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ASSESSING THE EFFECT OF EXPANSION OF BUILTUP AREAS ON VEGETATED AREAS IN DAR-ES-SALAAM CITY

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ASSESSING THE EFFECT OF EXPANSION OF BUILTUP AREAS ON VEGETATED AREAS IN DAR-ES-SALAAM CITY

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A dissertation submitted in the department of Geospatial Sciences and Technology in partially Fulfilment of the requirements for the Award of Bachelor of Sciences in Geoinformatics (BSc.GI) at Ardhi University.

CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the Ardhi University dissertation titled "**Assessing the Effect of expansion of Builtup areas on Vegetated areas in Dar-es-salaam city**" in partial fulfillment of the requirements for the award of degree of Bachelor of Science in Geoinformatics at Ardhi University.

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(Main Supervisor)	(Second Supervisor)
Date…………………	Date……………….

DECLARATION AND COPYRIGHT

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

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Jonasy Kihalule

22728/T.2019

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DEDICATION

I dedicate this research and all my efforts upon its completion to my family. My mother Maulina Mgumba who encouraged and pray for me, my uncle Dr Batista Mgumba who give me a support in everything I need during my studies, I appreciate their unconditional love and guidance assisting me both morally and academically. God bless you and give you a long life.

ABSTRACT

Expansion of built-up areas has become a significant challenge during the process of urban development in many countries, often characterized by low-density growth that leads to various environmental and socio-economic issues. A prominent illustration of this dynamic urbanization can be observed in Dar-es-Salaam city, which continues to experience rapid development. The lack of proper planning in the expansion of built-up areas has posed substantial threats to the preservation and sustainability of vegetated areas.

The central objective of this study was to quantitatively assess the impact of the expansion of built-up areas on vegetated areas in Dar-es-Salaam. To achieve this, remote sensing data and Geographic Information System (GIS) techniques employed. Landsat images from 1998, 2014, and 2022 were utilized in analysis. Also UEII used so as to indicates the level of urban expansion of built-up areas over the specified period.

The research utilized a supervised classification approach to generate a land use land cover (LULC) map, revealing four distinct classes: built-up, bare land, vegetation, and waterbodies. Subsequently, change detection analyses were conducted to observe transformations over three time periods: 1998-2014, 2014-2022, and 1998-2022.

Accuracy assessments yielded LULC classification rates of 81.41%, 77.87%, and 76.99% for the years 1998, 2014, and 2022, respectively, with corresponding kappa statistics of 0.6918, 0.6617, and 0.6543. Analysis of change maps unveiled significant trends: the built-up area expanded from 317.854 sq.km in 1998 to 772.587 sq.km in 2022, while vegetated area diminished from 1128.788 sq.km in 1998 to 651.068 sq.km in 2022.

In general, the study sheds light on the noticeable effects of the expansion of built-up areas on vegetated areas in Dar-es-Salaam city, emphasizing the need for informed urban planning and conservation strategies to ensure a sustainable and harmonious urban environment.

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ACRONYMS AND ABBREVIATIONS

ETM	Enhanced Thematic Mapper
GIS	Geographical Information System
LULC	Land Use Land Cover
OLI	Operational Land Imager
RS	Remote Sensing
TIRS	Thermal Infrared Sensor
UEII	Urban Expansion Intensity Index
UGS	Urban Green Spaces
USGS	United State Geological Survey
WHO	World Health Organization

CHAPTER ONE
INTRODUCTION
1.1 Background

Vegetated areas, comprising regions rich in vegetation within urban landscapes, manifest in various forms, including semi-natural zones, well-maintained parks, gardens, and pockets of greenery along roads and unexpected corners (Karutz , 2019). These spaces offer a multitude of benefits, contributing to the physical, social, and mental well-being of individuals. In today's urbanized context, they play a vital role by providing essential ecosystem services, enhancing air quality, mitigating climate change, and elevating the overall quality of life for urban inhabitants. Moreover, these green spaces provide opportunities for physical activity, social interactions, a connection with nature, and an avenue to appreciate cultural heritage.

The Tanzania Ministry of Land and Human Settlement defines vegetated areas as land portions partially or entirely covered by grass, trees, shrubs, or other vegetation (URT, 2016). Unfortunately, these vegetated areas in Dar-es-Salaam have experienced degradation and loss over time (URT, 2016) .The effect of this decline are most pronounced in distinct locales, notably the city center, where heightened density, new construction, and road development have led to the removal of trees and greenery. Consequently, significant reductions in green areas have transpired, particularly within the city center and densely populated informal settlements. Additionally, on the city's outskirts, natural and agricultural lands are undergoing conversion into urban areas, particularly along the main roads leading out of the city (Karutz , 2019) .

The primary driver of the decline vegetated area is the expansion of built-up areas, a phenomenon characterized by unregulated growth and the emergence of megacities (Fenger, 1999).The swift urbanization and population surge in Dar-es-Salaam have resulted in the expansion of built-up areas at the expense of vegetated regions. With escalating migration rates, urban areas undergo transformations in land use and land cover, inducing negative impacts, including overcrowding, water scarcity, air pollution, and the loss of productive agricultural land and forest cover. As per the 2002 census, Dar-es-Salaam's population was 2,487,288 in 2002, which incrementally rose to 4,364,541 in 2012, signifying a 43% increase. Presently, according to the 2022 census, the city's population stands at 5,383,728, reflecting an 18% rise from 2012 to 2022. The escalating population growth has led to spatial expansion to accommodate the burgeoning populace. This research endeavors to elucidate the correlation between increasing urban land usage (expansion of built-up areas) and the corresponding reduction and disappearance of vegetated areas.

The principal aim of this study is to assess the effect of the expansion of built-up areas on vegetated areas in Dar-es-Salaam City using Geographical Information System (GIS) and Remote Sensing (RS) technology. The specific objectives encompass producing a comprehensive land cover map of Dar-es-Salaam, generating change maps illustrating the city's evolving landscape, investigating the impact of built-up expansion on vegetated areas, and creating urban land maps to scrutinize the ramifications of urban sprawl on green spaces. Employing satellite imagery and GIS techniques, this study will classify land use/cover, identify vegetated and built-up areas, and analyze their spatial distribution.

The findings of this study will substantially contribute to our comprehension of the effects of built-up area expansion on vegetated areas in Dar-es-Salaam. Utilizing GIS and remote sensing technologies, the study will provide accurate assessments of the extent and distribution of vegetated areas within the city. The results hold significant value for urban planners and policymakers, assisting them in formulating strategies to promote sustainable urban vegetated areas. Furthermore, this study will lay the groundwork for future research endeavors focusing on this pertinent topic.

1.2 Statement of the Research Problem

The ongoing expansion of urban areas in Dar-es-Salaam often encroaches upon natural spaces and open areas, leading to the conversion of vegetated areas into built-up spaces, causing the problem of green area loss. As is well-known, vegetation plays a crucial role in absorbing carbon dioxide and releasing oxygen, thereby contributing to cleaner air. It also regulates the climate by sequestering carbon dioxide and mitigating the impact of climate change, while helping offset greenhouse gas emissions responsible for global warming. Consequently, there exists a need to assess and understand the extent to which built-up areas are affecting vegetated regions. Such an examination provides valuable insights for urban planners and policymakers as they work to develop strategies that promote the sustainable existence of vegetated spaces. By comprehending the complex interplay between urban expansion and the availability of green spaces, stakeholders can better address the pressing challenges that arise from this growth and its impact on our essential natural areas.

1.3 Research objectives

1.3.1 Main objective

To assess the impact of expansion of builtup areas on vegetated areas in Dar-es-salaam City.

1.3.2 Specific objective

i. To produce the land cover map of Dar-es-salaam for the period 1998,2014 and 2022
ii. To produce the change map of Dar-es-salaam city for the period 1998-2014,2014-2022 and 1998-2022
iii. Examine the effect of builtup expansion on the vegetated areas

1.4 Significance of the research

The study will contribute to the understanding of the effects of expansion of Builtup areas on vegetated areas in Dar-es-salaam city. The use of GIS and remote sensing will provide a detailed and accurate assessment of the extent and distribution of vegetated areas in the city. The findings of the study will be useful for urban planners and policymakers in developing strategies for promoting sustainable urban green spaces.

1.5 Research questions

After completion of this study based on above objectives the following questions can be answered;

i. How has the land cover of Dar-es-salaam changed over the years 1998, 2014, and 2022?
ii. What is the spatial distribution and extent of green areas and builtup areas within Dar-es-salaam?
iii. What are the observed effects of builtup expansion on the extent and quality of vegetated area in Dar-es-salaam

1.6 Study Area

Dar es Salaam City is located on the east coast of Tanzania, between latitude 6º45‟S and 7º25‟S, and longitude 39ºE and 39º55‟E, the city borders the Indian Ocean to the east and the Coast Region to the north, west and south (see figure 1.1). It has a total surface area of 1,628 Sq.km, out of which 235 Sq.km or 14.4% is covered by water bodies, mainly deriving from the Indian Ocean, the remaining 1393 km2 is covered by land area (Gombe & Asanuma, 2017).

Dar es Salaam, like many rapidly growing cities around the world, has experienced urban expansion to some extent. From the year 1998 up to 2022, there was a significant change in land use, with agricultural land and natural areas on the outskirts of the city being converted to residential and commercial use as the city expand (as observed in figure 1.1 where by yellow color which shows builtup coverage in 1998, magenta color for builtup in 2014 and red color for builtup in 2022).

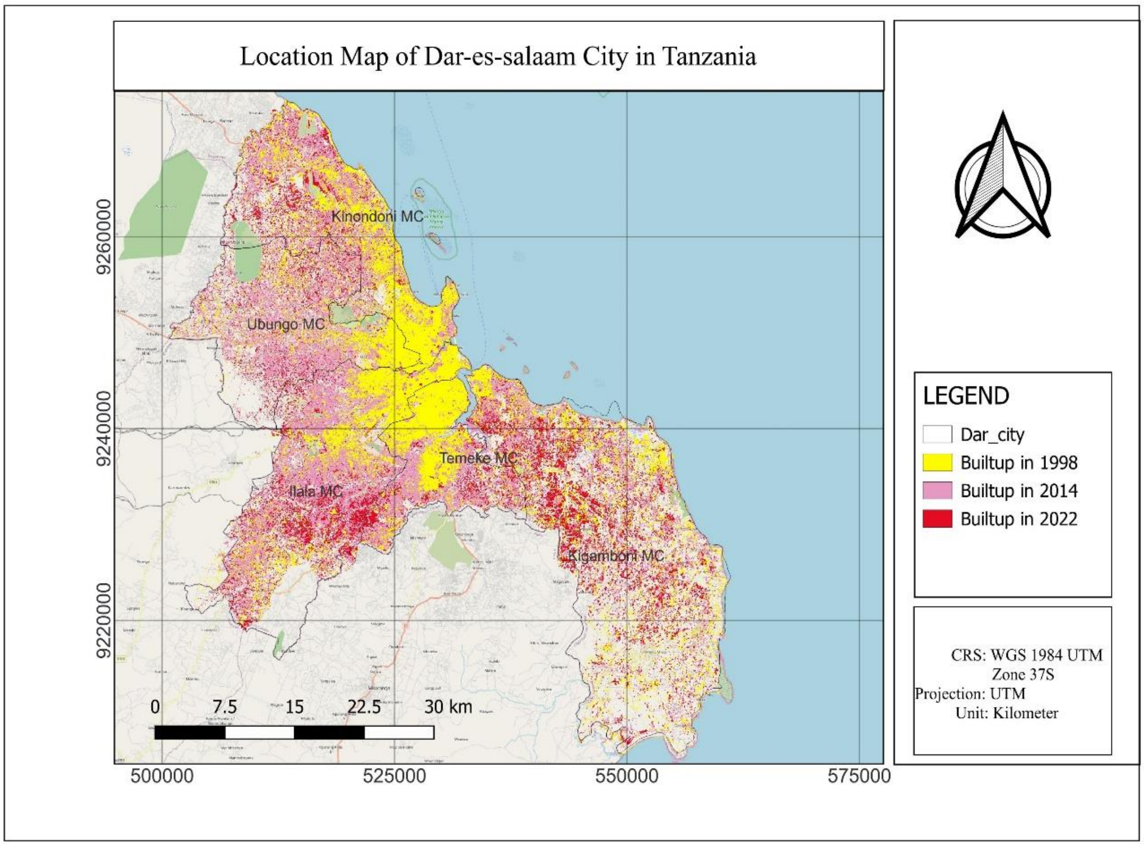

Figure 1.1 Location Map of study area-Dar es salaam city, Tanzania

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview

This chapter reviews important literatures that explain expansion of built-up areas, whole concept of urban vegetated areas and how they can be analyzed and assessed through remote sensing techniques

2.2 Urban expansion and Its Implications

Urban expansion refers to the process by which cities and towns grow outward, both in terms of physical size and population, involves the extension of urban areas into previously undeveloped or rural land, often resulting in the conversion of natural landscapes, agricultural land, or open spaces into built-up areas (Gillham et al, 2002). Urban expansion can manifest as the construction of new residential, commercial, industrial, and infrastructure developments on the outskirts of existing urban centers (Gillham N. J., 2000).It is associated with a range of social, economic, and environmental challenges, including increased infrastructure costs, traffic congestion, air pollution, reduced green spaces, and habitat loss. The following are the causes of urban expansion as explained by (Michael & Michael , 2005);

a) **Population Growth:** As cities experience population growth, there is a higher demand for housing, infrastructure, and services. This can lead to the expansion of urban areas to accommodate the increasing population.
b) **Economic Factors:** Economic activities and opportunities in urban areas attract people from rural areas and other regions, resulting in the outward growth of the city to accommodate new residents and businesses.
c) **Transportation Infrastructure:** The construction of new roads and highways can facilitate suburban development, as these transportation corridors can encourage the establishment of residential and commercial areas along their routes.
d) **Land Use Policies:** Zoning regulations, land use policies, and development incentives can influence the spatial distribution of urban growth. Policies that promote low-density development or lack of enforcement of land use regulations may contribute to sprawl.

2.2.1 Urban expansion in Dar-es-Salaam: Causes and Patterns

Urban expansion in Dar-es-Salaam, like in many other cities, is a complex phenomenon driven by a combination of factors. These factors have led to the expansion of the city's built-up areas and the transformation of surrounding vegetated area. One of the key drivers of builtup areas expansion is population growth, which has resulted in increased housing demand and urban development (Ibrahim, 2007). Economic activities, including trade and commerce, have contributed to the spatial expansion of the city. Moreover, transportation networks and road infrastructure play a role in shaping the patterns of urban expansion, with major roads often serving as corridors for development radiating from the city center. Land use policies and regulations, both at the local and national levels, have also influenced the direction and extent of builtup areas expansion.

2.2.2 Environmental and Ecological Consequences expansion of builtup in Dar-es-salaam

The process of builtup areas expansion in Dar-es-Salaam has not been without environmental consequences. The loss of greener area and natural habitats due to the expansion of built-up areas has led to deforestation, habitat destruction, and alterations in land cover. The city's rapid growth has resulted in the conversion of green areas into built environments, contributing to changes in the urban landscape and impacting local ecosystems (Mnyali, 2021)

2.3 Urban vegetated areas and their importance

Vegetated area in urban areas refers to any space within an urban environment that contains vegetation, whether it is naturally occurring or artificially introduced. This can include parks, gardens, green spaces, tree-lined streets, and any other areas where plants and vegetation are present (Mensah, 2014). According to the Tanzania Ministry of Land and Human Settlement, urban green areas are defined as land that is partially or fully covered with grass, trees, shrubs, or other vegetation (URT, 2016) .

Vegetated areas can be categorized in different ways. One categorization is based on ownership, which includes privately owned and used spaces, spaces open to the general public, and spaces accessible for public use upon payment (Roy, 2018) .Another categorization is based on their nature, encompassing semiprivate spaces, designated green areas, public green spaces, public and private tree plantations, rangelands and forests near urban areas, natural forests influenced by urbanization, and trees planted for environmental protection and beautification (Mensah, 2014).

In Dar-es-Salaam, a variety of vegetated areas can be found. However, this study focuses specifically on green areas, including public green spaces, private and public tree plantations, and forests near urban areas. Within Dar-es-Salaam city, these green spaces play a pivotal role in enhancing the overall quality of life for its residents. The benefits and roles provided by these green spaces include

a) **Environmental benefit;** Green spaces in Dar-es-Salaam provide several important environmental benefits. They contribute to improved air quality by acting as natural filters for pollutants and producing oxygen through photosynthesis (Rwiza, 2012). These areas help mitigate the urban heat island effect by providing shade and reducing surface temperatures. Additionally, green spaces can support local biodiversity by providing habitats for various plant and animal species

b) **Social and Health Benefits;** Urban green spaces contribute to the social well-being and health of Dar-es-Salaam's residents. They offer spaces for recreational activities, exercise, and relaxation, promoting physical fitness and mental well-being. Green spaces serve as important community gathering places, fostering social interaction, and cultural activities (Kabisch, 2015). These areas provide opportunities for residents to connect with nature and experience psychological rejuvenation.

2.4 Remote Sensing and GIS Techniques

Remote sensing and Geographic Information System (GIS) technology are powerful tools used in urban studies to analyze and visualize spatial data. These tools play a crucial role in assessing various aspects of urban development, including urban sprawl and its impact on green spaces.

a) **Remote Sensing;** -Remote sensing involves collecting information about the Earth's surface without direct physical contact (Campbell J. B., 1987). It typically uses satellite or aerial imagery, capturing data in the form of images or digital data. Remote sensing allows to monitor changes in land cover, detect spatial patterns, and analyze urban development over time.

b) **Geographic Information System (GIS):** is a software-based technology that allows to create, manage, analyze, and visualize geographic information (Longley, 2015). It involves layering different types of spatial data to create comprehensive maps and perform spatial analysis.

2.4.1 Application of Remote Sensing and GIS in Urban Studies

a) **Satellite Imagery:** it enabling the monitoring of urban growth, land use changes, and the expansion of built-up areas over time. Help to use multi-temporal satellite images to track the evolution of urban sprawl and identify areas undergoing significant development.

b) **Spatial Analysis;** - GIS allows to perform various spatial analyses, such as buffer analysis, density mapping, and hotspot analysis. These analyses help identify areas with high urbanization rates, highlight zones of increased sprawl, and pinpoint locations where greener areas are at risk due to development.

c) **For Mapping Techniques; -**GIS is instrumental in creating accurate and detailed maps that display various urban characteristics, such as land use, transportation networks, and green spaces. Mapping helps visualize the spatial relationships between urban sprawl and green spaces, enabling better understanding and decision-making.

2.4.2 Assessing Builtup areas expansion and Its Impact on vegetated areas

Remote sensing and GIS technology used to study the effects of builtup areas expansion on vegetated areas in different urban contexts; -

a) **By Land Use Classification; -** Remote sensing data can used to classify land cover types, distinguishing between built-up areas, green spaces, water bodies, and bare land (Puplampu, 2021). This classification helps quantify the extent of builtup areas expansion and identify areas where greener area is being encroached upon.

b) **Change Detection; -**By comparing satellite images from different time periods, you can detect changes in land cover and track the expansion of builtup areas over time (Puplampu, 2021). This allows for a quantitative assessment of builtup areas expansion impact on vegetated area.

In this research on assessing the effect of expansion of builtup areas on vegetated areas in Dar-es-Salaam, remote sensing utilized to analyze satellite imagery from different time periods, classify land use types, and detect changes. GIS enabled to perform spatial analyses, create detailed maps, and model the relationship between builtup areas and vegetated areas.

2.5 Image Classification

Classification is the process of sorting pixels into a finite number of individual classes, or categories of data based on their data file values. Therefore, image classification is the process of extracting information from the multi-band raster images such as satellite images (Lillesand, 2008). Classification can be done using a single band, in a process called density slicing, or using many bands commonly known as multi-spectral classification. The choice of the method for image classification mostly depends on the research objectives, the nature of the image and the level of detail or accuracy required for a specific application (Lillesand, 2008) .There are broadly two methods of image classification which are:

a) Supervised classification
b) Unsupervised classification

A) Supervised classification

The supervised classification depends on the prior knowledge of the location and identify of land cover class that are in the image such that it is based on the external knowledge of the area of interest (Mather P. , 2004). The supervised classification has commonly used algorithms after the user have provided an input. They include:

i. Maximum likelihood-This algorithm base on the normal distribution of each class in each particular band. The maximum likelihood also calculates the probability that a pixel belongs to specific class.
ii. Minimum distance – it uses the mean vector for each class and computers the Euclidean distance from each unknown pixel to the mean vector for each class whereby the pixels are classified to the nearest class

The supervised classification is the approach which has been applied to this study as there are several advantages to using this approach to classification. First, the analyst has full control of the classes to be assigned in the final classification which allows for easier comparison with other classifications by using the same classes for both. Second, through the process of selecting training areas, the resulting classification is tied to specific areas on the image of known identity. Third, the analyst does not the problem of matching spectral classes to informational classes, because it is already addressed during the selection of training areas. Specific areas on the image of known identity (Campbell J. , 2002)

B) Unsupervised classification

This type of classification does not depend on the prior knowledge since it relies on a computed algorithm. Here the user only required to specify number of classes. And the computer will perform classification automatically. This method is sustainable in evaluating areas where you have no or a little knowledge of the site and it is advantageous because it has unbiased geographical assessment of pixels. However, it is not sensitive in covariation and variation in the spectral signature of objects.

2.6 Classification scheme

Classification scheme is a hierarchical structure that defines different levels of land cover categories. Each level represents a different level of detail, allowing land cover data to be organized from general to specific (AEE, 2007). There are more than six types of classification scheme but in this study CORINE classification scheme Level 1, used because represents the broadest categories. The land cover categories used are, bare land, water bodies, vegetation, and built-up areas, both these fall under the CORINE Level 1 classification scheme as follows:

a) Bare Land: This category generally falls under the "Bare Areas" class in the CORINE Level 1 classification. "Bare Areas" includes areas with minimal or no vegetation, such as deserts, rocky terrain, and other non-vegetated land surfaces. So in this research all area falls under the mentioned characteristics named as bareland.

b) Water Bodies: Water bodies like rivers, lakes, reservoirs, and coastal waters are typically categorized under the "Water Bodies" class in the CORINE Level 1 classification. This class represents various natural and artificial water features. So all natural and artificial water features in this study named as waterbodies.

c) Vegetation: Vegetation-rich areas, including forests, woodlands, grasslands, and other natural and semi-natural landscapes, are usually grouped under the "Forests and Semi-Natural Areas" class in the CORINE Level 1 classification. This category encompasses both natural and managed vegetation areas.

d) Built-Up Areas: Built-up areas, which include urban and developed areas with man-made structures like buildings, roads, and infrastructure, fall within the "Artificial Surfaces" class in the CORINE Level 1 classification. This class covers all artificial surfaces created by human activities.

CHAPTER THREE
METHODOLOGY

3.1 Overview

This chapter presents the following, methodological flowchart, methods, techniques and materials used to achieve the research objectives. It mainly explains the data used and their characteristics, image pre-processing, techniques used in image classification, method of change detection, accuracy assessment and list of software packages used in each process of this research. Figure 3.1 shows the methods and processes used in summarized flowchart

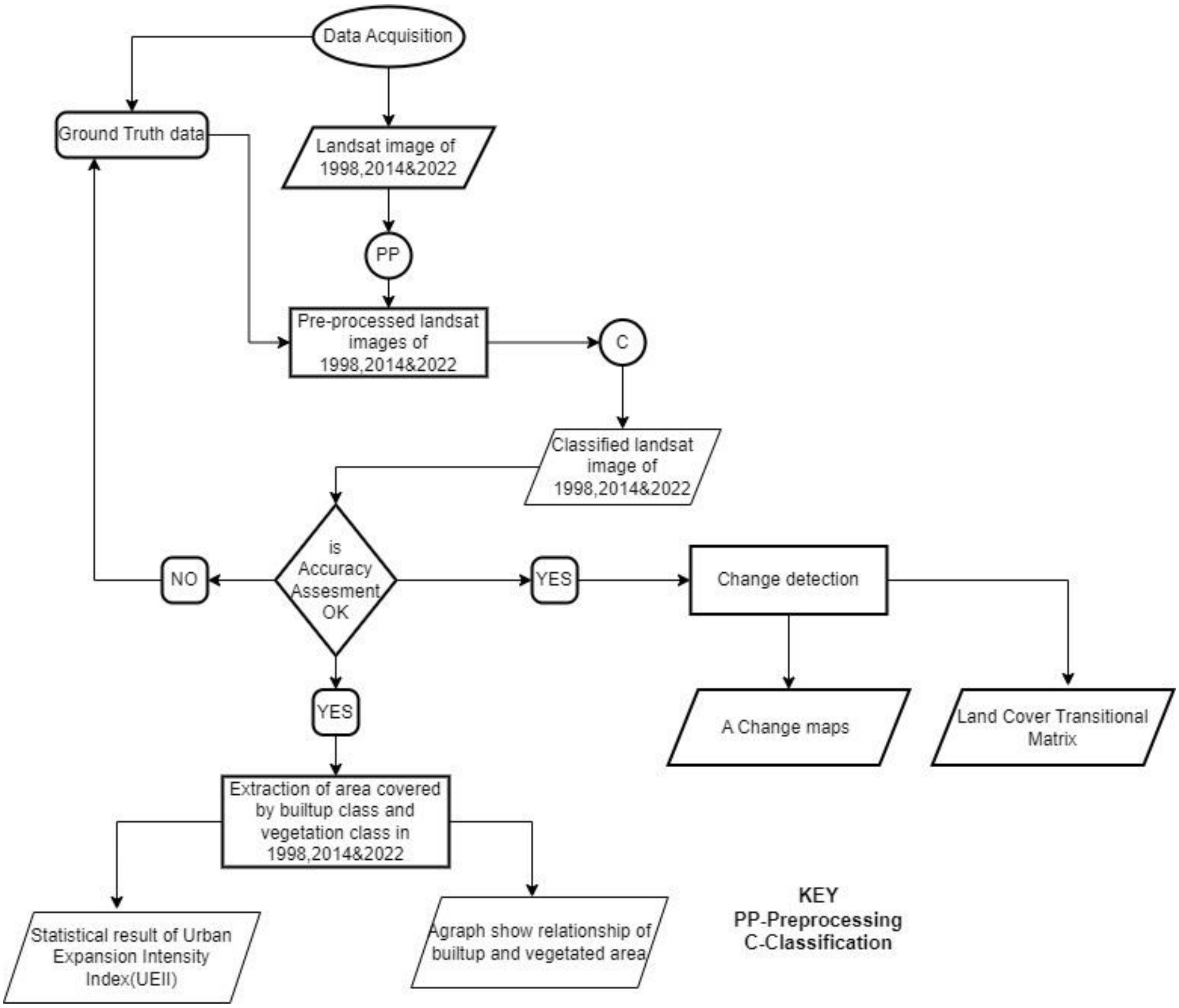

Figure 3.1 A Methodological flow chart

3.2 Data Acquisition

According to the research objectives, the data identified to respond to the research questions are summarized in table 3.1 below. The study involves the collection of data from primary sources. The data collected are satellite images for the years 1998, 2014, and 2022. These data are freely downloaded from USGS Earth Explorer (Landsat 5TM, and Landsat 8 OLI) and used in generating land cover and change maps. Admistrative boundaries downloaded freely from NBS for the extraction of areas of interest.

Table 3. 1 Research Data and their sources

DATA	FORMAT	SOURCES	DATE	SPATIAL RESOLUTION	USE/PURPOSE
Landsat 8OLI/TIRS Images	TIFF	USGS	13/06/2014& 03/06/2022	30m	For land cover Map and change map
Landsat 5 ETM Image	TIFF	USGS	16/05/1998	30m	For land cover Map and change map
Admistrative boundary	Shapefile	NBS	2019		In order to extract the area of Interest

3.3 Image pre-processing

This process involves preparation of data for analysis, the aim of pre-processing was to improve the image data by suppressing the unwanted distortions and enhancing important features for further processing. It involves the atmospheric correction of Landsat images so as to increase image resolution, stacking/mosaicking of bands, projection and clipping of the study area after classifying them.

A)-layer stacking

This involves the process of combining multiple bands of Landsat images to form one band image with the aim of improving classification accuracy using the layer stack tool in ERDAS IMAGINE 2015 software. The bands used for Landsat 5 TM were band 1 to 7 excluding band

6 which is thermal band. For Landsat 8 OLI/TIRS bands used were band 2 to 7, excluding band 1 which is a coastal aerosol band, band 8 which is panchromatic and band 10 and 11 which are thermal bands.

B) Atmospheric corrections

This is done in order to remove the scattering and absorption effects from the atmosphere so as to obtain the surface reflectance characterization of surface properties. The process performed are haze and noise reduction using the haze reduction and noise reduction tool respectively in ERDAS IMAGINE 2015

C) Projection

The corrected stacked Landsat images of 1998, 2014 and 2022 were transformed to local coordinate system of UTM zone 37S with datum Arc 1960 so as to match the coordinate of the Landsat images with the coordinates of the shapefile.

D) Image sub-setting

The shapefile containing the Admistrative boundaries of Dar-es-salaam was used to extract the Area of Interest (AOI) from classified satellite images. This was done by using ERDAS IMAGINE 2015 software using the raster mosaic tool.

3.4 Training Samples

The training samples collected by linking the ERDAS IMAGINE 2015 software with the google earth through the use of shapefile of the study area where by Classification scheme used was CORINE, Level 1, in which help to have four classes to be used which are;

- Built-up
- Vegetation
- Bare land
- Water bodies

3.5 Image Classification

The method used for the classification of the study area was supervised classification and the algorithms used was maximum likelihood algorithm, this process was done on ERDAS imagine 2015 software. The classes used in classification were four which are:

- Built-up
- Vegetation

- Bare land
- Water bodies

3.6 Accuracy Assessment

The Dar-es-salaam Urban Images of year 1998, 2014 and 2022 were then checked their accuracy after been classified so as to assess the effectiveness of pixels that were sampled into correct land cover classes. The coordinates extracted from google earth were used as the reference coordinates to assess the classified images. This whole process was done using the ERDAS Imagine 2015 software.

3.7 Change detection

The algorithm performed in change detection process is post classification comparison technique. In this study the change detection is between 1998 and 2014, 2014 and 2022 and, 1998 and 2022. The change detection done by using QGIS 3.30.1 where by the minimum of two classified images used to track changes between the studied years.

3.8 Map making

The maps prepared by using ArcGIS software version 10.8 and QGIS 3.30.1 due to their capability in spatial data analysis and ability to create thematic map.

3.9 The use of GIS and RS data

To analyse the development, pattern, and extent of builtup areas expansion, this study utilized GIS and remote sensing data. Satellite images for the years 1998, 2014, and 2022 were obtained from the USGS and underwent pre-processing. The supervised classification approach was employed to assess the changes in Land Use and Land Cover (LULC). The images were categorized into four classes: built-up areas, water bodies, bare land, and vegetation.

To assess urban expansion, the primary focus was on the built-up class, which signifies the expansion of urban areas across various years. Changes within the built-up class were analyzed to gain insights into the progression of urbanization. Furthermore, the extent of the built-up regions was utilized to calculate the Urban Expansion Intensity Index (UEII), a measure that quantifies the degree of urban expansion.

3.10 Urban Expansion intensity index (UEII)

UEII can be used to quantitatively assess the variations in urban spatial expansion. It used to compare the rate or intensity of changes in urban land use through time and to identify the preferences of urban expansion. Equation to calculate UEII is

$$UEII_{it} = \left[\frac{ULA_{i,b} - ULA_{i,a}}{TLA_{i} \times t} \right] \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(i)}$$

Where; UEII- it is the annual average urban expansion intensity index of (i^{th}) zone in time period (t), ULAi;a and ULAi;b -are the quantity of built-up areas at time periods 'a' and 'b' in (i^{th}) spatial zone respectively, TLA_i -is the total area of (i^{th}) spatial zone.

According to (Acheampong, 2016),The division standard for interpreting UEII values is as follows;

Value; 0-0.28-slow

Value; 0.28-0.59-low speed

Value; 0.59-1.05-medium speed

Value; 1.05-1.92-is fast speed

Value>1.92-high speed

3.11 Urban expansion in Dar-es-salaam

The land area covered by the built-up class in square kilometers, extracted from land cover maps of 1998, 2014, and 2022, was utilized to quantify urban expansion in Dar-es-salaam within an Excel spreadsheet. Additionally, the Urban Expansion Intensity Index (UEII) was calculated based on the built-up area coverage in 1998, 2014, and 2022. This index serves to measure urban expansion while specifically considering a distinct form of spatial growth characterized by decentralized and low-density development patterns. These patterns often result in adverse social, economic, and environmental impacts, including effects on green spaces

3.12 Urban Vegetated areas

In this study vegetated area included all area covered by vegetation whether are natural or artificial which can be partially or fully covered with grass, trees, shrubs and other vegetation. The area covered by vegetation class in Sq.km obtained from the land cover map of the year 1998, 2014 and 2022.

CHAPTER FOUR
RESULTS, ANALYSIS AND DISCUSSION

4.1 Overview

The output of this research is discussed in detail and well presented in this chapter. These outputs are supported by the use of Maps, Graphs and Tables. This chapter starts in analyzing the changes in land cover, and the effect of expansion of builtup areas to vegetated areas

4.2 Classification Results

The satellite images were classified to identify spatial changes between the years 1998, 2014, and 2022. The Land Use Land Cover classification was conducted using a supervised classification algorithm, grouping each class into their respective pixel groups. The findings of the classified images are presented in Figures 4.1, which demonstrate alterations in the land surface pattern. It is evident that builtup areas have undergone significant expansion due to urbanization. Table 4.1 displays the Land Use Land Cover classification specifically for Dar-es-salaam.

To validate the accuracy of the results, an assessment was conducted on the datasets. The classification was obtained with an overall accuracy of 81.41%, 77.87% and 76.99% for the years 1998, 2014, and 2022 respectively, the accuracy assessment report for both years are presented in table 4.2.

The total extent of Dar-es-salaam city classified into 4 main classes, which were Builtup, Vegetation, Bareland, and water bodies. In 1998, the builtup area covered 317.854 sq. km, vegetation occupied 1128.788 sq. km, Bareland covered 120.226 sq. km, and water bodies accounted for 49.79sq. km. By 2014, the urban area had expanded by 52.17% compared to 1998.

Table 4.1 Coverage of an area for each class

CLASS NAME	Area covered in sq.km for 1998	Area Covered in Sq.km for 2014	Area Covered in Sq.km for 2022
Builtup	317.854	664.57	772.587
Vegetation	1128.788	739.59	651.068
Bareland	120.226	159.37	137.628
Waterbodies	49.97	53.39	55.806

During the period 1998-2014, the city experienced infrastructure development, the construction of transportation networks, and initial industrialization, resulting in increased migration from rural areas (Haixiao, 2014). The results indicate a decrease in vegetation area from 1128.788 sq. km in 1998 to 739.59 sq. km in 2014, representing a reduction of 34.47%. This decline in vegetation highlights the significant impact of builtup areas expansion on vegetated areas within the city.

The migration of people from rural to urban areas during this period led to the conversion of vegetated areas into impervious surfaces such as roads, buildings, and parking lots. Consequently, there was a loss of vegetation cover. Vegetation plays a crucial role in mitigating air pollution by acting as a natural filter, absorbing pollutants, and producing oxygen. The decrease in vegetation cover has resulted in a diminished capacity to purify the air naturally, thereby exacerbating air pollution levels.

Between 2014 and 2022, the urban area expanded by 13.98%. The city experienced substantial economic and population growth due to urbanization. The need for land for housing resulted in the conversion of different types of land for urban use, leading to an imbalanced environmental situation (Haixiao, 2014). As the built-up area expanded, there was a decrease of 11.96% in vegetation from 2014 to 2022.

The result below obtained by doing classification of Landsat image, for year 1998 Landsat 5 TM used while for 2014 and 2022 Landsat 8 OLI used. Classes used are Builtup, Vegetation, Bareland and Waterbodies. Vegetation includes all vegetated area covered to the map which are parks, gardens, green spaces, tree-lined streets, and any other areas where plants and vegetation are present and builtup class involve all builtup areas used to indicate the urban coverage

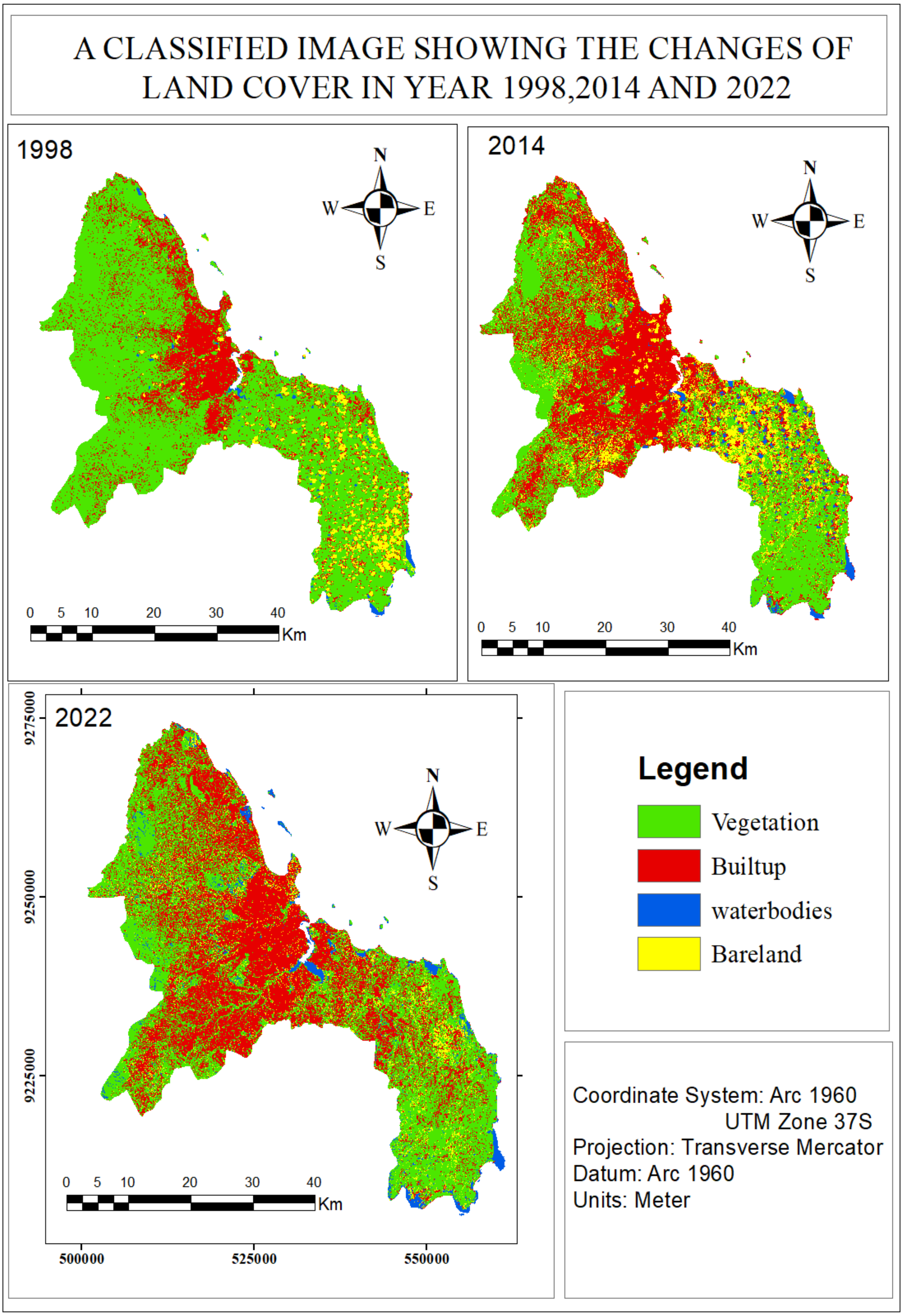

Figure 4.1 Land Cover Map of 1998, 2014 and 2022

Table 4.2 Accuracy assessment report for the years (A) 1998 (B) 2014 (C) 2022

a) Classification accuracy assessment report 1998

Class Name	Waterbodies	Bareland	Vegetation	Builtup	Raw Total	Correct Classified	Producer Accuracy	Users Accuracy
Waterbodies	22	1	1	1	**25**	25	84.62%	88.00%
Bareland	1	6	0	0	**7**	7	37.5%	85.71%
Vegetation	1	9	49	3	**62**	49	94.23%	79.03%
Builtup	2	0	2	15	**19**	15	78.95%	78.94%
Total	**26**	**16**	**52**	**19**	**113**	96		
Overall classification Accuracy (%): 81.41								
Overall Kappa coefficient: 0.6918								

b) Classification accuracy assessment report 2014

Class Name	Waterbodies	Bareland	Vegetation	Builtup	Raw Total	Correct Classified	Producer Accuracy	Users Accuracy
Waterbodies	23	1	2	1	**27**	22	88.46%	85.18%
Bareland	0	3	1	1	**5**	5	26.32%	60%
Vegetation	1	10	48	2	**61**	49	88.88%	78.68%
Builtup	2	1	3	14	**20**	16	77.77%	70.00%
Total	**26**	**15**	**54**	**18**	**113**	92		
Overall classification Accuracy (%): 77.87								
Overall Kappa coefficient: 0.6617								

c) Classification accuracy assessment report 2022

Class Name	Waterbodies	Bareland	Vegetation	Builtup	Raw Total	Correct Classified	Producer Accuracy	Users Accuracy
Waterbodies	21	2	1	1	**25**	25	84.00%	84.00%
Bareland	1	5	1	0	**7**	7	26.32%	71.43%
Vegetation	1	11	47	2	**61**	47	90.38%	77.05%
Builtup	2	1	3	14	**20**	14	82.35%	70.00%
Total	**25**	**19**	**52**	**17**	**113**	87		
Overall classification Accuracy (%): 76.99								
Overall Kappa coefficient: 0.6543								

4.3 Land cover statistics

The statistics of land cover results show how the coverage of the classes have been changing over the year (1998,2014 and 2022) whereby it is seen that the built-up areas have been expanding, vegetation decreases. These statistics can be observed on the graph in Figure 4.2,4.3 and 4.4 respectively.

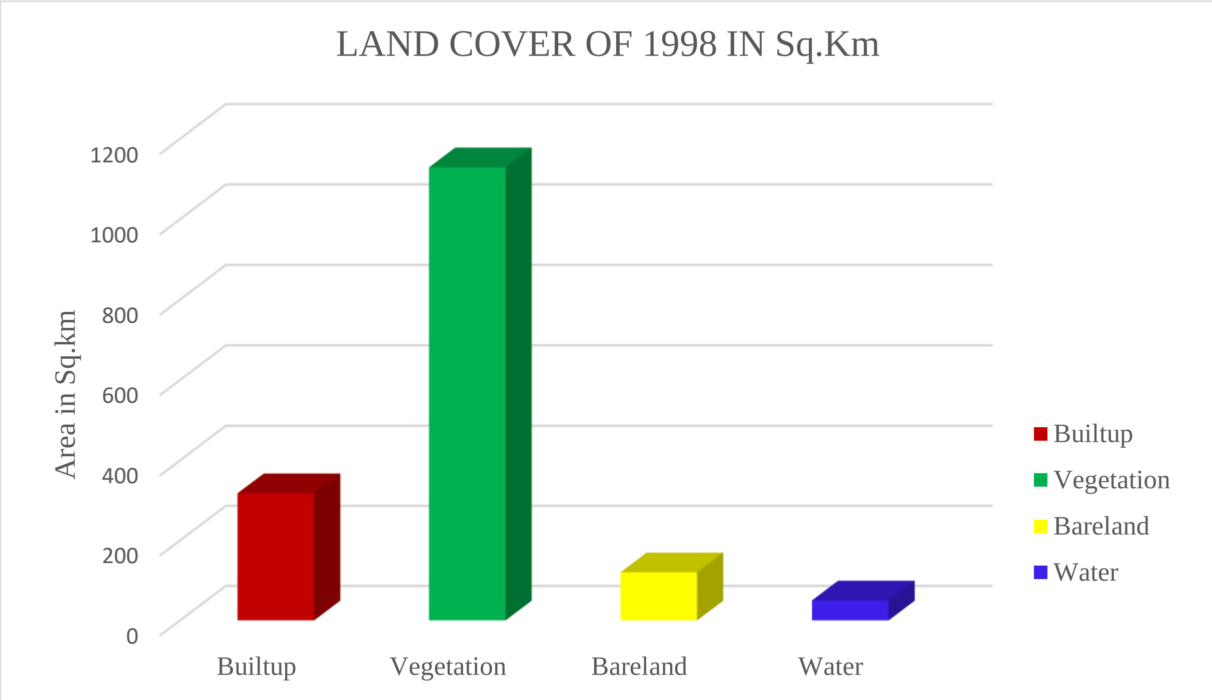

Figure 4.2 A graph of land coverage in 1998

Figure 4.2 above shows a graph of land cover in 1998 with four land cover which are built-up with 20%, vegetation with 73%, bare-land with 6% and waterbodies with 1%. Vegetation class shows large coverage to compare with others classes. This shows that small area in Dar-es-salaam for this period covered with water.

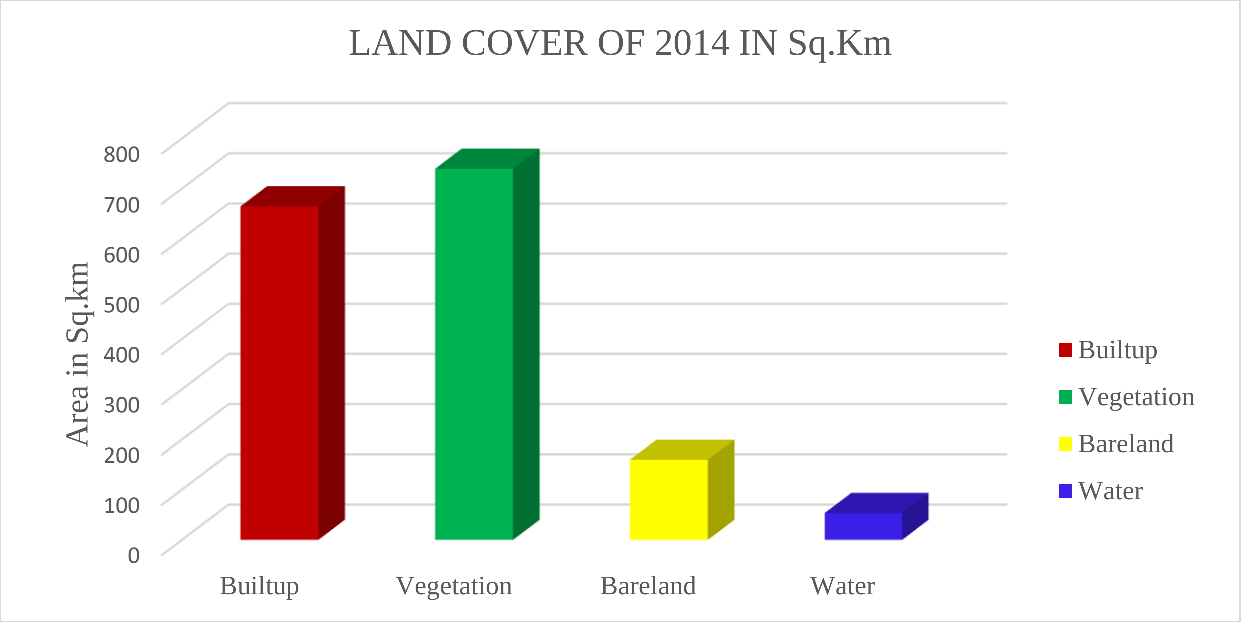

Figure 4.3 A graph of land coverage in 2014

A figure 4.3 show a graph of land cover of 2014 with a four land cover types, large area covered by vegetation of 46%, followed with urban of 41%, then bare-land with 10% and waterbodies with 3%. To compare with 1998, the built-up increases while vegetation decreases

Figure 4.4 Graph of land coverage in 2022

Figure 4.4 show a graph of land cover in 2022 with four land cover which are built-up with 48%, vegetation with 40%, bare-land with 9% and waterbodies with 3%. This shows how increase in population impact the spatial coverage of different land cover types especially builtup areas which increase from 20% in 1998 to 41% in 2014, while vegetation decreases from 70% in 1998 to 46% in 2014.

4.4 Land Cover change results

The land cover changes from 1998 to 2014, 2014 to 2022 and 1998 to 2022 are presented below whereby each class between the years has shown both positive and negative changes. Each class either increased or decreased to another class in area size as shown in Figure 4.5, 4.6 and 4.7 respectively.

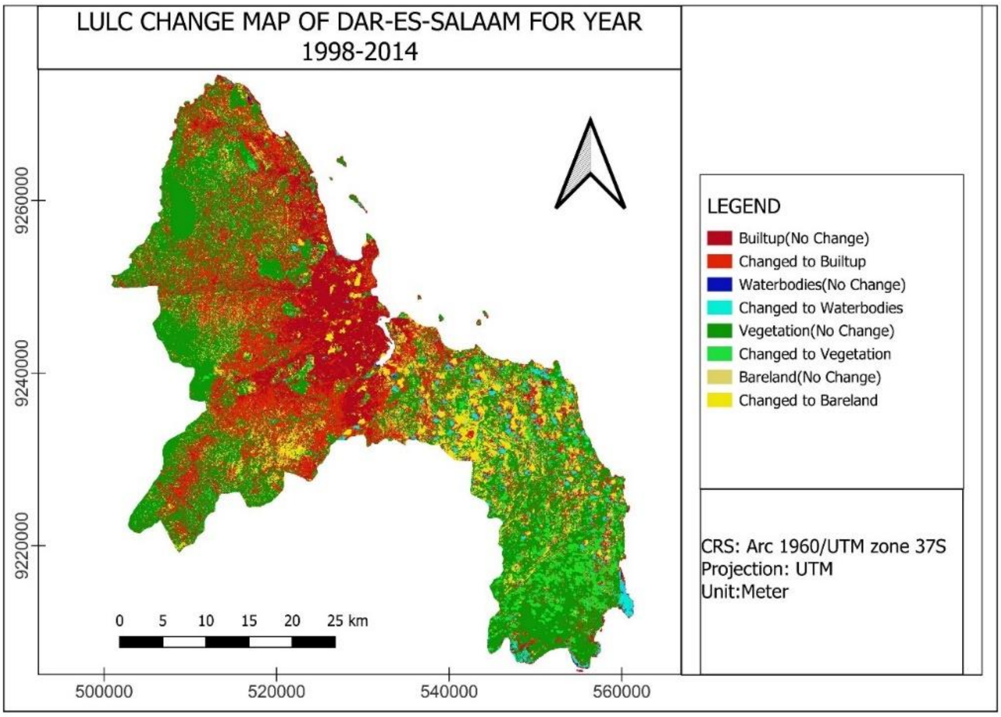

Figure 4.5 Change Map from 1998 to 2014

From the figure 4.5 shows how the one class changed to another class where by the larger changes is to built-up, followed those changed to vegetation, example in 1998 to 2014 area of Sq.km 392.752 of vegetation changed to Builtup while 65.332Sq.km of built-up changed to vegetation.

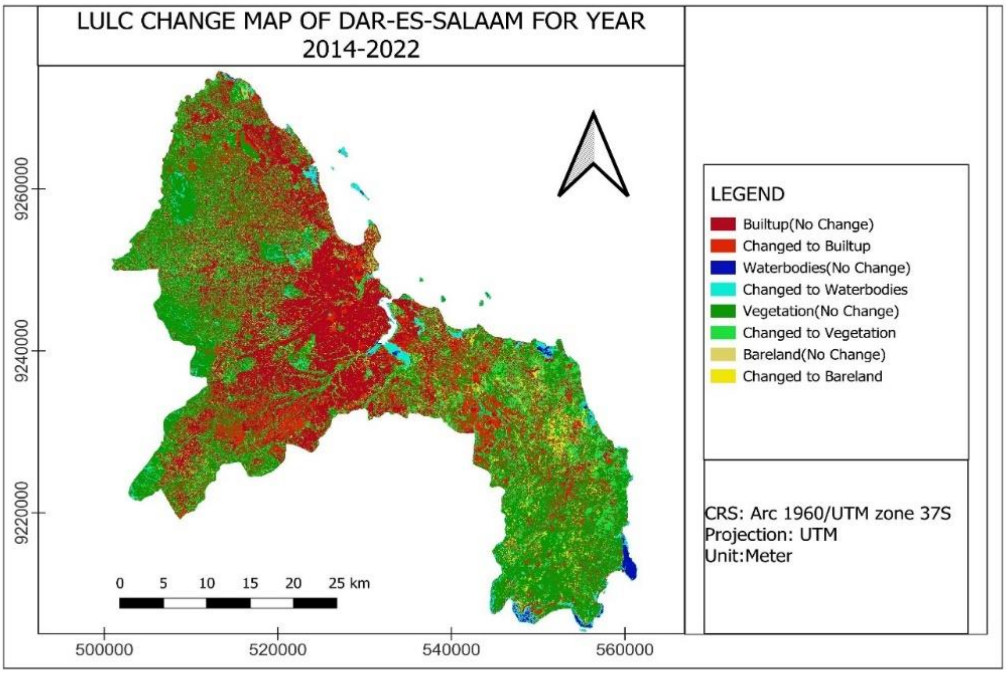

Figure 4.6 Change Map from 2014 to 2022

From the figure 4.6 shows the changes of classes from 2014 to 2022 whereby the larger changes are changed to built-up, in which vegetation of area about 116.852 Sq.km and area covered by Bareland of 117.553 Sq.km changed to built-up.

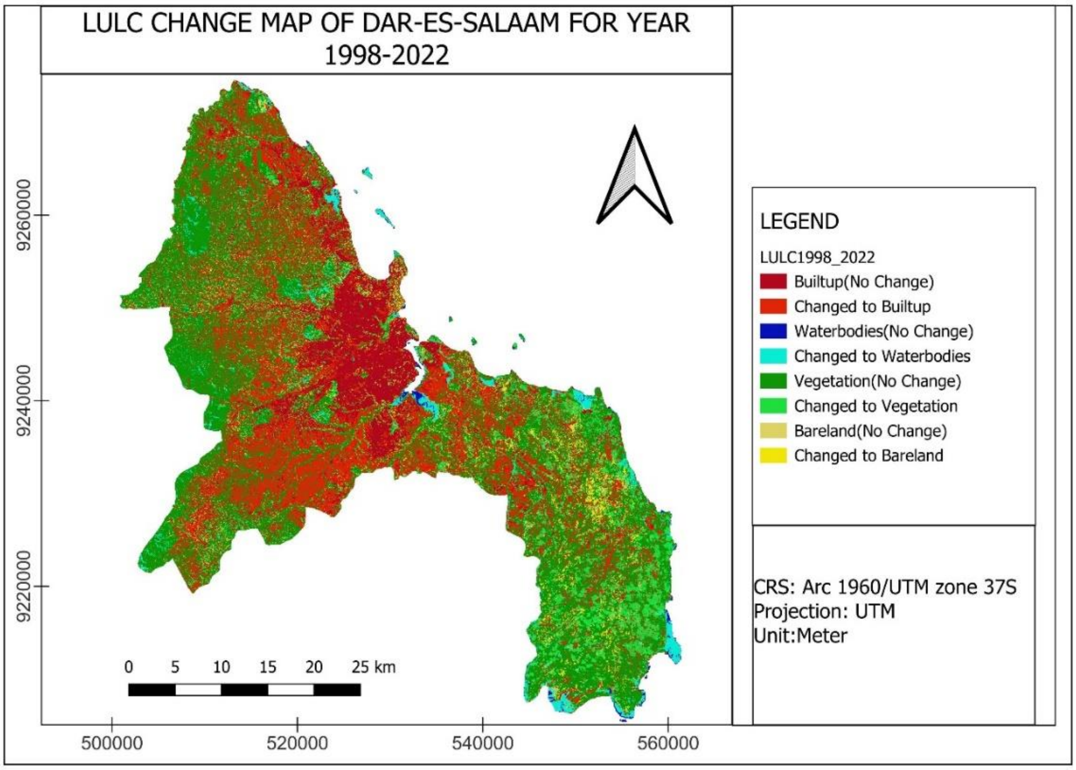

Figure 4.7 Change Map from 1998 to 2022

4.5 Statistical Result of land cover Changes

The land cover changes were observed between year 1998 to 2014, 2014 to 2022 and 1998 to 2022. There was a transition of classes between all these years whereby each class changed to another as shown in Table 4.3, 4.4 and 4.5 respectively

Table 4.3 Change detection statistics between 1998 and 2014

Classes	Vegetation (2014)	Waterbodies (2014)	Bareland (2014)	Builtup (2014)
Vegetation (1998)	613.2033	24.282	156.1473	392.7528
Waterbodies (1998)	3.5838	1.5696	1.1007	7.0623
Bareland (1998)	52.1559	4.4505	13.5342	20.1636
Builtup (1998)	65.3328	3.3948	36.234	222.0372

Table 4.4 Change detection statistics between 2014 and 2022

Classes	Vegetation (2022)	Waterbodies (2022)	Bareland (2022)	Builtup (2022)
Vegetation (2014)	537.113	31.9338	48.3768	116.852
Waterbodies (2014)	14.225	10.5345	3.1032	5.833
Bareland (2014)	79.517	2.5623	7.3827	117.553
Builtup (2014)	154.84	13.7763	40.9383	432.46

Table 4.5 Change detection statistics between 1998 to 2022

Classes	Vegetation (2022)	Waterbodies (2022)	Bareland (2022)	Builtup (2022)
Vegetation (1998)	640.95	42.777	74.8116	427.84
Waterbodies (1998)	3.48	6.8949	0.6534	2.28
Bareland (1998)	55.606	3.8565	7.2306	23.61
Builtup (1998)	85.64	5.2785	17.1054	218.96

NB: The highlighted diagonal cells are the classes which have been sustained and the value in non-diagonal cells are classes which have been changed between 1998 -2022 (Area in Sq.km)

4.6 Urban Expansion Intensity Index

The UEII calculated and presented on the table 4.6 whereby the formular used to calculate UEII is in equation (i) from chapter 3.10; -

Table 4. 6 Values of the Urban Expansion Intensity Index from 1998 to 2022

$ULA_{i,a(1998)}$ in Sq.km	$ULA_{i,b(2022)}$in Sq.km	$t_{in\ Years}$	TLA in Sq.km	UEII (1998-2022)	Level
317.854	772.587	22	1617	1.427	High speed of urban expansion

Calculated Urban Expansion Intensity Index (UEII) based on the given data is 1.427. This index value indicates the level of expansion of built-up areas are very high. UEII of 1.427 means that the built-up area in 2022 is approximately 1.427 times larger than it was in 1998. This suggests a substantial growth in urban areas over the studied period. The higher the UEII value, the greater the extent of urban expansion relative to the initial built-up area. Such significant urban expansion implies that:

a) **Land Use Change:** The substantial increase in built-up area indicates a transformation of land use from natural or vegetated areas to urban developments. This can lead to changes in the landscape and loss of vegetated area.
b) **Population Growth:** The expansion of built-up areas is often associated with population growth and increased urbanization. This could be driven by factors such as rural-to-urban migration and economic opportunities in the city
c) **Infrastructure Development:** A higher UEII may indicate increased infrastructure development, including housing, commercial buildings, roads, and utilities. This can have both positive and negative impacts on the local economy and quality of life.
d) **Environmental Impact:** Rapid urban expansion can lead to environmental challenges such as habitat loss, reduced green spaces, increased pollution, and potential strain on resources like water and energy

Generally a UEII of 1.427 indicates a considerable urban expansion in Dar-es-Salaam city, emphasizing the need for thoughtful and sustainable urban planning to address the challenges and opportunities associated with such growth.

4.7 Effect of expansion of builtup areas in vegetated areas

The figure shows the coverage of built-up and Vegetation where by it seen that built-up have been expanding year to year while vegetation cover decreasing year to year. The coverage of Vegetation in 1998 was 80% while built-up was 20%, in 2014 vegetation decreased to coverage of 58% while built-up increased to coverage of 42% and in 2022 vegetation decreased up to coverage of 38% while built-up increased up to coverage of 62% (Refer Figure 4.9).

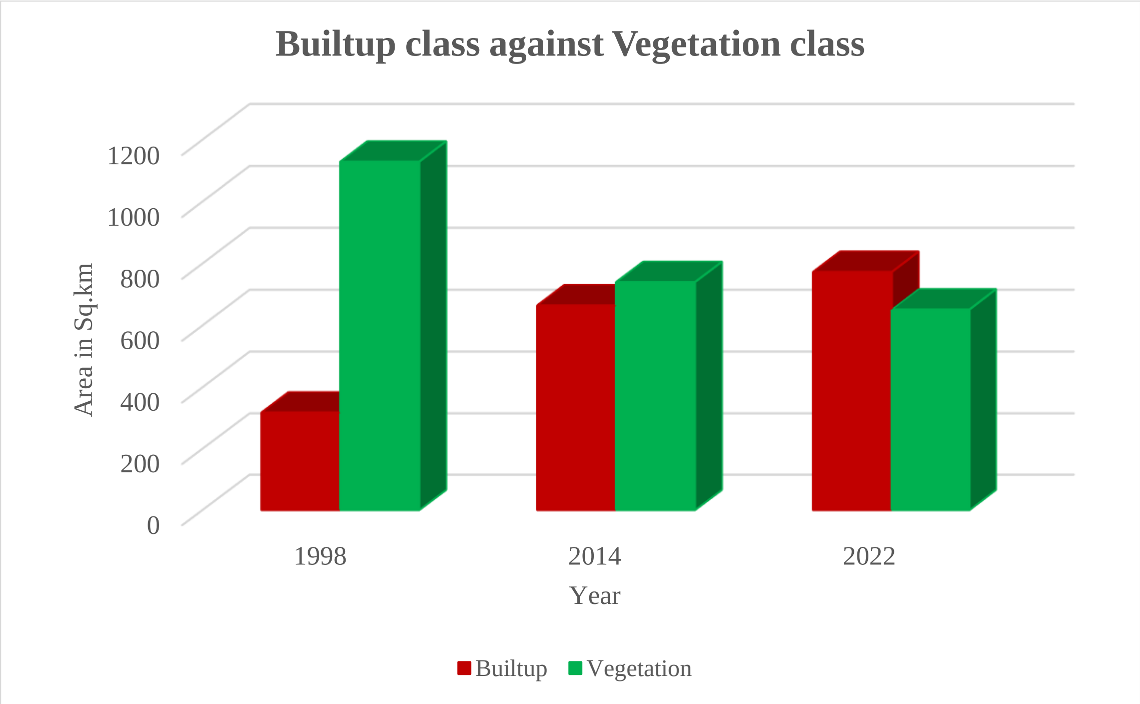

Figure 4.8 A graph to show how expansion of builtup area affect the vegetated area

Analysis of the figure above reveals notable changes in both the built-up and vegetated areas over the study period. Specifically in 1998, the built-up area covered 317.854 sq.km, by 2014, the built-up area expanded significantly to 664.57 sq.km, further expansion occurred by 2022, resulting in a built-up area of 772.587 sq.km while the vegetated area in 1998 spanned 1128.79 sq.km, however, by 2014, a reduction was observed, shrinking the vegetated area to 739.59 sq.km. This decline continued through 2022, with the vegetated area further decreasing to 651.086 sq.km. Based on this analysis, we can observe the following trends:

a) **Urban Expansion:** The built-up area has consistently expanded over the years, indicating ongoing urbanization and development in Dar-es-Salaam city.
   The expansion is particularly noticeable between 1998 and 2014, and it continues at a slightly slower pace between 2014 and 2022.

b) **Vegetation Loss:** Concurrently, the vegetated area has experienced a decline over the same period. There is a notable reduction from 1998 to 2014, and this trend persists with a smaller decrease from 2014 to 2022.

c) **Impact on vegetated areas:** The decrease in vegetated areas suggests that the expansion of built-up areas has led to the loss of vegetation within the city. This could have implications for environmental quality, air and water quality, biodiversity, and the overall well-being of residents.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the year 1998 to 2022 there are changes in land use that can be found in Table 4.1. It is identified that the urban area in the city has expanded by 58.9% over the study period. The data clearly illustrates a significant and continuous expansion of built-up areas in Dar-es-Salaam city over the studied period. This expansion has led to a noticeable reduction in vegetated areas, which play a crucial role in maintaining ecological balance and enhancing the quality of urban life.

Therefore proper measures should be taken to maintain the expansion of urban area so as to conserve the vegetation cover.

5.2 Recommendation

Based on the analysis conducted, the following recommendations are put forth to address the issues arising from the expansion of built-up areas on vegetated areas in Dar-es-Salaam city:

a) **Urban Planning and Zoning:** Enhance urban planning and zoning regulations to promote responsible and sustainable land use practices. Implement measures that prioritize the protection and enhancement of existing vegetated areas within the city.

b) **Green Infrastructure Development:** Invest in the creation and maintenance of green infrastructure, such as parks, gardens, and urban forests. These spaces not only provide essential ecosystem services but also contribute to residents' physical and mental well being.

c) **Public Awareness and Engagement:** Raise awareness among residents, stakeholders, and policymakers about the importance of preserving green spaces and the adverse consequences of their loss. Foster community involvement in green space conservation initiatives

By adopting these recommendations, Dar-es-Salaam city can better manage urban expansion, mitigate the loss of vegetated areas, and ensure a sustainable and vibrant urban environment for current and future generations.

REFERENCES

Acheampong, R. A. (2016, May 2). Quantifying the spatio-temporal patterns of settlement. *GeoJournal*, 823-840. doi:10.1007/s10708-016-9719-x

Abiy, D. (2010). "Land Use/ Land Cover Dynamics and soil Erosion Risk for sustainable Land Management. North Central Ethiopia.

AEE. (2007). *CORINE Land Cover technical guide - Addendum 2006.* Technical Report . Retrieved from http://www.eea.europa.eu/publications/technical_report_2007_17. CEC (1994): CORINE Land Cover Technical Guide

Afify, H. A. (2011). Evaluation of change detection techniques for monitoring land cover-changes: A case study in new Burg El- Arab area. *Alexandria Engineering Journal*.

Alberti, M. (2000). *The impact on urban patterns on Ecosystem dynamics.* Washngton: University of Washington.

Assessment, M. E. (2005). *"Ecosystem and Human Well being: A Framework for Assessment." Washington, DC.*

Cadima, I. T. (2016). Principal component analysis: a review and recent developments.

Campell, J. (2002). Introduction to Remote Sensing. 3rd edition, Newyork: Guilford Press.

COUNCIL, N. B. (2019). *KIGAMBONI MUNICIPAL COUNCIL SOCIAL ECONOMIC PROFILE 2019.* DAR ES SALAAM.

Feng, l. (2012). Investigation of urban sprawl on the basis of remote sensing data. China.

Frenkel, A. (2008). Measuring Urban Sprawl; How Can We Deal With It? *Article in Environment and Planning Design*. doi:10.1068/b3215

Galster, G. (2001). Wrestling Sprawl to the Ground: Defining and Measuring an Elusive Concept. *Housing Policy Debate, 12*, 681-717.

Gillham et al. (2002). *A Prime on the Urban Sprawl Debate.* Washngton D.C: The Limitless City. Retrieved April 02, 2023

Gombe, K. E., & Asanuma, I. (2017). Quantification of annual urban growth of Dar es Salaam Tanzania. *Advances in Remote Sensing*(6(3)), 175–191.

Haixiao, P. (2014). Dar es Salaam city temporal growth and its influence on transportation. *Urban,Planning and Transport Research*, 423-446. doi:10.1080/ 21650020. 2014.978951

Hao, R. S. (2012). Integrated approaches to long-term studies of urban sprawl and dynamic changes in shenzhen. 407-415.

Hornby, A. S. (2005). *Oxford Advanced Learners Dictionary. 7th Edition* . New York: Oxford University Press.

Jackson, M. (2005). *Roadside Concentration of Gaseous and Particulate Matter Pollutants and Risk Assessment in DarEs-Salaam.* Dar-es-salaam, Tanzania.

Jat, M. K. (2007). Monitoring and Modelling of urban sprawl using remote sensing ang GIS techniques. International Journal of Applied Earth Observation and Geoinformation. 10.

Kabisch, N. (2015). Green spaces and human well-being: A narrative approach. *Urban Forestry & Urban Greening*(14(4)), 806-816.

Karutz , R. (2019). *A Thematic Atlas of Nature's Benefits to Dar es Salaam.* Leipzig and Cape Town: Helmholtz Centre for Environmental Research and ICLEI Africa Secretariat.

Krannich, J. M. (2006). Agricultural Land, Urban Growth and the need for a Federraly Organized Comprehensive Land Use Planning Model. Model Disaster.

Lindley, S. (2013). A GIS based assessment of the urban green structure of selected case study area and their ecosystem services. *Climate change and urban Vulnerability in Africa-CLUVA.* Retrieved April 02, 2023, from https://www.researchgate.net /publication/260192278

Longley, P. A. (2015). *Geographical information science and systerm* (4th ed.). U.S.A: John Wiley & Sons,.

Lu, D. (2002). Change Detection Technique. *International Journal of remote sensing*.

Manesha, A. J. (2021). Measuring urban sprawl of small and medium towns using GIS and Remote sensing techniques: A Case study of Sri Lanka. *Egyptian Journal of remote sensing and space science*, 1051-1060. Retrieved April 02, 2023, from http://www.sciencedirect.com

Mensah, C. (2014, January). Urban Green Spaces in Africa: Nature and Challenges. *International Journal of Ecosystem 2014, 4(1):*, 1-11. doi: DOI: 10.5923/j.ije. 20140401.01

Michael, S., & Michael , M. (2005). Behaviour, Preferences and Cities: Urban Theory and Urban Resurgence. *Urban studies*(43(8)), 1247-1274. Retrieved August 14, 2023, from https://www.jstor.org/stable/43201655

Mnyali, E. T. (2021, December 1). Analysis of the Current and Future Land Use/Land Cover Changes in Peri-urban area in Dar-es-salaam Tanzania using Remote sensing and GIS technique. *Tanzania Journal of Science*, 1622-1636. doi:10.4314/tjs.v47i5.12

Njee, R. M. (2016). Spatial Variability of Ambient Air Pollution Concentration in Dar es Salaam. *Journal of Environment Pollution and Human Health, iv*(04), pp. 83-90. doi:10.12691/jephh-4-4-2

Nowak, D. J. (n.d.). *The effect of urban Trees on Air Quality.* USDA Forest Service: USDA Forest Service. Retrieved April 03, 2023, from http://groundworksdenver.org/devs/ Trees_airquality.pdf

Oluseyi, O. (2006). Urban Land use change analysis of traditional city from remote sensing data. *The Case of Ibadan metropolitan area*, 42-62.

Puplampu, D. A. (2021). Exploring the impacts of urban expansion on green spaces availability and delivery of ecosystem services in the Accra metropolis. *Environmental Challenges*. Retrieved from https://doi.org/10.1016/j.envc.2021.100283

Raphael Karutz, A. B. (2019). *A Thematic Atlas of Nature's Benefits to Dar es Salaam:Critical reasons for greening the city and for keeping urban and peri-urban ecosystems intact.* Dar-es-salaam: Helmholtz Centre for Environmental Research and ICLEI Africa Secretariat. Retrieved March 12, 2023

Roy, M. (2018). *Climate change and declining levels of green structures: Life in informal settlements of Dar-es-salaam.* Dar-es-salaam: Landscape and Urban Planning. doi:10.1016/j.landurbplan.2017.11.011

Rwiza, Z. (2012). Assessment of air pollution in Dar es Salaam City using selected bio-indicators. *Environmental Monitoring and Assessment*(10), pp. 5997-6008.

URT. (2016). *Dar-es-salaam City Master Plan 2016-2036.* Dar-es-salaam: MLSHSD. Retrieved March 12, 2023

WilsonHoffhin, E. (2003). Development of Geospatial Model to Quantify,Describe and Map Urban Growth. *Remote sens. Enveron*, 275-285. doi:10.1016/S00344257(03)00074-9

Yuan, Y. (2023, June 23). Unmanaged Urban Growth in Dar es Salaam: The Spatiotemporal Pattern and Influencing Factors. *Suistainability*, *15*(13). doi:10.3390/su151310575

Zhenfeng Shao, N. S. (2020). Urban sprawl and its impact on sustainable urban development: a combination of remote sensing and social media data.