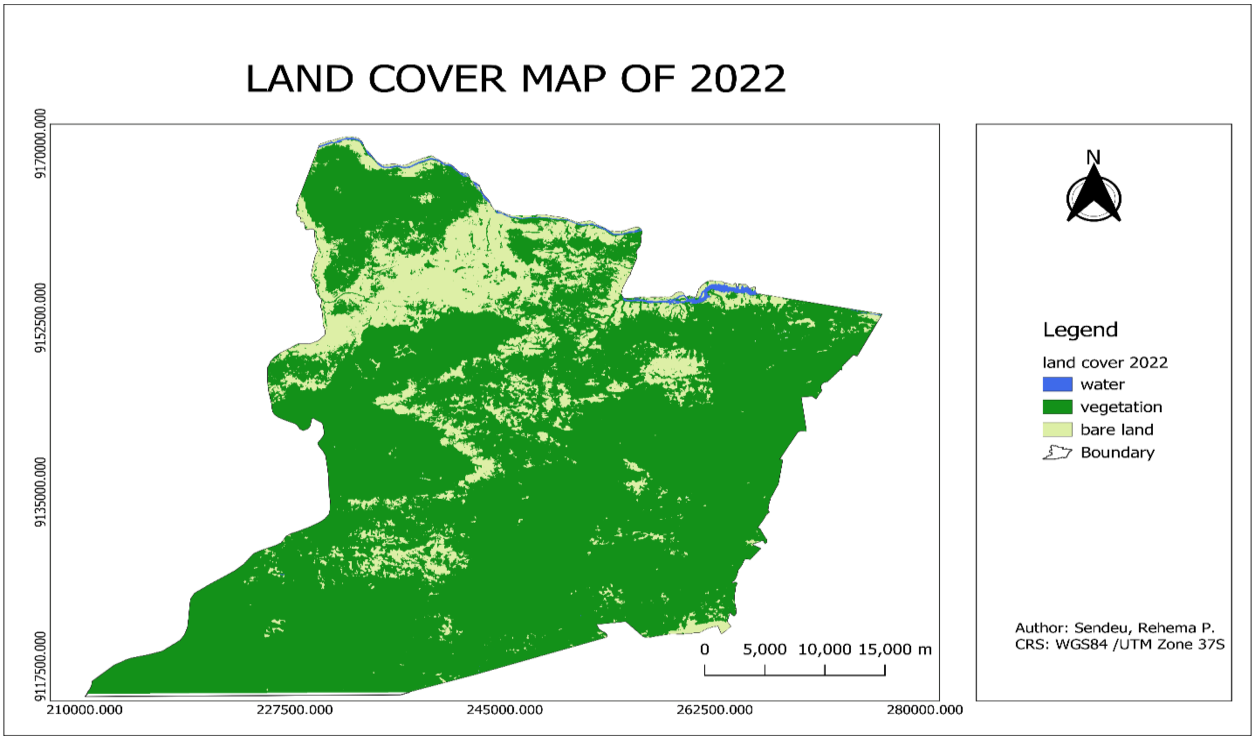

Figure 4.6 Udzungwa mountains land cover map of 2022

4.4 Land cover change mapping

The changes found between land cover maps of different years are shown, where, the classes (as land covers) changed with time meaning that, there are some gradual transformations to the areas with vegetation cover that changed to bare land and water and some places covered with bare land changed and became covered with vegetation and water same applies to areas covered with water. The habitational increase and decrease are well depicted or presented as the change of vegetational area to another land cover type such as water and bare land.

The transition of classes shows to what extent the habitats (vegetation) changed to bare land showed by substituting the area cover in square metre of one class per year with another area cover in square metre per year. From the tables below, the change of habitational areas indicated by negative sign numbers shows that there is gradual decrease of the area in range of two years. The change statistics for classes (land covers) between years are tabulated in the table 4.2 and table 4.3 for changes from year 2018 to 2022.

Table 4.2 Area changes from 2018 to 2020

Class	Area changes per year					
	2018	2020	Change (Δ)	2018%	2020%	Δ %
Water	7.58 km^2	10.04 km^2	2.46 km^2	0.39	0.52	0.13
Vegetation	1713.28 km^2	1704.95 km^2	8.33 km^2	89.15	88.72	-0.43
Bare land	200.95 km^2	206.82 km^2	5.87 km^2	10.46	10.76	0.31

Table 4.3 Area changes from 2018 to 2022

Class	Area changes per year					
	2018	2022	Change (Δ)	2018%	2022%	Δ %
Water	7.58 km^2	8.51 km^2	0.93 km^2	0.39	0.44	0.048
Vegetation	1713.28 km^2	1608.36 km^2	104.92 km^2	89.15	83.69	-5.46
Bare land	200.95 km^2	304.93 km^2	103.99 km^2	10.45	15.87	5.41

The outputs from the table above lead to the formation of land cover change maps indicating the real transition or change from one land cover to another as shown in figures 4.7 and figure 4.8.

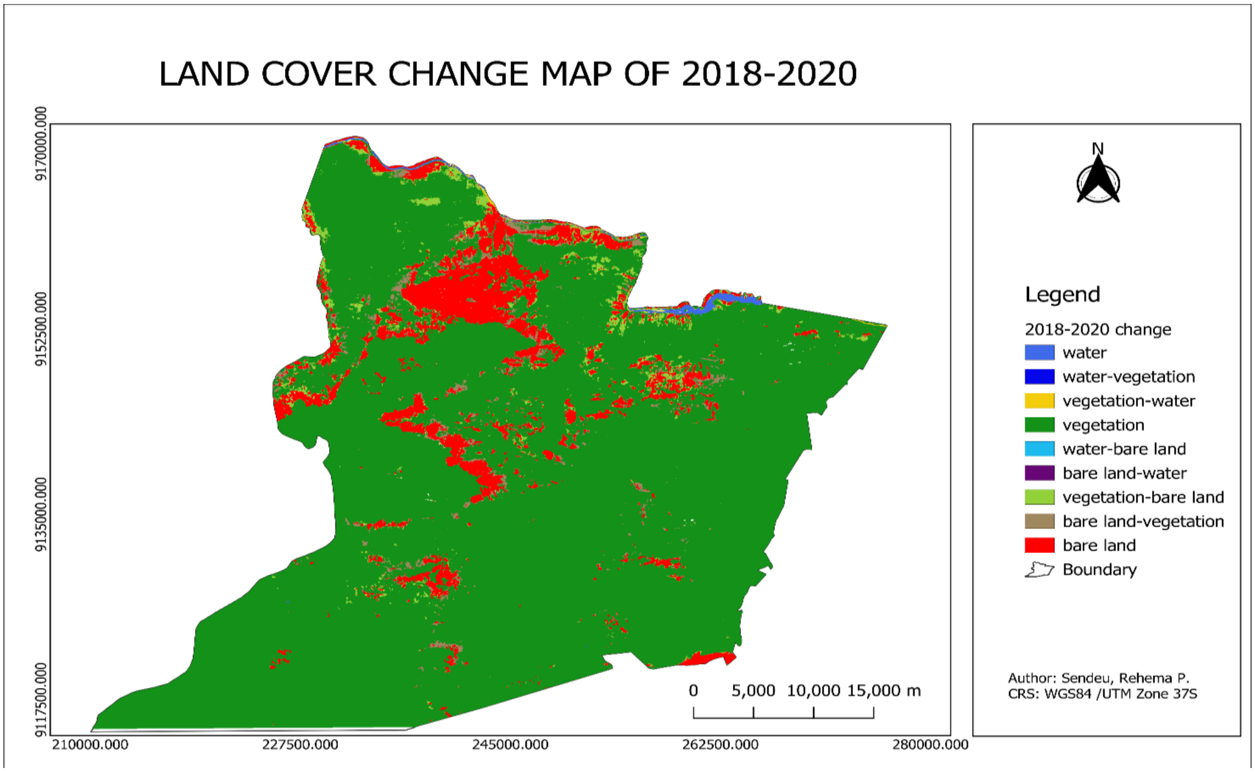

Figure 4.7 Udzungwa Mountains land cover change map of 2018-2020

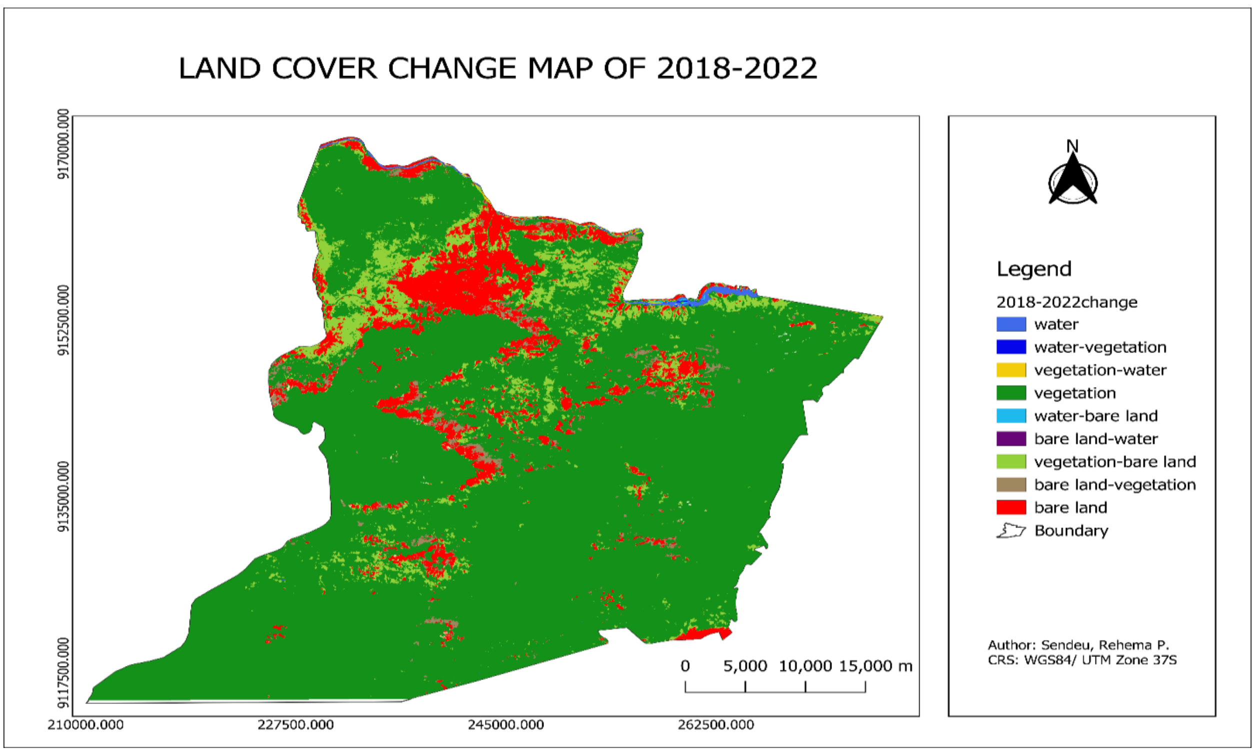

Figure 4.8 Udzungwa Mountains land cover change map of 2018-2022

4.5 Predictive Modelling

The output shows the predicted land cover of Udzungwa mountains national park for the coming 10 years. In the model validation part, a model was validated using the initial cover map as a reference map to produce number of validation iterations with correctness of 90%.

According to the nature of the vegetation cover and land use of national park areas, the prediction based on the fact that the vegetation growth takes quite a time from seedling stage to forest maturation stages considering the species of trees, environmental conditions and human interventions like deforestations and forest fires (Kimmins, 2003). The range of 10 years resonate the concept that there is enough time for growth, change, falls and damages of vegetation and water resources. The model is depicted in figure 4.9.

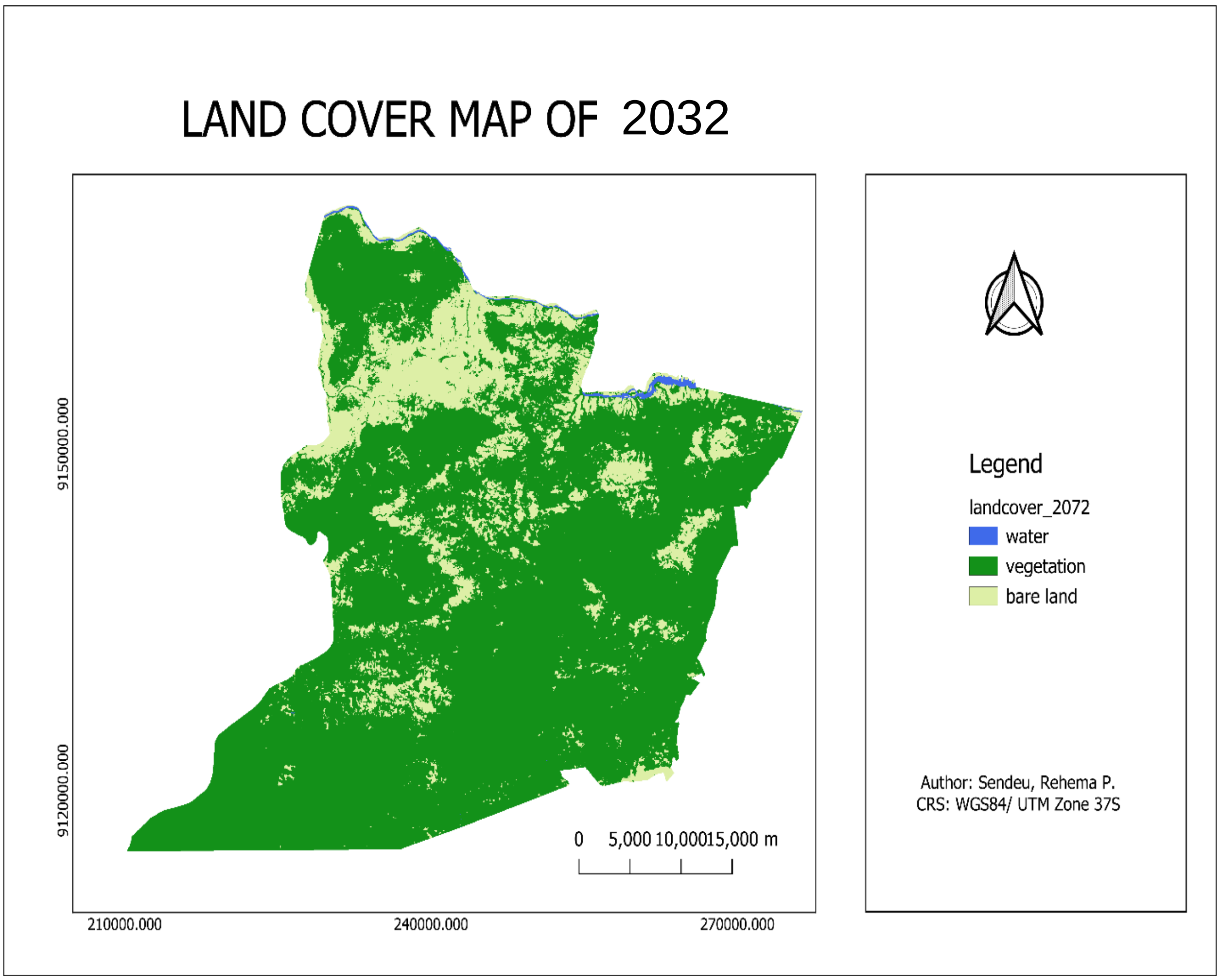

Figure 4.9 The predicted land cover of Udzungwa Mountains for the coming 10 years

In the model created, the future land cover consists of areas with increased bare land cover in the areas contained vegetation and water in previous years land covers. This indicates that, the land cover that once contained the vegetation will soon or later being occupied with bare land cover. In the case of habitats, they will decrease and cause the specie from those areas to migrate or perish from lack of habitats and associate requirements for existence.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The research aimed to implement the stated objective of identifying and indication of the habitat zones for Iringa red colobus, assessing and mapping them in range of three years (2018-2020-2022) and predict the habitation occurrence for 10 years in the future. From the output produced under this study, the land cover showed to what extent the vegetation coverage patterns as the species habitats increase or decrease from one year to another and the change obtained, estimated the rate of vegetation area change as species habitat degradation measured in square metre. So, in the future the rate will gradually increase if the situation will not be taken into an account. Since, vegetation and water play the vital role in maintaining the existence of the specie, the proper measures must be undertaken to conserve the green and water areas to avoid the extinction of Iringa red colobus.

5.2 Recommendations

From the analysis done and implications discussed above, this research provides several recommendations for several decision makers such as respective conservation authorities, Government and all citizens to;

i. Initiate strong monitoring strategies to ensure that, the specie is well maintained and protected many ages to come.
ii. Develop a comprehensive strategy in environmental conservation in land cover changes problems caused by the climate change.
iii. Provide prior knowledge to all citizens on forest conservation significance together with the associate species lives in the forest to avoid poaching and hunting the species found in it.
iv. Enhance strictly the laws and policies upon any violation done in within the conserved areas.
v. Analyze further on the factors for climate change as primary cause of habitat degradation for Iringa red colobus species.

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