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Analysis of land use / land cover changes in surface water dynamics, a case study of Singida urban a part of Tanzania.

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DECLARATION

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Acknowledgement

The authors wish to acknowledge the work of Ms Zsófia Krisztina Varga and Dr Jung Andras from the Institute of Cartography and Geoinformatics at Eötvös Loránd University who assisted in preparation, editing and advice while processing this thesis.

Abstract

The global need to study dynamics of land surface water bodies has become demanding for sustainability. This study focused on the development of the complete work flow on analysis the changes in the land surface water bodies in Singida Urban region. In the region the problem was reported in year 2020 by local government authorities as two part of Lake Kindai happened to merge and overlap a road network of a section of about 1.1km out of 4.4km which was the main passage way from Singida Urban to South-West outskirt regions including Nyranga.

Huge rainfall variability was noted by the findings of this study from year 2018, 2019 and year 2020. The region always experience average annual rainfall amount of about 66.67mm, in the year 2018, 2019 and 2020 the region experienced average annual rainfall amount of about 138.82mm, 118.93 and 141.46 respectively. This rainfall variability highly impacted the changes in land surface water bodies in Singida Urban in year 2020.

Surface water bodies specifically the Lakes were highly impacted of which the Lakes in 2020 increased in their area coverage by around three quarter of their original area coverage from year 2000. From year 2000 to year 2010 an increase of Lakes by 6.19% of the original area coverage was noted while the Swamps decreased by 30.84% of the original coverage. From the year 2000 to 2020 an increase in Lakes was noted to be by 76.05% of the original area coverage while the Swamps were noted to decline by 25.18% from the original coverage.

The significant increase in Lakes coverage of about three quarter of the original area coverage from year 2000 was noted in the area. The region was found to be having two Lakes namely Lake Kindai and Lake Singidani, both Lakes were subjected to change and an increase in their areas coverage was noted.

As for the direction of change Lake Kindai was examined to have an extension in North-West ward extension, South ward extension and South-East ward extension. As for Lake Singidani a significant extension in North-East ward direction was noted.

This study made use of land use / land cover change mapping techniques to quantify the amount of change, the direction of extensions of the Lakes and later the study employed GIS geometric network analysis to analyse the road network which was affected by the problem reported by local government authorities in the area. Also temporal rainfall data were analysed to draw connection on the possible source of the dynamics of the land surface water bodies in Singida Urban in year 2020.

Keywords: Surface water bodies; land cover; GIS; satellite images; land use; Geometric network

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CHAPTER ONE

1. INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Land use / land cover change studies have been globally studied by scholars to address the scenarios that arise due to land transformation from time to time. It has been noted to have a substantial contribution to ward land use / land cover mapping and planning. From early 20th century after the start of the use of satellite images and the lunch of satellites in the space, land use / land cover change studies has gained momentum as scholars started to gain an access to several types of data sets that were proven worth to contribute to the monitoring of land transformation in a time friend and cost effective way. Furthermore this study has been identified globally by researchers as one among of the themes that require global attention as land resources has proven itself to hold the sustainability of the generation on the planet earth. The human population is changing over time but the size of the land is still the same, so the studies on mapping and monitoring land use / land cover changes have been identified as of high importance for sustainability of life (Turner et al, 1994).

In the global context studies have been done to look into the dynamics of land surface water bodies as a part of land use / land cover category. The study done by (Prigent et al., 2012) examined the change in the spread and area coverage of global land surface water bodies from 1993 up to 2007 almost two decades interval found that there was a decline in land surface water bodies in relation to an increase in population pressure primarily in tropical and sub-tropical south America and south Asia. The study suggested that it was an effect of human interventions on land surface fresh water bodies. The local hydrology including the marshes and wetlands were found to be highly affected by human population interventions. The study developed a methodology for assessing the dynamics of land surface water bodies by the use of multi-satellite multi-spectral remote sensed data alongside with secondary data from Global Runoff Data Centre, 2009, gravimetric satellite measurements from GRACE and Global Precipitation Climatology Project, 2003.

In the local context in Tanzania scholars have done studies to quantify land use/ land cover changes in different epochs. (Niboye, 2010) did a study to quantify changes in land use land cover in Ngorongoro Conservation Area Authority, a part of Tanzania in three different years from 1975-1991-2000. He made use of Landsat MSS sensor for 1975 and 1991 images sensor and Landsat TM sensor for 2000 images. Through satellite image pre-processing and post-processing he identified several land use / land cover categories including forest land, wood land, shrubs, grass land, bare land, wet land and water bodies. These land use / land cover categories were identified as subjected to change as he reported that there was a gain in wood vegetation by 48.7%, a gain in bush land by 42.7%, a loss in shrub land by 29.1%, loss in grass land by 37.0%. The loss in grass land was highlighted as due to the invasion of a new revolting grass species by 34.4%.

Another study done by (Seki et al., 2018), has identified that changes in land use/ land cover has impacted the biodiversity of Kibasira swamp in Kilombero valley a part of Tanzania. Landsat5 MSS and Landsat 7 TM were used to quantify changes in land use/ land cover from 1990 up to 2011. A decrease of water bodies coverage by 35% and forest land by 9% whereas cultivated land increased by 8% highly affected the biodiversity of the swamp and its adjacent as the number of mammals declined notably.

1.2 STATEMENT OF THE PROBLEM

Several studies has been done to quantify changes in land use / land cover including the study done to analyse changes in vegetation cover in Ngorongoro Conservation Area Authority in Arusha region part of Tanzania by (Niboye, 2010). Also another study was done in the tropical catchment along Kilombero River in Morogoro region a part of Tanzania to study impacts of changes in land use / land cover in water balance quantities for hydrological components under different climatic scenarios (Näschen et al., 2019).

In the region so far there is no study which has been done to look at the changes in land surface water bodies in Singida Urban. This study will make a significant contribution to the society in general as it will help to analyse the problem that has been reported at the area in 2020 by authorities as two parts of lake Kindai happened to merge due to an increase in water levels and encroach the road network that was separating them and serving as the main passage from Singida Urban to South West outskirts regions including Nyranga.

1.3 OBJECTIVES

1.3.1 MAIN OBJECTIVE

The main objective of this study is to analyse the dynamics / changes in the land surface water bodies as a part of land use / land cover of Singida urban region.

1.3.2 SPECIFIC OBJECTIVES

a) To determine the amount of change of land surface water bodies from 2000-2010-2020 by using satellite images.
b) To determine the direction of change of land surface water bodies from 2000-2010-2020 by using satellite images.
c) To analyse the geometric network of Singida urban and suggest the alternative solution to the road network that was affected by water coverage as reported in 2020.
d) To determine the temporal variability of rainfall in the region as one of the hypothetical cause of the problem under the study.

1.4 RESEARCH QUESTIONS

a) How much did land surface water bodies change as a part of land use/ land cover of Singida region from 2000-2010-2020?
b) What directions did land surface water bodies changed from 2000-2010-2020?
c) What is the best alternative solution for the affected road network to be adopted to address the problem?
d) How did rainfall vary from 2000-2010-2020 in the region?

1.5 SIGNIFICANCE OF THE STUDY

This study will help to analyse the problem that has been reported at the area in 2020 by authorities as two parts of Lake Kindai happened to merge due to an increase in water levels and encroach the road network that was separating them and serving as the main passage from Singida Urban to South West outskirts regions including Nyranga. On the other hand the study will help researchers as an eye opener for further studies in the area as still there are questions that needs research in the region including the study of analysing the geographical factors contributing to the extension of the Lakes in the regions.

1.6 EXPECTED OUTPUTS

a) Land cover maps of 2000-2010-2020
b) Land cover change maps from 2000-2010-2020
c) Report for suggested solution for the affected road network
d) Rainfall variability statistical graphs

1.7 DESCRIPTION OF THE STUDY AREA

Singida Urban District is one among of the six districts of the Singida Region of Tanzania. It is bounded to the south and west by the Ikungi District and to the north and east by the Singida Rural District. The region is the administrative base of the Singida region. The region has a total population of 150,379 as of 2012 national census data. In regard to climate there are two key features which are temperature and rainfall. The region forms part of the semi-arid central zone of Tanzania, which experiences low rainfall and short rainy seasons which are often erratic, with fairly widespread drought in one year out of four. Total rainfall ranges from 500 mm to 800 mm per annum, with high geographical, seasonal and annual variation. There are two rather well defined seasons, the short rainy season during the months of December to March or sometimes goes to April and the long dry season from April to November (Lema & Majule., 2009) . Figure number 1 that follows shows the map of Singida urban region.

Figure 1: Singida urban

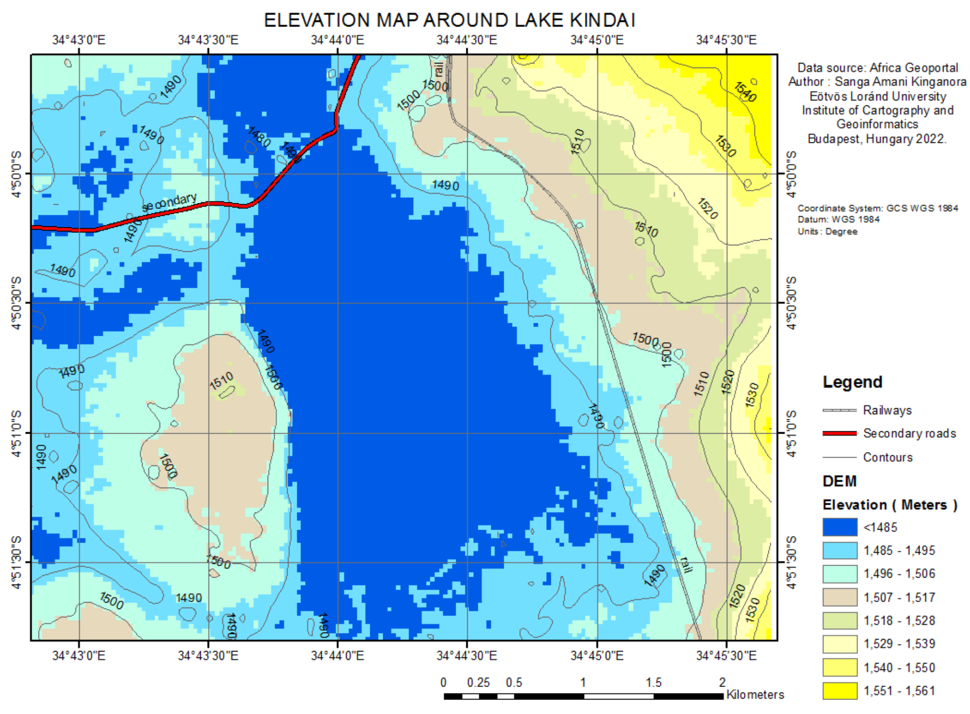

Figure 2: Elevation map around Lake Kindai

CHAPTER TWO

2. LITERATURE REVIEW

2.1 AN OVER VIEW OF LAND USE/ LAND COVER

Land cover has been defined by many scholars as the physical cover of the earth's surface not limited to but ranging from vegetation cover, water bodies, rock surfaces, barren lands, shrubs, thickets, built up areas and snow cover. These categories they vary from one area to another area based on climatic conditions and soil properties (Weng, 2010).

On the other hands researchers has described land use as how the human intervention make use of the land in a particular area. Land use includes but not limited to residential land use, agricultural land use, commercial land use, industrial areas, parks and gardens, open markets and game reserves. Remote sensing and Geographical Information System has been identified as appropriate tools for mapping land use / land cover in a time friendly and cost effective way than conventional surveys. The use of satellite images has been widely adopted to map land use / land cover in many occasions (Weng, 2010).

2.2 AN OVER VIEW OF LAND USE / LAND COVER CHANGES

Many scholars have done studies to quantify land use / land cover changes in different epochs. (Niboye, 2010) did a study to quantify changes in land use / land cover in Ngorongoro Conservation Area Authority a part of Tanzania in three different years from 1975-1991-2000. He made use of Landsat MSS sensor for 1975 and 1991 images and Landsat TM sensor for 2000 images. Through satellite image pre-processing and post-processing he identified several land use / land cover categories including forest land, wood land, shrubs, grass land, bare land, wet land and water bodies. These land use / land cover categories were identified to be subjected to change as he reported that there was a gain in wood vegetation by 48.7%, a gain in bush land by 42.7%, a loss in shrub land by 29.1%, loss in grass land by 37.0%. The loss in grass land was highlighted as the invasion of a new revolting grass species by 34.4%.

A study done by (Seki et al., 2018) identified that changes in land use / land cover has impacted the biodiversity of Kibasira swamp in Kilombero valley a apart of Tanzania. Landsat5 MSS and Landsat 7TM were used to quantify changes in land use / land cover from 1990 up to 2011. A decrease of water bodies coverage by 35% and forest land by 9% whereas cultivated land increased by 8% highly affected the biodiversity of the swamp and its adjacent as the number of mammals declined notably.

A study done by (Näschen et al., 2019) identified impacts of land use/ land cover change in water balance in Sub-Sahara-Africa. The study first quantified historical changes in land use / land cover in complex tropical catchment in Tanzania and later projected the change toward 2030 under different climatic scenarios. The study conclude that there is a low flow by 6%-8% for land use/ land cover change scenarios and there is high a flow by 84% for combined changes in land use/ land cover and change under different climatic change scenarios. This study contributed to understanding possible under flows and over flows for better management of the catchment for controlling floods and the use of water for supporting human activities including agriculture. The study made use of Landsat images from 1970 for Landsat pre-collection images level 1 to 1994 for Landsat5 MSS to 2004 for Landsat7 TM up to 2014 for Landsat8 OLI. Land Change Modeller was used to predict the changes in land use / land cover up to 2030 and finally Soil and Water Assessment Tool was used to simulate the water balances.

2.3 AN OVER VIEW OF SATELLITE IMAGE PROCESSING

Satellite image processing has been described by scholars as the range of processes done by the use of computer based algorithms to support extraction of information from a raw satellite image. In satellite image processing the processes have been categorised into two major steps which are pre-processing and post-processing. Pre-processing are steps done in order to remove the flaws in the raw data and rectify its geometry. Pre-processing involves radiometric corrections and geometric corrections. The causes of radiometric errors are atmospheric effects including absorption and scattering, sun azimuth and elevation, sun earth distance and detector response. Radiometric corrections are done in order to improve signal to noise ratio (SNR). On the other hand geometric corrections are done due errors that arise due to relief distortion, earth rotation and curvature. Geometric correction is done in order to obtain better geometric integrity of an image (Lu & Weng, 2007).

After successfully satellite image pre-processing then image post-processing is followed, satellite image post processing includes image classification, accuracy assessment, image reclassification, and change detection, band rationing and zonal statistics. Image classification has been defined by scholars as the process of assigning pixels to categories based on their reflectance values. Several classification algorithms have been used including minimum distance, maximum likelihood, random forest, neural network, support vector machine and k-means clustering. Satellite image classification has been categorised into three groups for hard satellite image classification category. They are as follows; supervised classification of which the user train the pixels by using user's pre-defined categories, un-supervised classification of which the algorithms classify the pixels without the training data. Also there is another method termed expert knowledge based classification of which it makes use of decision tree pixel grouping approach (Lu & Weng, 2007).

Scholars have done studies to determine and compare the accuracy of different image classification algorithms. A study done by (Patil et al., 2012) made a comparison of accuracy obtained using error matrix for the image classified using minimum distance algorithm and maximum likelihood algorithm for four major land cover categories in the area which were vegetation, barren land, water and built-up area. Error matrix was used to compute overall accuracy for two classification algorithms and both of them score more than 80% of accuracy. Minimum distance score 87% and maximum likelihood scored 91%. Thus the findings of this study justifies that both classification algorithms are more or less effective in studying image classification for land use / land cover mapping in urban areas.

In the beginning of 21st century machine learning algorithms has been widely adopted in image classification process. A study done by (Talukdar et al., 2020) made a comparison of accuracy obtained from different machine learning algorithms which were random forest, support vector machine, artificial neural network, fuzzy adaptive resonance theory-supervised predictive mapping, spectral angle mapper and Mahalanobis distance. The accuracy was assessed by using several methods including kappa coefficient and root mean square error. The study found that random forest scored a high kappa coefficient value of 89% followed by artificial neural network which scored 87% then support vector machine scored 86%, fuzzy adaptive resonance theory-supervised predictive mapping scored 85%, spectral angle mapper scored 84% and Mahalanobis distance scored 82% for kappa coefficient measure of accuracy. Thus both algorithms scored more than 80% and thus they are effective for studying urban land use land cover classification studies.

2.4 AN OVER VIEW OF SURFACE WATER DYNAMICS

Several studied have been done to look into the dynamics of land surface water bodies. The study done by (Prigent et al., 2012) examined the change in the spread and area coverage of global land surface water bodies from 1993 up to 2007 almost two decades interval found that there was a decline in land surface water bodies in relation to an increase in population pressure primarily in tropical and sub-tropical south America and south Asia. The study suggested that it was an effect of human interventions on land surface fresh water bodies. The local hydrology including the marshes and wetlands were found to be highly affected by human population interventions. The study developed a methodology for assessing the dynamics of land surface water bodies by the use of multi-satellite multi-spectral remote sensed data alongside with secondary data from Global Runoff Data Centre, 2009, gravimetric satellite measurements from GRACE and Global Precipitation Climatology Project, 2003. An interesting observation is that in central part of Tanzania covering areas including Dodoma city and Singida region which is the area under the study was found to experience an increase in land surface water bodies with the range of between 30km^2 and 40km^2. The global results of 15 years interval for this study are further described by figure number 3 that follows.

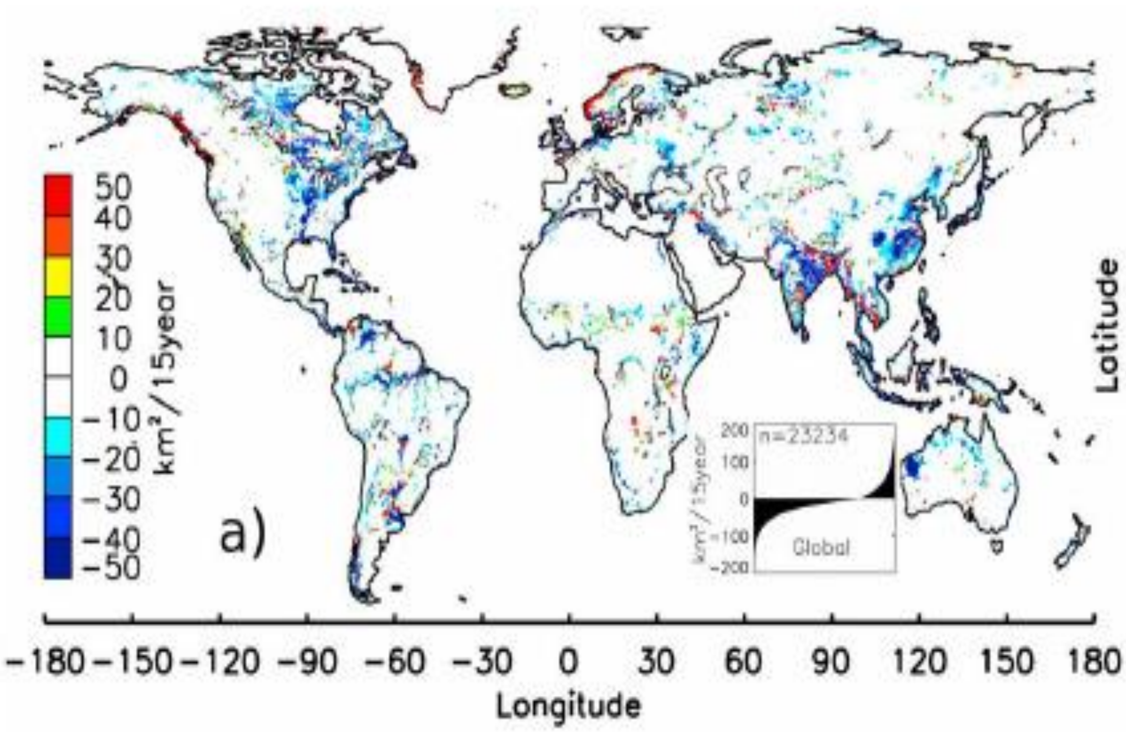

Figure 3: (Prigent et al., 2012), Global surface water dynamics.

Furthermore (Wang et al., 2018) did a study in middle Yangtze River basin in China and made use of Landsat satellite images and Google earth engine from 1990-2000-2010-2017. A new method of calculating annual maximal and annual minimal extent of surface water bodies was introduced and employed in Google earth engine platform. Vegetation based index and water based index was used to discriminate and identify surface water bodies from other land cover categories. The study identified significant changes in both minimal and maximal extent of surface water bodies for both years. In the study rainfall data was also incorporated and indicated there was rainfall variability with the Yangtze River basin. Influence of human activities, seasonal floods and rainfall variability they were both identified as factors contributing to the dynamics of surface water bodies in Yangtze River basin.

2.5 AN OVER VIEW OF RAINFALL VARIABILITY

A study done by (Zorita & Tilya, 2002) identified the inter seasonal rainfall variability in the northern part of Tanzania for two major rainfall seasons which are march-may rainfall season and October-December rainfall season. Also the study highlighted that the area under the study is found to be experiencing two annual maxima rainfall seasons which are March-May and October-December seasons. March-May rainfall season was found to be much less consistent than October-December rainfall season.

Another study done by (Mbigi & Xiao, 2021) identified that there is a connection between inter annual rainfall variability for October-December rainfall season and Indian and Pacific ocean in Tanzania. Sea surface temperature anomalies were found to be one among the driving factor for variation.

2.6 AN OVER VIEW OF GEOMETRIC NETWORK ANALYSIS

Up on addressing complex transportation planning scenarios (Ngereja, 2009) did a study to answer complex transportation questions including shortest route between two locations based on the impedance of travel time and travel distance in Dar-es-salaam city part of Tanzania. The study made use of simulated real life scenarios including occurrence of an accident and identifying the shortest possible route towards a health care centre. Also service area analysis was simulated to identify the service area that health centres will cover spatially. Figure number 4 that follows show the shortest route from a simulated accident toward the nearest hospital.

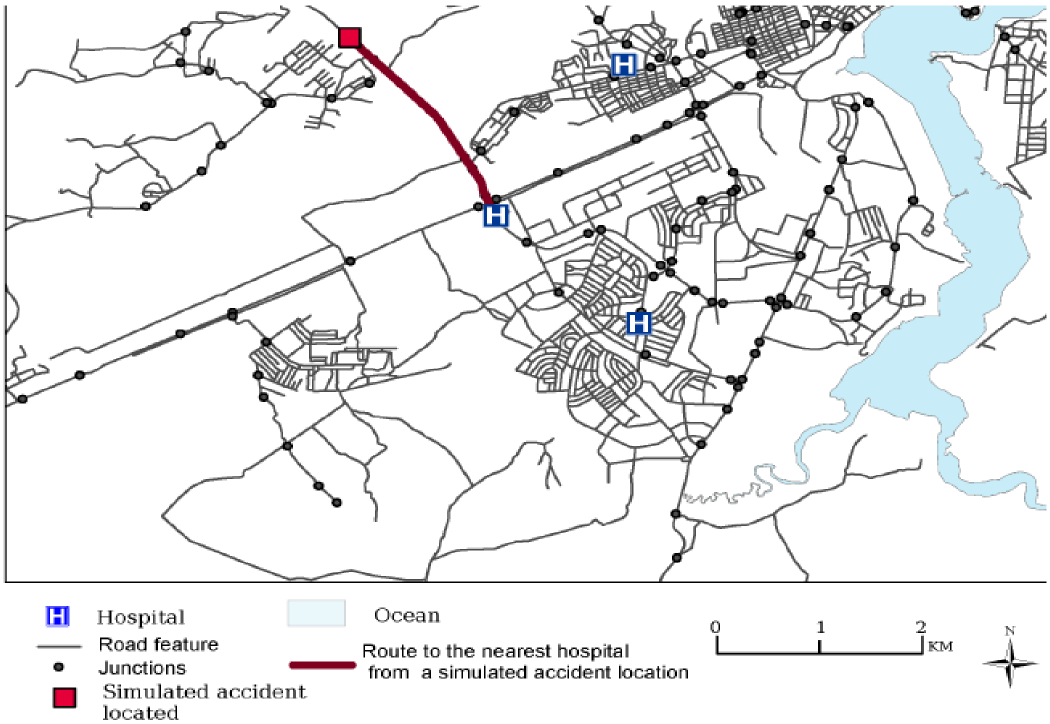

Figure 4: (Ngereja, 2009), Geometric network analysis.

CHAPTER THREE

3. METHODOLOGY

3.1 DATA SOURCE AND THEIR IDENTIFICATION

This study made use of both primary data and secondary data sources up on its completion.

a) Primary data sources: ground truth coordinates which were collected from the field by using handheld GPS receiver collected back around August 2018 will be used to help supervised image classification. 295 coordinates was evenly collected from the study area for nine land cover categories which were water bodies, grass land, farm land, deep vegetation cover, rock surface, thickets, shrubs, swamps and built up areas.

b) Secondary data sources: secondary data employed under this study includes satellite images from Landsat7 for the year 2000 and 2010 and Landsat8 for the year 2020. Both images had more or less some similar qualities. Visible bands of the spectrum was used which were blue, green and red alongside with near infrared to produce land use/ land cover maps. The images were collected from USGS online archives. Another secondary data included the background map elements of Singida region including the boundary and road networks which were collected from Tanzania National Bureau of Statistics (NBS). Also another secondary data was topographical map of Singida urban which was used to assess the accuracy of land use land cover classification. Also rainfall temporal data from NASA global precipitation data accessed from the link https://power.larc.nasa.gov/data-access-viewer/ 9th January 2022 was employed for statistical analysis to analyse rainfall temporal variation in the region.

3.2 TOOLS AND MATERIALS

a) QGIS: QGIS software alongside with Semi-Automatic Classification plugin was used for satellite data pre-processing including radiometric correction for improving signal to noise ratio of a satellite image, correcting the missing scan line error in Landsat7 data by using fill tool. Also the software was used for post-processing including image classification and accuracy assessment. The software was further used to analyse changes in land use / land cover maps. Finally QGIS software was used to create final land use land cover maps layouts.

b) Microsoft excel: Microsoft excel alongside with its analysis tool pack was used to analyse temporal variation of rainfall data from 2000-2010-2020 and to plot statistical graphs and charts.

3.3 DATA PROCESSING AND ANALYSIS

3.3.1 SATELLITE IMAGE PRE-PROCESSING

Satellite images for both years 2000-2010-2020 were pre-processed for radiometric correction and geometric corrections. Radiometric corrections were done for correcting signal to noise ratio which rises due to energy interaction with the atmosphere. Also pan sharpening was performed in order to improve the resolution of the coloured bands Geometric correction was done in order to rectify the image which is originally registered to UTM zone 36 N and the region is in UTM zone 36 S. Radiometric correction was done with the use of QGIS Semi-automatic Classification Plugin, the raw satellite images were imported alongside with their Meta data file. Figure number 5 that follows describes how radiometric corrections and pan sharpening was done for the year 2000 as a sample but the same work flow was adopted for the rest of the datasets.

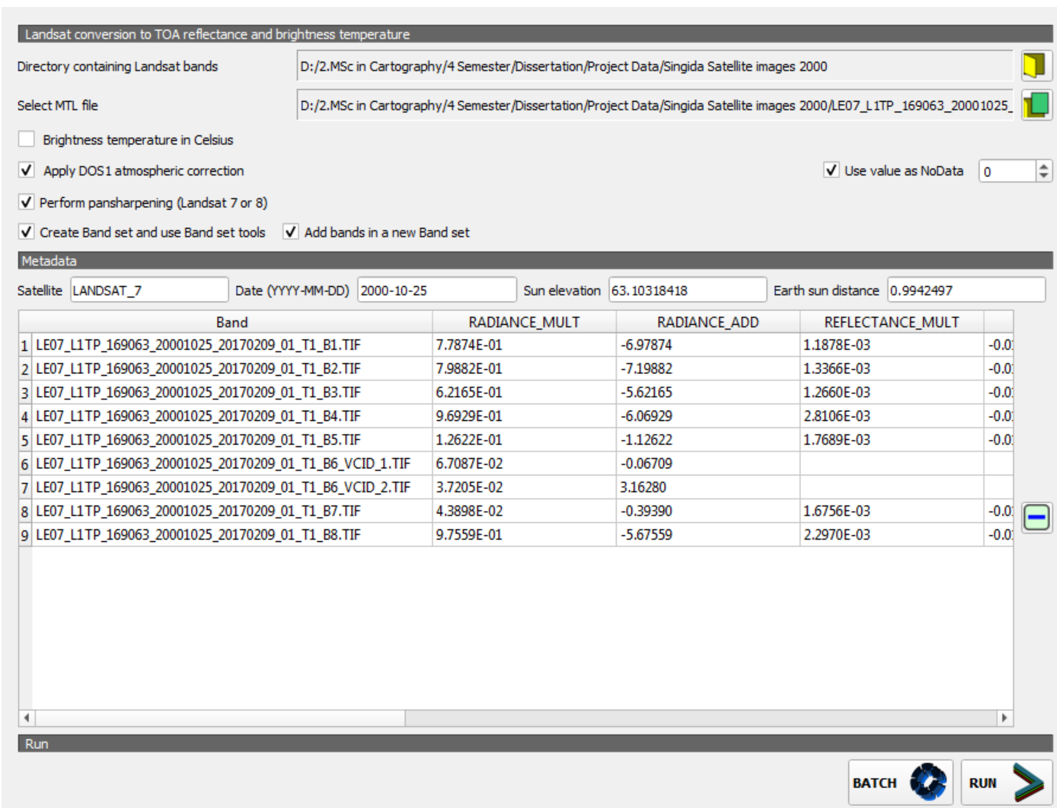

Figure 5: Image pre-processing

For the case of Landsat7 data sets they had a problem of missing scan line which was first corrected by the use of fill no data tool in QGIS in which the new values were interpolated from the edges. The values for the no-data regions were calculated by the surrounding pixel values using inverse distance weighting method.

3.3.2 SATELLITE IMAGE CLASSIFICATION

After successful image pre-processing then image classification was the next work flow in the process. A layer stack image was created containing the first four satellite pre-processed bands which were B1, B2, B3 and B4 which were then used to create a false colour composite image. The ground truth data were then added to help training of the classification as for this study supervised image classification with the use of Minimum distance to mean algorithm were used for classifying the images. Spectral signature was then created for generating ROIs prior to be used in classifying the images. Figure number 6 that follows describes the work flow of the process of creating a layer stack image and ROIs for the year 2000 as a sample and the same work flow was adopted for the rest of the datasets.

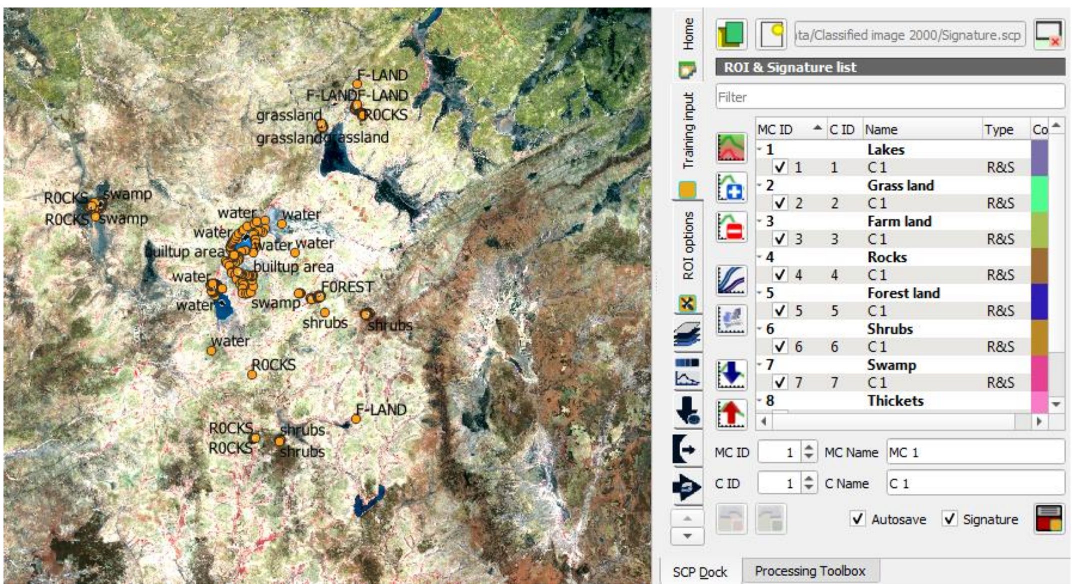

Figure 6: Layer stack image

A classified image of nine land cover categories ranging from water bodies, swamps, shrubs, thickets, grassland, forest land, farm land, rock surface and built up areas was created with the use of Semi-automatic Classification Plugin in QGIS. The work flow was done for both years 2000-2010-2020 but year 2000 is described by the figure number 7 as a sample workflow.

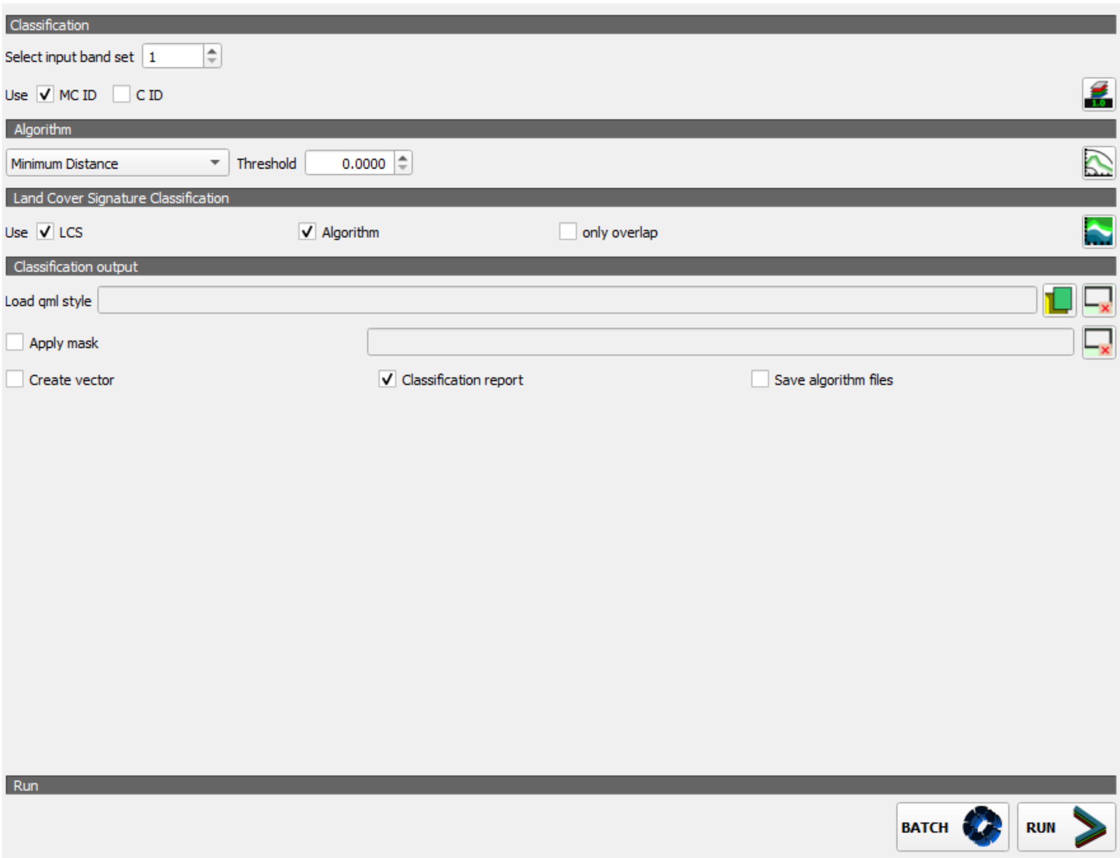

Figure 7: Image classification

3.3.3 ACCURACY ASSESSMENT

Up on assessing the usability of the land use / land cover classified image, accuracy assessment was done for the classified images for both years 2000-2010-2020. Forty five random sample pixel distributed evenly across the classified images was created, then high resolution Google earth images and a topographical map of Singida urban was used to cross validate the classified images. Finally a confusion matrix was derived by the use of QGIS Semiautomatic Classification Plugin. Overall accuracy was found to be 65.78%, 67.78% and 64.27% for the year 2000, 2010 and 2020 respectively. A Kappa coefficient was found to be 0.61, 0.62 and 0.60 for the year 2000, 2010 and 2020 respectively. The accuracy report entails that the classification is significantly better than a random classification which can be trusted with conditions. As for the purpose of this study which is to study land surface water bodies the classification is significantly better though it can be improved by the use of high resolution satellite images.

Figure number 8 that follows shows the intermediate work flow of accuracy assessment in QGIS Semi-automatic Classification Plugin, Year 2000 is presented as sample but the same work flow was done for the year 2010 and 2020.

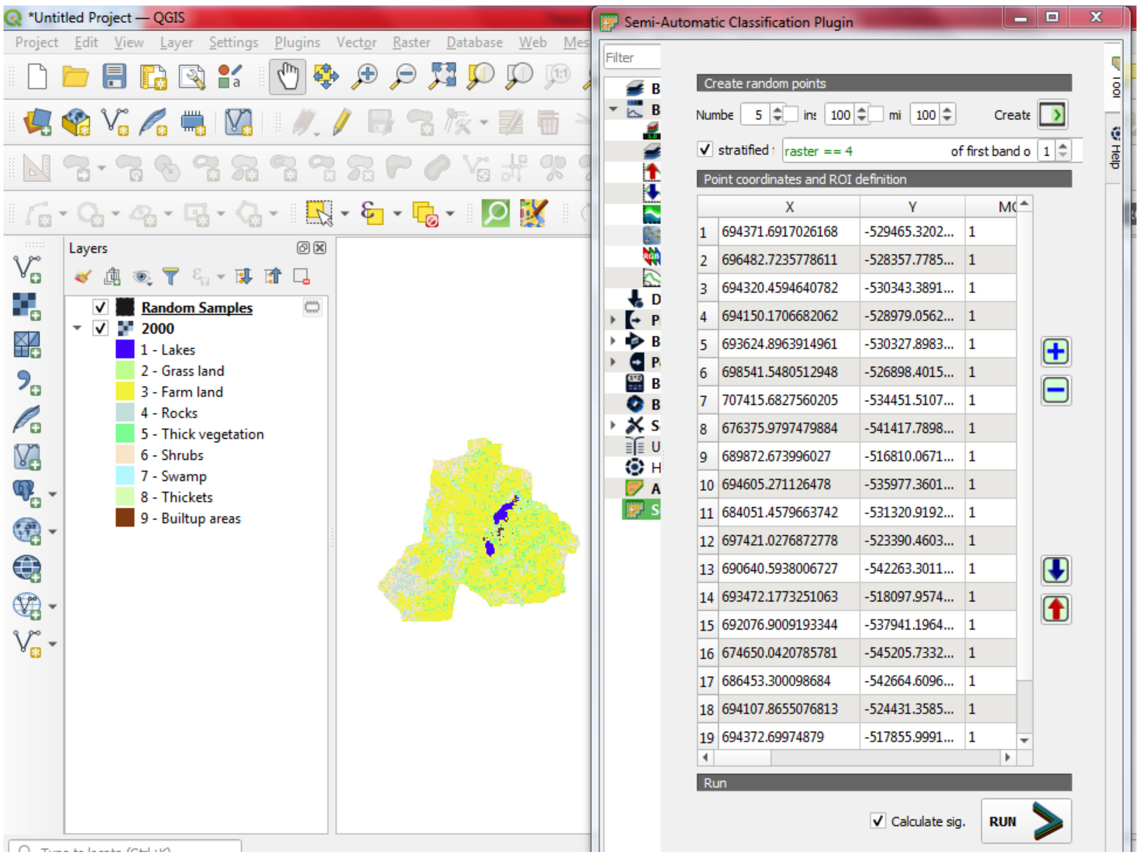

Figure 8: Accuracy assessment

3.3.4 CHANGE DETECTION AND ANALYSIS

After creating classified images for the years 2000, 2010 and 2020 then change detection and analysis was performed using QGIS Semi-automatic Classification Plugin. The year 2000 was used as a reference year then it was compared to the year 2010 and 2020. Figure number 9 that follows shows the intermediate process of change detection and analysis and detection, the change between 2000 and 2020 is presented as a sample but the same work flow was repeated for the year 2000 and 2010.

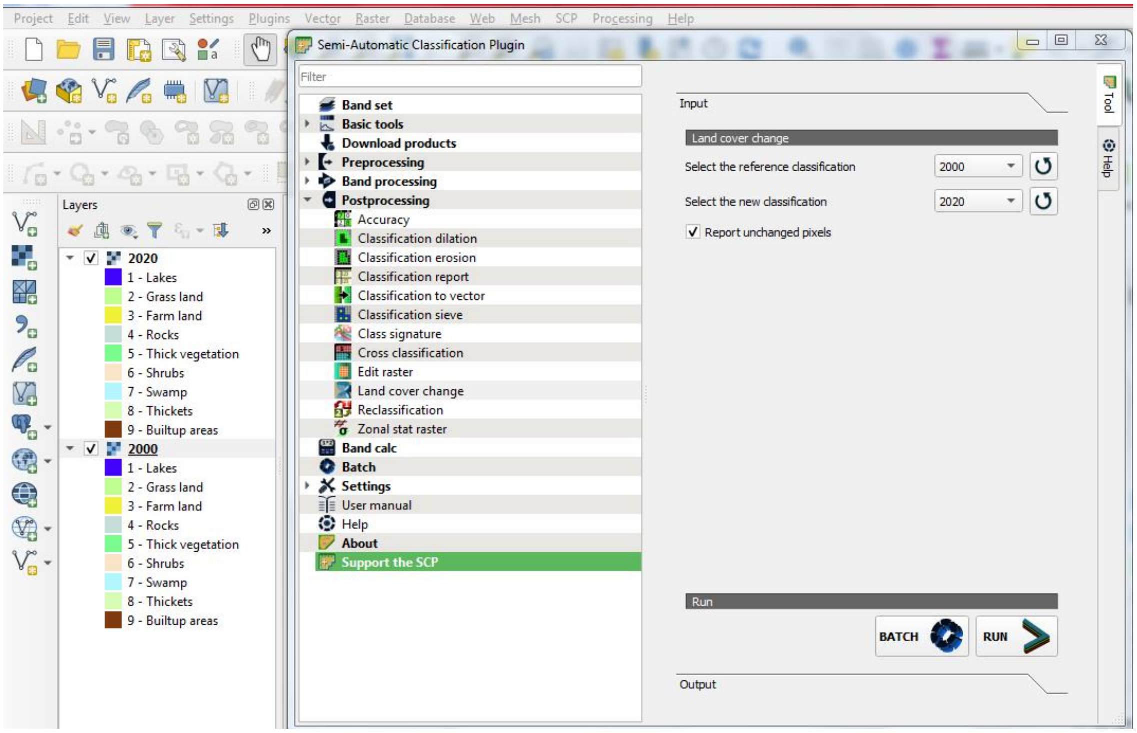

Figure 9: Change detection and analysis

3.3.5 GEOMETRIC NETWORK ANALYSIS

Up on analysing the current existing route which connects Singida Urban and the southwest outskirts regions including Nyranga region geometric network analysis were performed using ArcGIS network analyst tool. First network data sets were created containing the junctions and the stops for the existing road networks in the region. Then two stops were added to the created network data sets to find the shortest route between Singida Urban town centre and the south-west outskirts regions, the existing road network was found to be the best route having about 4.4km based on the impedance of shortest travel distance. Figure number 10 that follows shows the intermediate work flow on analysing the geometric network of Singida Urban region to find an alternative solution for the affected part of the road.

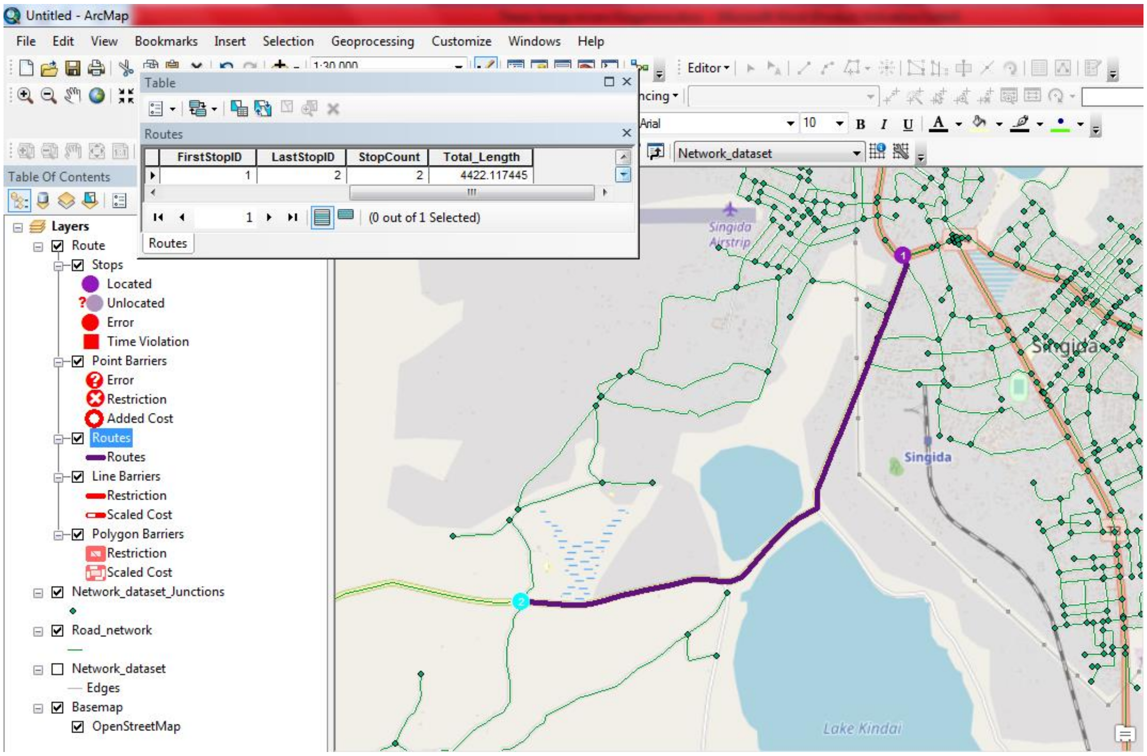

Figure 10: geometric network analysis

A section of around 1.1Km was found to be affected by the problem reported under this study. The section of 1.1Km was overlapped by surface water in 2020 as two parts of Lake Kindai merged and overlapped a road network. The network data sets were added to QGIS software and the base map from Open Street Map were added, with the use of QGIS distance measuring tool the affected part of the road network was quantified. Figure number 11 that follows shows the intermediate work flow on QGIS software.

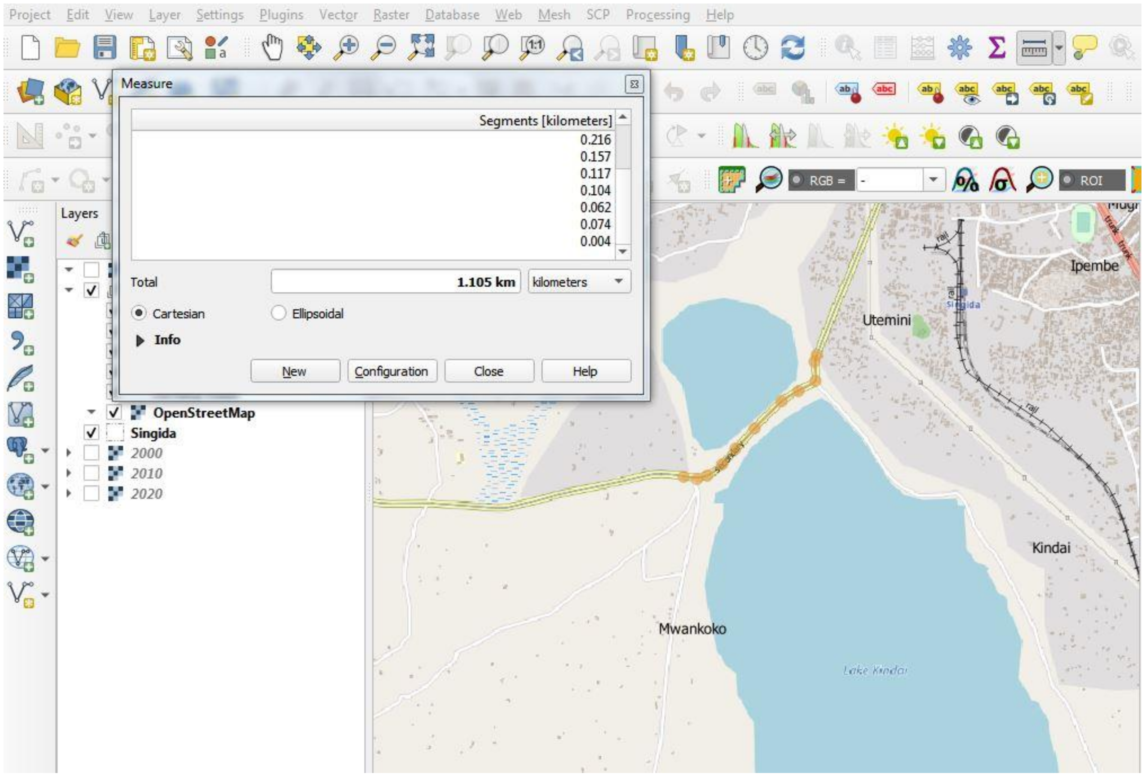

Figure 11: Affected part of the road network

3.3.6 RAINFALL DATA PROCESSING AND ANALYSIS

By using Microsoft excel tool rainfall from Global NASA / POWER CERES/MERRA2 Native Resolution Monthly and Annual were opened in Microsoft excel, sorted and plotted to show the temporal rainfall variability from year 2000 up to the year 2020 in one year basis. Figure number 12 that follows shows the intermediate work flow of processing and analysing rainfall data.

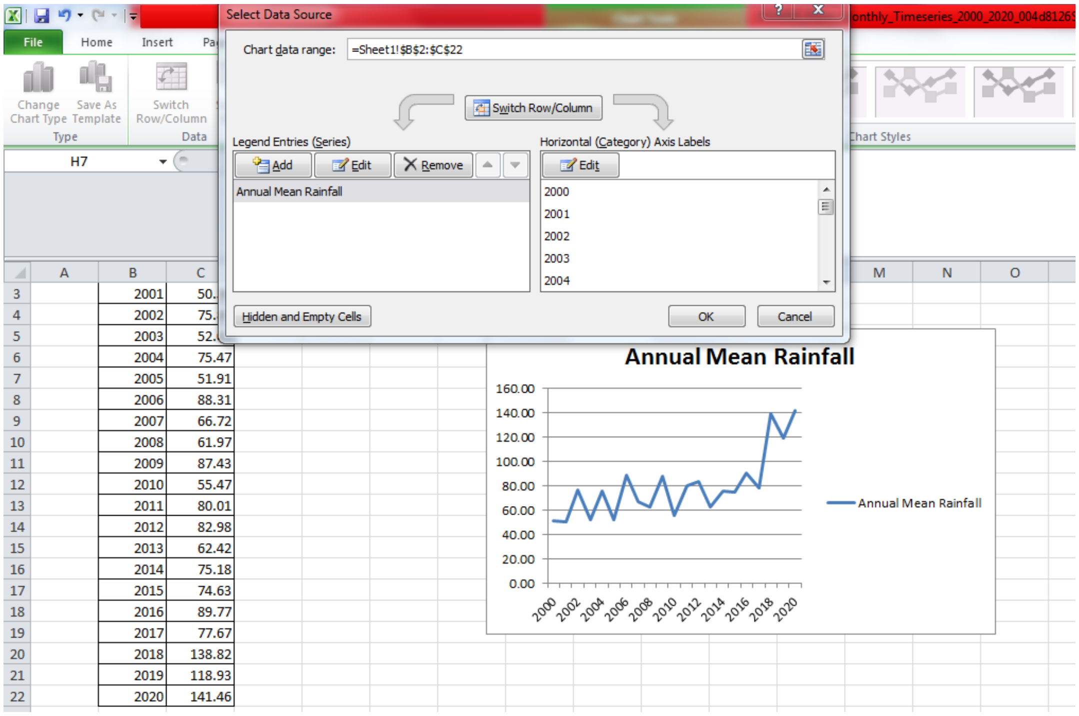

Figure 12: Rainfall data processing and analysis

CHAPTER FOUR

4. RESULTS AND DISSCUSION

4.1 LAND USE / LAND COVER FOR THE YEAR 2000

After satellite images pre-processing then the virtual raster was created prior for satellite image classification. After creating ROIs and training the virtual raster according to the ground truth coordinates and topographical map of Singida urban then supervised satellite image classification was followed by using minimum distance to mean classification algorithm. Thus for the year 2000 nine land use land / land cover categories were identified which were lakes, built up areas, rock surface, swamps, grass lands, farm lands, thickets, thick vegetation and shrubs as indicated by the land use / land cover map 2000. Lakes were found to cover 1.45% of the total land of Singida urban, the Swamps covering 2.79% while farm land was the leader covering 56.86% followed by shrubs covering 12.99%. Figure 13 that follows shows the proportional of land use / land cover categories in Singida urban region in year 2000.

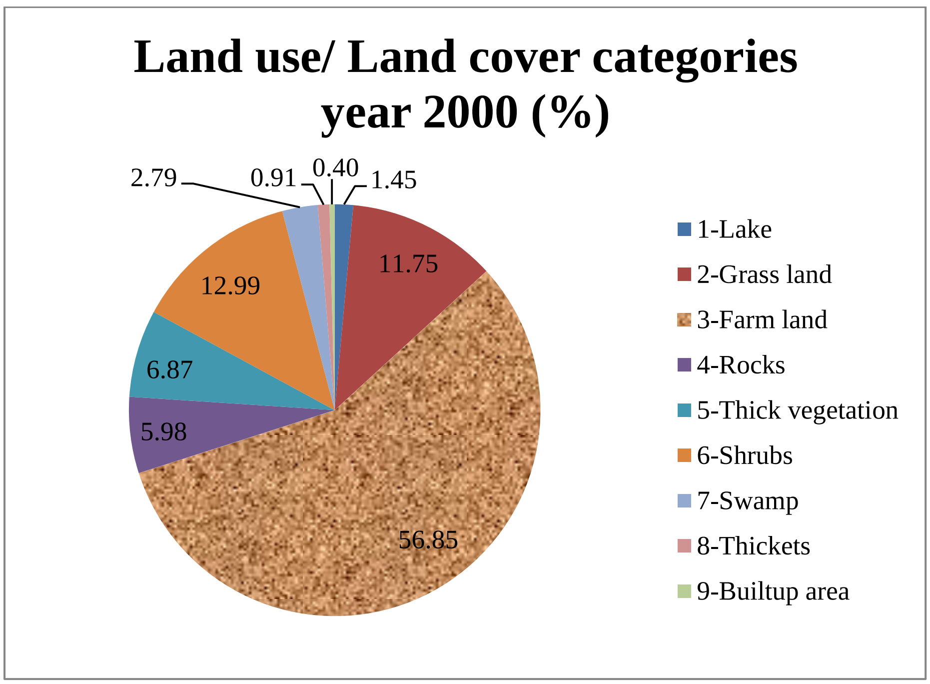

Figure 13: Land use / land cover categories year 2000

4.2 LAND USE / LAND COVER FOR THE YEAR 2010

For the year 2010, nine land use / land cover categories were identified which were lakes, built up areas, rock surface, swamps, grass lands, farm lands, thickets, thick vegetation and shrubs as indicated by the land use / land cover map 2010. As indicated in Figure 14 that follows, the lakes were found to occupy 1.51% of the total land, the Swamps covering 1.02%. An increase in the Lakes coverage was noted with a decrease of Swamps from previous year 2000 as the Lakes were found to cover 1.45% and the Swamps covered 2.79%. Still the farm lands were the leading categories covering 54.33% followed by Thick vegetation covering 14.66% of the total area of Singida urban.

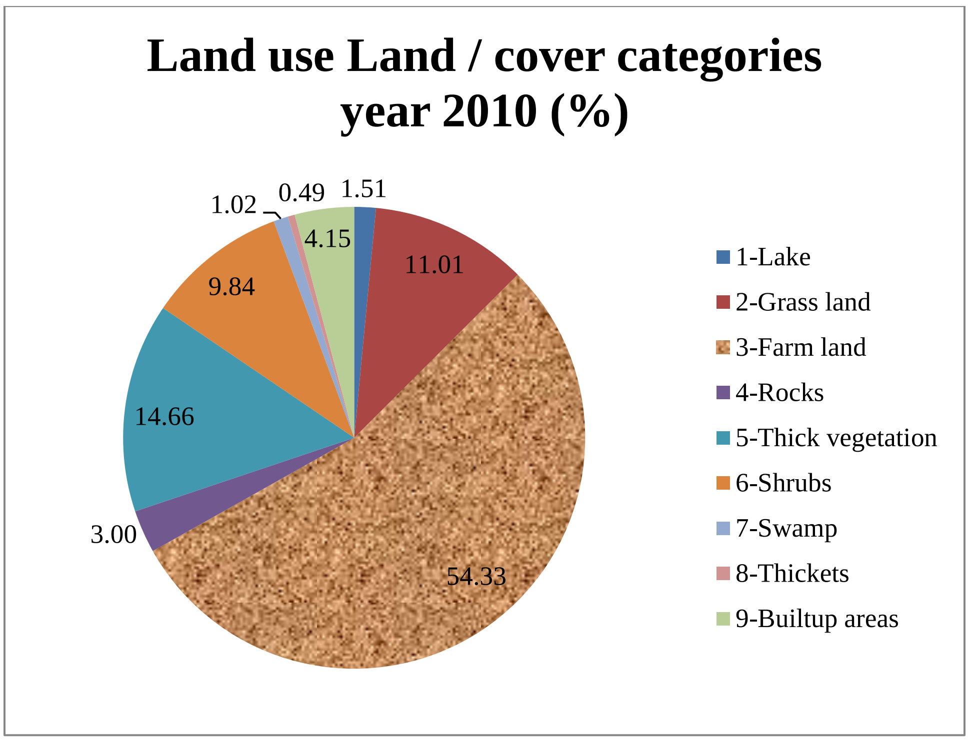

Figure 14: Land use / land cover 2010

4.3 LAND USE / LAND COVER FOR THE YEAR 2020

For the year 2020 nine land use / land cover categories were identified which were lakes, built up areas, rock surface, swamps grass land, farm land, thickets, thick vegetation cover and shrubs as indicated by the land use / land cover map 2020. Figure 15 that follows indicates that there a significant increase in lakes area coverage which is around twice the original coverage. As indicated the lakes was found to cover 2.54% of the total land, the Swamps covering 1.29% while in year 2000 the Lakes covered 1.45% and the Swamps covered 2.79% a decrease in Swamps was noted in between the intervals, the significant increase in Lakes created a problem of which two parts of Lake Kindai happened to merge and overlap the road network which was serving as the main route connecting Singida Urban and south west outskirts including Nyranga area. Thick vegetation cover was found to be leading one covering 64.25% followed by farm land covering 9.91%.

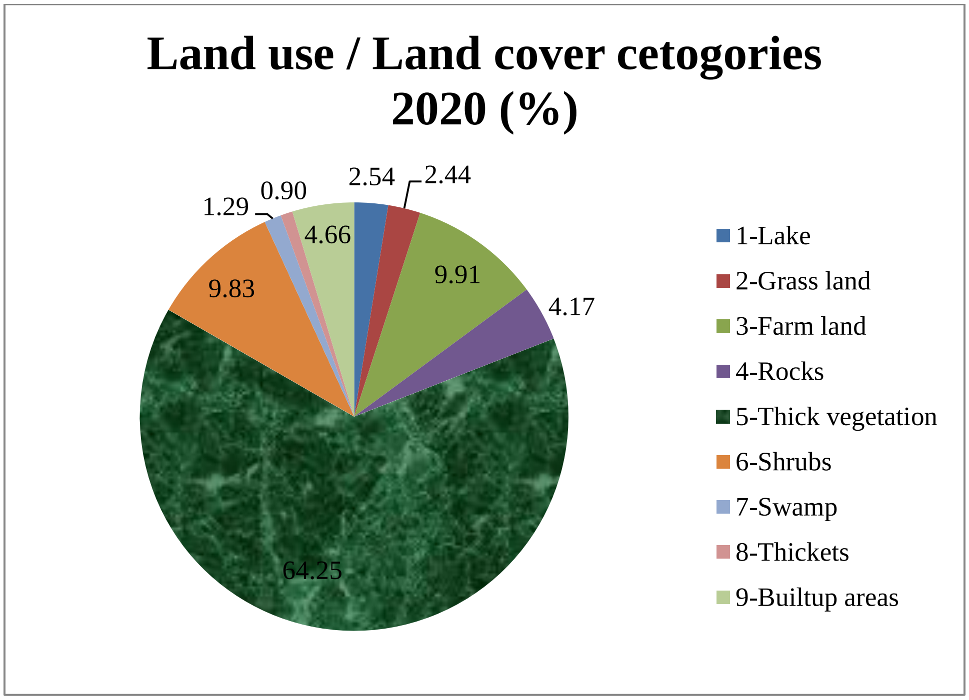

Figure 15: Land use / land cover year 2020

4.4 LAND USE / LAND COVER MAPS

Figure number 16 that follows represent the land use / Land cover maps of Singida urban region from 2000-2010-2020 in one layout for 1:300,000 presentation scale while indicating the research problem under this study which is two parts of Lake Kindai which happed to merge in year 2020 and overlap a road network.

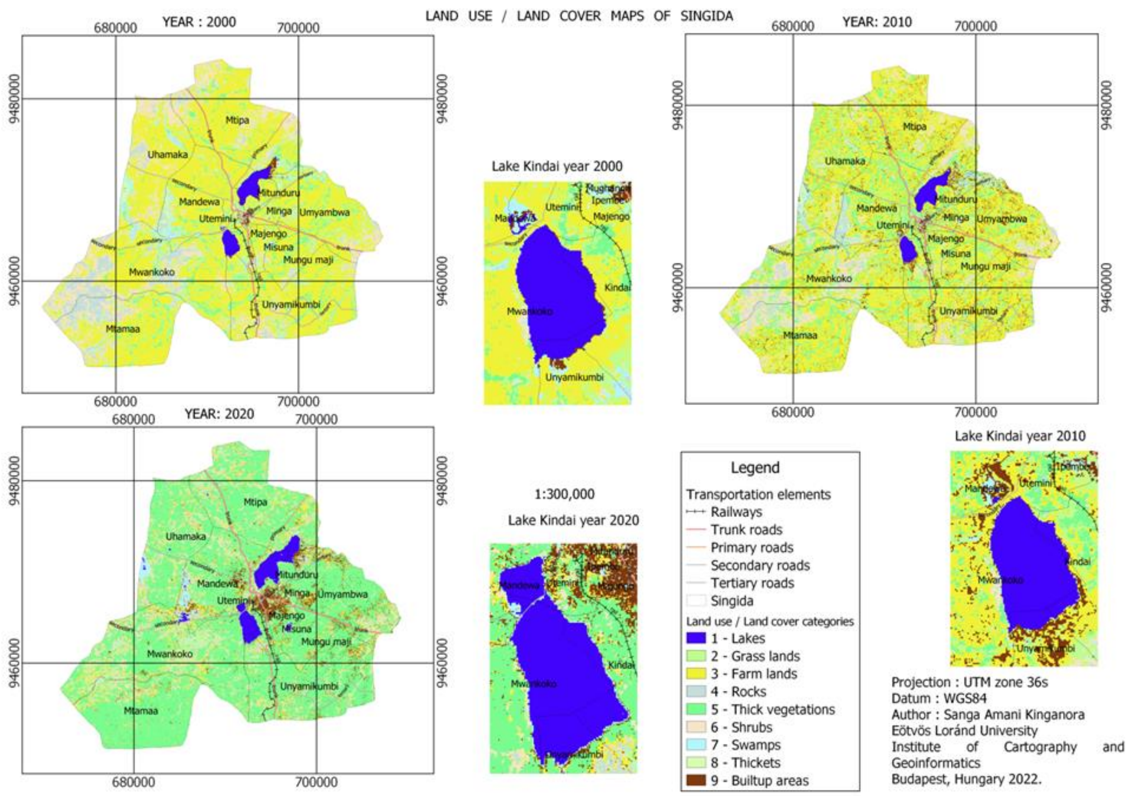

Figure 16: Land use / land cover maps

4.5 SATELLITE IMAGE CLASSIFICATION ACCURACY ASSESSMENT

Up on assessing usability and validity of the classified land use / land cover maps accuracy assessment was done. 80 random sample points were created then used to assess the classified land use / land cover maps. For the year 2000 overall accuracy was found to be 65.78% and Kappa coefficient being 0.61, for the year 2010 overall accuracy was found to be 67.47% and the Kappa coefficient being 0.62 finally for the year 2020 overall accuracy was found to be 64.27% and Kappa coefficient being 0.60. The accuracy was found to be consistent and it indicates that the classification was significantly better than a random classification. It was quite bit challenging to be able to get better classification accuracy report for nine land use / land cover categories but as for the purpose of this study as is to be able to discriminate lakes from other land use / land cover categories it was more than enough.

4.6 LAND USE / LAND COVER CHANGE MAPS

After successful creation of land use / land cover maps for the three years 2000-2010-2020, then change detection and analysis was followed. As for the focus of this study Swamps and Lakes were examined. From year 2000 to year 2010 an increase of Lakes by 6.19% of the original area coverage was noted while the Swamps decreased by 30.84% of the original coverage. From the year 2000 to 2020 an increase in Lakes was noted to be by 76.05% of the original area coverage while the Swamps were noted to decline by 25.18% from the original coverage. The significant increase in Lakes coverage of about three quarter of the original area coverage from year 2000 was noted in the area which created a problem reported by the local authorities that in year 2020 as two parts of Lake Kindai happened to merge and overlap the road network which was connecting Singida urban region and the south west outskirts including Nyranga region. Figure number 17 that follows describe the changes of land use / land cover for year 2000-2010 and for the year 2000-2020 in a 1:200,000 scaled map. In the map the pixels with black colour highlight the area which was subjected to an increase in Lakes area coverage.

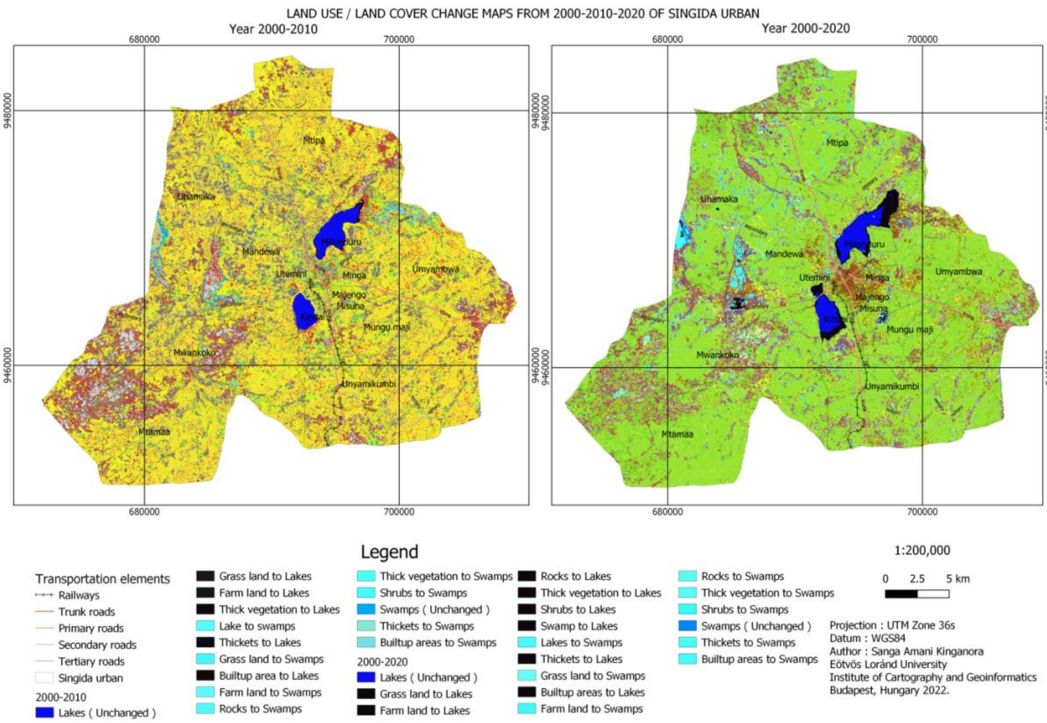

Figure 17: Land use / land cover change maps

The region was found to be having two Lakes namely Lake Kindai and Lake Singidani, both Lakes were subjected to change and an increase in their areas coverage was noted. As for the direction of change Lake Kindai was examined to have an extension in North West ward extension, south ward extension and south east ward extension. As for Lake Singidani a significant extension in North east direction was noted.

4.7 TREND OF LAKES AREA COVERAGE

Up on assessing the trend of Lakes area coverage in Singida urban region the Lakes were found to have a significant progressive increase in their area coverage. In 2000 the Lakes were found to cover an area of about 10.45km2, in 2010 the area coverage was found to be10.86km2, for the year 2020 were the incident were noted the Lakes area coverage was around double the original area coverage in 2000. In 2020 the Lakes area coverage was found to be 18.33km2. This significant increase leads to two parts of Lake Kindai merge and overlap a road network. Figure number 18 that follows describes the trend in bar diagram.

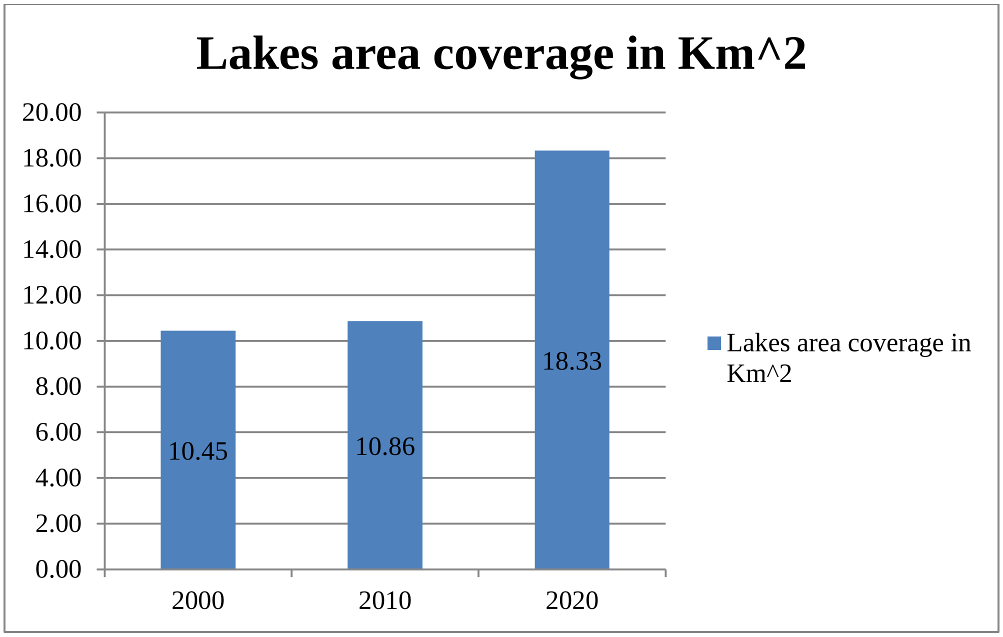

Figure 18: Trend of Lakes area coverage

4.8 TREND OF SWAMPS AREA COVERAGE

The Swamps were found to have a declining trend as compared to original area coverage in year 2000. Year 2000 the Swamps were found to cover 20.08Km2, in year 2010 the coverage declined to 7.38Km2, in year 2020 the Swamps area coverage were found to be 9.28Km2. Figure number 19 that follows describes the changes of Swamps area coverage from 2000-2010-2020.

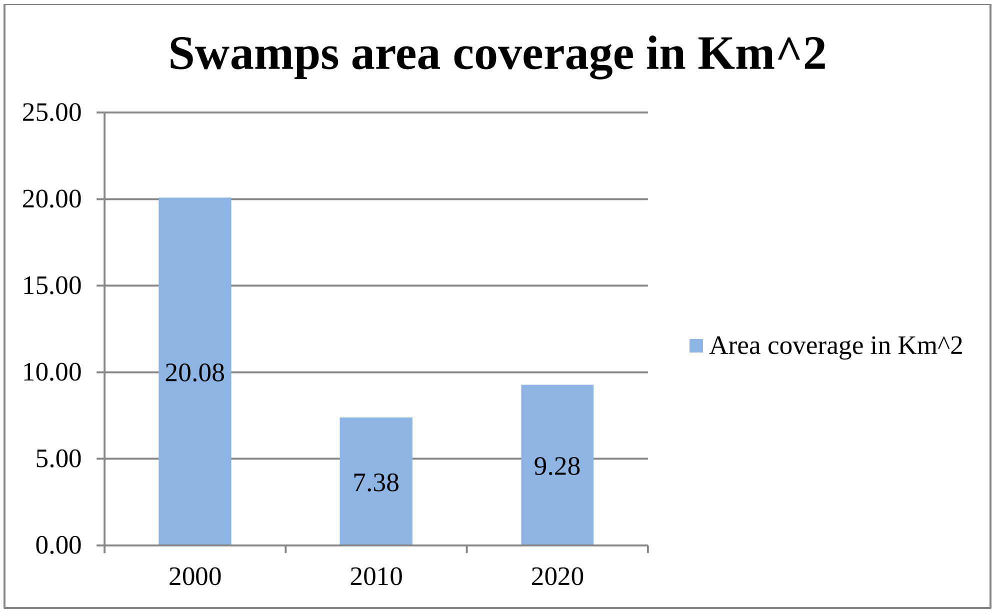

Figure 19: Trend of Swamps area coverage

4.9 GEOMETRIC NETWORK ANALYSIS REPORT

Up on analysing geometric road network for the secondary road network connecting Singida urban region to the south-west outskirts, the road network was found to be the shortest route covering a distance of about 4.4Km as indicated by the Figure number 10. The route which is secondary road connects Singida urban region and south-west out skirts regions.

From a total of 4.4Km a section of 1.1Km was found to be affected by the problem reported under this study. The section of 1.1Km was overlapped by surface water in 2020 as two parts of Lake Kindai merged and overlapped a road network. Up on assessing the problem and the current infrastructure construction technology in Tanzania a bridge should be considered to be constructed for connecting the affected parts of the road network. The project should start with evaluating the current scenario, estimating the cost of the project and then designing phase should follow and finally project execution. Figure number 11 describes the affected section of road network of about 1.1Km.

4.10 ANALYSIS OF RAINFALL TEMPORAL DATA OF SINGIDA URBAN REGION

Up on assessing the rainfall temporal data in Singida region from 2000 up to 2020 huge rainfall variability was noted with a range of about 90.88mm. With excluding the variability noted from 2018 up to 2020, the rest temporal data were found to have a smooth variation of a range of about 39.18mm. The rainfall temporal data shows that an extreme rainfall amounts were noted from 2018, 2019 and 2020 which prove the hypothesis of the study that rainfall variations were one among of the contributing factors to the changes in surface water bodies area coverage in Singida region which caused a problem under this study. Figure number 20 that follows shows the temporal variability of rainfall amounts in Singida region.

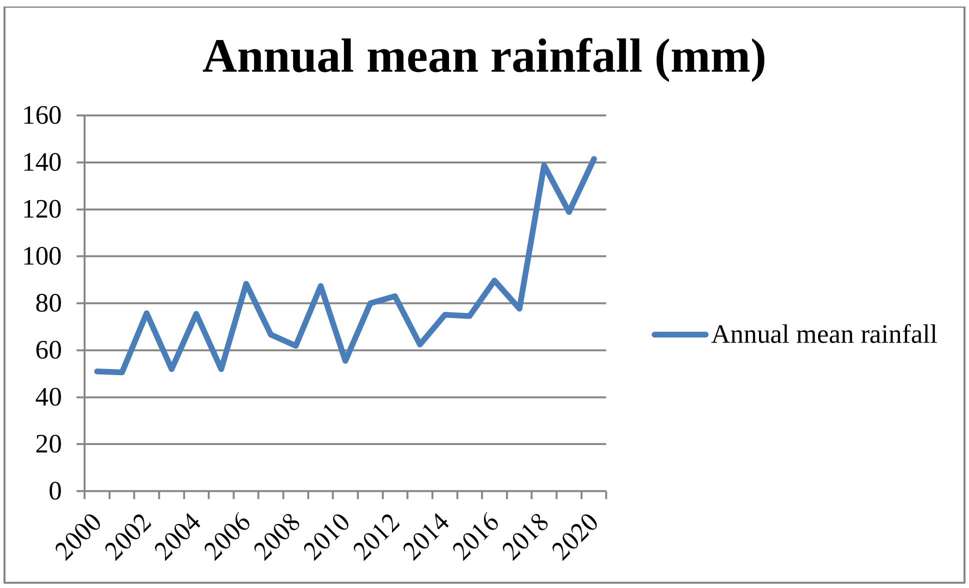

Figure 20: Rainfall temporal variability from 2000 to 2020

CHAPTER FIVE

5. SUMMARY OF THE THEME / CONCLUSION AND RECOMMENDATION

5.1 SUMMARY OF THE THEME / CONCLUSION

The findings of this study identified that there were huge rainfall variability from the year 2018 to 2019 and to 2020. This variability high impacted the land use / land cover of Singida Urban region and led to a notable land transformation in the region. If the rainfall values of the last few years are maintained in the future, it is also conceivable that the previously typical level of 70 mm can be set around this new range of close to 130 mm. This corresponds to almost double the amount of water in the area.

Surface water specifically the Lakes were high impacted of which the Lakes in 2020 increase in their area coverage by around three quarter of their original area coverage from year 2000 up to year 2020. From year 2000 to year 2010 an increase of Lakes by 6.19% of the original area coverage was noted while the Swamps decreased by 30.84% of the original coverage. From the year 2000 to 2020 an increase in Lakes was noted to be by 76.05% of the original area coverage while the Swamps were noted to decline by 25.18% from the original coverage.

The significant increase in Lakes coverage of about three quarter of the original area coverage from year 2000 was noted in the area which created a problem reported by the local authorities that in year 2020 as two parts of Lake Kindai happened to merge and overlap the road network which was connecting Singida urban region and the south west outskirts regions including Nyranga region. The region was found to be having two Lakes namely Lake Kindai and Lake Singidani, both Lakes were subjected to change and an increase in their areas coverage was noted. As for the direction of change Lake Kindai was examined to have an extension in North West ward extension, South ward extension and South east ward extension. As for Lake Singidani a significant extension in North east ward direction was noted.

Based on Figure 2, the area can be said to be relatively closed in topography, so in the case of higher rainfall, the water flow points in this direction, to the deeper “lake area” (also from the east side, from the south-west and from the north too). In addition, the area around the road shows a very small difference in height (with 10 meters isolines), and on the north-west side, along the “road area” is another similarly low area. Thus, these spatial features must be taken into account in possible engineering solutions.

From a total of 4.4Km a road network connecting Singida Urban and South-West outskirt regions, a section of 1.1Km was found to be affected by the problem reported under this study. The section of 1.1Km was overlapped by two parts of Lake Kindai in 2020.

5.2 RECOMMENDATION

a) To the Local government authorities

The findings of this study recommend that the Local government authorities of Singida Urban to work on finding the alternative solution to the affected part of the road network which is a section of about 1.1km out of 4.4km. The bridge or a round road can be considered as an alternative solution considering the scenario and the current construction technology in Tanzania. Another possibility can be some water engineering, water management solution, which can even be connected to the farmlands.

It is also important to highlight for the planning that the examined rainfall data were average datasets, and these data don’t show the rapid rainstorms, which are characterized by large amounts of water in a short period of time. Globally we are seeing a drastically increasing trend, so the infrastructure development must also take these effects into account.

b) To researchers

The findings of this study recommend the community of researchers to research more on the area as there are questions which still need answers, the questions of what are the geographical factors that contribute to the extension of the Lakes and also the question about what are the future possible scenarios for the predicted rainfall variability and the rapid rainfalls.

c) To the general community

The general community should be well informed and preparedness plans should be considered to avoid scenarios that are related to extreme climatic situations such as flooding in built-up areas as the findings of this study identified extreme rainfall variability with in the region. People should high consider the new land use plan for the areas around the surface water bodies in the region for sustainability.

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