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DEPARTMENT OF GEOSPATIAL SCIENCE AND TECHNOLOGY (DGST)

ASSESSMENT OF THE IMPACT OF LAND COVER CHANGE ON SURFACE WATER TEMPERATURE OF LAKE RUKWA

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ASSESSMENT OF THE IMPACT OF LAND COVER CHANGE ON SURFACE WATER TEMPERATURE OF LAKE RUKWA

By

Majele, Obedy A

This dissertation is submitted to department of Geospatial Science and Technology (DGST) as partial fulfillment of the requirements for award of the Bachelor of Science degree in Geographical Information System and Remote Sensing of Ardhi university, Dar es salaam

CERTIFICATION AND COPYRIGHT

The undersigned certify that they have proof read and hereby recommend for acceptance of a dissertation The Ardhi University a dissertation document entitled "**Assessment of The Impact of Land Cover Change on Surface Water Temperature of Lake Rukwa**" In fulfilment of the requirements for the Bachelor of Science degree in Geographical Information System and Remote Sensing.

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Dr. Anastazia Msusa	Mr. Iriael Mlay
(Main Supervisor)	(Second Supervisor)
Date ………………………	Date ……………………

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I, Majele Obedy, declare that the contents of this dissertation are the results of my own findings, obtained through studies and investigations. To the best of my knowledge, it has not been presented to any other university as a thesis for an award of Diploma, Degree or similar professional award.

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MAJELE OBEDY

Date…………………………………...

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.

DEDICATION

I dedicate this dissertation to family, friends and whoever involved in my academic journey by being a constant source of support and encouragement during the challenges of school and life. Their strong prayers, love and support in my education have brought these achievements. Also, I dedicate research to those who believe in Almighty God as father of the Earth. May God bless them and grant them joyful life

"*Trust in the Lord with all your heart, and do not lean on your understanding. In all your ways acknowledge him, and he will make straight your paths*. "Proverbs 3:5-6

ABSTRACT

As an important ecological environmental factor, the lake surface water temperature (LSWT) has an important impact on the ecological diversity of lakes and basin or watersheds This study, investigate the role that Land Cover Change (LCC) of lake Rukwa basin plays on the surface water temperature change of lake Rukwa, from 2013 to 2022 using remotely sensed land cover and surface temperature data. The Random Forest Classification algorithm was used obtain Land Cover Change map and Lake Surface Water Temperature has been retrieved with the use of MODIS satellite. Correlation between Land Cover Change and Lake Surface Water Temperature was done by using spearman correlation method. Results indicated the strongest negative correlation was associated with forest class as forest class would be expected to be the most dominant Land Cover for cooling. The most notable positive correlation was between the land cover class of cropland surface, which had a correlation of 0.56. A cropland surface increase would be related to residential development of clearing forests. These findings consistently demonstrate that cropland decrease has a strong positive impact on lake surface water temperature increase. However, urbanization does not show any positive correlation with the lake surface temperature change. This is likely caused by the small proportion of urban area surrounding this basin, there was only minor urban surface like small settlements. If there were significant settlements, such as a town, a higher rate of water temperature change would be expected. Also, barren cover shows strong negative correlation of 0.9 which demonstrate that bare land decrease has a strong impact on lake surface water temperature increase. Therefore, from the stud results lake surface water temperature is said to be affected by the change in landcover type of the area around the lake

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LIST OF ABBREVIATION

LSWT	Lake Surface Water Temperature
LCC	Land Cover Change
CCDC	The Continuous Change Detection Classification
SMW	Statistical Mono-Window
TANAPA	Tanzania National Park
USGS	United State Geological Survey
WGS	World Geodetic System
UTM	Universal Transverse Mercator

CHAPTER ONE

INTRODUCTION

1.0 Overview

Lake water surface temperature (LSW) is an extremely important factor as it affects the ecological balance of lake ecosystem and hydrological studies as well as for water quality management. LSWT is one among water quality parameters, and the LSWT is highly related to the characteristics of the ecosystem and the level of biodiversity in the watershed as compared to other environmental factors. Land Cover Change (LCC) has been shown to significantly impact the magnitude and trend of Land Surface Temperature (LST). However, the influence of LCC near waterbodies outside of an urban environment remain less understood. The importance of lake water surface temperature has long been highlighted for eco-logical and hydrological studies as well as for water quality management. Land cover transitions are known to result in warmer temperatures when transitioning from vegetated, evaporative, pervious surfaces to less vegetated, impervious surfaces, and surfaces with less heat storage. Transitions from one land cover type to another can alter how water moves, sensible and latent heat, and thermal infrared radiation. Water bodies have been noted to have a cooling effect by mitigating surface temperatures that are increasing nearby. Generally, water quality change has great interaction with land cover changes though it is complex and is varying with location and type of land cover

Also, the LSWT is sensitive to climate change (Woolway & Merchant, 2018) ,so the changes of temperature, pressure, solar radiation, cloud cover, and wind speed will affect the LSWT (Yang, Shang, & Chen, 2020). Moreover, the number of people, IS and the morphological characteristics, water color and transparency of the lake itself will also affect the LSWT

Lake Rukwa is one of the principal freshwater resource of Tanzania especially for southern highlands people. The lake saves both domestic and economic demands such as drinking water, irrigation, transport and fishery activities. The lake and its catchment support numerous fish species, crocodiles, water birds and hippopotamuses. Changes on lake water quality of lake Rukwa and rivers in the catchment area may have devastating effects on public water supplies and aquatic life, and lead to effect to human health (Mshana, 2015)

LWST remote sensing monitoring has the advantages of wide observation range and strong spatial continuity. Moreover, remote sensing monitoring data provide a good visual effect for the extraction of LWST. The application of remote sensing techniques can be an attractive alternative to studying water temperature when compared to traditional methods that are expensive, both in cost and time (Imane & Farida , 2021).Compared to conventional observation methods which are used at meteorological stations, remote sense tracking of LWST provides a wide range of measurements and good spatial consistency. Remote sensing of lake water is often limited to high spatial resolution satellites (Hasti, 2015)

1.1 Problem statement

Altered water surface temperatures can lead to altered species migration and distribution in aquatic species depending on a given species thermal boundary. In this study, using remotely sensed land cover and surface temperature data, the investigation of the role that LCC plays on the surface water temperature change of lake Rukwa in lake Rukwa Basin, from 2013 to 2022 is performed. Furthermore, as an important ecological factor, the lake water surface temperature (LSWT) has an important impact on the ecological diversity of lakes and watersheds. This imply that the change in lake water surface temperature effect the types and number of fish present in the lake. This is because it is responsible for the rate of chemical and biological reactions for example Stunted growth and reduction of local fish species Oreochromis rukwaensis, which scientists say has its origin in the lake ecosystem. LWST also affects the dissolved oxygen in water, photosynthesis of aquatic plants, metabolic rate of aquatic organism and sensitivity of these organism to pollution, parasites and diseases. Water surface temperature of lake Rukwa and its inflowing is recently being measured through laboratory techniques. This approach consumes a lot of time and the government incur a lot of expenses. Also, only samples are taken to represent the whole water body. Hence Remote Sensing techniques and methods can be developed for assessing water temperature changes.

1.2 Objectives

1.2.1 **Main objective**

The main objective of this study is to explore the role of land cover changes on water surface temperature variation of lake Rukwa during 2013–2022 using Remote Sensing and GIS techniques

1.2.2 Specific objectives

- To prepare land cover maps of lake Rukwa basin for the years 2013, 2017 and 2022.
- To prepare land cover change maps of lake Rukwa basin.
- To prepare lake water surface temperature distribution maps of lake Rukwa for the years 2013, 2017 and 2022.
- To study relationship between land cover changes with water surface temperature variation for the studied period.

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1.3 Research questions

In this study, the following questions will be answered

- What is land cover change in the study area for the studied period?
- What changes has occurred over a period of years?
- What is change water surface temperature for the studied period?
- What is the influence of land cover changes on water surface temperature change?

1.4 Significance of the research

This research will help other researchers with interest to understand the effect of change of lake water surface temperature and those related to loss of biodiversity in lake Rukwa basin

Also, this study will help different natural resource agencies such as Tanzania National Parks (TANAPA) as lake Rukwa basin is a part of Katavi National Park and Uwanda Game Reserve

CHAPTER TWO

LITERATURE REVIEW

2.1 Land cover and land cover change

Land cover Land cover maps represent spatial information on different types (classes) of physical coverage of the Earth's surface, e.g., forests, grasslands, croplands, lakes, wetlands. Dynamic land cover maps include transitions of land cover classes over time and hence captures land cover changes (Smets & Bertels, 2020). Land cover change denotes a change in certain continuous characteristics of the land such as vegetation type, soil properties, and so on. Land cover map are produced through classification of satellite images

2.2 Lake surface water temperature

Lake surface water temperature (LSWT) is an important factor of water ecological environment. Research on the main reasons of LSWT rising is the basis for controlling and improving the regional ecological environment. Lake surface water temperature (LSWT) describes the temperature of the lake surface, one important indicator of lake hydrology and biogeochemistry. Lake surface water temperature (LSWT*) is* a critical physical property of the aquatic ecosystem and an evident indicator of climate change

2.3 Image classification

Image classification is the process of assigning pixels to nominal, which results to the thematic classes (Mather & Koch, Computer Processing of Remotely-Sensed Images, 2011). The principle of image classification is that a pixel is assigned to a class based on its feature vector by comparing it to the predefined clusters in the feature space where by doing so all image pixels results in a classified image. This is also a process in which the (human) operator instructs the computer to perform an interpretation according to certain conditions. Image classification is based on the different spectral characteristics of different materials on the earth’s surface.

2.4 Impervious surface

Impervious surface refers to all hard surfaces like paved roads, parking lots, roofs, and even highly compacted soils like sports fields. The problem with impervious surfaces is that they prevent the natural soaking of rainwater into the ground and slowly seeping into streams. Urbanization brings forth the replacement of natural landscapes with built-up surfaces, often compromising the environmental quality. Other consequences of impervious surface extension are increased flooding susceptibility, diminishing groundwater recharge, and pollution of receiving water, thus raising environmental, infrastructural, and health concerns (Pradip, 2008). It is most influenced by urbanization

2.5 Remote Sensing

Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft). Special cameras collect remotely sensed images, which help researchers "sense" things about the Earth

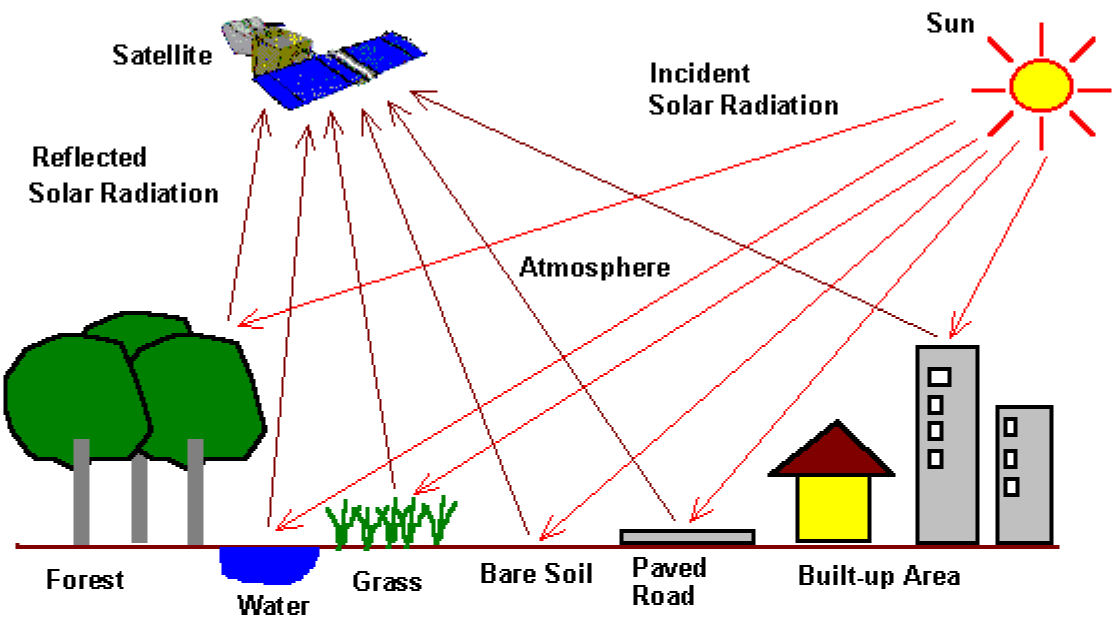

Figure 2. 1:Remote Sensing process

Remote sensing imagery has many applications in mapping land-use and cover, agriculture, soils mapping, forestry, city planning, archaeological investigations, military observation, and geomorphological surveying, land cover changes, deforestation, vegetation dynamics, water quality dynamics, urban growth (Aggarwal, 1997)

2.6 Lake Surface Water Temperature

Lake Surface Water Temperature (LSWT) describes the temperature of the lake surface, one important indicator of lake hydrology and biogeochemistry. It is also critical physical property of the aquatic ecosystem and evident indicator of climate change. The LSWT is sensitive to climate change (Woolway & Merchant, 2018) ,so the changes of temperature, pressure, solar radiation, cloud cover, and wind speed will affect the LSWT (Yang, Shang, & Chen, 2020). Moreover, the number of people, IS and the morphological characteristics, water color and transparency of the lake itself will also affect the LSWT

2.7 Related studies

There are different other researches concerning variation of lake surface water temperature as a function of land cover change:

One of the studies investigated the role that LCC around small lakes (500 m) plays on the surface water temperature change of nine small lakes in the Cataraqui Region Conservation Authority's watershed, located in Eastern Ontario, from 1985 to 2020. The Continuous Change Detection Classification (CCDC) algorithm was used alongside the Statistical Mono-Window (SMW) algorithm to calculate LCC and LST, respectively. Results indicated a strong positive relationship (R2 = 0.81) between overall LCC and lake surface water temperature (LSWT) trends, where LSWT trends in all inland small lakes investigated were found to be positive. The land cover class sparse vegetation had a strong positive correlation with water temperature, whereas dense vegetation displayed a strong negative correlation. This 35-year study contributes to the broader understanding of the impact that LCC has on the surface water temperature trends of inland lakes. (Matthew, Senyshen, & Dongmei, 2023)

Another research concerned with the acceleration of urbanization in China, it introduced the spatial influence(G) equation, selected MOD11A2, impervious surface (IS), digital elevation model (DEM) and Landsat series remote sensing images as data sources, and took six lakes with rapid urban expansion in China as the empirical research object to explore the variation characteristics of urban expansion and LSWT in six lake watersheds and the spatial influence of urban expansion on LSWT. Finally, the following conclusions can be drawn: The results show that (a) The IS in the six watersheds all experienced significant expansion, with an increase of 1.80–3.91 times. (b) From the annual average LSWT from 2001 to 2018, only one lake LSWT-night shows a cooling trend, while other lakes, whether LSWT-day or LSWT-night, show a warming trend. (c) G is used to comprehensively consider the area change of IS in the watershed, the influence of distance and the change of lake area, which can quantify the impact of IS on LSWT, so as to further explain and describe the spatial influence process and characteristics of IS expansion on LSWT. (Linfeng , Kun , Chunxue , Zongqi , & Yi , 2022)

CHAPTER THREE

METHODOLOGY

3.0 Description of the study area

Lake Rukwa is situated between half between Lake Tanganyika and Lake Nyasa extending between 74°01′ to 74°39′ longitude and 31°30′ to 33°30′ S latitude at an altitude of approximately 800 meters above mean sea level. It strides the region of Mbeya, Songwe, Rukwa and Katavi. It is fed by Rungwe River flows in from the north, while the Momba approaches the lake from the western area. Three other large inflows come in from the South, the Lupa, and Chambua and Songwe rivers (Lake Rukwa Bathmetry Report, 2014)

The lake doesn't have any outlet. The lake basin northern part is often dry, whilst the western area is shallow, and hence is for crocodile habitats. The southern basin is deeper, while half of the reservoir is part of the Uwanda Game Reserve and an extension of the Katavi National Park

The rainy season is experienced between November and May while the dry season lasts between late May and early November. Temperature is ranging between 12°C in the highlands during the cold period and 30°C in the lowlands during the hot period while winds blow from southeast to northwest (Lake Rukwa Bathmetry Report, 2014)

The main economic activities that are carried out in lake Rukwa basin are cattle grazing commonly in Rukwa region, agriculture commonly in Mbeya and Songwe regions, mining in Chunya district and wildlife conservation part of Katavi region

The lake Rukwa basin is subdivided into six sub basins include Muze, Luika, Momba, Rungwe, Katuma and Songwe

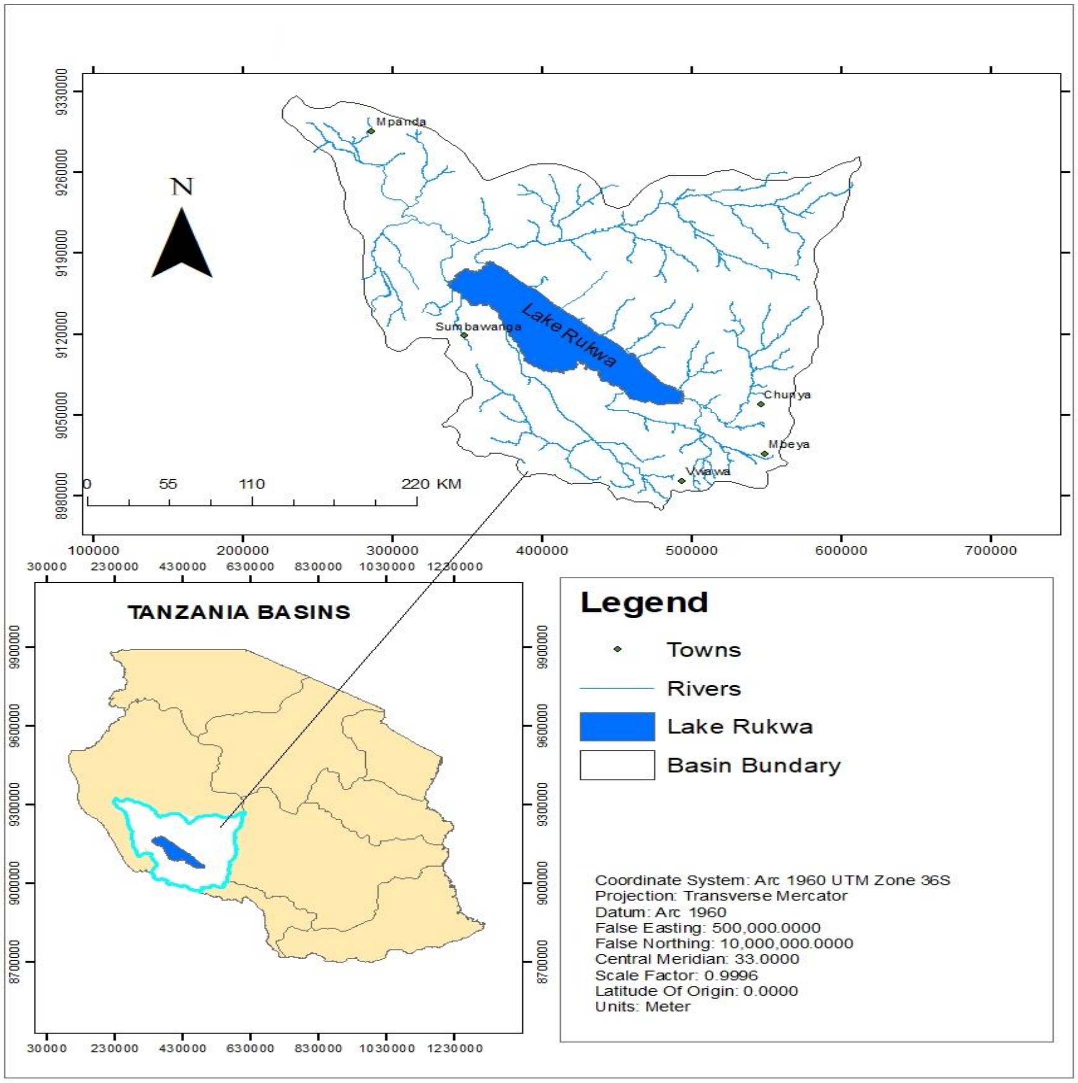

Figure 3. 1:Tanzania map showing regional administrative boundaries and Lake Rukwa basin

3.1 Data acquisition

This research involves different data which includes satellite images and lake surface water temperature sample data

Table 3. 1:Summary data, source and uses of data in this research

DATA	SOURCE	USES
Landsat 8 satellite image	USGS Earth Explorer	➢ Land cover and land cover change mapping
Modis Satellite image	NASA Ocean Color	➢ Mapping the spatial distribution of lake water surface temperature

Table 3. 2:Satellite image description, sensor, path/row and acquisition time

Satellite	Sensor	Acquisition date	Path/Row	Band used
Landsat 8	OLI_TIRS	21/10/2013	169/065	1-7
	OLI_TIRS	21/10/2013	169/066	1-7
	OLI_TIRS	13/11/2013	170/065	1-7
	OLI_TIRS	13/11/2013	170/066	1-7
	OLI_TIRS	19/10/2013	171/064	1-7
	OLI_TIRS	19/10/2013	171/065	1-7
	OLI_TIRS	01/09/2013	171/066	1-7
Landsat 8	OLI_TIRS	17/11/2017	169/065	1-7
	OLI_TIRS	30/09/2017	169/066	1-7
	OLI_TIRS	07/10/2017	170/065	1-7
	OLI_TIRS	07/10/2017	170/066	1-7
	OLI_TIRS	11/08/2017	171/064	1-7
	OLI_TIRS	26/07/2017	171/065	1-7
	OLI_TIRS	05/04/2017	171/066	1-7
Landsat 8	OLI_TIRS	14/10/2022	169/065	1-7
	OLI_TIRS	14/10/2022	169/066	1-7
	OLI_TIRS	19/09/2022	170/065	1-7
	OLI_TIRS	08/12/2022	170/065	1-7
	OLI_TIRS	08/10/2022	170/066	1-7
	OLI_TIRS	26/09/2022	171/064	1-7
	OLI_TIRS	28/10/2022	171/065	1-7

Other properties

Collection number = 02, level number = 02

projection attributes

map projection =UTM, datum = WGS84. ellipsoid = WGS84, UTM zone = 36

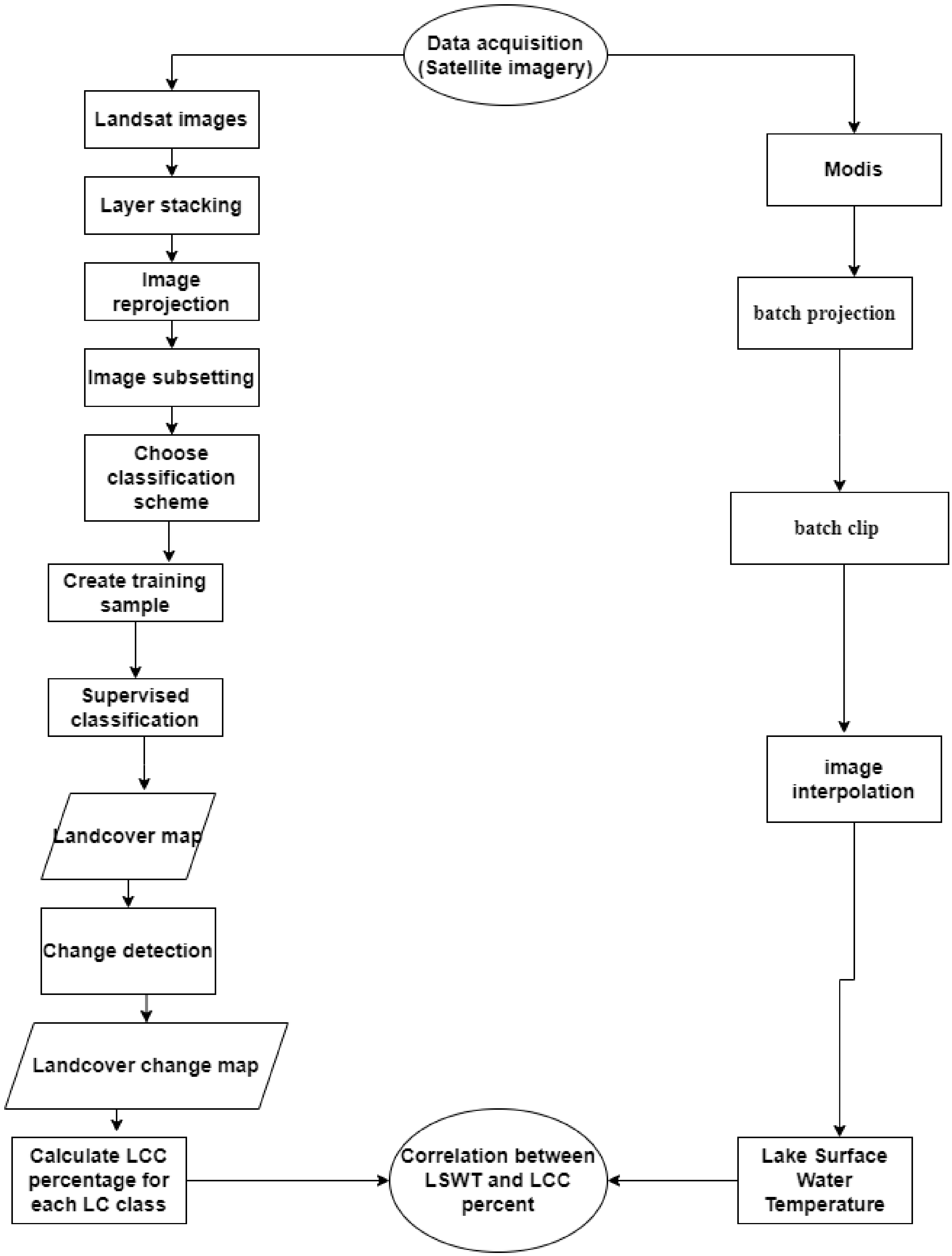

Figure 3. 2: The work flow of the methodology

3.2 Layer stacking

It is image pre-processing; Layer stacking involves combining all bands of multispectral image into a single band. Layer stacking process was done by combining band 1 up to band 7 of Landsat 8 image. This step is important as it assist in noise removal and improve image quality as far as colour composite display is concerned so as to distinguish land features

3.3 Image re-projection

The Geographical Coordinate System of downloaded Landsat8 images were in WGS 84 Universal Transverse Mercator (UTM) projection but the shapefile of the area of interest was in Arc_1960 Geographic Coordinate System. Therefore, the images were converted to Arc_1960 Geographic Coordinate System so as to conform with the Geographic Coordinate System of the shapefile of lake Rukwa basin

Area of Interest

Geographic Coordinate System: Arc_1960

Datum: Arc_1960

Angular Unit: Degree

Images

Map projection = "UTM"

Datum = WGS84

Ellipsoid = "WGS84"

UTM zone = 36

3.4 Mosaicking

This task involves combining several images with overlapping parts into a large scale seamless high-resolution image. This process was carried out since lake Rukwa basin is too big such that it covers eight different satellite scenes. These scenes include 169/065, 169/066, 170/065, 170/065, 170/066, 171/064, 171/065, 171/066

3.5 Image sub setting

The process was done on the images to obtain the representation of the area of interest on the images by adding the shape file of lake Rukwa basin area. The extraction by mask algorithms were used to clip the area of interest from re-projected stacked images.

3.6 Lake Surface Water Temperature (Lake water surface temperature extraction and missing value interpolation method)

The data of LSWT is inevitably polluted by clouds, resulting in the lack of data. Therefore, for the downloaded Aqua MODIS images. First batch projection is performed on the data and convert them to Geo Tiff format in SeaDAS software and then use the lake boundary to batch clip them to obtain the LSWT data of the lake. The image exported into Tiff /Big Tiff format so as to be compatible with ArcMap software. The missing values are calculated by Interpolation method using Inverse Distance Weighting. Finally, the brightness temperature of the Aqua MODIS image is converted into degrees Celsius (° C).

3.7 Correlation between LSWT and LCC

The correlation between landcover change and variation in lake surface water temperature tested by using Spearman's rho for the changes of these two variables that occurred between 2013-2022 Correlation coefficient rho value describe the strength of correlation between two variables

CHAPTER FOUR

RESULT, ANALYSIS AND DISCUSSION

This chapter shows the results obtained from the research. Here the results that are going to be presented includes the classified map of lake Rukwa basin for 2013, 2017 and 2022, Landcover change map for 2013-2017, 2017-2022 and 2013-2022 and other result is Lake Surface Water Temperature distribution map of lake Rukwa for 2013, 2017 and 2022

4.1 Result of classification

4.1.1 Landcover map of 2013

The map showing geographical distribution over an area of each land cover in 2013 is shown in figure 4.1 Also their land cover percentages and graphical representation are listed in Table 4.1 and Figure 4.2 respectively. The study area was classified into four land cover classes which includes water bodies represented by light blue colour, urban areas represented by red colour, cropland class represented by light green colour and barren cover represented by rose gold colour.

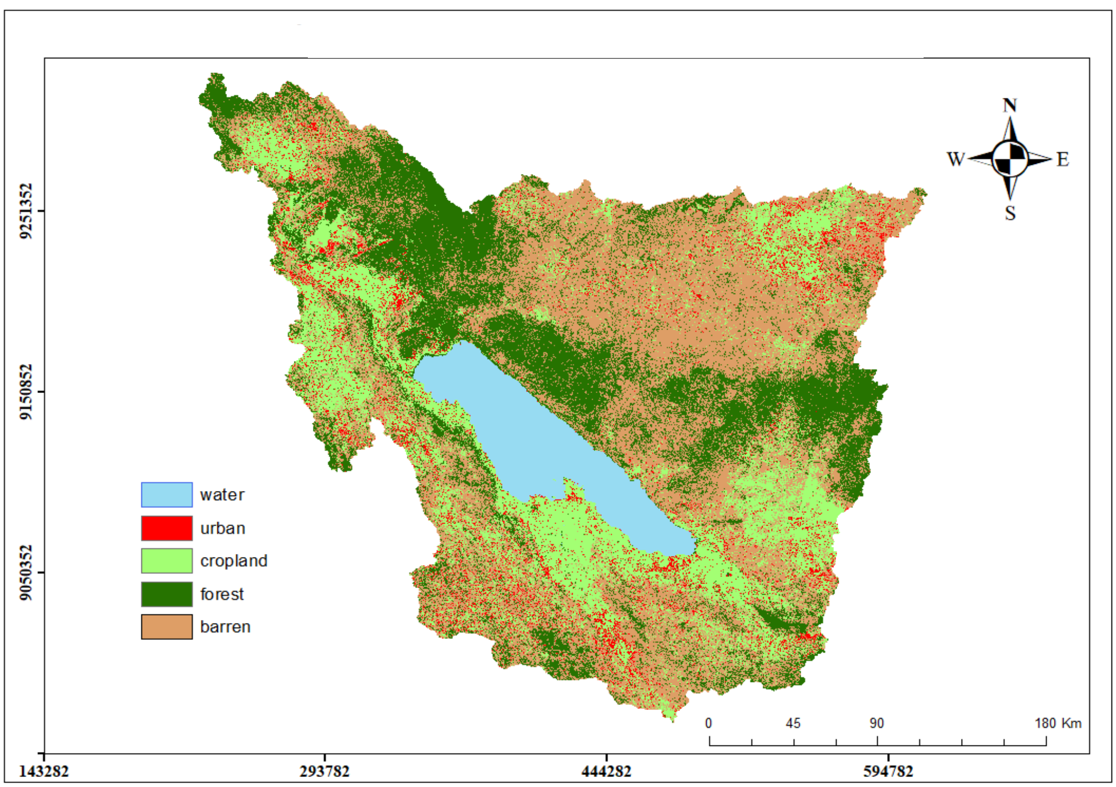

Figure 4. 1:show the landcover map of lake Rukwa basin in 2013

4.1.2 Area computations for land cover classes in 2013

The areas were computed for each land cover after classification has been done. Below is the percentage composition of each class

Table 4. 1:Shows area covered by each class in 2013

class	Area(hectares)	Coverage (%)
Water	553115.8693	7.111
Urban	371173.4	4.772
Cropland	1695377	21.795
Forest	1989965	25.582
Barren	3169213	40.741

4.1.2 Graphical representation of land cover types for 2013

The above result is presented in on the bar graph with class area coverage placed on the vertical axis and the class names being placed on the horizontal axis

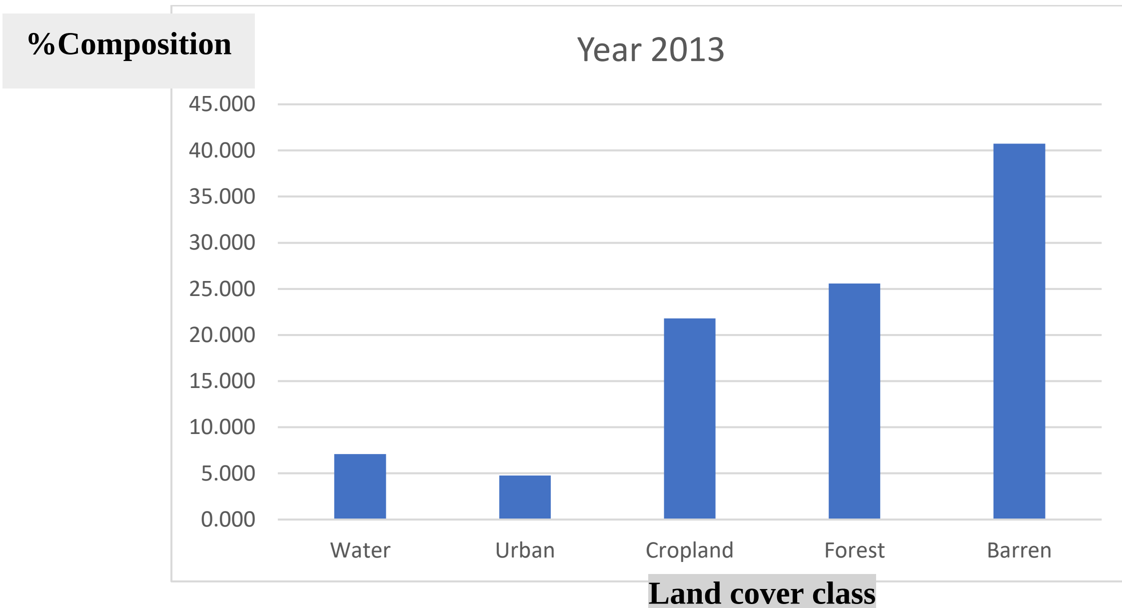

Figure 4. 2:Histogram representation of landcover classes in 2013

4.1.3 Landcover map of 2017

The map showing geographical distribution over an area of each land cover is shown in figure 4.3. Various land cover categories are depicted, including water bodies, urban, cropland forest and barren class. The study area was classified into four land cover classes which includes water bodies represented by light blue colour, urban areas represented by red colour, cropland class represented by light green colour and barren cover represented by rose gold colour.

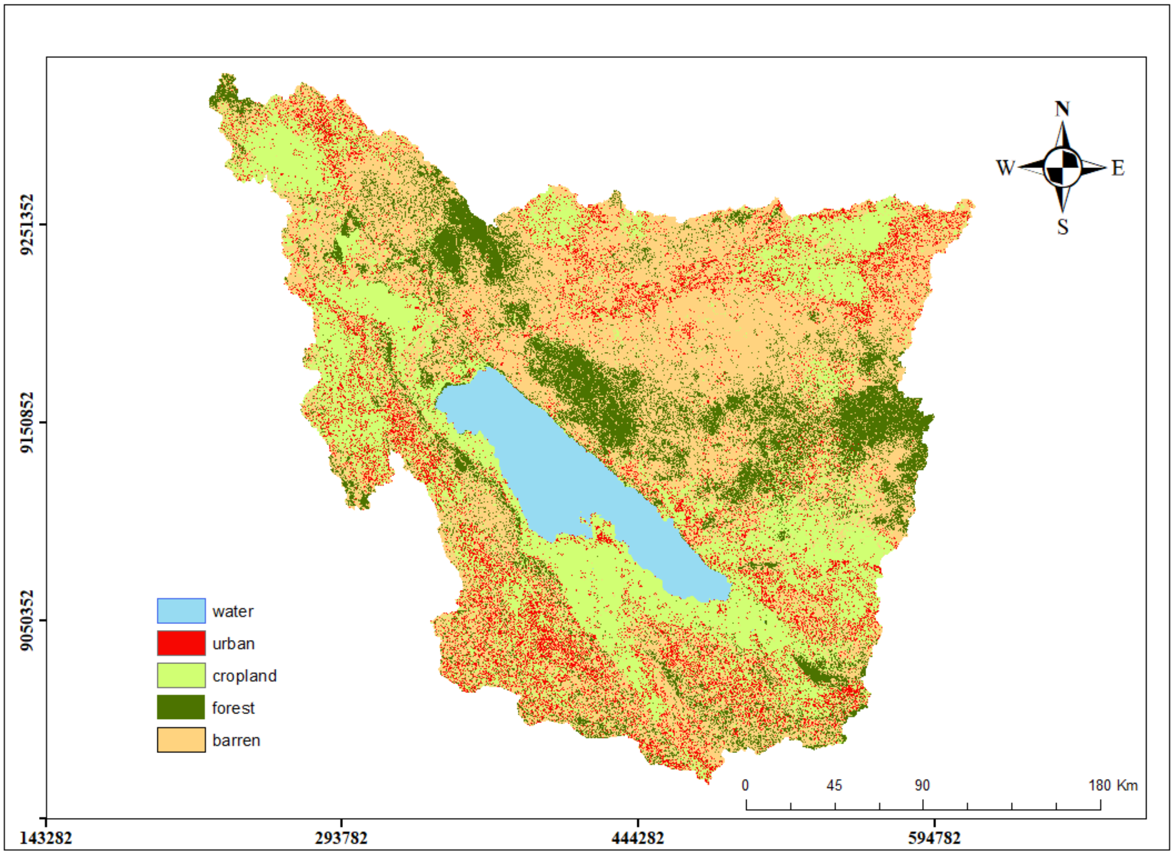

Figure 4. 3:Landcover map of lake Rukwa basin in 2017

4.1.4 Area computations for land cover classes in 2017

The areas were computed for each land cover after classification has been done. Below is the percentage composition of each class

Table 4. 2:Area covered by each class in 2017

class	Area(hectares)	Area (%)
Water	538217.7282	6.919
Urban	746246.2277	9.593
Cropland	2153660.293	27.686
Forest	1130945.925	14.539
Barren	3209767.63	41.263

4.1.5 Graphical representation of land cover types for 2017

The bar graph with class area coverage placed on the vertical axis and the class names being placed on the horizontal axis

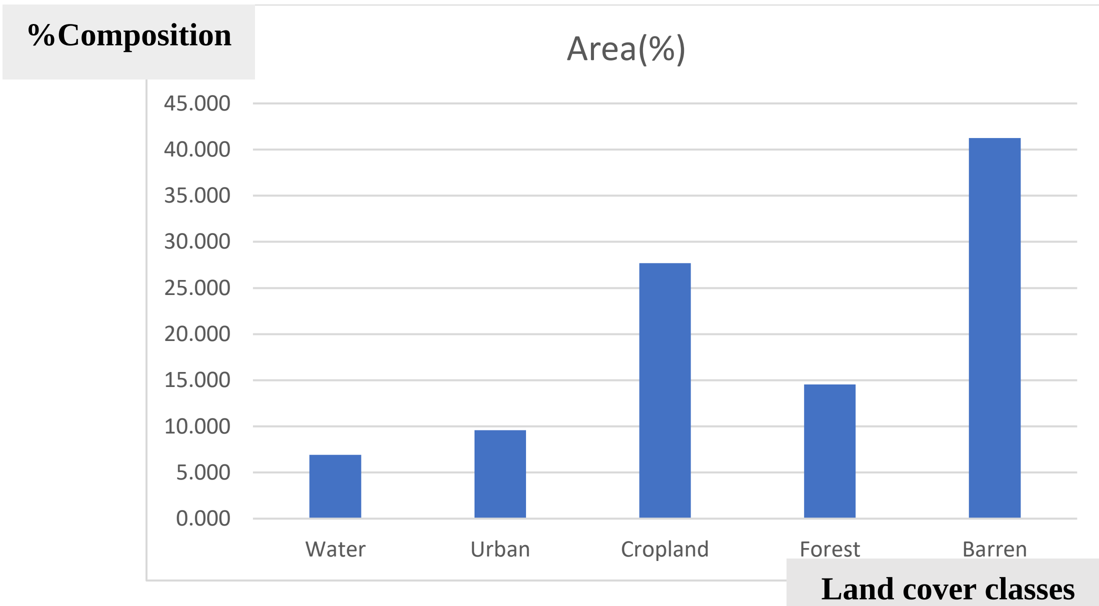

Figure 4. 4:Histogram representation each landcover class occupy in 2017

4.1.6 Landcover map of 2022

The map showing geographical distribution over an area of each land cover is shown in figure 4.5. The study area was classified into four land cover classes which includes water bodies represented by light blue colour, urban areas represented by red colour, cropland class represented by light green colour and barren cover represented by rose gold colour.

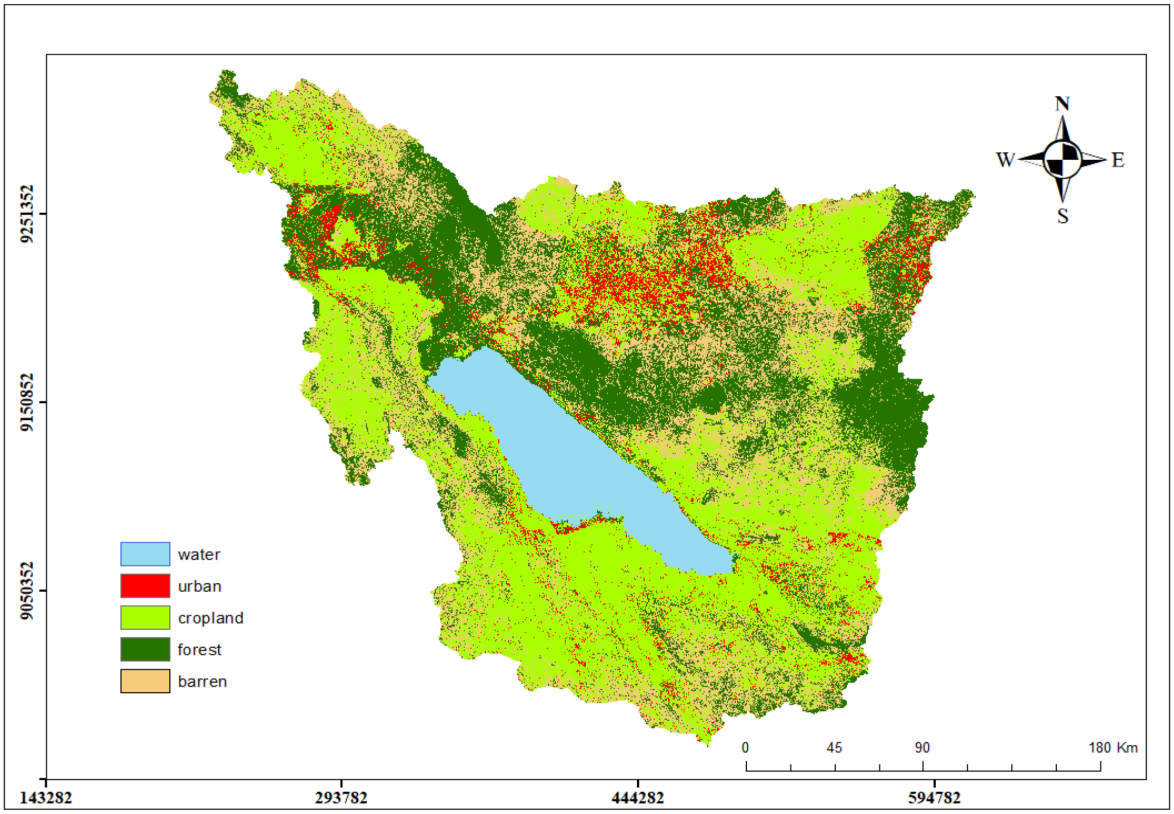

Figure 4. 5:Landcover map of lake Rukwa basin in 2022

4.1.7 Area computations for land cover classes in 2022

The areas were computed for each land cover after classification has been done. Table 4.3 is the percentage composition of each class. Cropland area occupied a substantial portion of the landscape indicating a significant presence of cultivated land

Table 4. 3:Area covered by each class in 2022

class	Area(hectares)	Area (%)
Water	600907.8895	7.725
Urban	373839.1232	4.806
Cropland	2977188.206	38.273
Forest	2060756.245	26.492
Barren	1766146.783	22.705

4.1.8 Graphical representation of land cover types for 2022

The above result is presented in on the bar graph with class area coverage placed on the vertical axis and the class names being placed on the horizontal axis. Cropland area occupied a substantial portion of the landscape indicating a significant presence of cultivated land

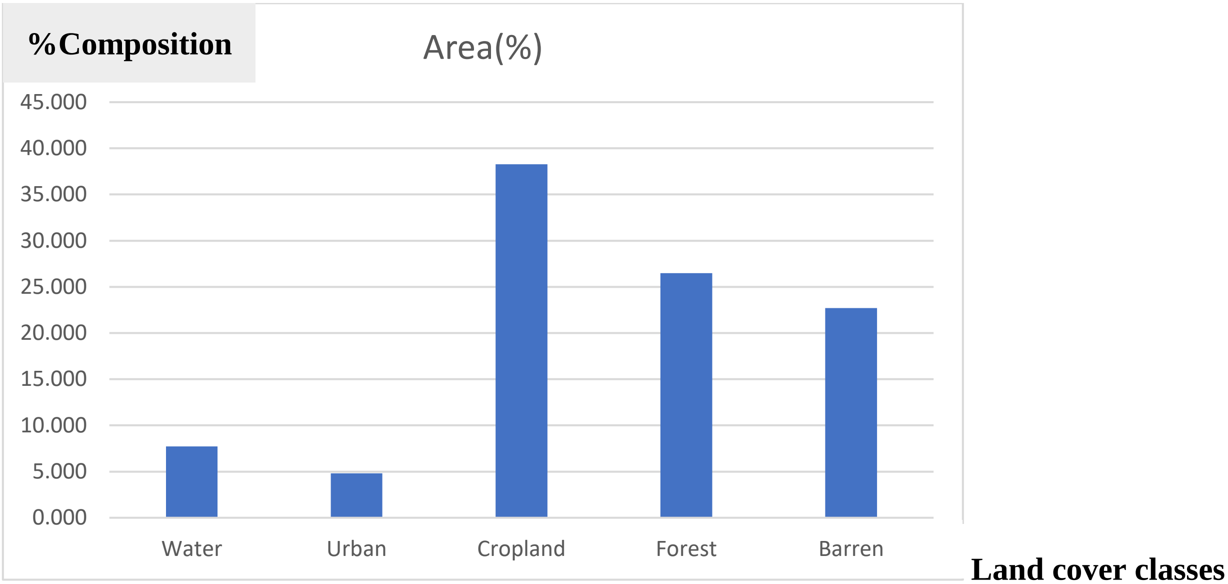

Figure 4. 6:Histogram representation each landcover class occupy in 2022

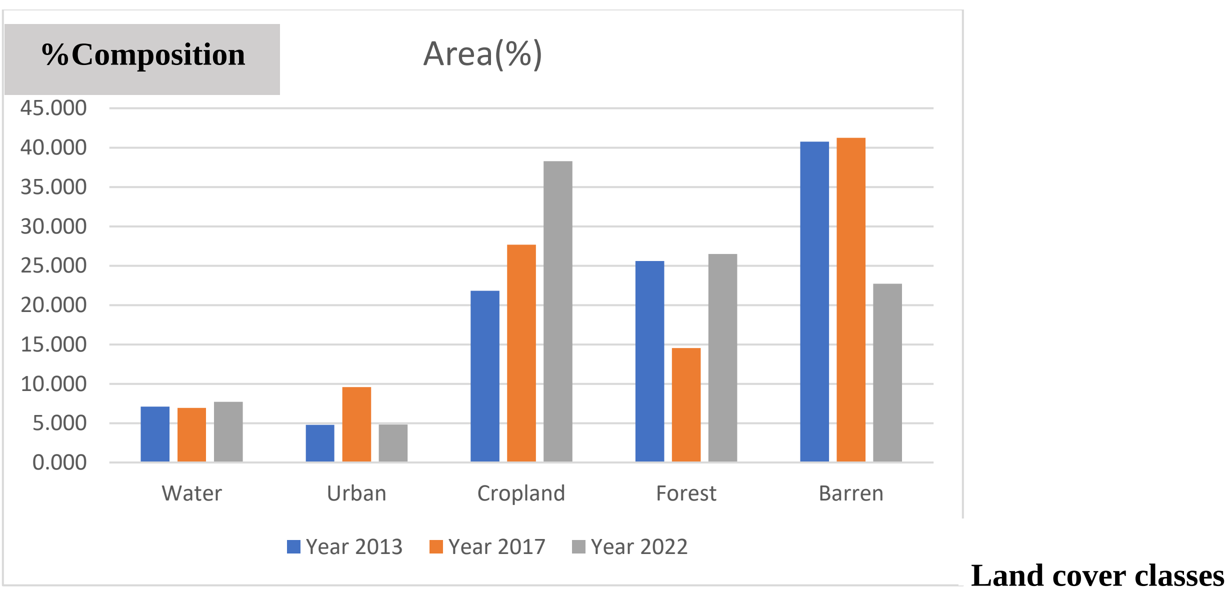

Figure 4. 7:Overall histogram representation of landcover classes for 2013, 2017 and 2022

As shown in 4.7 there are changes over three periods on the classes with one class developed in 2018 classified image. Waterbodies did not change much as compared to other classes

4.2 Change detection result analysis

The change detection result for 2013-2017, 2017-2022 and 2013-2022 are presented. Various pixel values of defined classes had changed, where by some increased, decreased and other remained unchanged

4.2.1 Land cover change map for 2013 to 2017

The land cover maps for the changes occurred over 2013-2017 is as illustrated in the figure 4.8. The map showing geographical distribution of each land cover class change over the study area as shown in figure 4.8. The map displays arrange of distinct landcover change classes, each represented by unique colours and symbols in the accompanying legend

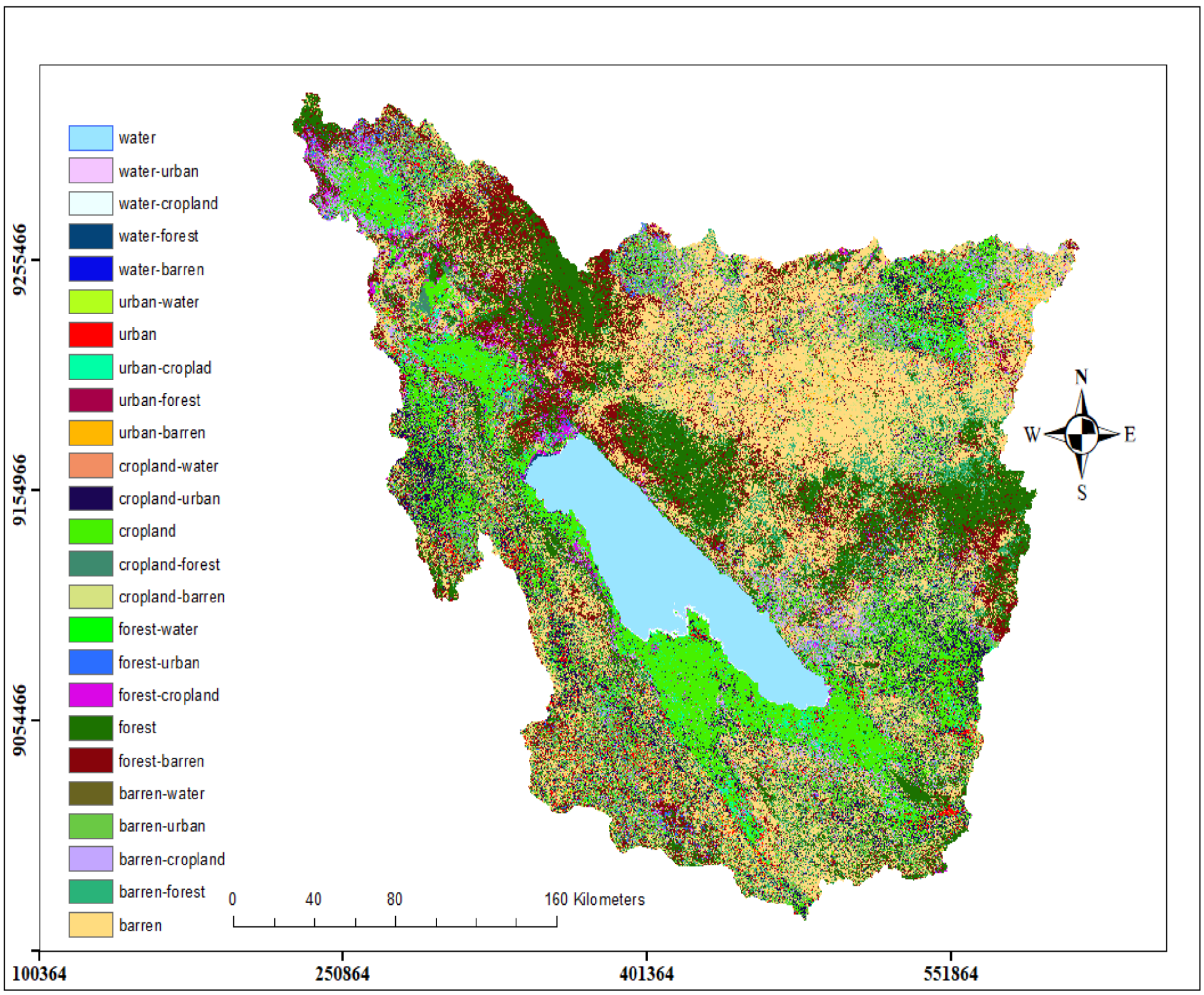

Figure 4. 8:Landcover change map from 2013 to 2017

4.2.2 Land cover change map for 2017 to 2022

The land cover maps for the changes occurred over 2013-2017 is as illustrated in the figure 4.9. The map showing geographical distribution over an area of each land cover class change as shown in figure 4.9. The map displays arrange of distinct landcover change classes, each represented by unique colours and symbols in the accompanying legend

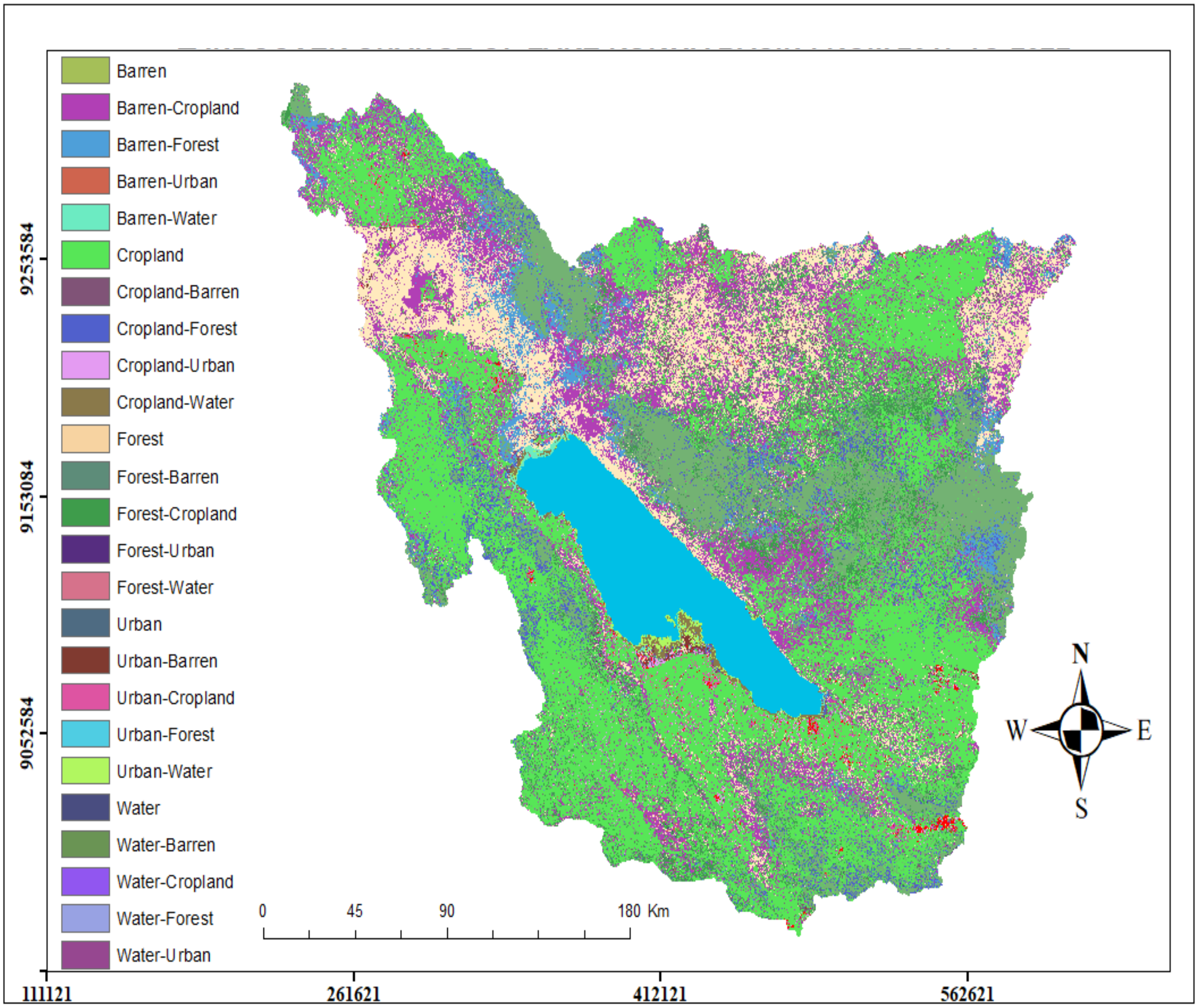

Figure 4. 9:Landcover change map from 2017 to 2022

4.2.3 Land cover change map for 2013 to 2022

This land cover change map illustrate alteration in the types of land cover such as forest, agriculture urban areas and water bodies from 2013 to 2022. The land cover maps for the changes occurred over 2013-2017 is as illustrated in the figure 4.10. The map displays arrange of distinct landcover change classes, each represented by unique colours and symbols in the accompanying legend

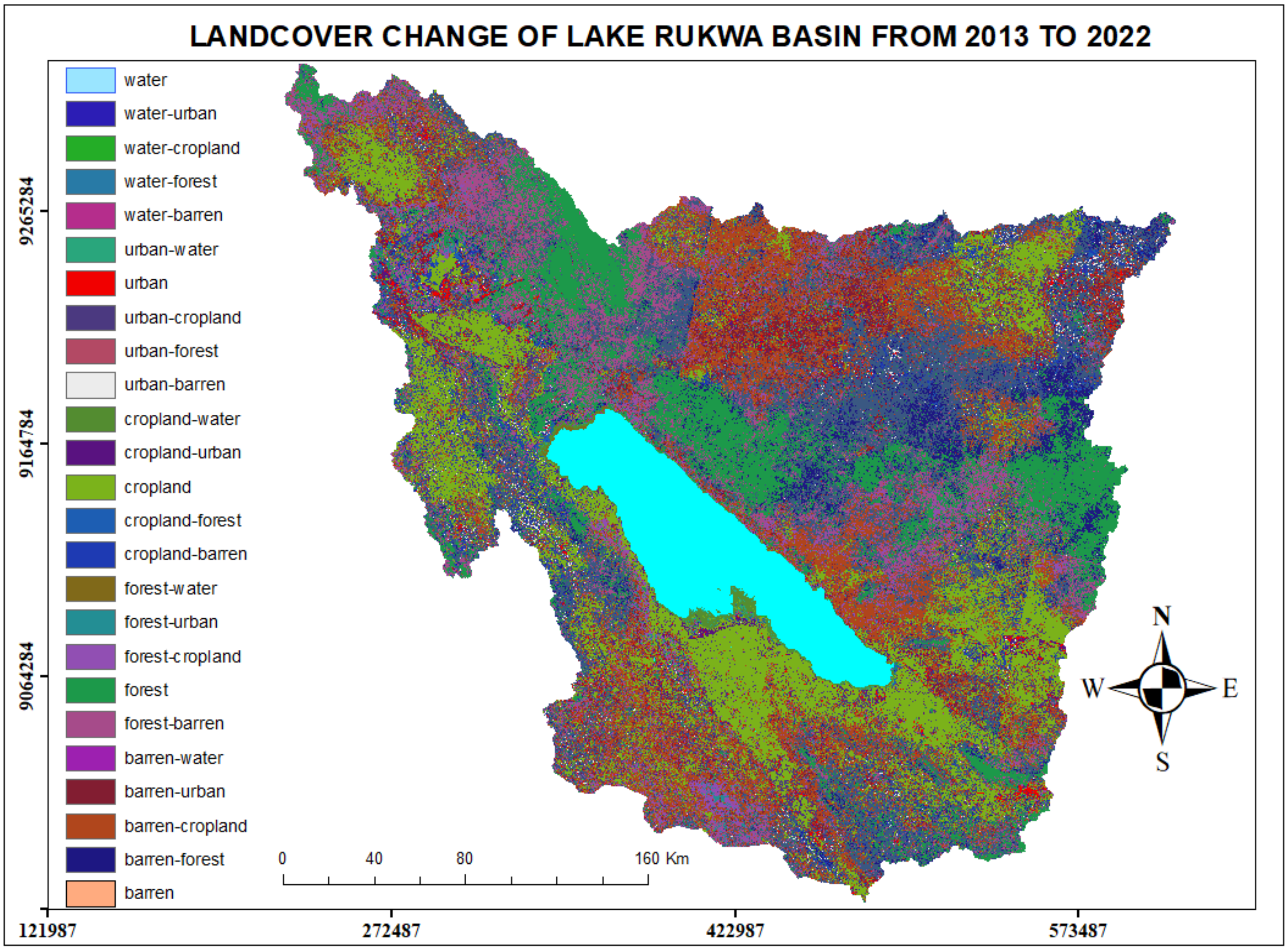

Figure 4. 10:Landcover change map from 2013 to 2022

4.3 Area computations for land cover change classes

Table 4.4 shows the the area composition in hectares occupied by each land cover change class. It gives the description of how much area have been altered to other form of land cover class. The calculated land cover change areas

Table 4. 4: Table shows area coverage by each LCC in hectares

LCC	**2013-2017**	**2017-2022**	**2013-2022**
Water	538228.66271	552681.98113	536294.38467
water-urban	2057.47626	67.87308	2.75816
water-cropland	10608.78347	275.66301	22.64614
water-forest	2212.22295	98.26408	1.46118
water-barren	3.28495	1.91805	15.09098
urban-water	31.107674	6516.03485	17530.18389
Urban	187251.82984	78774.87836	21283.58172
urban-cropland	145379.94153	248054.75832	43045.03104
urban-forest	3546.97911	5110.08328	1890.64227
urban-barren	43945.31219	38817.48421	14522.56311
cropland-water	48.04573	34864.31295	26716.39794
cropland-urban	507942.81453	94570.53697	35451.54881
Cropland	994457.44174	1344832.954	2943002.45321
cropland-forest	35926.22131	94570.536973	252748.54512
cropland-barren	157697.96324	192888.89191	183812.82351
forest-water	131.13223	6459.66685	311.34046
forest-urban	69895.67559	56087.96977	2952.97097
forest-cropland	97528.15575	251180.09844	274659.12341
Forest	1036956.59943	1023622.94834	963388.25413
forest-barren	787399.09513	654984.77484	107772.99181
barren-water	3.81896	1128.24789	13731.51943
barren-urban	680979.73783	275363.07514	15053.11433
barren-cropland	330175.37944	1226745.34923	1183321.24352
barren-forest	238403.60015	290437.38023	1008.43412
Barren	1908022.06343	1363780.45643	880784.33543

4.4 Surface Water Temperature distribution map of lake Rukwa

4.4.1 Surface Water Temperature distribution map of 2013

It illustrates the varying temperature across the surface of lake Rukwa in 2013. The map likely uses colour gradient different temperature ranges, with warmer areas appearing in red like colour and cooler areas in blue like colour. This visualization helps to identify temperature patterns. Such as warmer waters or colder regions providing valuable insight into the thermal characteristics

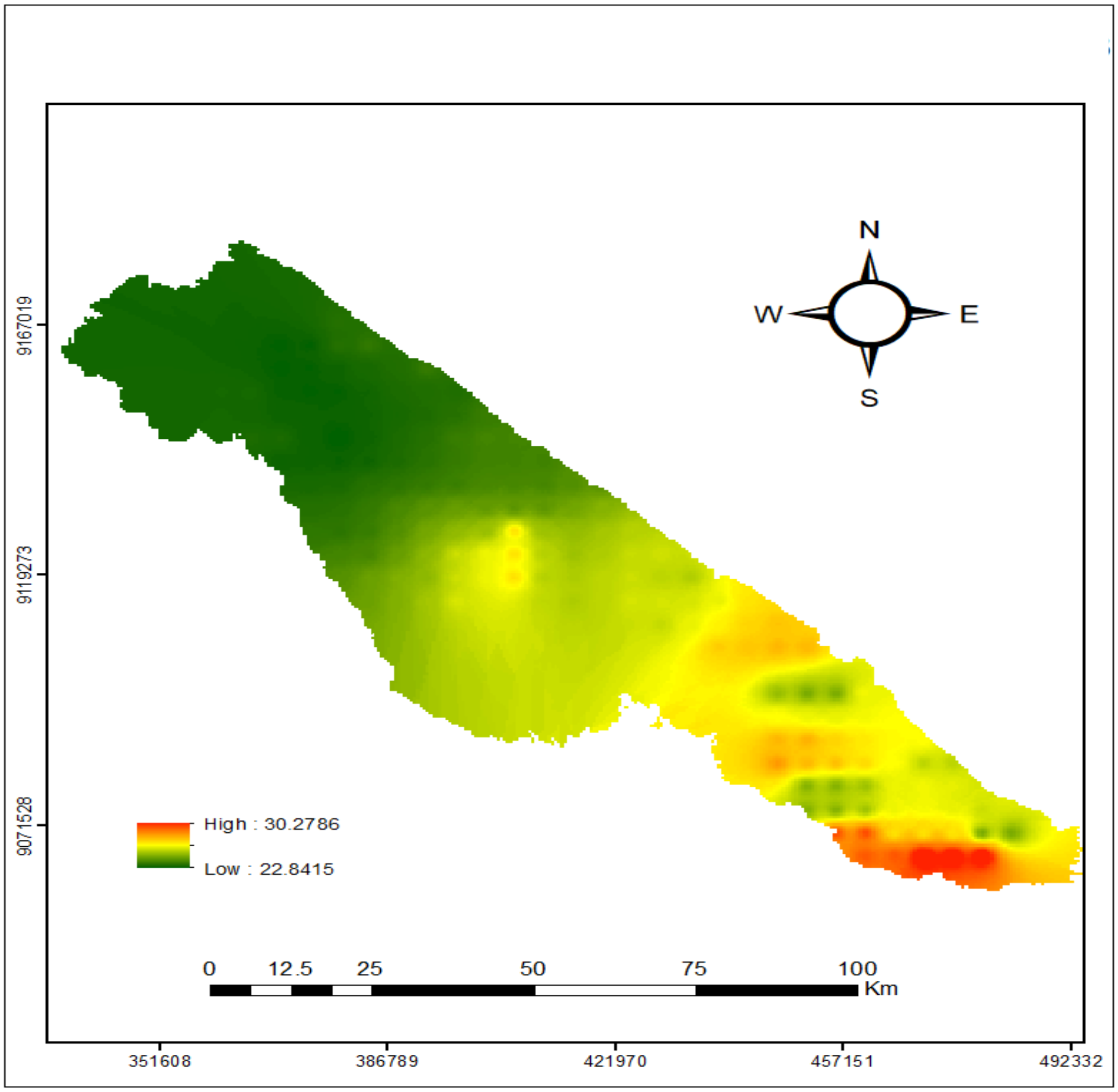

Figure 4. 11:Lake Surface Water Temperature of lake Rukwa basin in 2013

4.4.2 Surface Water Temperature distribution map of 2022

It illustrates the varying temperature across the surface of lake Rukwa in 2022. The map likely uses colour gradient different temperature ranges, with warmer areas appearing in red like colour and cooler areas in blue like colour. This visualization helps to identify temperature patterns. Such as warmer waters or colder regions providing valuable insight into the thermal characteristics

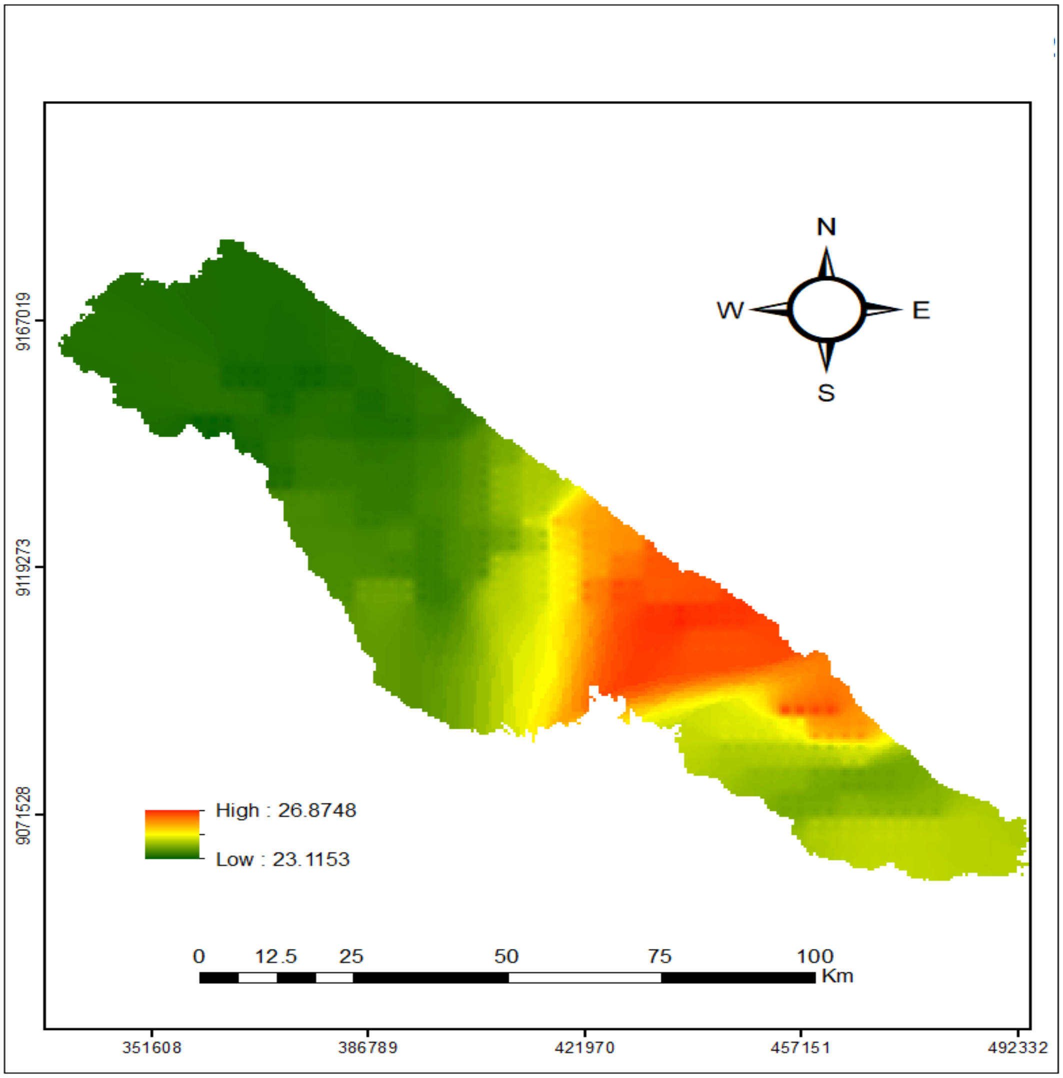

Figure 4. 12:Lake Surface Water Temperature of lake Rukwa basin in 2022

4.4.3 Surface Water Temperature distribution map of 2017

It illustrates the varying temperature across the surface of lake Rukwa in 2017. The map likely uses colour gradient different temperature ranges, with warmer areas appearing in red like colour and cooler areas in blue like colour. This visualization helps to identify temperature patterns. Such as warmer waters or colder regions providing valuable insight into the thermal characteristics

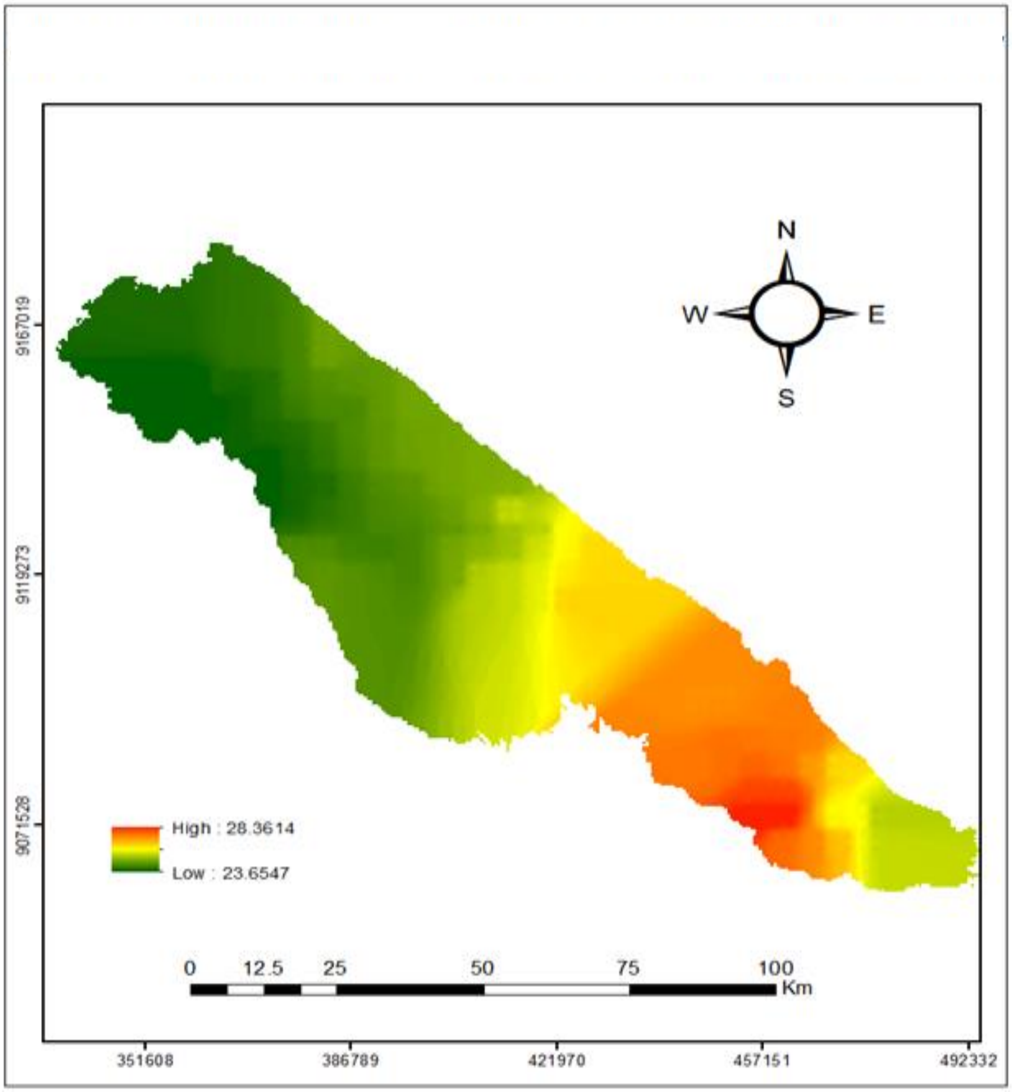

Figure 4. 13:Lake Surface Water Temperature of lake Rukwa basin in 2017

Table 4. 4:Summary of surface water temperature of lake Rukwa in different observed years in form of the highest and lowest value

Year	Lowest	Highest
2013	22.84	30.2786
2017	23.6547	28.3614
2022	23.1153	26.8748

Relationship between Landcover changes and Lake Surface Water Surface variation

Statistical methods used in relevant research mainly include correlation analysis, regression analysis, redundancy analysis

A Spearman correlation coefficient is also referred to as Spearman rank correlation or Spearman's rho. It is typically denoted either with the Greek letter rho (ρ), or rs. Like all correlation coefficients, Spearman's rho measures the strength of association between two variables.

$$\rho = 1 - \frac{6\Sigma\, \mathrm{d}_i^2}{n(n^2 - 1)}$$

ρ = Spearman's rank correlation coefficient

d_i = difference between the two ranks of each observation

n = number of observations

The Spearman Rank Correlation can take a value from +1 to -1 where,

A value of +1 means a perfect association of rank.

A value of 0 means that there is no association between ranks.

A value of -1 means a perfect negative association of rank.

Then five sample points are taken to represent lake surface water temperature of lake Rukwa as summarized in the table below

Sample point	**Easting**	**Northing**	**2013 LSWT**	**2017 LSWT**	**2022 LSWT**
1	346,951.312	9,172,493.070	22.97	23.90	23.30
2	399,675.703	9,092,035.040	25.16	24.50	23.84
3	472,819.366	9,065,215.697	29.24	26.46	24.57
4	450,571.502	9,108,797.130	26.79	26.44	26.53
5	460,432.787	9,102,593.028	25.68	27.34	26.26

Table 4 1:Lake Surface Water Temperature sample point of lake Rukwa

The correlation between landcover change and variation in lake surface water temperature tested by using Spearman's rho for the changes of these two variables that occurred between 2013-2022 as summarized in the table below

Table 4. 2:Showing LULCC of each class and their lake surface Water temperature change of sample points

Class	**Water**	**Urban**	**Cropland**	**Forest**	**Barren**	**LWST change**	**Sample**
Water	7.1	-0.084	0.448	0.083	0.0145	0.33	**1**
Urban	0.000873	1.013	1.216	0.721	3.54	-1.32	**2**
Cropland	-0.003544	-3.19	17.288	3.229	15.77	-4.67	**3**
Forest	-0.001263	-0.066	1.216	13.159	-3.734	-0.09	**4**
Barren	0.0000247	-0.499	-2.48	-8.42	-17.532	0.58	**5**

RStudio was used to compute the values of correlation coefficient rho and significant value (p value) of spearman correlation of landcover change and lake surface water temperature variation and result is as shown in the table below

4. 1:Table shows the results of spearman correlation as rho and p value

Variable		Water	Urban	Cropland	Forest	Barren
LSWT	Rho value	−0.05	-0.08	0.56	-0.9	-0.53
	P value	0.12	0.31	0.08	0.011	0.083

Correlation coefficient rho value describe the strength of correlation between two variables by following the given guidelines such as

The rate change of LSWT is also not evenly distributed within each lake. The distribution of rate change appears to be impacted by the LCC and its type. The strongest negative correlation was associated with forest class as forest class would be expected to be the most dominant LC for cooling. The most notable positive correlation was between the LC class of cropland surface, which had a correlation of 0.56. A cropland surface increase would be related to residential development of clearing dense forests and increasing residential grassland areas. These findings consistently demonstrate that cropland decrease has a strong positive impact on lake surface water temperature increase. Contrary to previous findings that urbanization plays a warming role on land surface warming, however urbanization does not show any positive correlation with the lake surface temperature change. This is likely caused by the small proportion of urban area. Surrounding this basin, there was only minor urban surface like small settlements. If there were significant settlements, such as a suburb or a town near within lake Rukwa basin, a higher rate of water temperature change would be expected

Scatterplot for Cropland cover change Vs Rate of LWST change

A correlation analysis was done to examine the relationship between cropland cover change and the rate of LWST change as indicated in figure 4.13. This plot depicts the existing relationship between LSWT and the rate of cropland change cover and specific value is given in the table 4.1

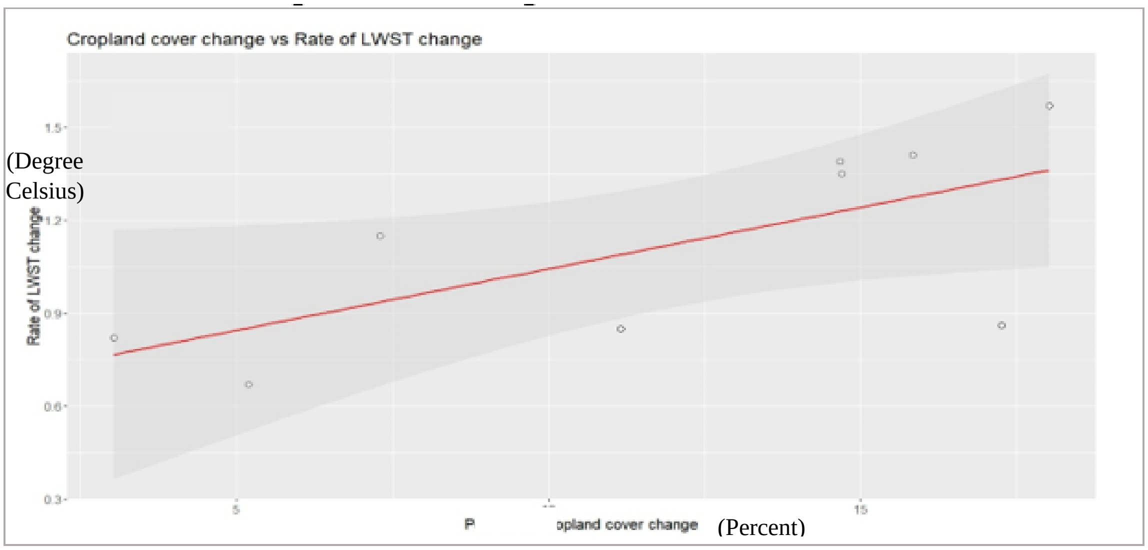

Figure 4. 14:Scatterplot for Cropland cover change Vs Rate of LWST change

Scatterplot for Forest cover change Vs Rate of LWST change

A correlation analysis was done to examine the relationship between cropland cover change and the rate of LWST change as indicated in figure 4.15 and its specific correlation value is indicated in the table 4.1

(Degree Celsius)

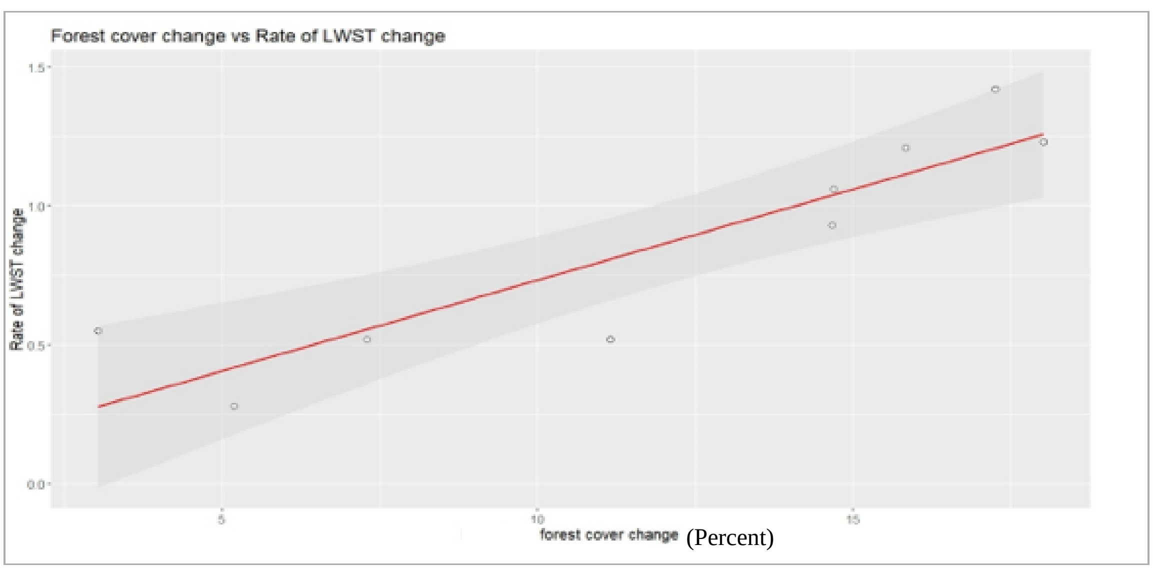

Figure 4. 15:Scatterplot for Forest cover change Vs Rate of LWST change

Scatterplot for Urban cover change Vs Rate of LWST change

A correlation analysis was done to examine the relationship between cropland cover change and the rate of LWST change as indicated in figure 4.16, where by as presented by its rho value in the table 4.1

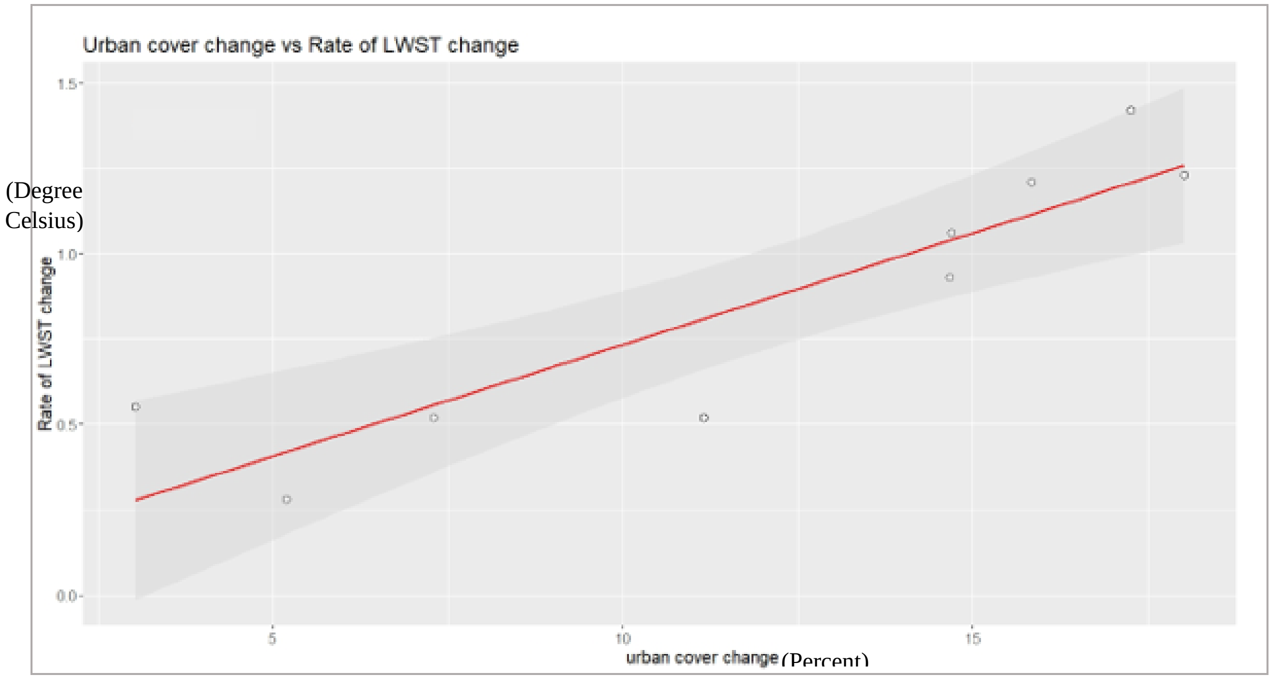

Figure 4. 16:Scatterplot for Urban cover change Vs Rate of LWST change

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From the study, the lake surface water temperature is said to be affecting by the change in landcover type of the area around the lake. The study interesting in lake water surface temperature and land cover change as they are most important parameter when it comes to matter relating to ecological relationship

When compared with previous studies, this research investigated results related to other research concerning lake water temperature, LCC impacts on lake surface water temperatures, and made contributions to the analysis of LCC on water bodies by investigating trends of lake water surface temperature. The strongest positive correlation between LC class and water temperature was cropland (0.57), while forest indicated a strong negative correlation (−0.9).

5.2 Recommendations

Other factors to consider include the incorporation of bathymetric data and additional variables such as wind speed, surface pressure, and cloud cover. Investigating waterbodies in different watershed could lead towards a better understanding of local inputs on water temperature trends. Exploring additional watersheds could provide the opportunity to determine the influence of regional variables such as rainfall, wind, and ice cover on water temperature trends, hence other studies can be conducted on other factors influencing variation in lake water surface temperature such as climatic factor. Also land surface temperature is important to be included in other study relating lake water surface temperature

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