MAPPING LAND-USE TRANSITIONS IN KILAKALA AREA: A REMOTE SENSING PERSPECTIVE

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ABSTRACT

The Kilakala area, located in the Municipality of Morogoro, Tanzania, is mainly elevated and situated on the slopes of the Uluguru Mountains. However, the rapid pace of urbanization has resulted in the problem of vegetation and water land use encroachment in this area, which has caused significant changes in the land use patterns over the years. In this regard, a comprehensive study was conducted to create a detailed land use and cover map for the Kilakala area, which could help assess the changes in the area from 1994 to 2018.

To create this map, two primary sources of information were used. Firstly, Landsat 5 imagery and a topographical map of the Kilakala area (Topo Sheet number E6-2) were used. Secondly, a high-resolution satellite image captured in 2018 was used to obtain the necessary information. Furthermore, the Geographical Information System (GIS) was integrated into the study to understand better the changes that had taken place in the area.

The classification results indicated a general trend of increasing built-up areas and declining areas covered by water, vegetation, and bareland land uses. Therefore, the study concluded that built-up land cover has expanded at the expense of vegetation, water, and bareland land covers, which has resulted in significant changes in land use patterns in the Kilakala area. This variation implies that the information on Kilakala land uses, including the 1994 base map, still currently used for land use planning, is no longer adequate without revision.

Keywords: *Land Use Classification, Change Detection, Remote Sensing, Kilakala area*

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1. Introduction

Land use changes and their impacts are a major issue that affects the whole world. As urban areas continue to grow, there are significant changes in land use and land cover, especially in developing countries. Tanzania is one such country where the increase in population and unregulated urban development activities have resulted in the invasion of vegetation, water bodies, and reserved land uses and covers.

The changes are mainly due to human development. They can happen more quickly in urban areas (Msemakweli and Lyimo, 2002), especially because people move from rural to urban areas in search of better living conditions. According to Silayo (1997), information on land use (e.g. base maps) remains static while terrain features change due to urbanization, leading to outdatedness. For example, in urban areas, construction activities change land use from croplands to built-up areas as migrants from rural areas try to establish new settlements in townships. Similarly, in the study conducted by Hegazy and Kaloop (2015), urban and highly developed areas are more likely to experience changes in land use due to human activities. This could involve cutting down vegetation to make way for urban built-up areas.

It is by change detection technique that land use changes can be analyzed. The technique involves comparing two sets of multi-spectral band data that have been obtained from the same geographic area at different times (Belal and Moghanm, 2011). The data can be obtained using either aerial photographs or satellite imagery (ibid.). According to Armenakis et al. (2002), this technique helps identify changes in terrain features over time, especially those caused by human activities that have positive or negative environmental impacts.

With the advancement of technology and improvement in remote sensing data, change detection has become even more effective nowadays. Satellite images are now an effective means of detecting changes in land use and cover since they provide a high temporal resolution and cover a large area (Usery and Welch, 1989), which makes it more cost-effective compared to traditional methods of monitoring land-use change (El-Raey et al., 1995). Mapping experts, land use researchers, and other professionals find remote sensing data highly valuable since it provides a broad view of the area being studied, and collects data in near-real-time. (Quarmby and Cushine, 1989). By leveraging the power of satellite imagery, we can gain insights into the changes taking place on our planet and make informed decisions to ensure sustainable development. (Peter and Tini, 2011).

The use of Geographic Information Systems (GIS) and Remote Sensing in combination is recommended for detecting land use changes in a more efficient and timely manner. This approach is a powerful tool that is widely appreciated by scholars, as it enables the detection of digital changes (Jamebozorg et al. 2014), by involving the use of co-registered remote sensing data to determine and describe changes in land cover and land-use properties. This can be useful in a variety of applications, such as tracking urban growth and identifying other changes in land use/cover (Muchoney and Haack, 1994).

Morogoro town, which includes the Kilakala Area, is situated on the slopes of the Uluguru mountains. This region was once abundant in water resources and lush vegetation (Nkombe, 2003). Unfortunately, due to the lack of a land monitoring system in the highlands and an increase in people clearing vegetation for buildings, the water land cover is gradually drying up. This can be easily observed by comparing published land use information (like the 1994 base map) with current ground features. As a result, the authorities are struggling to manage land use due to the lack of up-to-date information.

The present state of land cover in the highlands is a matter of concern due to the environmental damage caused by human activities and natural disasters. To address this issue, it is imperative to implement a modern approach to monitor land cover in the region. The authorities should leverage the advancements in geospatial technology, such as GIS and remote sensing, to collect precise and accurate data on land cover. This information can then be utilized to take suitable measures to manage land use effectively in the region. By doing so, the authorities can ensure that the highlands are well-protected from further environmental degradation and are preserved for future generations.

The objective of this study was to analyze the impact of Morogoro urban growth towards the Uluguru Mountains on vegetation and water land uses using remote sensing and GIS. The following aspects were required to achieve the main objective:

1. Detect changes in urban growth.
2. Analyze the urban land cover and existing land use changes.
3. Examine the urbanization impact on the land cover/land use changes.

2. Materials and methods

2.1. Location of the studied area

This research study was conducted in the Kilakala area, covered by the Topographical Map sheet number E6-2. The area is situated in the Morogoro Municipality in Tanzania, and its geographical coordinates are between latitude 6^{0}49’10” and 6^{0}49’59” South of the Equator and longitude 37^{0}40’51” and 37^{0}41’48” East of the Central Meridian (refer to Figure 1). The study area was selected based on the author's knowledge, experience, proximity to data, and the rapid rate of people moving into the mountain reserve. The selection aimed to satisfy the requirements postulated in the study's objectives.

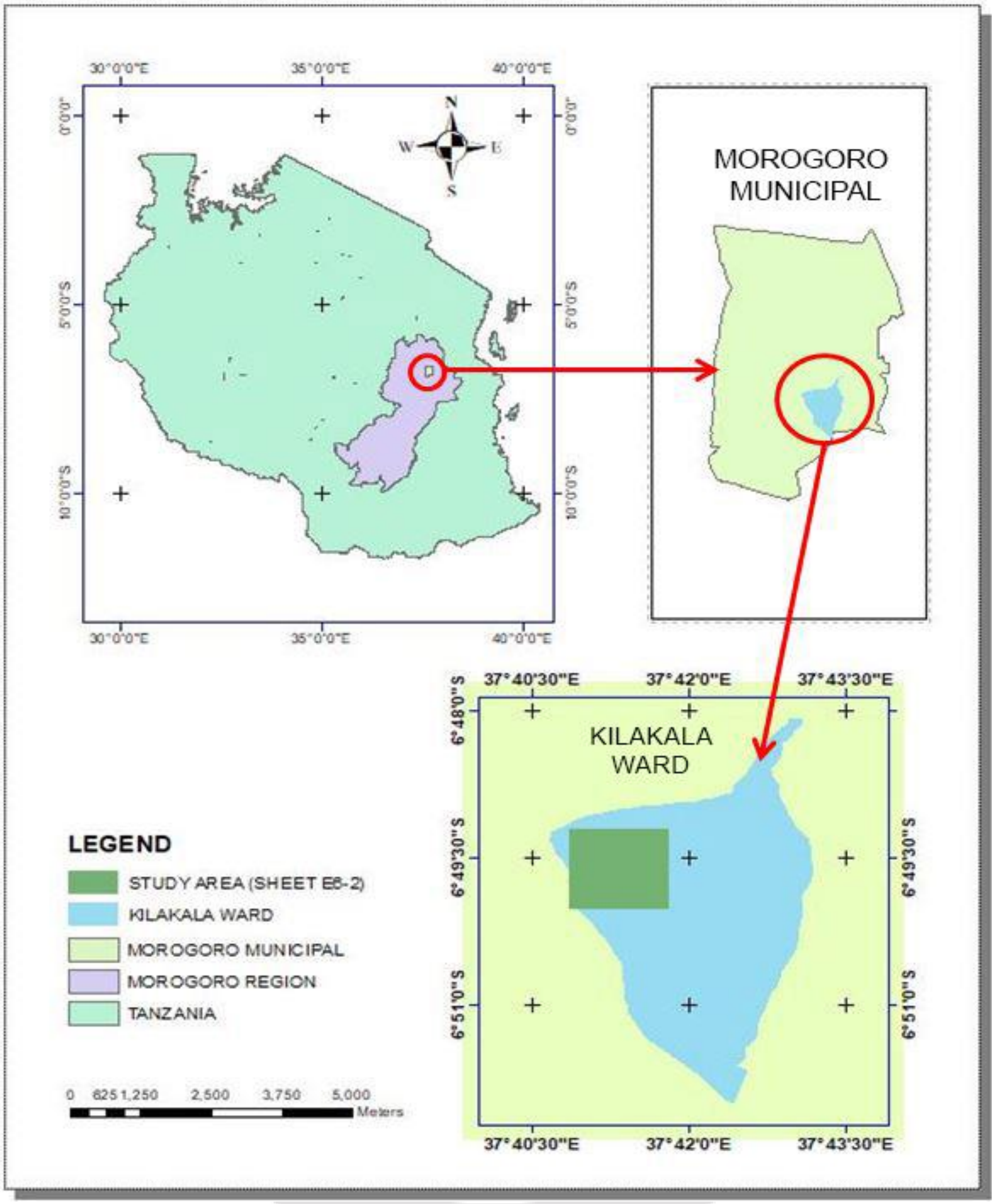

Figure 1: The location of the Study Area

2.2. Digital image processing

The Landsat 5 image, taken in 1994 with a spatial resolution of 30 meters, was digitally processed using ArcGIS version 10.4 and QGIS 3.0 software to ensure its geometrical accuracy, calibration, and dropout removal. Next, the image was resampled to match the 2018 Pleiades imagery, which has a spatial resolution of 0.5 meters. This was done to ensure that both images could be compared accurately.

A specific process was followed to identify different types of land use shown in Landsat 5 imagery. Firstly, training samples were created by digitizing the 1994 Topo Map. These samples were then used to train software to identify different classifications of land use for the year 1994. Similarly, training samples were created for the classification of 2018 imagery based on the knowledge of the area. A joint model for multi-temporal classification was used to assess the land cover and use change detection in the Kilakala area over 24 years, from 1994 to 2018. The post-classification change detection technique was found to be the most accurate method. This technique involves separately classifying the data, which helps minimize the problem of normalizing atmospheric and sensor differences between different dates.

3. Results and Discussions

3.1 Results of Land Use Classification

The results of the land use classification for 1994 show that the area covered by the vegetation class was larger compared to areas covered by other classes, while the area covered by the built-up class was the largest in the 2018 classification. The land use classification results for 1994 and 2018 are respectively presented in Figures 2 and 3.

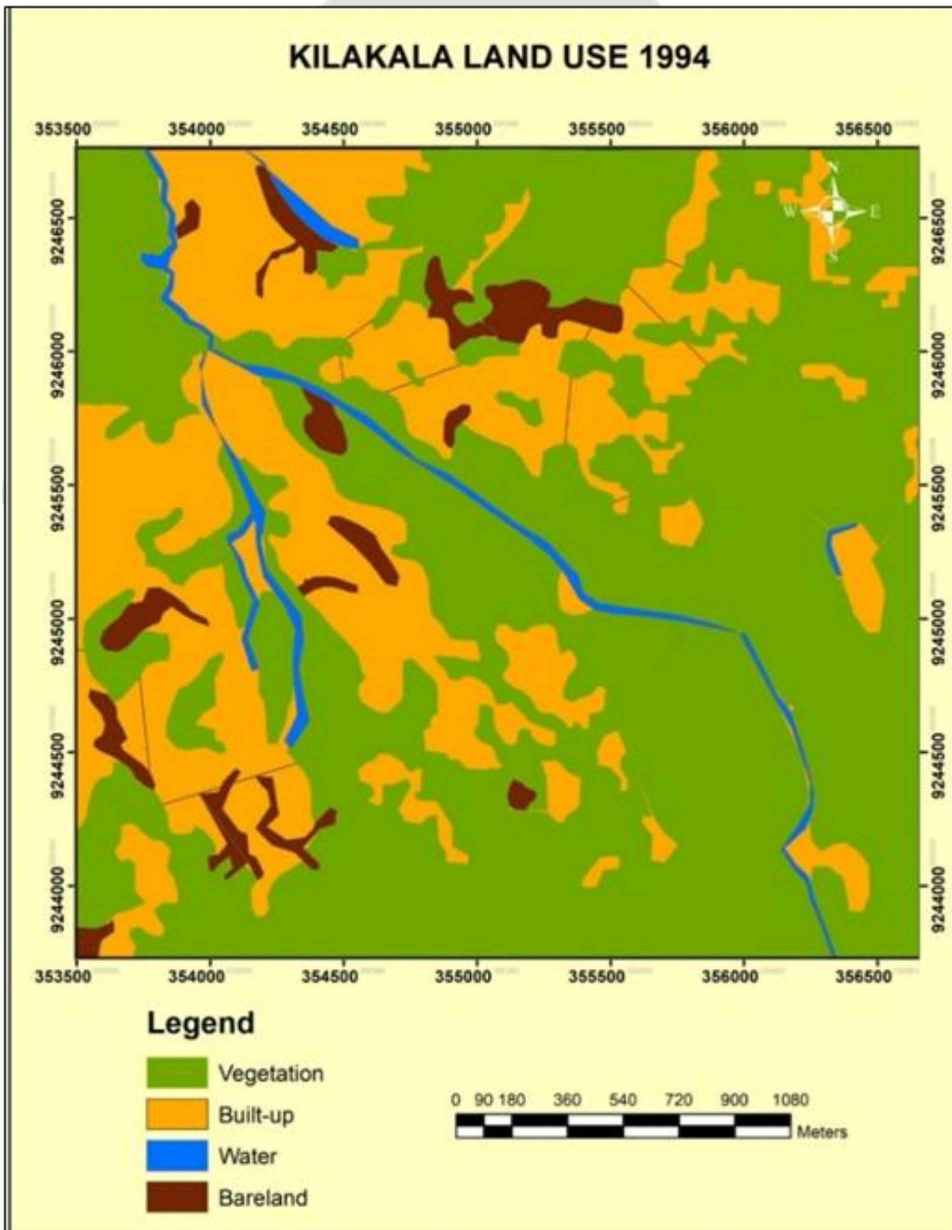

Figure 2: The 1994 land cover of the Kilakala area

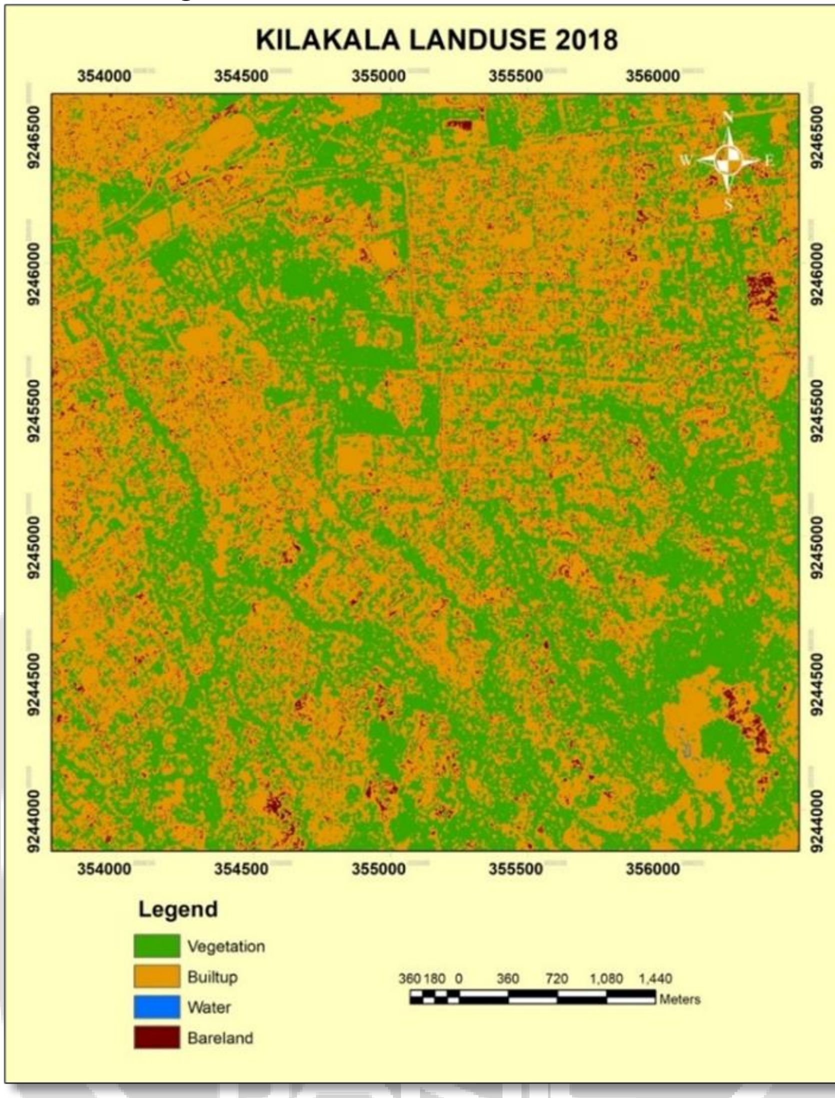

Figure 3: The 2018 land cover of the Kilakala area

3.2 Land Cover Change since 1994

The area of each land use class was computed by knowing the pixel size from raster resolution and by the use of units as defined in the projection. In 1994, vegetation was the major type of land use, accounting for about 61.53% of the total area. However, in 2018, the built-up area was the major type. During the 24-year time frame, vegetation and water land uses declined by 33.06% and 70.54% respectively while the bareland land use area decreased by only 7.6%. The built-up area increased by 64.4%. (Table 1).

Table 1: Landuse areas (ha) comparisons based on four classes between 1994 and 2018

Landuse	2018		1994		Land Change between 1994 and 2018		Average rate of change 1994-2018	
	Area(ha)	%	Area(ha)	%	Area	%	ha/Year	%
Vegetation	409	41.19	610	61.53	-201	-33.06	-8	-1.38

Built-up	546	55.14	332	33.54	214	64.39	8	2.68
Water	4	0.42	14	1.41	-9	-70.54	-0.35	-2.94
Bareland	32	3.25	35	3.52	-2	-7.59	-0.54	-0.32
Total	991		991					

Based on the coverage of 9909974 square meters (i.e., 991ha), vegetation covered 609.76ha in 1994 but decreased to 408.19ha in 2018. This shows a decline in vegetation land use by 33.06%. Water and bareland also declined by 70.54% and 7.59% respectively. It is only the built-up class that expanded, which indicates that land from vegetation, water, and bareland classes was converted to built-up areas. For the period of 24 years (1994-2018), the built-up area gained 64.39% of land, at a rate of 2.68% per year.

3.3 The causes of the Land use change

Upon comparing the land use classification maps from 1994 to 2018 (Figure 4), it is evident that the areas covered by vegetation and water have significantly decreased over time. Additionally, this study observed that the streams flowing from the highlands to River Kilakala have transformed from permanent to seasonal streams. These streams only seem to flow during the wet season, and the flow stops in the dry season. Furthermore, there have been cases of tree cutting and site clearance for building construction.

According to a study conducted by Nkombe in 2003, the degradation of the Uluguru Mountains vegetation which is located in areas with low arable land capacity is majorly caused by population growth. That study finding was seconded by an article by Kimati (2015) published in the Daily News Magazine also reported that population growth was encroaching on water sources in the same area.

In the Morogoro municipality, where the study was conducted, there has been an increase in the number of people migrating from rural areas and other regions of Tanzania to Morogoro Urban. Furthermore, a report by NBS (2006) indicated that Tanzania's urban population growth was faster between 1967 and 2002 (as shown in Figure 5). Such growth has a significant impact on vegetation reserves as immigrants need to establish settlements

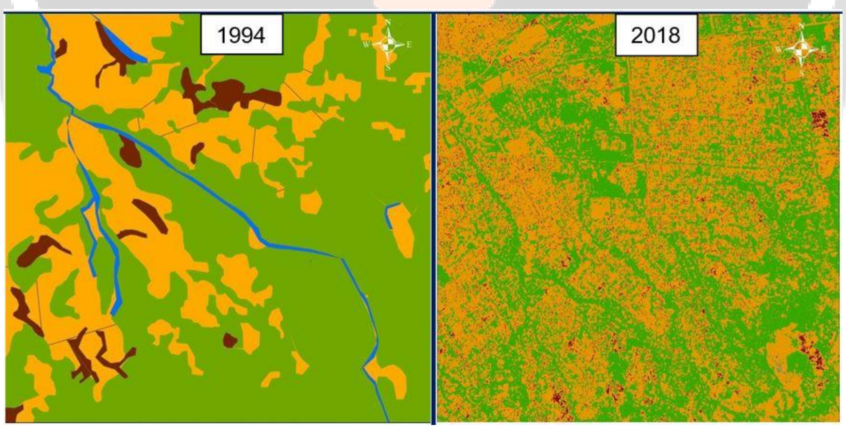

Figure 4: Comparison of land covers between 1994 and 2018

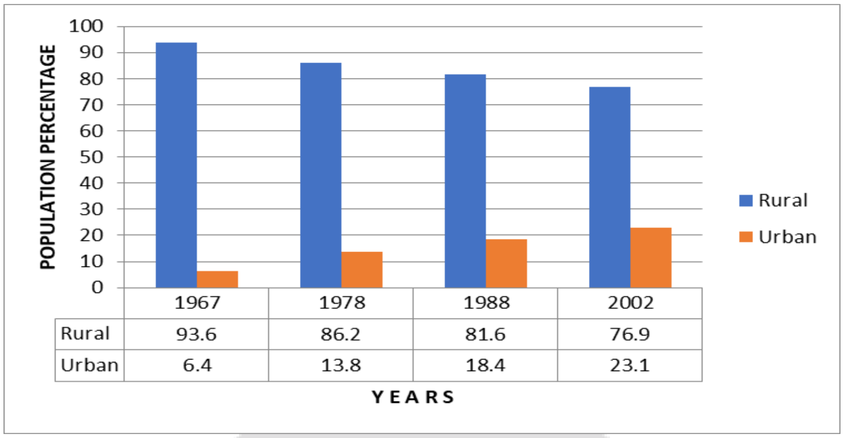

Figure 5: Rural-urban distribution of population for 1967, 1978, 1988, and 2002 years.
Source: Tanzania National Bureau of Statistics (NBS), 2006

A study conducted by Kloek (2011) revealed that many people are migrating to Morogoro in search of a better life. This is because most rural areas lack social services like healthcare and business opportunities. Unfortunately, the rate of immigration appears to be faster than the rate of planning for land use. When surveyed plots become difficult to acquire due to long processes or planning and surveying delays, migrants often encroach on the vegetation land cover to establish human settlements.

The vegetation in the Kilakala Highlands and the Uluguru Mountains plays a vital role in protecting the environment. It regulates the soil water of the area and protects the biodiversity of wildlife, including bird species that are unique to the Morogoro region. Several studies have highlighted the importance of this rich biodiversity, including research papers by Nkombe (2003), J. Finch et al. (2009), and papers funded by the Eastern Arc Mountains Conservation Endowment Fund (EAMCEF) from 2001 – 2010.

However, the continuous degradation of the vegetation in the mountains has significant negative effects on the environment, including the loss of biodiversity and stream degradation of the river Kilakala. As the population density increases in the highlands, trees are cleared to make room for settlements. Construction and urban expansion are still ongoing, and if the rate of urban expansion remains unchecked, the size of the vegetation land use will continue to decline.

4. CONCLUSIONS

The general trend observed from the classification results was an increase in built-up areas and declining in areas covered by bareland, water, and vegetation land covers. This indicated that built-up land cover has expanded at the expense of vegetation, water, and bareland land covers. With this variation, the existing information on land uses is rendered useless for planning without revision.

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