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Spatial Monitoring of Urban Growth Using GIS and Remote Sensing: A Case Study of Nairobi Metropolitan Area, Kenya

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Abstract Nairobi city expanded spatially leading to the formation of the 32,514 km^2 Nairobi Metropolitan Area. The region faces rapid urbanization challenges and lacks reliable data for urban planning. This study is aimed at monitoring the urban land cover using GIS and Remote Sensing techniques. Three different land cover maps produced at ten year epochs between 1995 and 2015 were used to evaluate and analyse urban growth visually and quantitatively. Spatial metrics indices and the Annual Urban Spatial Expansion Index were employed in the quantitative analyses. Urban land cover increased from 408.99 km^2 to 763.79 km^2 and to 2,187.82 km^2 with annual growth rates of 8.4% and 17.2% in the two study period epochs. The areas had annual spatial expansion indices of 4.58% and 6.32% respectively in the periods 1995- 2000 and 2000-2015. Radial-axial expansion of built-up areas along transport routes led to the expansion of urban areas into agricultural and forest land. The region's spatial plan forecasted an urban land cover of 1,717.72km^2 by the year 2030, yet by the year 2015, the urban area was 2,187.82 km^2. These growth characteristics will have an effect on the location of the proposed Cyber city, Knowledge-cum-Health city and the Aerotropolis, as proposed in the spatial planning concept of the NMR. The spatial analysis of the NMR growth trends could support in the urban growth management mechanisms and plans for sustainable development.

Keywords GIS, Remote Sensing, Spatial urban growth, Nairobi Metropolitan Region, Sustainable development

1. Introduction

Urbanization is the process by which large numbers of people become permanently concentrated in relatively small areas. It is induced by physical geography, living and property costs, demand for more living space transportation, and lack of proper planning policies [2]. The world is rapidly urbanizing and cities are experiencing the dynamic processes of urbanization and globalization [8]. A large percentage of the world's population reside in metropolitan areas of developing countries [18] thereby raising a need of urban planning. Kenya being one of Africa's fastest urbanizing countries had 215 urban centers in the year 2009 with Nairobi as the capital city [10]. Twenty four (24) of these urban centers are located within the Nairobi Metropolitan Region (NMR).

Previous land use/cover studies revealed that there was unsustainable sprawl of Nairobi city [12]. It is estimated that by the year 2030, 61.5% of the urban population will live within the NMR [13]. The Kenya Vision 2030, an economic and social development program, proposed flagship projects to spur development across the country, one being the creation of six metropolitan areas covering the main cities. The NMR project was the first be set up with a vision to grow and develop into a world class African metropolis capable of creating sustainable wealth and offer a high quality of life to its residents, the people of Kenya and investors by the year 2030 [7]. It was earmarked for rapid economic development since it plays an important role locally in the Kenyan economy, regionally, as well as globally.

Urban growth, being a land use/cover change phenomena from a non-urban category to an urban category [3] is a dynamic and complex phenomenon revealing economic development. Spatial temporal urban growth indicates the spatial and temporal dimensions of land cover/ use change at the level of the urban landscape [5]. Urban land covers a smaller area compared to other land covers but its impact to the surrounding environment is higher. It alters the land use pattern, land values and the intensity of site use [15]. Urban growth combined with urban sprawl, inadequate infrastructure and land use planning have posed a challenge in the Nairobi Metropolitan Region-NMR [8].

Urban growth generates a lot of problems and challenges economically, socially and environmentally [13]. It has both negative and positive effects on the ecological and social

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systems. Urbanization when ignored may intimidate sustainable development. [6]. Urban expansion in the NMR has induced significant socio-economic, environmental and health challenges [4] raising a need of urban planning.

Urban development is a large resource consumant that calls for proper planning and monitoring [10]. Lack of information about urban spatial growth taking place in different parts of the metropolitan region has limited the process of urban and regional planning and development management [8]. Urbanization in the NMR has led to high land prices, low forest cover, and encroachment on conservation areas such as the Athi and Tana River catchments [9].

The Ministry of Nairobi Metropolitan Development (MoNMeD) developed a spatial plan to determine how the NMR was to develop. The plan was to guide and coordinate development of infrastructural facilities and services and for the specific control of the use and development of land [10]. It proposed spatial modelling for the NMR through six new towns as new growth centres in the national economy as well as to accommodate new activities meant to decongest Nairobi city [7]. The selection of the proposed new towns locations were based on accessibility from the road network, topography, availability of low productivity agricultural land, low interference with ecologically sensitive and conservation areas, and good potential for landscaping. This left out the crucial urbanization factor.

Spatial planning requires information on the existing land-use/land-cover pattern, its spatial distribution and changes [17]. Urbanization determines the implementation of spatial planning proposals and of course has an impact on sustainability of urban ecosystems. For the comprehensive land-use planning of urban areas, current and accurate land use information is vital for spatial planning and management [11]. Monitoring urban growth in the NMR is necessary for implementing appropriate strategies regarding the urban planning decision making process and in redrawing urban policies in the NMR.

The main objective of this study was to monitor growth in the urban land cover by analyzing the spatial-temporal urban land use/cover changes that occurred in the region before and after the creation of the Nairobi Metropolitan Area using GIS and remote sensing techniques. Landsat images were characterised, mapped and quantified to reveal changes in the built-up land cover from which changes in growth and pattern were evaluated and analysed.

The study focuses on the expansion of urban areas as sign of economic development. Remote sensing and GIS technologies are used since they are a proper and effective tool to understand and present the phenomenon. Mapping unplanned urban expansion provides a “picture” of where this type of growth is occurring; its negative effects and suggests mitigation measures [17]. Accurate mapping of urban lands and monitoring urban expansions are significant for optimum urban analysis in urban planning of metropolitan regions [1]. Spatial temporal urban growth caused by infill and by the vertical dimension of space was not considered in assessing urban growth with regard to settlement expansion.

This study answers questions such as where did urban growth occur in the NMR between 1995 and 2005?; at what rate and how much land was converted to urban land cover within the study period?; and which urban growth theory explains the expansion. These questions were answered with the aid of spatial metrics(total area-TA, class area-CA, number of patches-NP, patch density-PD, largest patch-LP, largest patch index-LPI, mean patch size-MPS), urban growth indicators (annual urban spatial expansion index-AUSEI) and through visual interpretation of the resultant urban land cover maps. Spatial metrics are numerical indices to describe structure and patterns of a landscape [14]. They quantify and describe the underlying structure and patterns of urban landscape from geospatial data [16].

The study will enable spatial planners to determine the possibility to implement proposed development programs as it is possible to identify the available and lost land cover as a result of new urban development. With this information, urban growth management mechanisms such as urban growth boundaries and delineation of land uses can be implemented.

2. Materials and Methods

To acquire the information needed in monitoring spatial urban growth in the NMR, GIS and Remote Sensing technologies were used.

2.1. The Study Area

This study focuses on the Nairobi metropolitan region (NMR) comprising of four (4) out of the forty seven (47) counties in Kenya namely: Nairobi, Kiambu, Machakos, and Kajiado (Figure 1). The area is a highly urbanizing region with 24 urban centres. Nairobi city being the most dominant is the core of the metropolis. The region extends over an area of approximately 32514km^2 that substantially depend on Nairobi city for employment and social facilities.

The NMR is strategically located as a central gateway to the East and Central African region as well as its positioning on the Northern corridor and the Cape to Cairo highway. International trunk roads A104, A109 pass through the area enabling movement of traffic to/from Mombasa to neighbouring landlocked countries of Uganda, Rwanda, South Sudan and Ethiopia. These characteristics present significant strengths for the region as it provides useful access points to various markets in Africa and particularly for the Indian Ocean islands and South Asia.

The Metro Vision 2030 divided the NMR into foursub-regions: Core Nairobi (Nairobi county), the Northern Metro (Kiambu county), the Eastern Metro (Machakos county) and Southern Metro (Kajiado county).

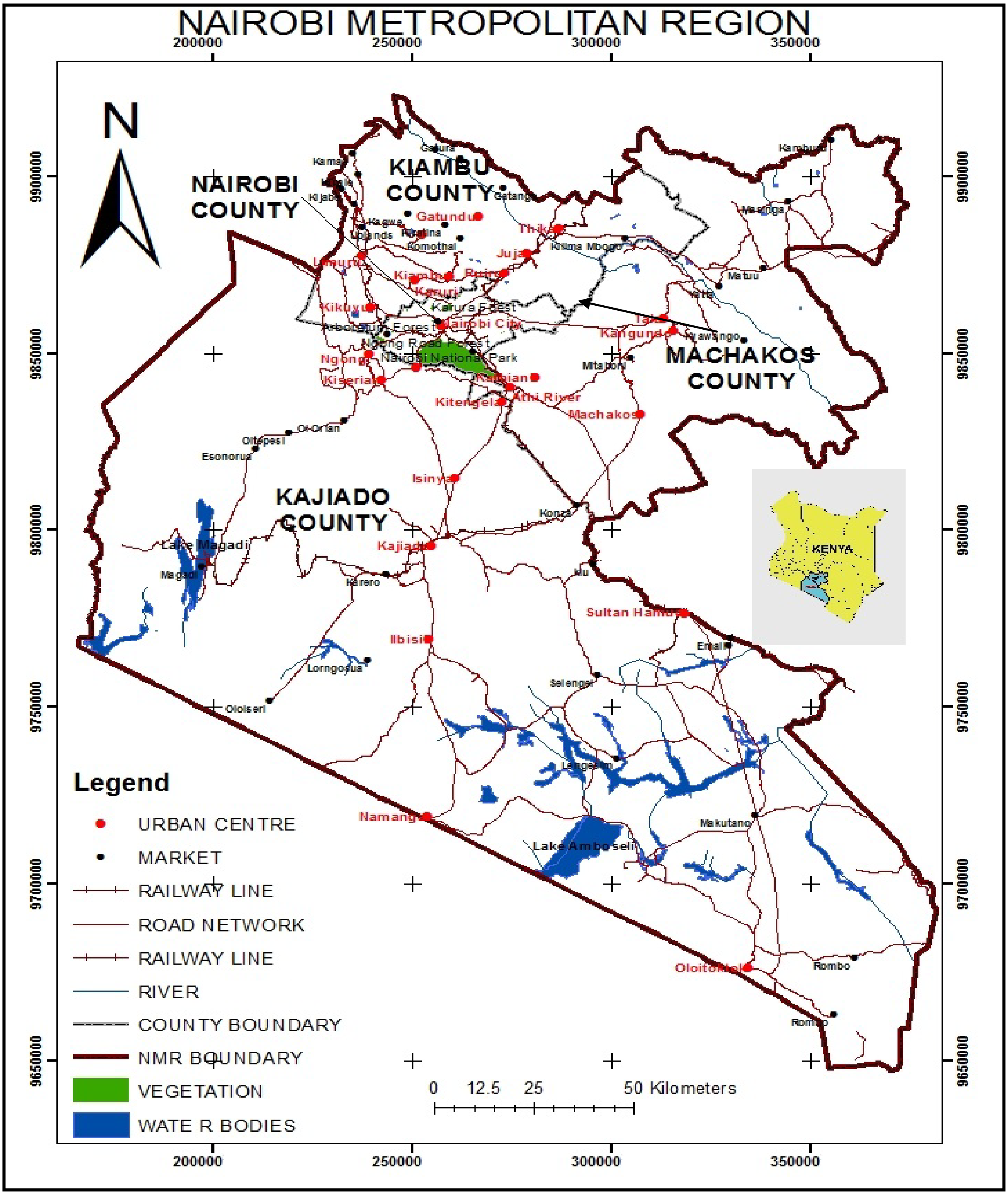

Figure 1. Study Area, The Nairobi Metropolitan Area

2.2. Study Approach

Figure 2 below graphically illustrates how the research was carried out to attain the main objective.

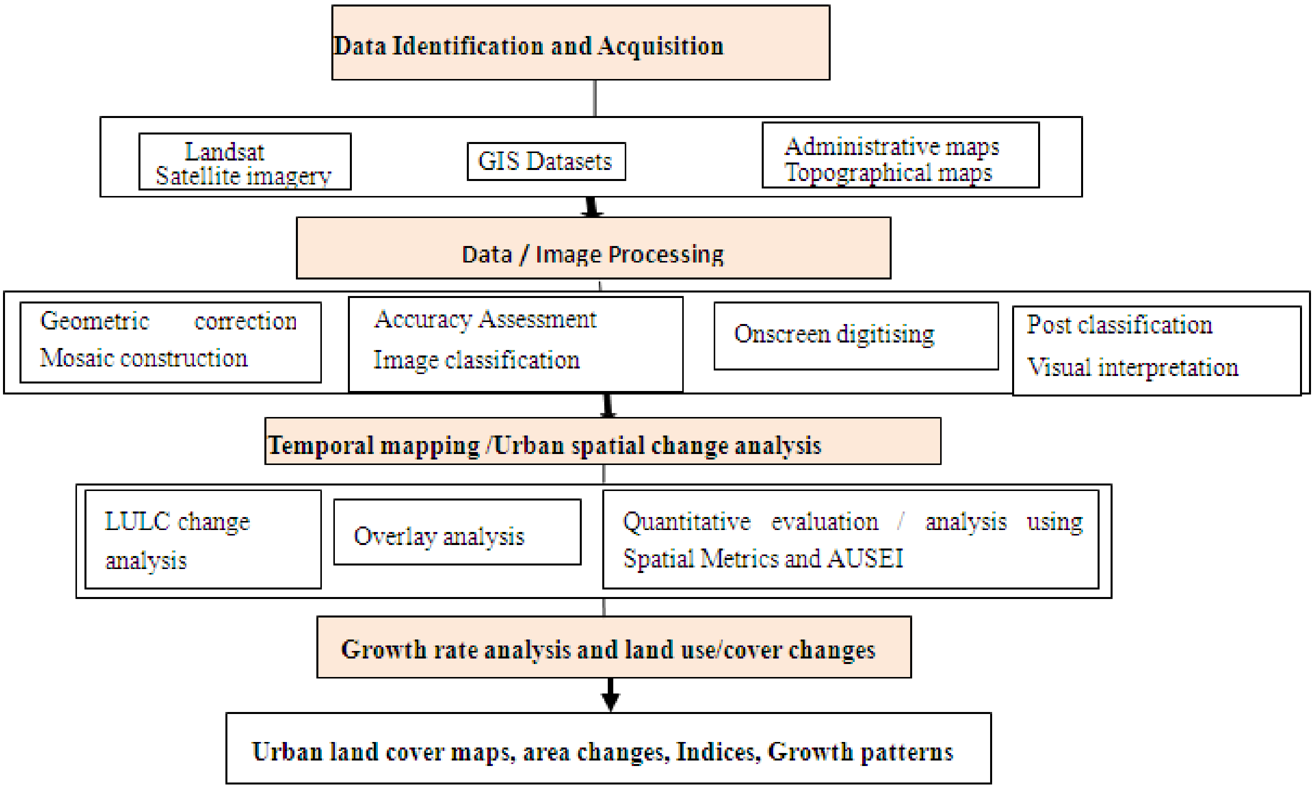

Figure 2. Study Approach

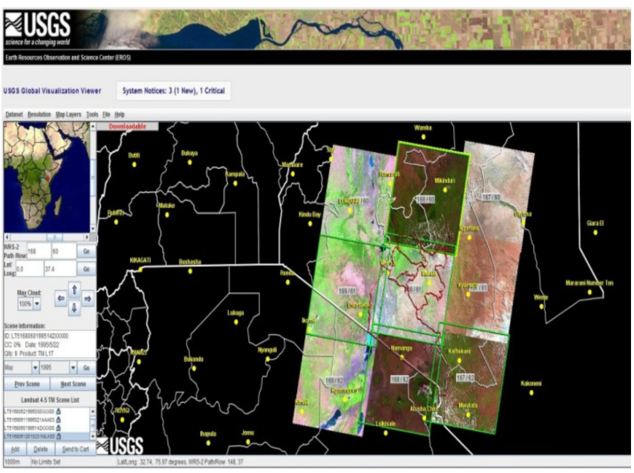

Figure 3. Landsat scenes overlay of the study area

Table 1. Images used

SENSOR	YEAR / PATH / ROW	SOURCE
Landsat 5 TM	1995, path 167 row 62, path 168 row 61,62& 62, path 169 row 61	USGS
Landsat 7 ETM+	2005, path 167 row 62, path 168 row 61,62 & 63, path 169 row 61	USGS
Landsat 8 OLI	2015, path 167 row 62, path 168 row 61,62& 62, path 169 row 61	USGS

2.3. Data

Landsat imagery downloaded from United States Geological Survey (USGS) archives were used to reveal the extent of urbanized land in the region. Five scenes of Landsat 5 TM for 1995, Landsat 7 ETM+ for 2005 and Landsat 8 OLI for 2015 covering path 167 row 62, path 168 row 61,62 & 62, path 169 row 61 were used in land cover mapping (Figure 3 and Table 1).

2.4. Methods

To capture the urban land use/cover in the study area from the imagery, data and image processing was done followed by temporal mapping and urban spatial change analysis. Digital image processing involved layer stacking, radiometric and geometric corrections, spatial enhancement, mosaicking, subsetting to curve out the AOI, and classification processes. The Scan Line Corrector (SLC) device in Landsat 7 malfunctioned in the year 2003 causing stripping (gaps) in the imagery. To fill these gaps in the 2005 image, (destripping), focal analysis which is an iterative process, was adopted. The images were then enhanced to improve their visual appearance by applying a contrast adjustment technique, (Histogram Equalization).

The images were classified into five feature classes namely: Built-up, Vegetation, Bare land, Water and Other lands using maximum likelihood classification algorithm in the supervised classification technique. The bare land class comprised the undeveloped or un-built-up areas in the study area. The classification process had some challenges. Surfaces with similar spectral properties led to misclassification of some land covers. Land covers that did not fall under built-up, vegetation, bare land or water classes were classified as other lands and the remaining cloud cover in the imagery after clearance was classified as water.

Classification accuracy assessment was done by referencing and assessing 40 randomly generated points of each class to the Google earth high resolution images by synchronizing the ERDAS view with Google earth. The accuracy assessment report was then evaluated.

The resultant classes were regrouped into built-up and non-built-up for easy analysis. The urban centre locations were singled out to capture built-up areas. Built-up areas characterized urban areas and were curved out from the classified images. The twenty four urban centres within the NMR were singled out and the built up areas mapped to display the nature of changes in the years 1995, 2005 and 2015 classified images. Post classification comparison approach was adopted for land use/cover change analysis. The analysis involved calculating the increase in the area of urbanized land over time and their growth rates using one urban growth indicator (the Annual Urban Spatial Expansion Index), growth rates and seven spatial metrics.

3. Results and Discussion

Post classification image differencing was used to show the changes in urban land cover. The classified study area was mapped, quantified, analysed and evaluated.

3.1. Classification

The classified images had five land cover classes which were presented in different tones (figure 4, 5 and 6). Surfaces with similar spectral properties presented a challenge in the classification process leading to misclassification of some land covers.

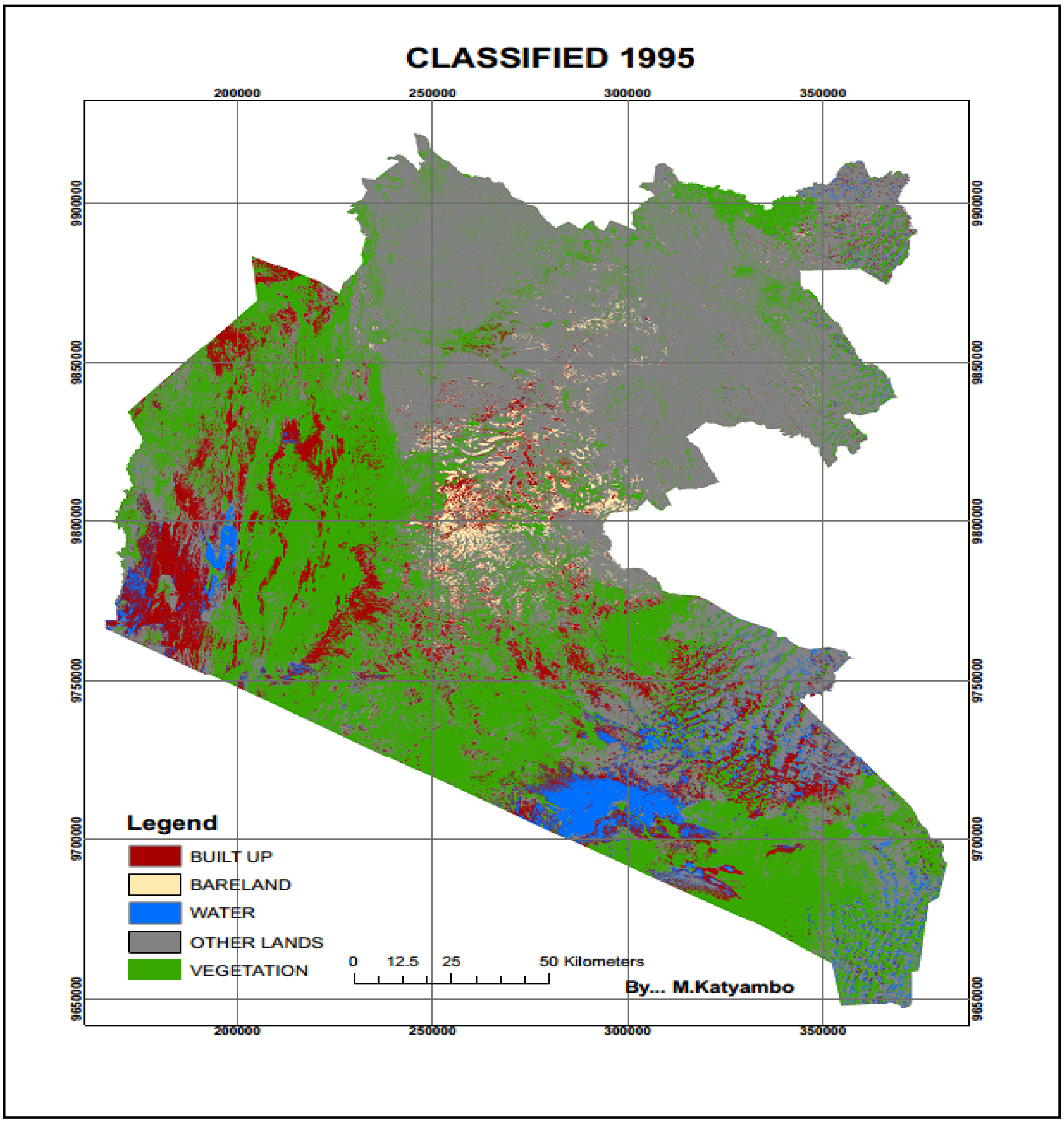

Figure 4. Classification Results 1995

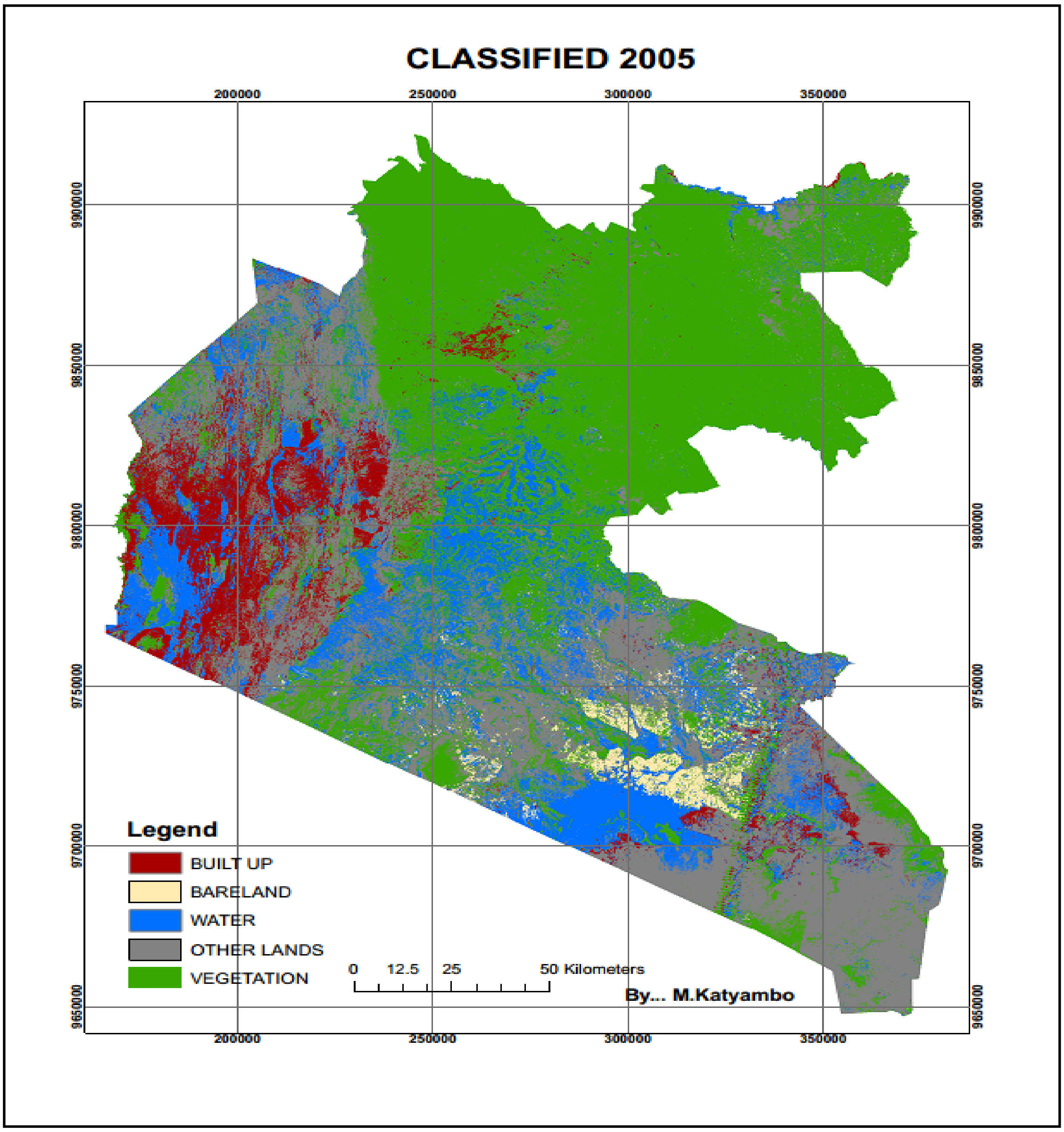

Figure 5. Classification Results 2005

3.2. Accuracy Assessment

The generated accuracy assessment report showed the Producer's, User's, Overall accuracies and Kappa Coefficients (Table 2).

Table 2. Accuracy Assessment results

YEAR	Overall Accuracy (%)	Kappa Statistics
1995	87.1	0.82
2005	87.62	0.81
2015	87.94	0.85

3.3. Class Area Change Detection

From the classified images, land cover class areas in square kilometres were generated (Table 3). Classification results show that the built-up land cover increased from 1254.30km^2 (3.9%) in 1995 to 2030.05km^2 (6.3%) in 2005 to 3494.62km^2 (10.9%) in 2015. Bare land and vegetation class areas reduced between 1995 and 2015 indicating a takeover. The areas reduced as e result of infill and extension developments. Bare lands were built-up while vegetation was cleared to create space for development (Table 3).

The built-up cover grew at a rate of 77.58km^2 per year between 1995 and 2005. Between 2005 and 2015 the built-up land cover grew at a rate of 146.46km^2 per year.

The built-up class area in Table 3 does not represent the urban area cover in the region since it excludes areas like open spaces, parks, airports, dump sites etc. and vegetation within the selected urban centres. On the other hand, the class reveals changes due to infill and extension developments including the built up areas in the rural parts of the NMR. The aim of this study was to monitor the urban land cover by quantifying the changes that occurred between 1995 and 2015.

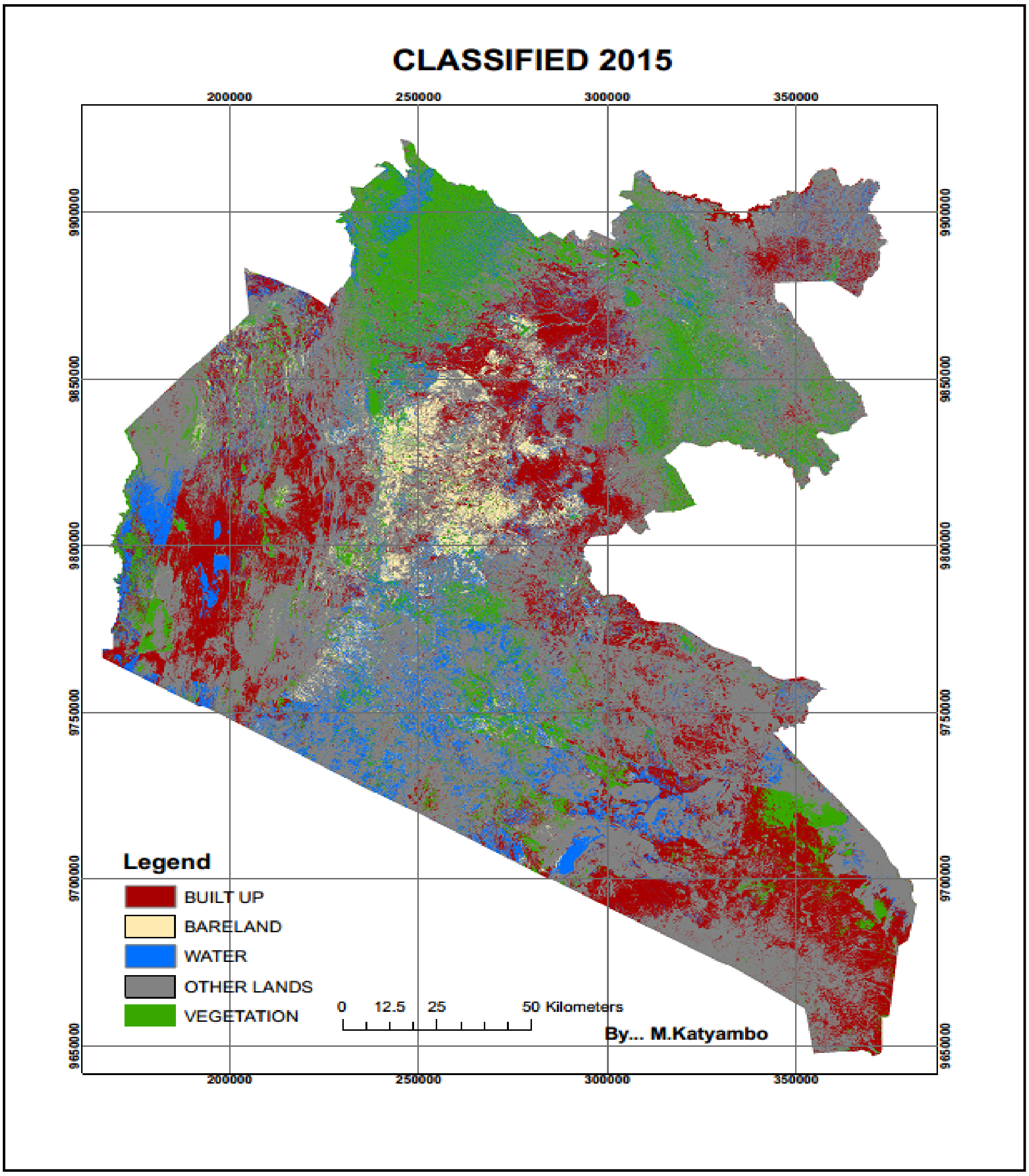

Figure 6. Classification Results 2015

Table 3. NMR Land cover class areas for 1995, 2005 and 2015

	Land Cover	YEAR/ Area (km^2)		
		1995	**2005**	**2015**
1	Built Up	1,254.30	2,030.05	3,494.62
2	Vegetation	14,722.22	14,465.15	13,783.75
3	Bare land	4,103.94	3,838.12	3,332.81
4	Water	5,421.15	5,398.17	5,350.74
5	Other Lands	6,657.71	6 ,427.87	6,197.31
	Totals	32,159.32	32,159.46	32,159.23

3.4. Description of Urban Land Use/Cover Changes

This study is all about urban expansion in the NMR only. To define and quantify urban areas in the study area, land cover classes were grouped into built-up and non-built –up (Table 4).

Table 4. Regrouped land cover classes

Category	Descriptions
Built Up	Comprises all buildings in selected urban centres (commercial & residential), roads (within the built up areas), and railway networks, impervious features, airports, vegetation, open spaces (Bareland), and dumpsites within these centres, sport and leisure facilities, parks, etc.
Non- Built-Up	Comprises vegetation (forests, grasslands, agricultural) away from the urban centres, Water, roads (in rural areas and those connecting urban centres) and Bare land not within the urban centres (open spaces) and the class other lands.

In a GIS environment, the 24 urban centres were curved out from the classified images (using ArcGis 10.1). Maps showing built-up(urban) and non built-up(rural) land cover for years 1995, 2005 and 2015 (Figures 7, 8 and 9).

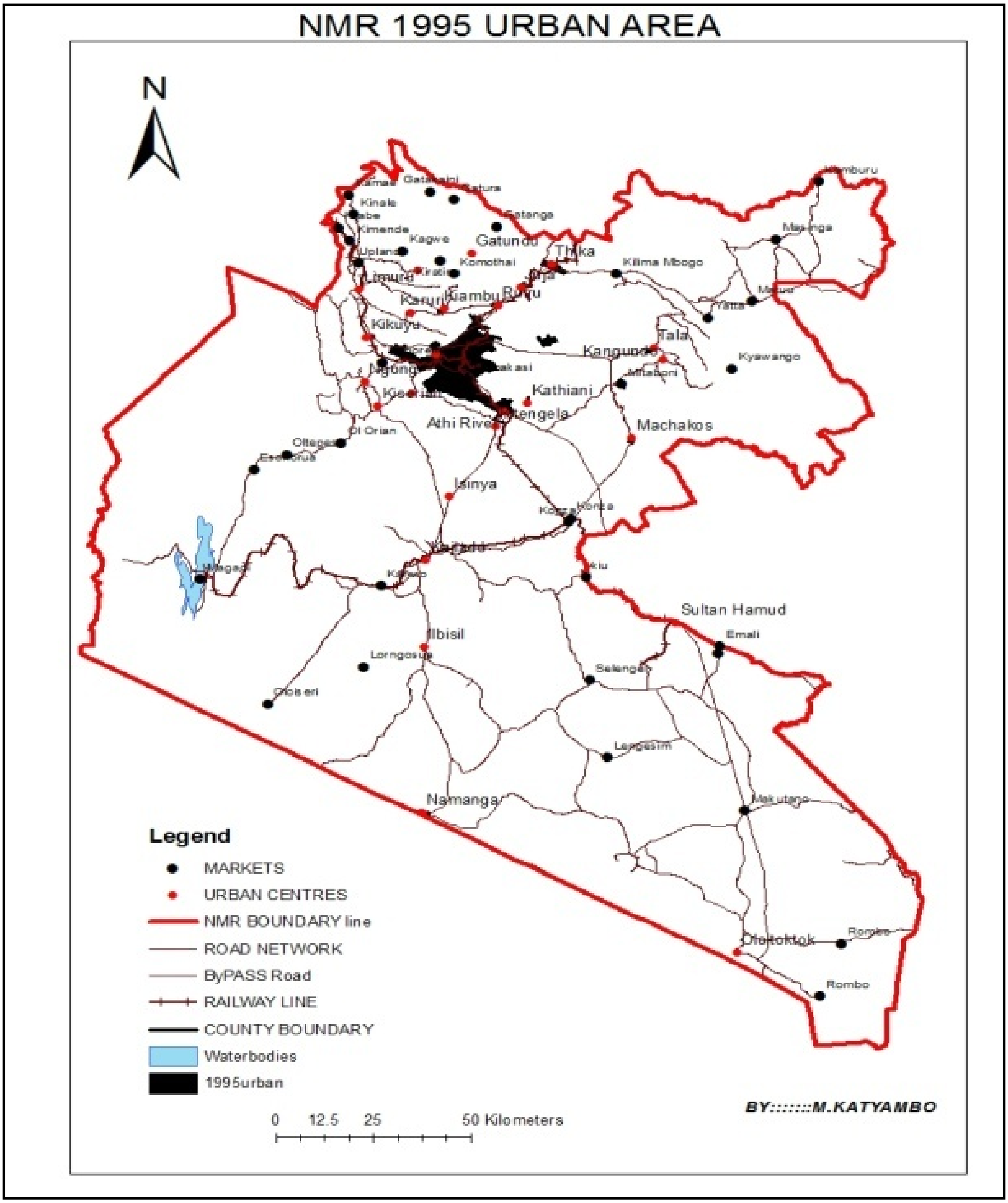

Figure 7. 1995 Urban Area

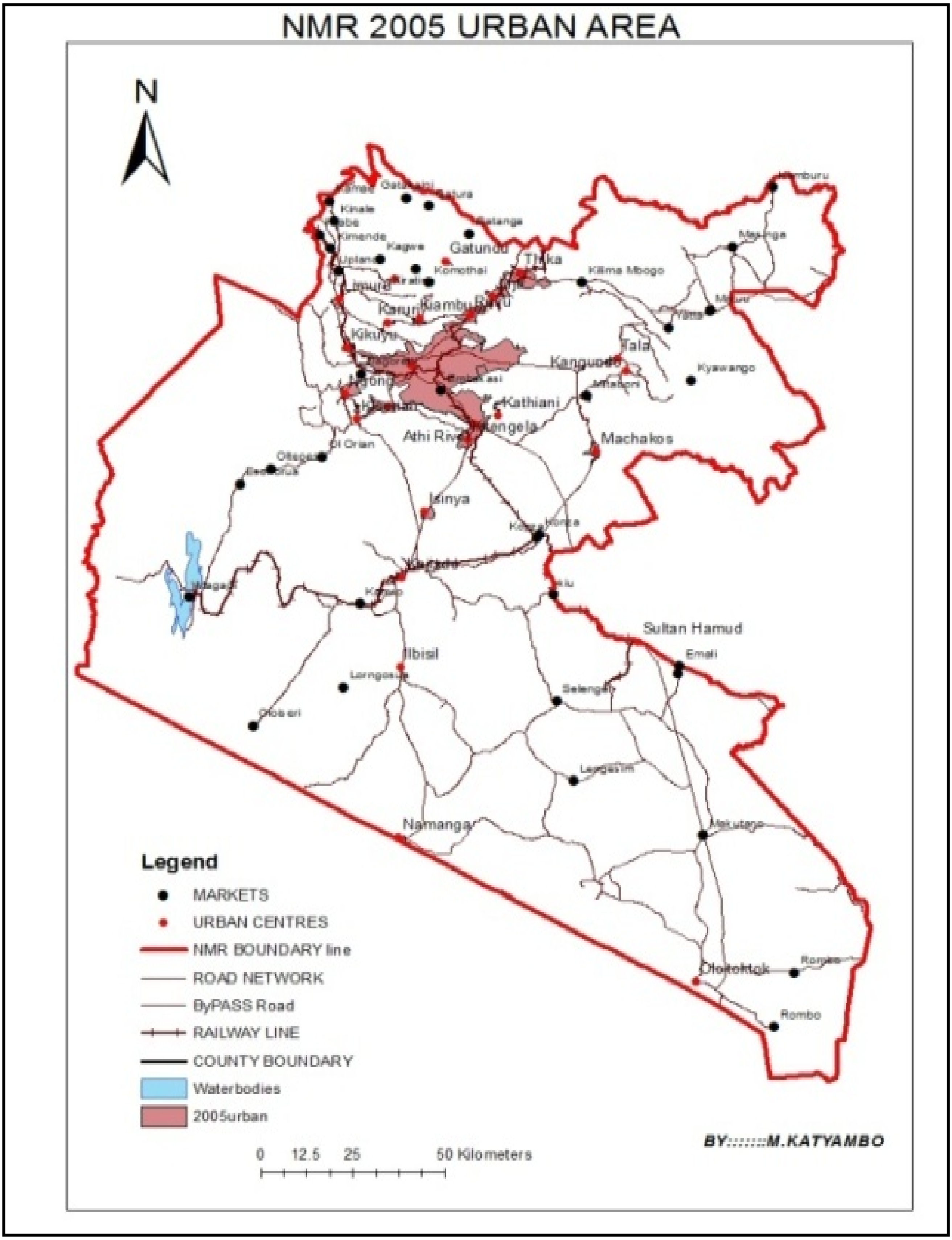

Figure 8. 2005 Urban Area

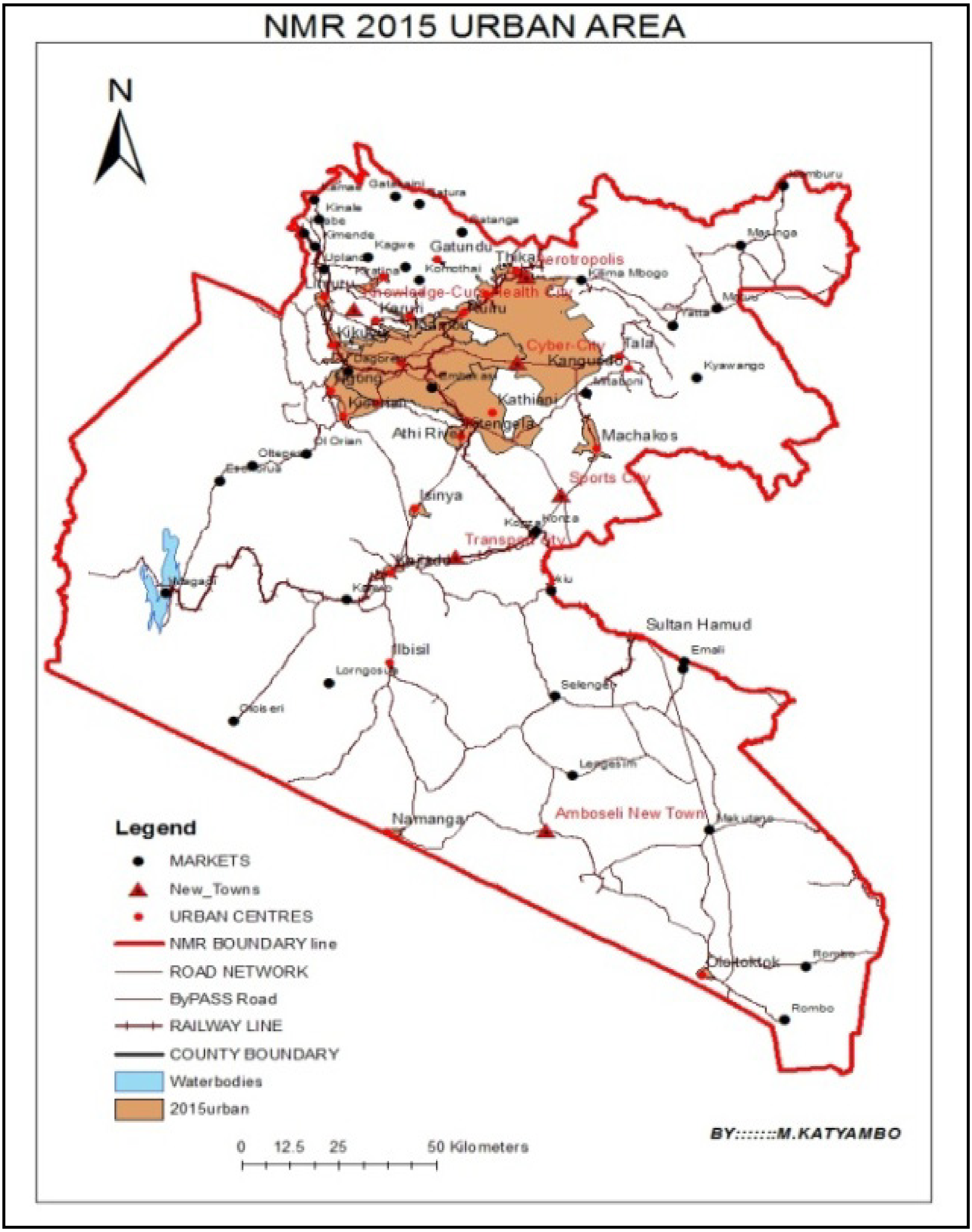

Figure 9. 2015 Urban Area

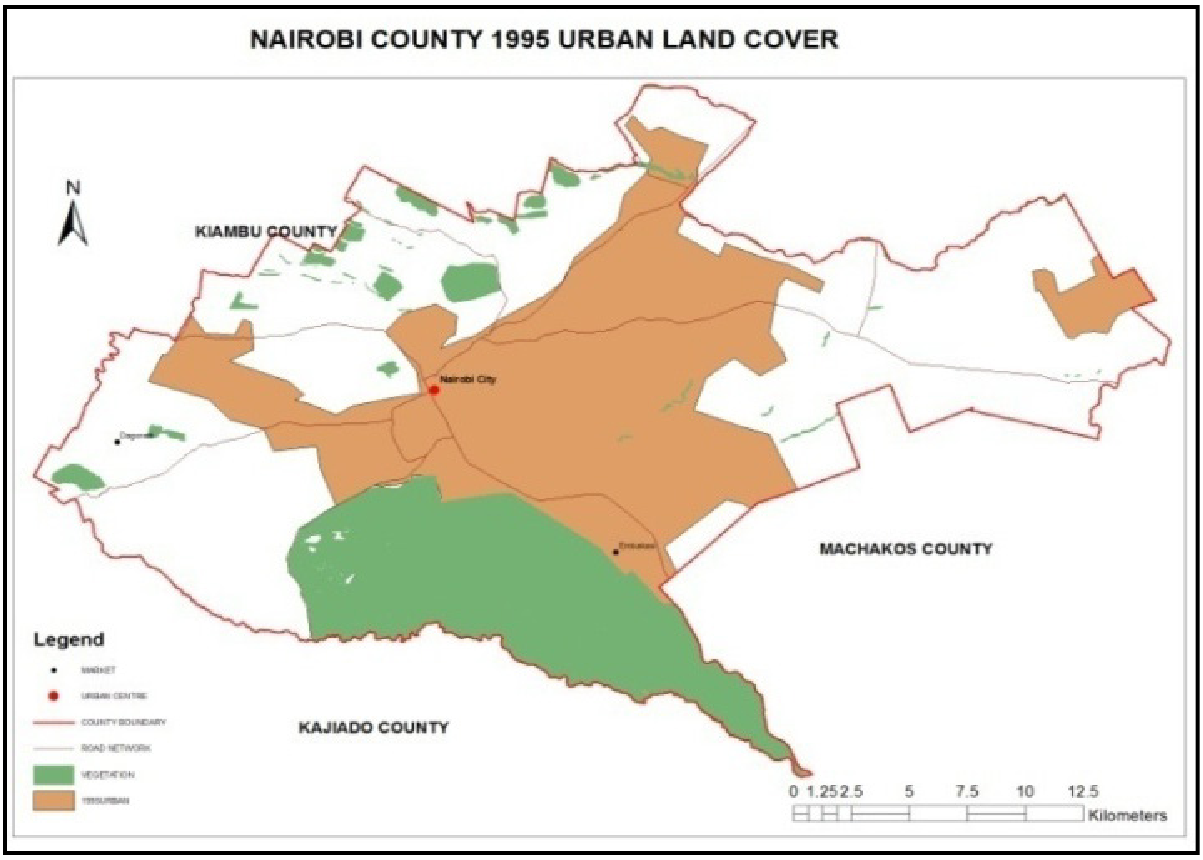

Figure 10a. Nairobi County 1995 Urban land cover

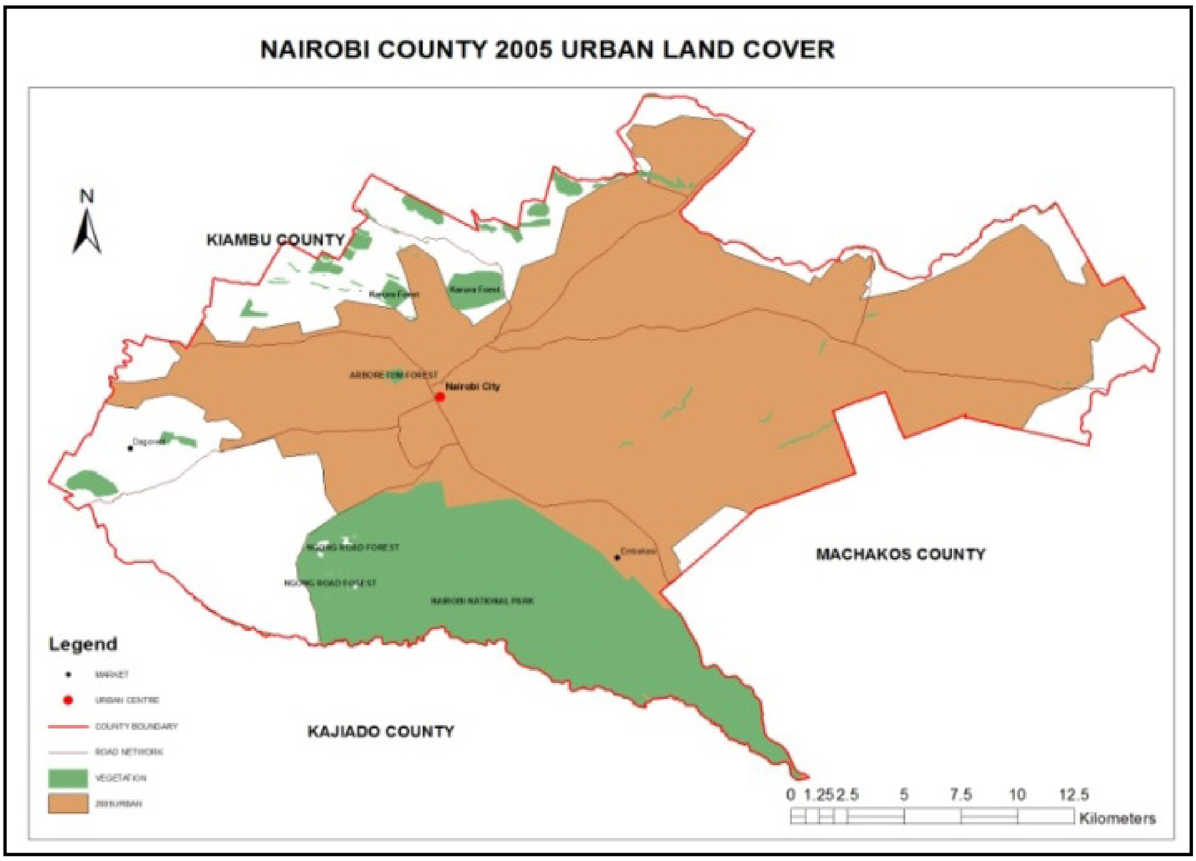

Figure 10b. Nairobi County 2005 Urban land cover

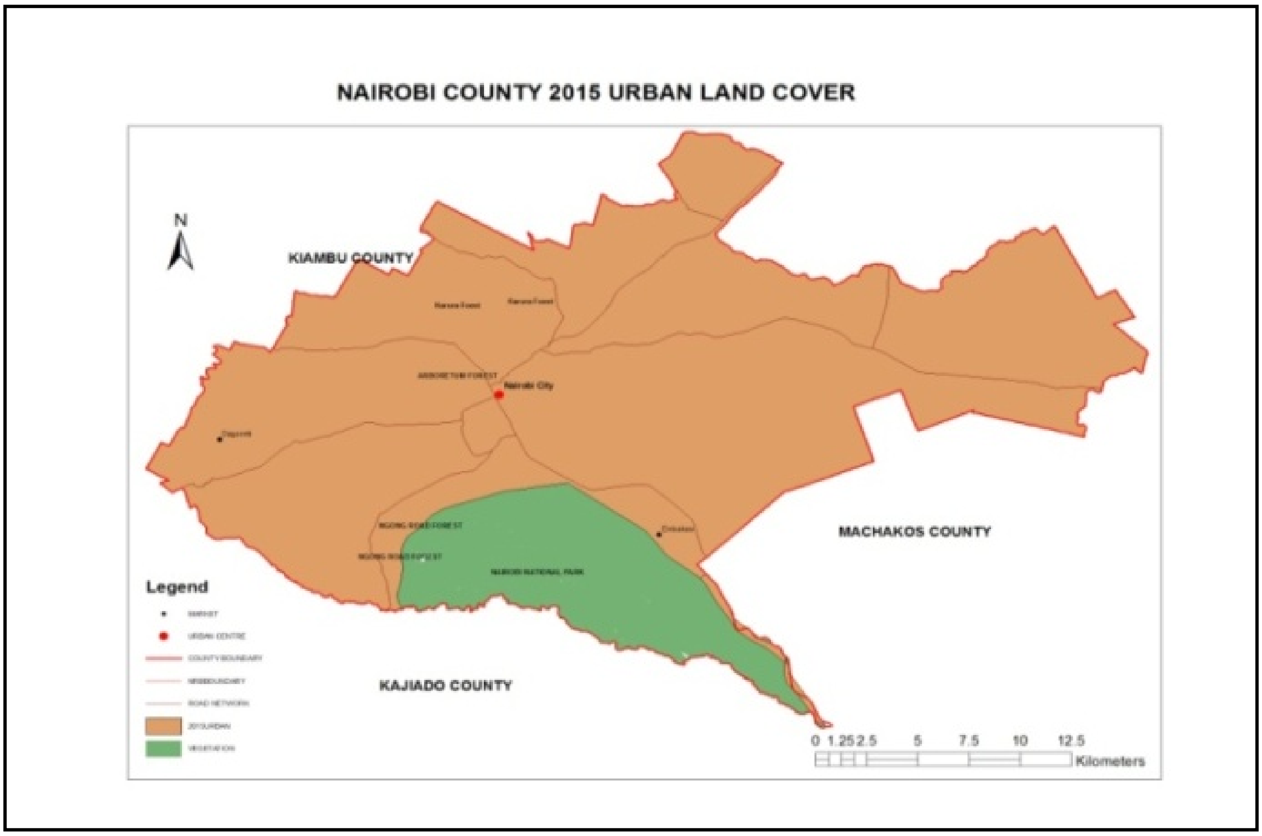

Figure 10c. Nairobi County 2015 Urban land cover

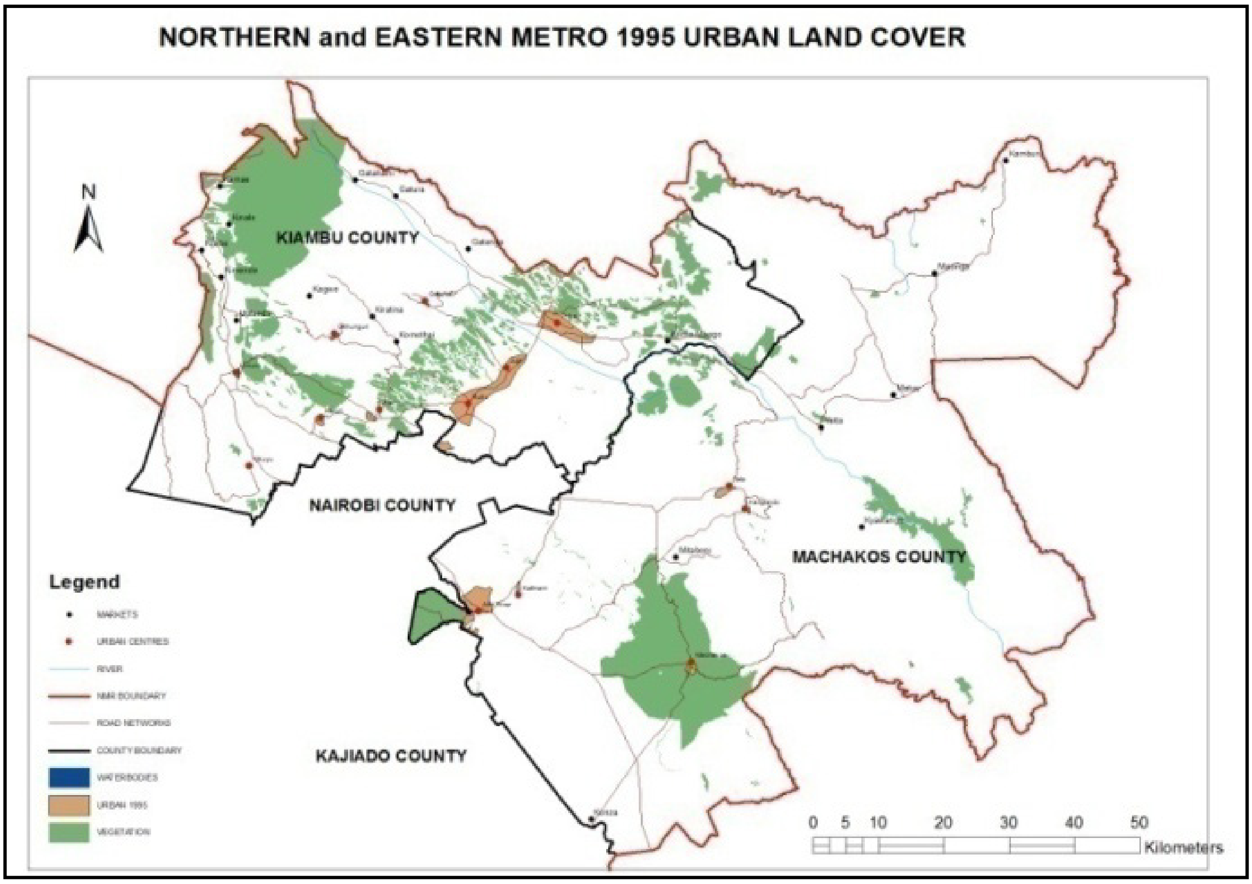

Figure 11a. Kiambu and Machakos 1995 Urban Land Cover

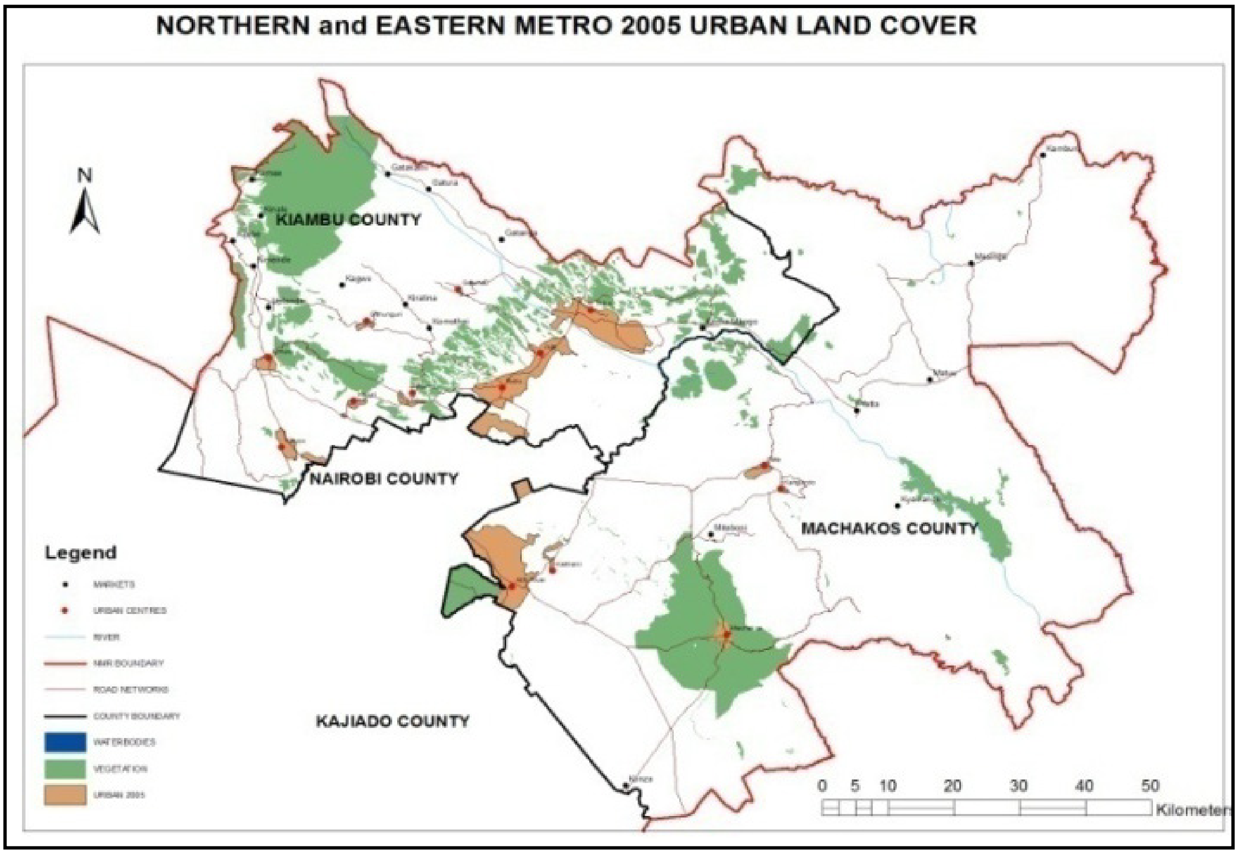

Figure 11b. Kiambu and Machakos 2005 Urban Land Cover

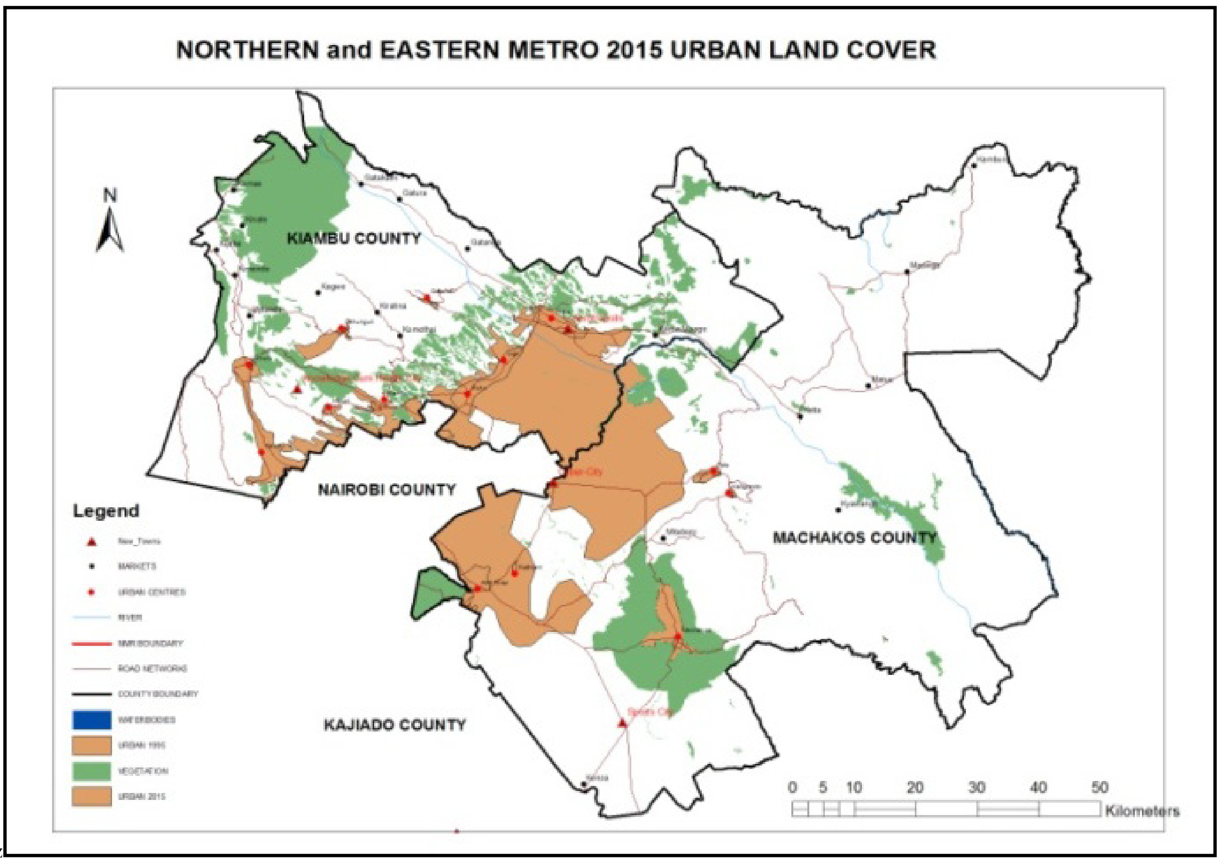

Figure 11c. Kiambu and Machakos 2015 Urban Land Cover

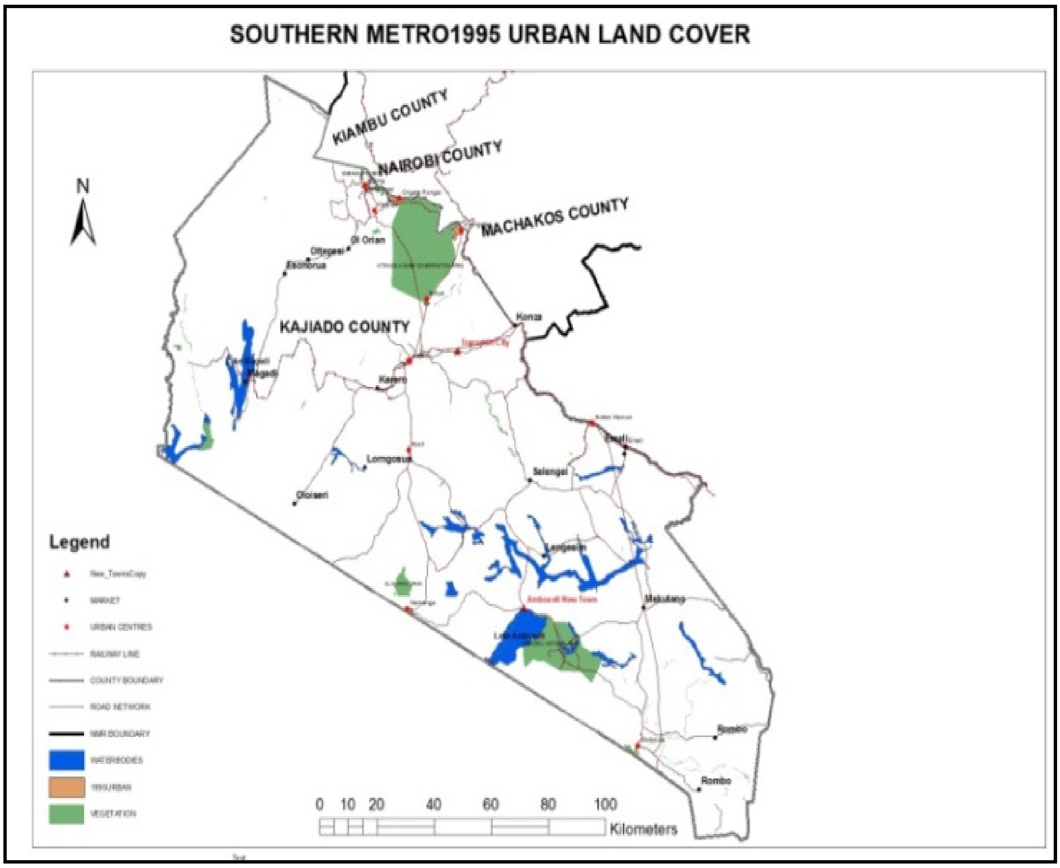

Figure 12a. Kajiado 1995 Urban Land Cover

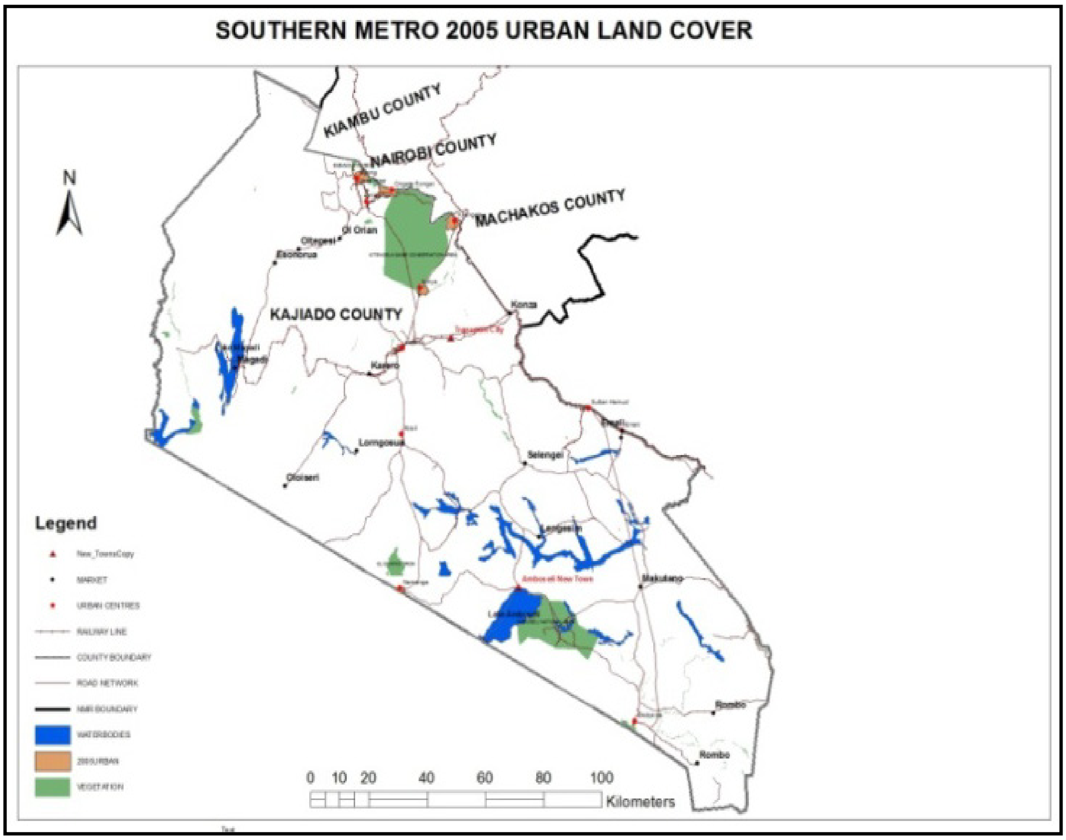

Figure 12b. Kajiado 2005 Urban Land Cover

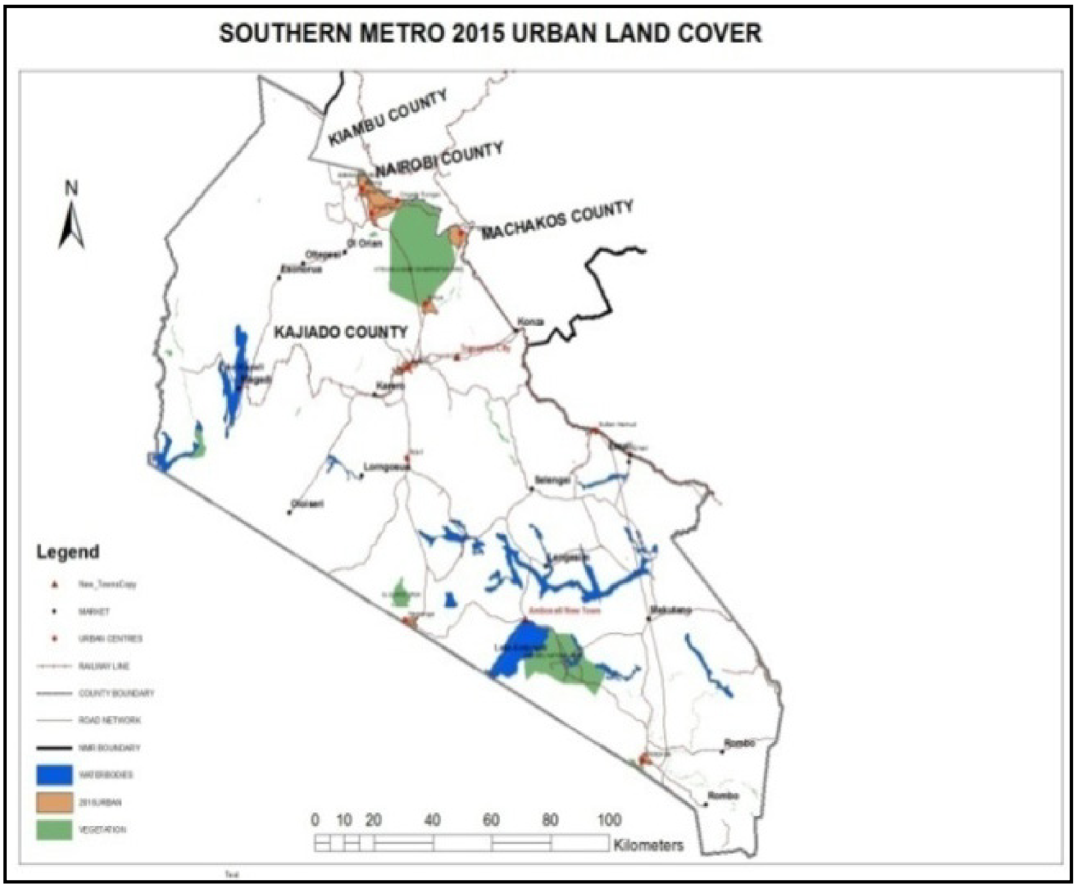

Figure 12c. Kajiado 2015 Urban Land Cover

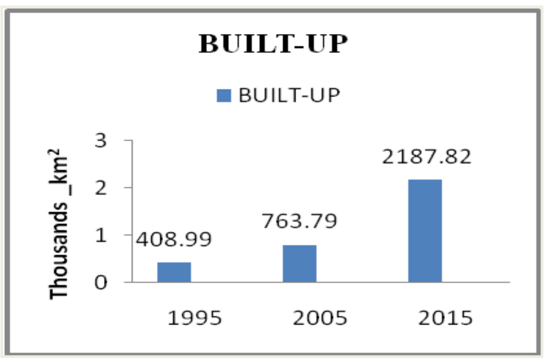

Figure 13. NMR Built-Up Land Cover between 1995 and 2015

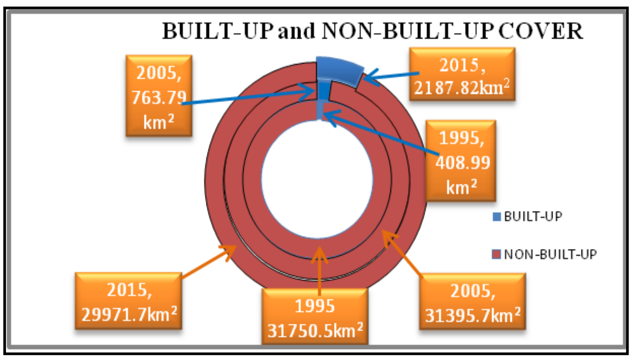

Figure 15. Built-Up and Non-Built-Up Land Cover

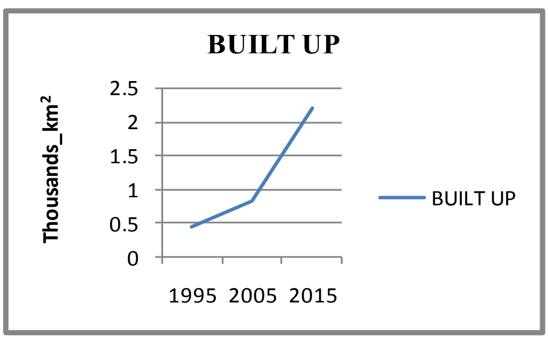

Figure 14. Graph showing the NMR built-up area between 1995 and 2015

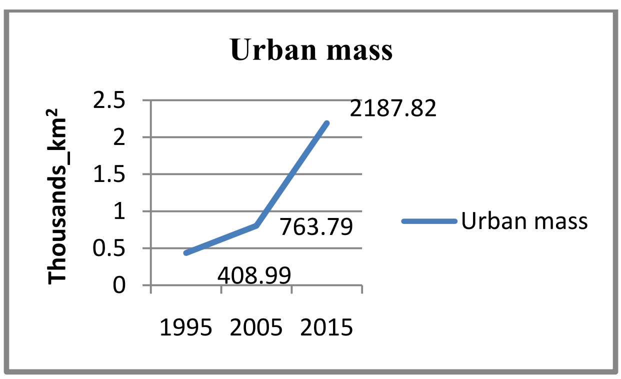

Figure 16. Urban Spatial Expansion between 1995 and 2015

Table 5. NMR urban area cover and changes

COUNTY	AREA	YEAR/URBAN AREA(km²)			CHANGE (km²)	
		1995	2005	2015	1995-2005	2005-2015
Nairobi	700.50	302.15	492.62	700.50	172.47	207.88
Kiambu	3,275	29.82	98.30	951.40	68.48	853.10
Machakos	6,281	21.72	97.23	379.17	75.51	281.94
Kajiado	2,1903	37.30	75.64	156.75	38.34	81.11
TOTAL	**32,159.50**	**408.99**	**763.79**	**2,187.82**	**354.80**	**1,424.03**

Table 6. NMR Urban Land Cover in square kilometres

County	Urban Centre	YEAR/AREA (km²)			Spatial Change (km²)	
		1995	2005	2015	1995-2005	2005-2015
Nairobi	Nairobi	320.15	492.62	700.50	172.47	207.88
	Kiambu	1.47	3.55		2.75	
	Karuri	1.59	2.71	65.51	1.12	59.25
	Lower Kabete	-----	------			
	Limuru	0.62	6.02		5.4	
	Kikuyu	-------	8.77	60.72	8.77	45.93
Kiambu	Thogoto	------	------			
	Ruiru	2.62	19.98		16.58	
	Juja	2.79	16.79	805.51		691.58
	Thika	13.05	37.47		46.48	
	Githunguri	0.89	2.41	17.66	1.52	15.25
	Gatundu	0.42	0.60	2.00	0.18	1.40
Total		**29.82**	**98.30**	**951.40**	**68.48**	**853.10**
	Machakos	2.47	10.67	44.97	8.20	34.30
	Mavoko	14.83	76.42		61.59	
Machakos	Kathiani	1.05	3.52	325.40	2.47	245.45
	Mulolongo, Syokimau	------	----------			
	Tala	3.06	5.96	7.25	2.98	0.30
	Kangundo	0.31	0.58	1.54	0.27	0.96
Total		**21.72**	**97.23**	**379.17**	**75.51**	**281.01**
	Kajiado	1.40	5.49	17.16	4.09	11.67
	Iibissil	0.18	0.33	1.17	0.15	0.84
	Isinya	1.49	7.52	13.71	6.03	6.19
	Namanga	2.82	3.14	10.54	2.04	7.40
	Kiserian	0.16	2.20		9.85	
Kajiado	Ongata Rongai	9.46	19.31	99.21	2.27	44.94
	Kitengela	14.07	16.34		10.59	
	Ngong	5.83	16.42		0.41	
	Oloitoktok	0.16	0.81	9.99	0.65	9.42
	Sultan Hamud	1.73	4.08	4.97	2.35	0.89
	Total	**37.30**	**75.64**	**156.75**	**38.43**	**81.11**
NMR urban Total		**408.99**	**763.79**	**2,187.82**	**354.80**	**1,424.03**

Table 7. Annual Urban Spatial Expansion Index for periods 1995 - 2005 and 2005- 2015

Year	Urban area (km²)	Spatial expansion (km²)	AUSEI (%)/UEII
1995	408.99	-------	------
2005	763.79	354.80	4.65
2015	2,187.82	1424.03	6.51

Table 8. Description of the NMR using spatial metrics

LULC	Year/ Metrics	TA (km^2)	CA (km^2)	NP	PD	LP (km^2)	LPI	MPS (km^2)
Built-up	1995	32159.50	408.99	24	0.05	320.15	78.3	17.78
Built-up	2005	32159.50	763.79	24	0.03	492.62	64.5	31.82
Built-up	2015	32159.50	2,187.82	17	0.008	700.5	32.0	136.74

Table 9. Analysis of built-up area expansion based on CA metrics

Study Period	CA Change (km^2)	Change %		Growth Rate (%)	Average	Annual rate of change (km^2)
1995-2005	354.80	86.80	10	8.70	14	36.85
2005-2015	1,424.03	186.40	10	18.60		142.40

The NMR sub-regions were curved out to enable the analysis of urban growth at sub-region level (Figures 10, 11, and 12).

3.5. NMR Land Use/Cover Status for 1995-2015

The urban area captured over three different years was quantified and compared (Figure 7, 8, 9, Table 5 and 6). Of the 32159.5 km^2 NMR area, urban centres covered 408.99 km^2 (1.27%), 763.79 km^2 (2.38%), and 2187.82 km^2 (6.80%) in 1995, 2005 and 2015 respectively (Figure 13 and 15).

Rural areas covered 31750.51km^2 (98.73 %), 31395.71 km^2 (97.62%) and 29971.68km^2 (93.20 %) in 1995, 2005 and 2015 respectively (Figure 15).

3.6. The NMR Urban Growth Analysis

The Concentric zone, axial development and multiple nuclei theories explain urban growth in the NMR.

Infrastructure projects like roads, electricity and water supply led to the expansion of the urban centres resulting from improved accessibility, service delivery and living standards in general. Built-up expansion occurred in a radial-axial manner along transport routes away from the core Nairobi city towards the urban centres and away from the urban centres towards Nairobi (Figures 7, 8 and 9).

Table 10. Built-up encroachment on non-built up land with regard to 1995

Year	2005	2015
% encroachment on non-built up land	1.12%	4.49%

The urban land mass expanded rapidly between 2005 and 2015 (1424.03km^2) compared to between 1995 and 2005 (354.80km^2) (Figure 16).

Urban growth was analysed using the indicator system. AUSEI was used to determine temporal changes in urban areas and growth rates (Table 8). Spatial metrics were used to describe and quantify changes in urban land cover (9).

The number of patches (NP) metric quantifies the number of individual urban centres. There were 24 patches in 1995 and in 2005. NP reduced to 17 as a result of urban centres expanding towards each other and merging into continuous urban land cover. Changes in LPI and PD (fragmentation metrics) imply a decrease in spatial heterogeneity. There is reduced fragmentation of the built-up area in the region. A decrease in PD from 0.05 in 1995 to 0.008 in 2015 indicated the expansion of patches as a result of rapid continuous development and a decrease in the number of patches (Table 9).

Nairobi city is the largest patch (LP) in the NMR. The significant decrease in the largest patch index (LPI) in the NMR indicated the expansion of the other urban centres or patches and a reduction in the non-built-up area in the region (Figure 17).

Continuous urban growth and development in the built-up area led to an increase in MPS and a reduction in fragmentation hence a reduction in the NP and PD caused by merging of the patches into larger patches. These patches grew as a result of their proximity to the dominant patch. NP reduced from 24 to 17 and PD from 0.05 to 0.008 (Table 8). The rates of urban land cover expansion varied during the 1995-2005 and 2005-2015 time periods (Table 9).

According to the CA metric, the total built-up area increased by 1778.83km^2 between 1995 and 2015.With regard to 1995, built-up land cover expanded by encroaching on non built-up land cover by 1.12% and 4.49% in 2005 and 2015 respectively (Table 10). 1778.83 km^2non urban land cover was converted to urban land cover within the study period.

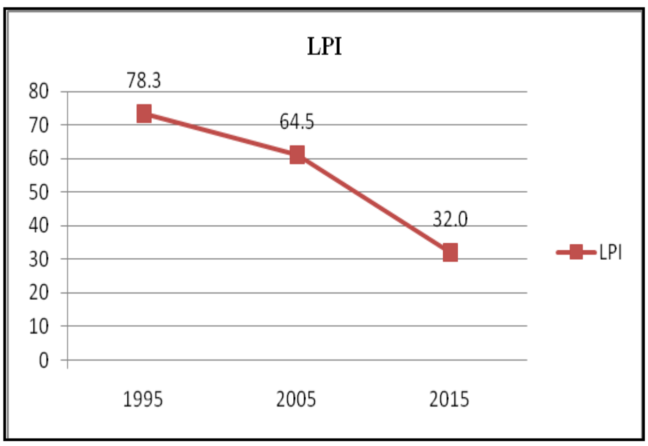

Figure 17. Graph showing NMR largest patch index (LPI)

The expansion of Kangundo and Tala urban centres demonstrate the effect of topography on urban growth. Kangundo town has not expanded extensively as compared to Tala trading centre due to the nature of the terrain at its location. By the year 2015, Nairobi County was 100% urbanised with an urban land cover of 700.50km^2. It was followed by the Northern metro (Kiambu county) and then the Eastern metro (Machakos county) with urban areas of 951.40km^2 and 379.17km^2 respectively. The Southern metro (Kajiado county) is the least urbanised region in the NMR with 156.75km^2 of urban land cover and a patch density of 4.47 (Table 11).

4. Conclusions

Significant urban growth influenced by both spatial and non-spatial factors occurred in the NMR within the study period especially after formation of the Ministry of Nairobi Metropolitan Development (MoNMeD) in the year 2008. Urban expansion in the NMR was dominated by extension developments and sprawl in a radial-axial manner at the Nairobi city periphery onto agricultural land in the rural areas. The expansion happened along transport routes from Nairobi city to other urban centres and from the urban centres to Nairobi city. The expansion was determined by environmental, social-economic, political, and technological factors. The government economic policy, improvements in infrastructure, part VI of the Physical Planning Act(CAP 286) of 1996, high values of land at the CBD's i.e at the core Nairobi city and at the NMR urban centres, topography, population increase in the region and people opting to live on less congested affordable land encouraged spatial urban growth. Urban growth in the region does not affect the location of the NMR spatial plan proposed Transport city and Amboseli new town. The Cyber city, Knowledge cum Health city and the Aerotropolis need to be relocated due to urbanization. The spatial plan forecasted an urban land cover of 1,717.72km^2 by the year 2030, yet by the year 2015, the NMR urban area was 2,187.82 km^2. Lack of information about spatial urban growth in NMR like up to date maps prepared from high resolution satellite imagery denies planners a synoptic view of built up and non-built up areas in the region needed to formulate sustainable urban development strategies.

Table 11. Description of the NMR regions using spatial metrics

Spatial Metric	Metro Region				
	Nairobi (Core)	Eastern Metro (Machakos)	Northern Metro (Kiambu)	Southern Metro (Kajiado)	Total
Region Area (km^2)	700.50	6,281	3,275	2,1903	32,159.50
CA (urban area (km^2)					
1995	320.15	21.72	29.82	37.30	408.99
2005	492.62	97.23	98.30	75.64	763.79
2015	700.50	379.17	951.40	156.75	2,187.82
NP (n)					
1995	1	5	8	10	24
2005	1	5	8	10	24
2015	1	4	5	7	17
PD (%)					
1995	0.31	23.02	12.23	26.81	
2005	0.2	5.14	5.74	13.22	
2015	0.14	1.05	0.52	4.47	
MPS (km^2)					
1995	320.15	4.34	8.18	3.73	
2005	492.62	19.45	17.42	7.56	
2015	700.50	94.79	190.56	22.39	
LP (km^2)					
1995	320.15	14.83	13.05	14.07	
2005	492.62	76.42	37.47	16.34	
2015	700.50	325.40	805.51	99.21	
LPI (%)					
1995	100	68.3	43.8	37.7	
2005	100	78.6	38.1	25.5	
2015	100	85.8	84.6	63.3	

Urban growth monitoring in the NMR will guide resource managers in making prudent decisions and for appropriate allocation of resources. The maps will guide the NMR planners in defining urban growth boundaries and delineate land uses.

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