University of Nairobi

School of Engineering

Department of Geospatial and Space Technology

MAPPING URBANIZATION AND ANALYSIS OF ITS IMPACT ON QUANTITY OF ARABLE LAND. A CASE STUDY OF NAIROBI CITY COUNTY

BY

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F56/11906/2018

A Project submitted in partial fulfillment of the requirement for the Degree of Master of Science in Geographic Information Systems, in the Department of Geospatial and Space Technology of the University of Nairobi

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DECLARATION OF ORIGINALITY

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DEDICATION

I dedicate this project to my late mom, Josephine Adhiambo Nyadero.

ACKNOWLEDGEMENT

My sincere gratitude goes to my supervisor Mr. Jasper N. Mwenda and the staff of the Department of Geospatial and Space Technology of University of Nairobi for their valuable support, critique, insights and guidance while conducting this research.

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ABSTRACT

Urbanization has been defined as an inter-sectoral trend that directly encompasses all aspects of human civilization and the economy. One of the major drivers of rapid urbanization in Kenya is demographic dynamics. Urban population in Kenya has been on the rise since the inception of census activities in 1897. Based on KNBS findings, it is projected that by 2050, 55% of the entire country's population will be living in urban areas. Urbanization has had major influence so far on our landscape with most arable lands, protected areas, riparian reserves and wetlands in Nairobi City County paving way for urban developments.

This project employed the use of Remote Sensing and GIS Technologies together with AHP Multi-Criteria decision-making tool in mapping urbanization and analyzing its effect on the quantity of arable land in Nairobi City County. The study delineated and categorized all lands in the county based on their level of suitability for crop farming as Very Highly Suitable, Highly Suitable, Suitable and Low Suitability.

Nairobi City County has undergone rapid urbanization in the past two decades. It's annual rate of urbanization stands at 5.02% as per the findings of this project during the past two decades. This has had a major impact on the quantity of lands potential for crop farming with an approximate 4,514 Hectares of land having been lost to Built-Up Areas in a time span of 18 years i.e. from 2000 to 2018. This clearly highlights the magnitude of the impact that urbanization has had on the quantity of arable land.

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LIST OF ABBREVIATIONS AND ACRONYMS

KNBS	Kenya National Bureau of Statistics
GIS	Geographic Information System
MDG's	Millennium Development Goals
FAO	Food and Agriculture Organization
UN	United Nations
UNHCR	United Nations High Commissioner for Refugees
GOK	Government of Kenya
USGS	United States Geological Survey
KMTD	Kenya Meteorological Department
DEM	Digital Elevation Model
SRTM	Shuttle Radar Topography Mission

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Urbanization has been defined as a process involving several sectors and incorporates all aspects of human civilization and the economy (World Bank, 2000). The impact of urbanization is usually depicted in the societal, economic and political improvements that spearhead over-concentration of cities, development of satellite towns and land use transformation from rural to urban setups. Urbanization has been associated with non-agricultural events since most of the urban dwellers find occupation in the service and industrial sectors. However, a minority of the inhabitants still practice urban agriculture. According to Hawley (1981), urbanization progressively facilitates migration from agricultural to commercial, manufacturing and industrial activities that influence progression in conduct of inhabitants. He also notes that all round development of the system is what enables the populace to preserve itself in the locale.

Population composition is among the factors that influence the growth of urban population. As at 1900 globally, the ratio of rural inhabitants to urban inhabitants stood at 6.7 to 1 with future projections as at 2025 having it at three urban residents to two rural residents as noted by Satterthwaite et al., (2010). As at 2050, the urban population in Africa is projected to be 1.339 billion from 395 million people as at 2010, accounting for 21% of projected world urban inhabitants (United Nations, 2014). This rapid development in urban population in Africa has been attributed to a swing in equilibrium between rural and urban economies. This shift is as a result of economic growth and evolving employment patterns in these regions as pointed out by Hope (1998).

In Kenya, the three most significant drivers of rapid urbanization that are demographic related are, natural population increase, rural-urban migration and influx in number of refugees (Hope, 1998). KNBS is a government agency whose mandate is to collect, analyze and disseminate statistical data and also serves as the custodian of official statistical information. Among its functions as spelt out in the Statistics (Amendment) Act 2019 is to conduct population and housing census every ten years. Since the inception of census activities in Kenya in 1897 to date, the country has experienced a steady rise in population as per the data collected every decade. In 1969, the population was 10.9 million people and to date, based on the 2019 census data, the

population stands at 47.6 million persons. This implies a 336.70% increase in inhabitants since 1969 as documented by KNBS (2019).

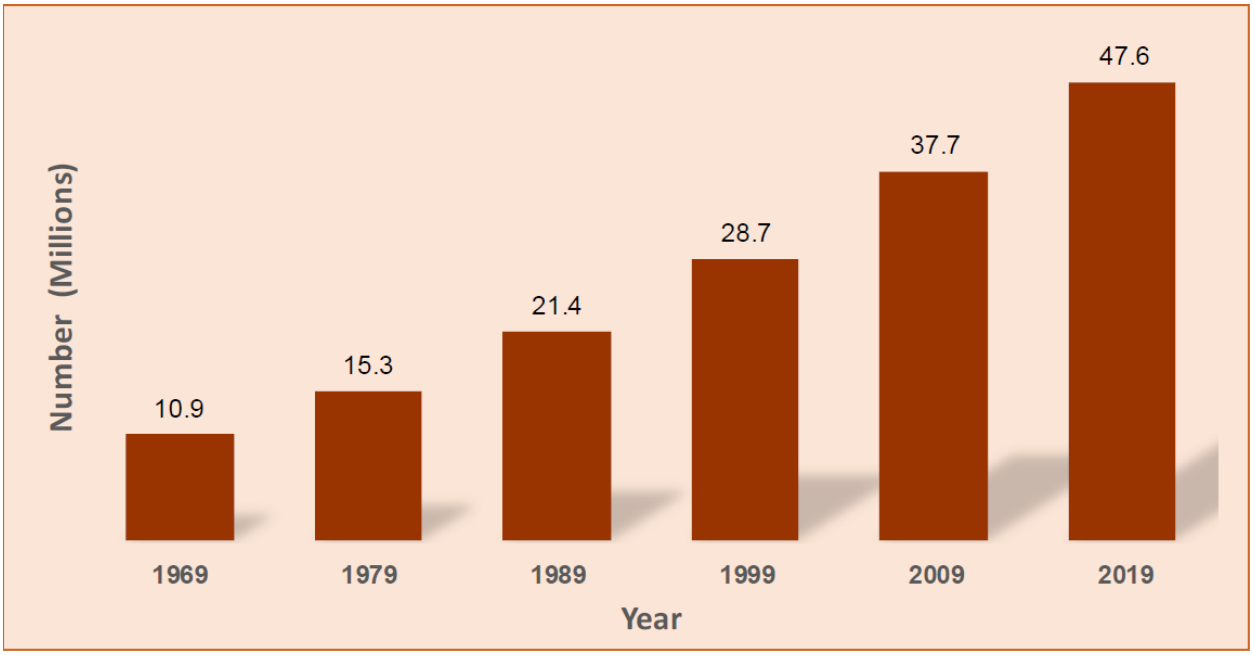

Figure 1:1: Population Trend 1969 to 2019 (KNBS, 2019)

Rapid population growth is associated with rapid urbanization. This has had negative effects on quantity of arable land as pointed out by Foley et al., (2005). Long et al., (2012) noted that arable land is a key natural resource to a country, as its productivity impacts how secure a country is in its food basket. Developed nations like China take with utmost seriousness matters relating to food security and preservation of arable land. Policies and regulatory measures have been put in place to ensure that arable land is safeguarded. The Prime Land Protection Regulation law enacted in 1994 and reviewed in 1998 in China requires the need to integrate guidelines on how to safeguard agricultural lands in all detailed land-use plans and to ensure clear demarcation of their boundaries (Zhonget al., 2012).

Nairobi City County hosts Nairobi City that is the capital of Kenya. The county has an administrative area of approximately 730 km^2, covering only 0.1% of Kenya's total land mass area. Based on (KNBS, 2019) census report, the county hosts an estimate of 4,337,080 people with 1,506,888 households. This accounts for 9.2% of the country's total population. The population trend as displayed in *Figure I.1* has influenced key environmental transformations in

the county in the past decades as more land have been subjected to human settlement, infrastructural development and industrialization as documented by UNEP (2005).

Rapid urbanization in Nairobi City County has not only had positive effects but also adverse effects. Industrialization and infrastructural development bias in urban areas vis-à-vis rural areas prompted rural to urban migration that contributed to rapid population increase (Hope, 1998). Nairobi City County is currently experiencing adverse urban planning and administrative challenges associated with over population. Housing has been a significant challenge prompting thousands of Nairobi inhabitants to reside in slums with others resorting to settle in suburb towns and cities. Rangelands and agricultural lands in suburbs next to huge cities like Nairobi have slowly been converted to urban areas to satisfy housing demand for the ever-increasing population (Flintan, 2011).

Tan et al., (2018) defined arable land as parcels of land that do qualify for cultivation. The term arable originates from Latin word *arabilis*, meaning "able to be ploughed". It is however noted that the amount of arable land a country has is not an indicator of its agricultural productivity. Productivity of arable land is dependent on climatic conditions such as temperature, and moisture, topography and soil characteristics. As the expansion of urban areas continues, most productive arable lands are slowly being lost. This has been attributed to housing pressure and appreciation of land prices in land markets making land owners preferring to leave the farm land uncultivated in anticipation of better price that the land may fetch through sale or by subjecting the land to other use. Poor land use planning policies have also been a driving force towards conversion of arable land to urban areas as indicated by Satterthwaite et al., (2010). They also draw attention to the fact that legislations and regulations meant to enforce land use planning and zoning have always been ignored by corrupt politicians and private developers with interest in real estate. This has resulted in major cities not being independent when it comes to meeting agricultural food demand for its populace and in turn depends on its neighboring administrative areas to fill this gap who also experience the same problem creating a complex global supply chain to fill this gap as mentioned by Rees (1992). This has made realization of food security for a country like Kenya as spelt out in its Big Four Agenda framework and in the Millennium Development Goals challenging. A country like Kenya should aspire to optimally utilize its

arable lands in agricultural food production through practicing sustainable farming and through irrigation in arid and semi-arid areas so as to boost food crop production.

The choice of Nairobi City County was informed by the fact that it is a very significant metropolis in Kenya that has undergone swift urbanization in the past four decades with huge implications on arable land within its boundaries.

1.2 PROBLEM STATEMENT

A country is said to have achieved food security when all its citizens have social, economic and physical access to adequate, safe and nourishing food as per their preference and dietary needs (Ministry of Agriculture, 2009). The government bears the sole responsibility and mandate of ensuring food security to its citizens.

Government of Kenya has made significant strides in pursuit of ensuring Kenya becomes food secure. As at 2008, Kenya had become self-sufficient in production of maize as a staple grain but it has continued to import rice and wheat due to insufficient production locally (Kenya Food Security Steering Group, 2011). Some of the long-term measures that the GOK is partaking with an aim of improving agricultural food production are by ensuring optimal utilization of arable land through training and education of farmers and also by increasing the amount of arable land under agricultural activities in arid and semi-arid areas through irrigation.

However, rapid urbanization in Nairobi City County has had huge negative impacts on agricultural food production. Overpopulation of urban areas has resulted in straining of existing housing resources and this has led to expansion of informal settlements and increased housing developments leading to diminishing agricultural and potential arable lands.

This project analyzed the effect that urbanization has had so far on quantity of arable land within Nairobi City County.

1.3 OBJECTIVES

1.3.1 GENERAL OBJECTIVE

To map urbanization and analyze how it affects quantity of arable lands in Nairobi City County.

1.3.2 SPECIFIC OBJECTIVES

1. To generate arable land suitability map of Nairobi City County.

2. To generate land cover maps of Nairobi City County for the years 2000, 2012 and 2018 and conduct change detection.
3. To perform statistical analysis on the quantities of arable lands lost to built-up spaces between the year 2000 and 2018.

1.4 JUSTIFICATION FOR THE STUDY

The Kenyan agricultural practice is mostly rain fed agriculture and partly irrigation in limited number of areas. Adverse weather conditions such as drought usually affect the sector negatively resulting in humanitarian crisis in arid and semi-arid areas and high food prices.

Some of the government's strategies for achieving food security are increasing the amount of arable land under irrigation and by improving skills and knowledge of farmers through training and sharing information. This is intended to optimize farm production. However, poor land use policies and rapid urbanization are impeding government's efforts. This has made the country vulnerable to hunger and starvation due to insufficient food production and also increased our vulnerability to unscrupulous traders who import sub-standard food products to meet the shortage.

Several public and private stakeholders in the Agricultural Sector, departments of planning at county and national level and policy makers at all levels stand to benefit from the findings of this research paper. These stakeholders will be in a position to address issues related to uncontrolled development which can be attributed to loopholes in land use policies and legislation so as to ensure sustainable development.

1.5 SCOPE OF WORK

The study area was Nairobi City County. Both ArcGIS 10.5 and Quantum GIS 2.18 software environments were used in this study to aid in delineating and classifying all lands in the county based on their level of suitability for crop farming. This was achieved through conducting weighted overlay analysis of soil properties, terrain characteristics and climate characteristics layers. Land Cover maps of Nairobi City County for the years 2000, 2012 and 2018 were generated and Built-Up Areas land cover were extracted and used in intersection analysis together with arable land suitability layer. The area information extracted from intersection

analysis output was used to conduct statistical analysis on the amounts of arable land lost to urban areas.

This study does not highlight the impact that loss of arable land has had on agricultural food production and food security in general. This to some extent failed to illuminate the magnitude that rapid urbanization has had on the agricultural sector.

The study focuses solely on rain-fed agricultural practice when delineating and classifying lands based on their levels of suitability for crop cultivation.

1.6 ORGANIZATION OF THE REPORT

The project report is covered in five chapters. Chapter One is an introduction to the study and this covers background information, problem statement, objectives of the study, justification of the study, scope of the study and a summary of the project organization. Chapter two delves deep into relevant literature review touching on urbanization, its trends overtime and how it has impacted the populace and our landscape. This chapter also looks into population dynamics as the main driver of urbanization. The chapter also covers arable land, factors that influence productivity and degradation of arable lands one being urbanization for the latter.

Chapter three covers the processes, data and materials that were used to help in achieving our set objectives while conducting this research. Chapter four touches on outputs of chapter three and discussion of some of the insights that were drawn from these outputs. Chapter five deals with conclusions that were drawn after analyzing the results, recommendations that were put forward to help in reversing and addressing the trends observed and lastly it also identifies areas of further research that this project failed to highlight. References section lists all literature material that were reviewed during this study and the Appendix section contains housing and population data tables.

CHAPTER 2: LITERATURE REVIEW

2.1 URBANIZATION

Orum (2011) defines urbanization as a systematic development in which a cluster of people inhabits a particular area and advance institution that are social in nature that may include businesses and government to better their lives. These areas end up attracting huge numbers of people resulting into increased settlements.

Towns and cities overtime have served as major residential areas for the urban populace. Dresher et al., (2002) state that a huge number of people nowadays settle in urban areas as compared to rural areas. The definition of urbanization has also been looked at with reference to population growth trend and the social impacts it has. Axel et al., (2002) define urbanization as the persistent increase in inhabitants of a particular geographical area and the multifaceted evolution impact this trend has on the social aspect of their livelihoods.

2.2 URBANIZATION TRENDS

Urbanization in Kenya dates back to the pre-colonial days under the British Rule when the rail network was being built. Most of the old towns started as railway depots that would overtime undergo transformation into manufacturing hubs resulting into an influx of rural-urban migrants. Nairobi started as railway terminus before formally earning capital status in 1948. The colonial government developed the first master plan of Nairobi that led to Nairobi becoming a modernized commercial center with an industrial area, network of road infrastructure and houses meant to house the Africans servants as noted by Anderson (2001). Upon Kenya gaining independence in 1963, the master plan was abandoned by African elites who furthered their personal interests instead (Huchzermeyer, 2006). In addition, prioritization of development in urban areas in the expense of rural areas together with lack of guiding principles on how to create jobs for the rural youth resulted in massive rural to urban migration in built-up areas such as Nairobi and Nakuru in pursuit of jobs. K' Akumu (2007) stated that as a result of the reversal on the native restriction law, urban areas were thronged with rural migrants and this had an effect on agricultural sector in the rural areas due to loss of manpower.

UN-HABITAT (2010) studies have found out that in the past four decades (1970 to 2010), urban inhabitants in East African countries increased from 11.2 million people to 77.2 million which

represents a rise from 10% to 24% of the total population within the same duration. Kenya's total population within the same period rose from 10.9 million as per the 1969 census to 38.6 million as per the 2009 census indicating a growth rate ranging between 2.9% to 3.4%. Future projections put the figures of urban population proportion to the total population as at 36% within the years 2030-2040. This trend is worrying as current figures illustrate that the current ratio of urban population to rural population stands at 1:5 as compared to ratios in the 1960's that stood at 1:12 (UNDESA, 2010).

2.3 IMPACTS OF URBANIZATION IN KENYA

2.3.1 HOUSING

Onyekachi (2014) states that housing serves to meet an individual's psychological and social needs and also provides a safe haven for one's privacy, refuge and shelter against climatic elements. Rural to urban migration has resulted in sharp increase in the urban population that has resulted in housing problems (Nabutola, 2004). UN-HABITAT (2007) pointed out that as result of rapid increase in urban population, there has been a severe shortage in housing units that stands at 20,000 units annually. One of the resultant effects of such shortage has been pressure on available arable land to pave way for construction of residential houses. This also posed a major challenge to private and public land that lies idle for longer durations as the poor tend to encroach and squat on it putting up shanties. Kibera, Mukuru kwa Njenga and Mathare are among the slums in Nairobi housing millions of the urban poor and low-income earners.

Inadequate housing is an indication of failure by the government to strategize and commit to addressing the problem. Onyekachi (2014) suggests that to address inadequate housing crisis in urban areas, the government needs to remain steadfast in its obligation and come up with effective plans and strategies on how to implement such development in a sustainable way. This therefore calls upon drafting of housing policies and frameworks to address housing problems.

2.3.2 UNEMPLOYMENT

Hope (1998) postulates that rapid development of urban areas and neglecting of rural areas has resulted in a sharp rise of urban population and this can partly be attributed to rural-urban migration. The immigration into urban areas has been linked to pursuit of employment opportunities and better lifestyle. This however has resulted to overpopulation of urban areas

whose impact has been scarce job opportunities and high rates of unemployment. Carney (1999) notes that most rural youth are in search of employment opportunities either through entrepreneurship or in the service industry but such prospects are rare in rural areas and as such most move to urban areas. Nzioki (2002) states that most of the urban poor settle in informal settlements with a majority of them being the low-income earners working as casual laborers and the unskilled and semi-skilled personnel in the informal districts with a majority of them being immigrants from rural areas. In Nairobi, a majority of the urban poor work in the Industrial Area.

2.4 URBANIZATION DRIVERS IN KENYA

Hope (1997) attributes the swift growth of urban population in Kenya to rural-urban migration which is a consequence of imbalance between the rural and urban economies. He links the imbalance to variation of economic development and demand *vs* supply for employment opportunities in this regions. This he attributes to bias when it comes to development of these areas by our political leaders.

Urban bias in East Africa has its roots in pre-colonisation era as supported by both Hope (1997) and UN-HABITAT (2010). The British Colonizers in pre-colonization era put up urban centers in regions that facilitated ease of access to ports and road infrastructure so as to smoothen haulage of goods from one location to another. These urban centers in due course transformed to cities and huge towns with better transport network infrastructure and large numbers of residents as compared to the rural areas which prompted urban immigration (Hope, 2012).

These cities and their suburbs had vast land masses for use by the British Colonizers. Polo, cricket, rugby field and parks served as the areas of separation between colonizers and the colonized which later was adopted by the African elites. Hope (2009) noted that upon gaining independence, the native elites maintained status quo by advancing development in urban areas and neglecting rural areas. This urban centers overtime evolved to cities and capital cities of various countries.

Some of the key factors responsible for rapid urbanization in Kenya are:

1. Natural increase in urban population
2. Rural to urban migration
3. Other factors

2.4.1 NATURAL INCREASE IN POPULATION

Oxfam International (2009) states that natural increase in inhabitants arises when the rate of births exceeds that of deaths. Africa has the highest rates of fertility with Kenya having a 27.3% difference between birth rates and death rates. Institute of Economic Affairs (2016) defines Total Fertility Rate (TFR) as the mean number of children a woman can give birth to during her child bearing years. Oxfam International (2009) also puts forward that 55% of urban population growth in Kenya can be accounted for by increasing fertility rates and normal growth. KNBS (2008) survey puts the national fertility rate as at 2005/2006 at 5 children. However there exists variation in fertility rate between urban women and rural women at 3.2 and 5.5 children respectively. It also notes that for the urban women populace, those from poor households have a higher fertility rate of 4.9 children as compared to their counterparts from rich households at 2.9 children. Thus rapid increase in urban population in Nairobi can be attributed to increased births and decreased death rates.

2.4.2 RURAL TO URBAN MIGRATION

Urbanization second most important key driver is rural to urban migration. Findley (1993) noted that between the years 1975 and 1990, the rate of rural-urban migration accounted for 64% of the total urban populace. Republic of Kenya (2004) and Wainaina (2008) also noted that within the years 1989 and 1999, rural to urban migration accounted for 17% of Nairobi's population and 16% of Mombasa's residents. Oxfam (2009) puts the figures at an average of 25% immigrants of urban population. The main push for Kenyans migrating to urban areas is usually the desire to improve on ones living standards. They migrate in search of employment and economic prospects. Hope (1998) also notes that people at times tend to migrate to urban areas as a way out from adverse environmental conditions such as conflicts, drought and famine, floods and in search of political opportunities.

Institute of Economic Affairs (2016) noted from their study conducted between 2000 and 2014 that overtime, there has been a consistent decrease in rural population and the opposite is true for urban population. It noted that there was a drop in the rural population by 5.73% from 80.11% in 2000 to 78.38% in 2014 while for the urban populace experienced a rise of 5.73% from 19.89% to 25.62% within the same duration. This shift in figures was attributed to rural-urban migration and partly to natural growth in population.

The *Figure 2:1* illustrates the variation in figures of rural vs urban population:

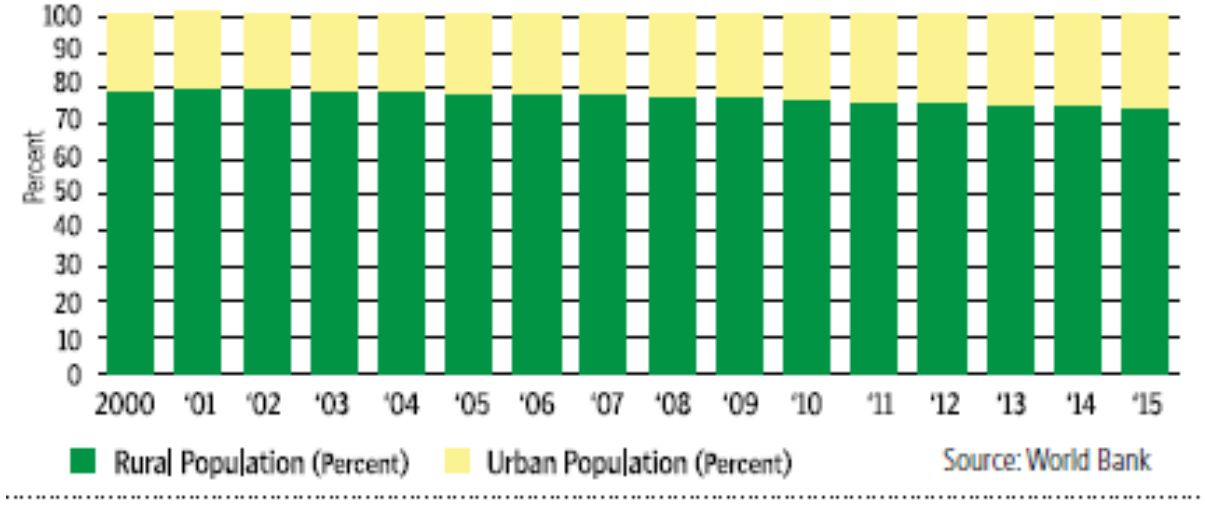

Figure 2:1: Population Variation in percentage between 2000 and 2015 (Source: World Bank)

2.4.3 OTHER FACTORS

Internal conflicts in our neighboring countries such as Somalia and South Sudan has resulted in a surge in numbers of refugees and persons seeking asylum. Based on UNHCR (2010), nearly half of the 15.2 million refugees do reside in urban setups in Kenya. Kenya currently ranks sixth when it comes to countries hosting the largest numbers of refugees. As at September 2010, Kenya hosted a population of approximately 412,193 refugee's majority of which were from Somalia as mentioned by OCHA (2010). The organisation also noted that there has been a steady increase in the number of refugees living in urban areas with nearly about 46,487 refugees estimated to be inhabitants of Nairobi County. This number signifies 11% drop with the actual numbers however not being known. Harsh conditions in camps (overcrowding and insufficient shelter) have been linked to immigration of refugees to urban areas who seek better opportunities.

Clustering of large scale and small-scale business ventures in a particular area together with setting up of government administrative offices in cities and towns also act as drivers for urbanization.

2.5 IMPACTS OF URBANIZATION

2.5.1 OVERPOPULATION OF URBAN AREAS

Hope (1998) refers to overpopulation of urban areas as over-urbanization. He defines over-urbanization as a stage in which the total non-agrarian inhabitants exceed that of significant non-agricultural work opportunities. This scenario he attributes to imbalance in development between rural and urban areas prompting rural to urban migration an opinion shared by Nyaura (2014). Neuwirth (2006) and Davis (2007) both noted that a majority of the agrarian rural dwellers who move to the cities in search of jobs end up in unsanctioned settlements in rapidly developing cities.

Nairobi City County has experienced population and household explosion for the past two decades based on KNBS (2019). KNBS is a body mandated by law to be the custodian of population and household's data. *The Table 2:1, A1, A2, A3 and A4* for household and population data for Nairobi City County by sub-counties clearly illustrate overpopulation as one of the major drivers of rapid urbanization in Nairobi City County.

Table 2:1: Distribution of Population by Sex and Sub County for the year 2019 in Nairobi (courtesy of KNBS)

S No.	Sub-County	Male	Female	Intersex	Total
1.	Dagoretti	217651	216526	31	434208
2.	Embakasi	492476	496270	62	988808
3.	Kamukunji	136670	131599	7	268276
4.	Kasarani	381234	399385	37	780656
5.	Kibra	94199	91569	9	185777
6.	Lang'ata	96698	100774	17	197489
7.	Makadara	96369	93157	10	189536
8.	Mathare	106522	100028	14	206564
9.	Njiru	307642	318809	31	626482
10.	Starehe	109173	101238	12	210423
11.	Westlands	153818	155021	15	308854
	TOTAL				**4,397,073**

From the *Figure 2:2*, the impact of urbanization on population growth can be clearly visualized.

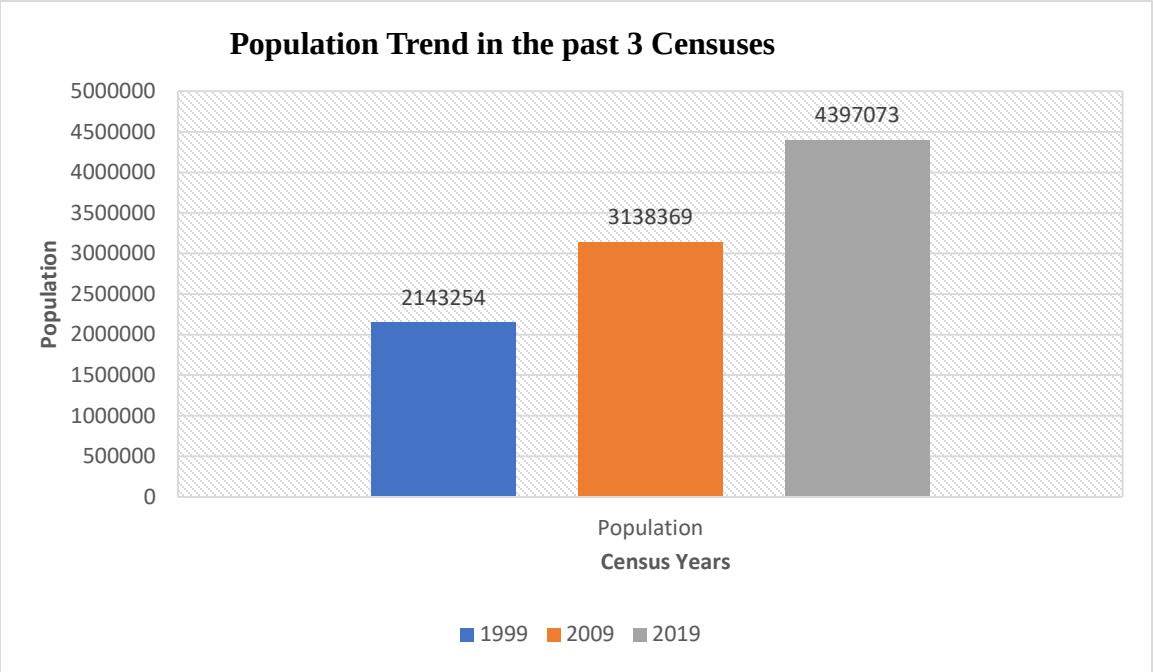

Figure 2:2: Nairobi City County Population Trend for the past two decade

The negative effects that come with over population are scarce employment opportunities to meet high job demands and also a strain in existing social amenities. Reduced agricultural production rural areas due to a diminished rural youth populace and conversion of arable land to urban areas is also an indirect impact of rapid urbanization. With most energetic rural youth moving to urban centers in search of jobs, the aging population left behind in rural areas resort to subsistence farming which is not in a position to meet the ever-growing demand for food in developed areas. This has had adverse effects on food production (Nyaura, 2014).

2.5.2 HOUSING PRESSURE

Rapid increase in urban population has resulted in strain in available housing facilities and shortage of housing. This trend has worsened year in year out due to swift rate of urbanization (Nyaura, 2014). Imbalance in supply versus demand of housing has resulted in rent sky rocketing and private developers on the other hand have taken advantage by putting up shelters that can easily be afforded by the urban poor. The resultant outcome has been slums and shanties together with sub-standard concrete residential areas that are characterized by luck of basic amenities

such as water, electricity, proper sanitation and road infrastructure as corroborated by Axel et al., (2002). This eventually has been the driving force of our landscape changes as most arable lands have been lost to cater for housing and office spaces.

2.5.3 LOSS AND SUBDIVISION OF ARABLE LAND

Iheke (2015) pointed out that with rapid urbanization, there is loss of arable lands. This trend impacts negatively on food crop production and the agricultural sector as a whole, a thought shared by Francis (2013). Iheke (2015) propossed the need to zone agricultural districts in urban areas and formulation of strict regulations and policies that will see to it that such parcels of land are not encroached on and other competitive uses that the parcel can be subjected to do not take precedence.

Flintan (2011) notes that the loss and subdivision of agricultural lands and rangeland within urban areas and in their suburbs can be linked to speculation of future land transactions based on their projected cost since land value doesn't depreciate.

Zhong et al., (2012) also recognized that urbanization has posed a major threat to arable land in developed nations like China which have in-turn taken with utmost seriousness that matter since it may impact negatively on food security. He points out that policies and regulatory measures are necessary to ensure that arable land is safeguarded. A good example is China's "Prime Land Protection Regulation" law enacted in 1994 and reviewed in 1998 that recommends the need to integrate guidelines on how to save from 'harm' arable lands in all detailed land-use plans and to ensure clear demarcation of their boundaries.

Huang et al., (2015) revealed that various factors influenced probability of arable lands being converted to urban spaces. Such factors included location i.e. proximity of arable land to urban centers puts it at a higher probability of being converted due to convenience and gentle sloping terrain. They also noted that land use policies and guidelines play a pivotal role when it comes to preservation of farm land. However they clarify that these policies do not provide absolute protection but only reduce probability of such conversions from happening.

2.6 ARABLE LAND

Tan et al., (2018) defines arable land as parcels of land that can be cultivated. Andersonet al., (2010) clearly pointed out the significant role soil plays when it comes to the survival of all flora

and fauna in maters production of food and fibre. They also noted that worldwide, the amount of arable land stood at 1.35 billion hectares as at 2010, equating to 0.20 hectares per person and that these masses of lands are unevenly distributed.

Africa and Asia have the largest chunks of arable land standing at 46% of the world's total sum. Asia accounts for 32% and is the largest shareholder with Africa having 14%, ranking third. These two continents also account for 71% of the global population and its arable lands are amongst the most degraded and infertile as verified by Anderson et al., (2010).

On an annual basis, 0.3-0.8% of arable land globally is declared unfit for agriculture due to soil degradation and erosion. Urbanization, which has been considered as an agent of soil degradation, accounts for loss of arable lands in built-up areas. As at 2008, 50% of the global populace lived in metropolitan areas as noted by Anderson et al., (2010). To illustrate how dire the trend has been, between the years 1971 and 2001, Canada lost 1.2 million hectares of highly productive agricultural land to Urban Areas (Anderson et al., 2010).

The *Figure 2.3* clearly illustrates the declination trend of arable land per person since 1990.

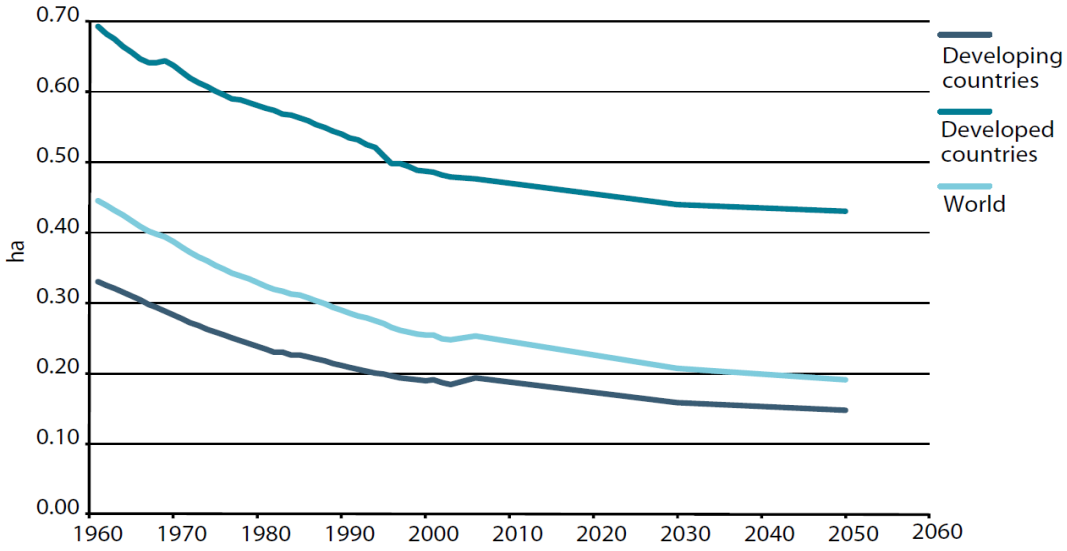

Figure 2:3: Arable Land per capita (Source: Food and Agriculture Organisation of the United Nations, 2005)

Food security is usually pegged on optimum utilization of arable lands. Tan et al., (2018) noted that reduction in the amounts of grain produced in china was as a resultant of loss and lying idle of arable lands. Ministry of Agriculture (2009) pointed out that rapid urbanization steers rapid growth in urban population and also causes food insecurity. This, the ministry attributes to development of houses on arable lands due to outburst of urban population so as to adress housing pressure. However, other factors also influence productivity of arable land; these include soil nutrients, climatic conditions and topography. This validates the analogy that possesion of vasts amount of arable land alone does not warrant food security (Tan etal., 2018). They also noted that land covers such as grasslands are arable and that the net arable land of a country is usually total arable land less arable lands covered by forest, protected areas and built-up spaces as noted by Bruinsma (2009).

Bruinsma (2009) also pointed out that for one to be able to delineate arable land, a weighted overlay analysis on soil, climate and terrain layers of data, considering crop requirements needs to be conducted.

CHAPTER 3: RESEARCH METHODOLOGY AND MATERIALS

3.0 INTRODUCTION

This chapter covers study area, datasets and their sources, cleaning, processing and analysis techniques that were employed so as to achieve the set objectives.

3.1 AREA OF STUDY

The study area is Nairobi City County. Nairobi City County is spatially located between the latitudes 1.163˚S and 1.283˚S and longitudes 36.817˚E and 37.104˚E. Nairobi City County has an administrative area of about 730 km^2 and covers only 0.1 per cent of Kenya's total land mass. The County hosts Nairobi City which is the capital city of Kenya.

Nairobi was founded in 1899 and it served as a railway terminus. As early as 1922, Nairobi had roughly 9000 inhabitants that rose rapidly in a duration of three decades to 80,000 persons. It was declared the capital city in 1954 and remained capital after Kenya gained independence from the British rule in 1963 then with a population of approximately 350,000 residents (UNEP, 2005). The County has an estimated population size of approximately 4.4 million dwellers accounting for about 9% of the country's total population with a population density of about 82 persons/Km^2 and approximately 1.5 million households (KNBS, 2019).

The county is divided into eleven (11) administrative zones referred to as constituencies. The city hosts an international airport, a national park and fairly well-developed infrastructures and has undergone brisk expansion since 1979. It acts as a booming cultural, architectural and commercial hub and is rated amongst the fastest growing economies in Africa and the world as a whole and this has motivated rapid growth in its populace.

The *Figure 3.1* illustrates our study area and its position in relation to other counties in Kenya.

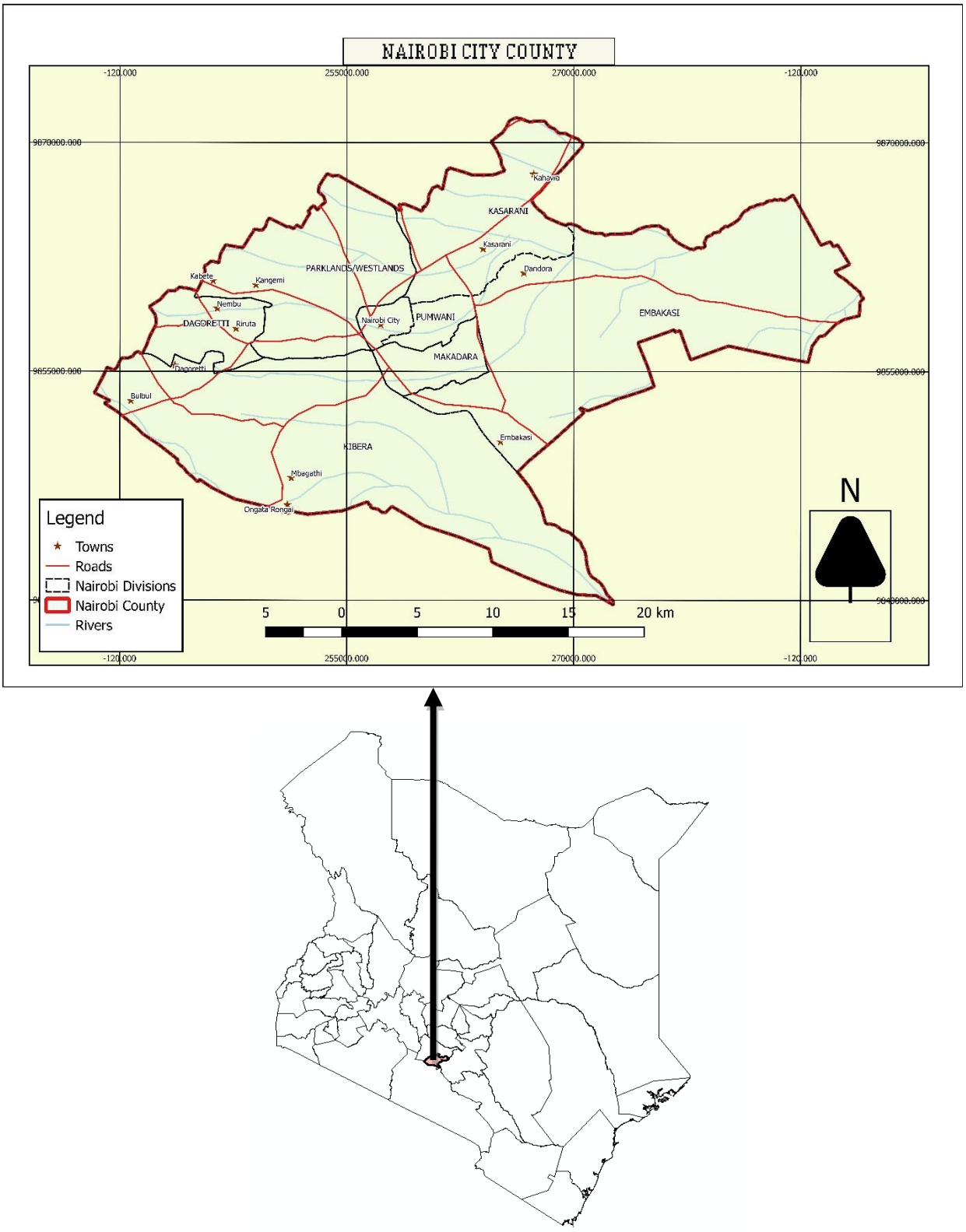

Figure 3:1: Map of Nairobi City County

3.2 RESEARCH METHODOLOGY FLOW CHART

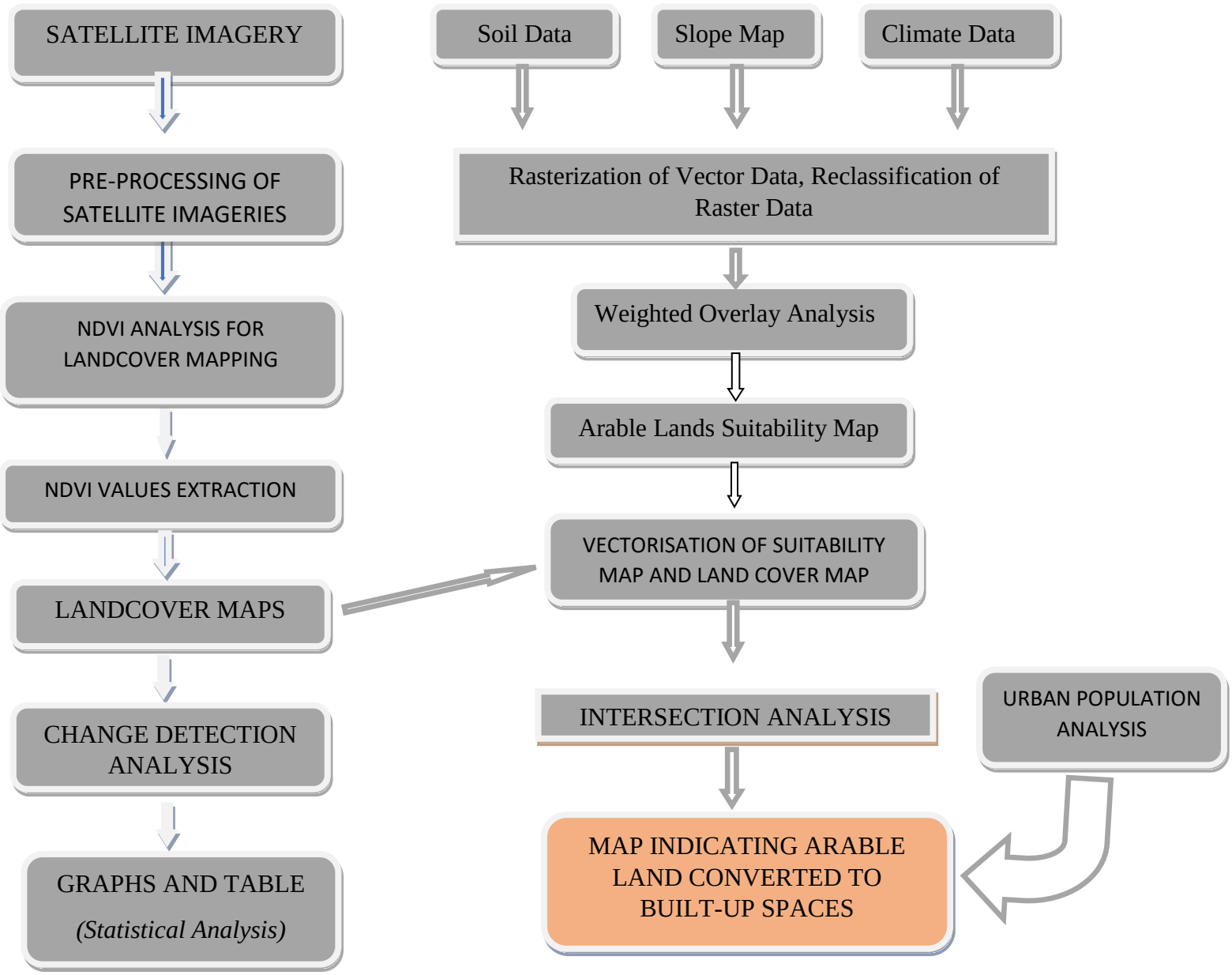

Figure 3:2: Research Methodology flow chart

The data processing and analysis techniques employed during the project that expound on the *Figure 3.2* involved;

1. Landsat 7 SLC-ON, Landsat 7 SLC-OFF and Landsat 8 ETM+, 30 meters' spatial resolution satellite imageries within the path 168 and row 061 for the years 2000, 2012 and 2018 were downloaded from USGS Online Portal upon creating an account.

2. Pre-processing of the downloaded bands was conducted and this included unpacking the compressed bands and layer stacking i.e. 5, 4 and 3 band combination for Landsat 7 and 6, 5 and 4 band combination for Landsat 8 ETM+ resulting in a false color image suitable for land cover mapping of urban areas.
3. The resultant false color images after layer stacking were then pan sharpened to improve on its spatial resolution by using pan-sharpening tool and band 8 (panchromatic band). It was then clipped to our area of interest using vector shapefile layer of Nairobi County as our input boundary clip extent in QGIS Software.
4. NDVI Analysis was conducted and point values extracted to help in land cover range identification and classification.
5. Land cover maps for the year 2000, 2012 and 2018 were the generated
6. The outputs were then converted to a vector shapefile using the raster to vector conversion tool in QGIS and area information for each land cover extracted.
7. Change detection analysis was then conducted and land cover information extracted and more analysis on the trends analyzed in Microsoft Office Excel environment.
8. Built-up areas land cover for the years 2000, 2012 and 2018 were then extracted and saved as separate layers.
9. Arable land suitability map was then generated through weighted overlay analysis of soil properties layers, slope and climate data layers.
10. The two resultant outputs i.e. built-up areas land cover and arable land suitability layer were converted from raster to vector and intersection analysis conducted.
11. Statistical analysis was then conducted on extracted areas of the intersection analysis output.
12. Recommendations on how to address the trends observed were then put forward.

3.3 RESEARCH INSTRUMENT

The listed software and applications were used to conduct this project.

1. ENVI 4.7: This is a remote sensing technology software that was used in conducting satellite imageries pre-processing.
2. ArcMap 10.5: This is an Esri GIS software that was used to process, manage, analyze and visualize spatial data.

3. Microsoft Office Word: Microsoft application that was used in documentation and compilation of project report.
4. Microsoft Office Excel: Microsoft application that was used in statistical analysis of population, arable land quantities and in change detection of land cover.
5. Microsoft Office PowerPoint: Microsoft application that was used in presentation of study findings before the examination panel.

3.4 DATA AND DATA SOURCES

The following datasets were used to carry out this project.

Table 3:1: Data and Data Sources

No.	Data	Data Sources
1.	Landsat Medium Resolution Satellite Imagery Data (2000, 2012 and 2018)	USGS Portal
2.	Administration Boundary Data	Survey of Kenya
3.	Soil Data	Kenya Agricultural and Livestock Research Organization (KALRO)
4.	Population Data	Kenya National Bureau of Statistics (KNBS)
5.	DEM (SRTM)	USGS Portal
6	Kenya Climate Surface Data	KMTD & KALRO

3.5 ARABLE LAND DELINEATION

This involved classification of masses of lands within Nairobi City County based on their level of suitability for crop cultivation. Suitability of land for cultivation is dependent on various factors which are not limited to topography, soil data and climate data. Delineation of arable land was achieved through weighted overlay analysis of soil, slope and climatic data layers which are among the key factors that influence productivity of arable land as noted by Tan et al. (2018).

Some of the data inputs of the weighted overlay analysis process are as explained hereafter:

3.5.1 DIGITAL ELEVATION MODEL

Topographical characteristics more so degree of slope are considered to be one of the factors that influence vulnerability of arable land to degradation through erosion.

SRTM DEM for Kenya with a spatial resolution of 30 meters was downloaded from USGS portal. Using the administration boundary of Nairobi City County, the raster data was clipped to obtain a digital elevation model for Nairobi County as shown below:

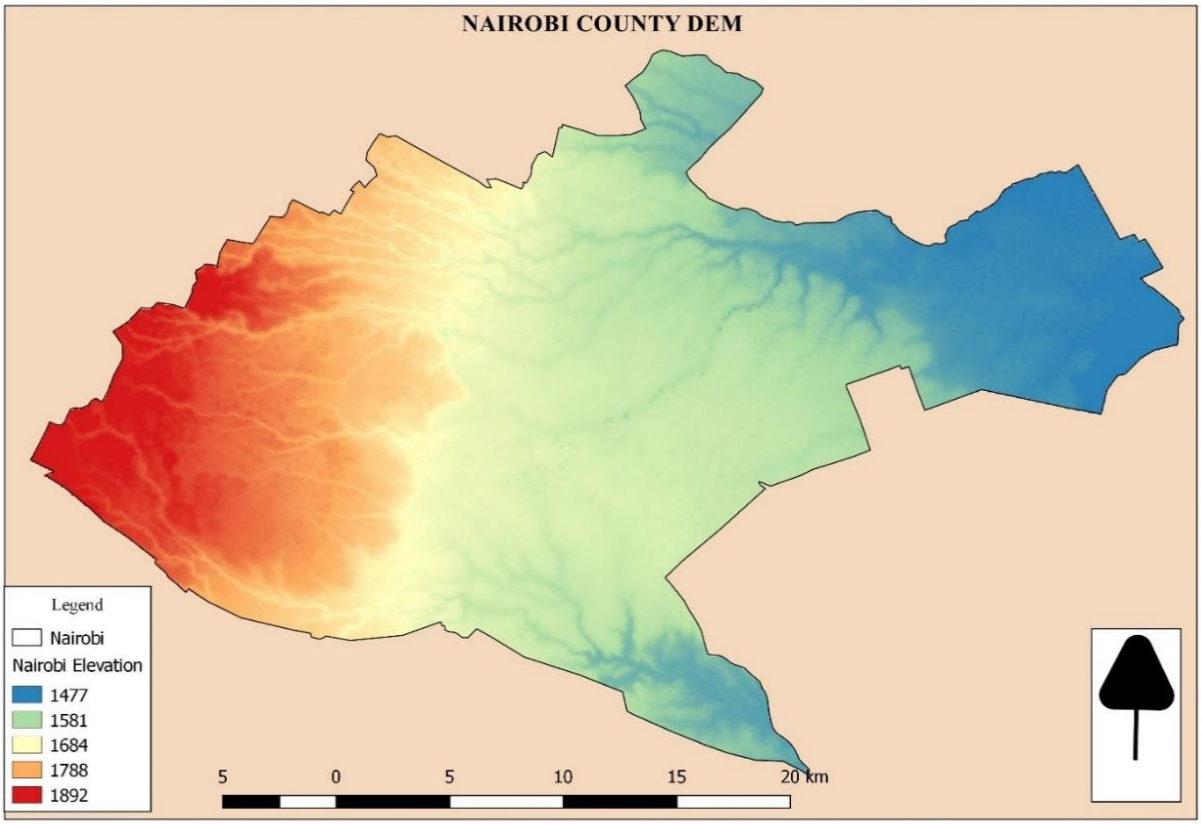

Figure 3:3: Nairobi City County Digital Elevation Model

Figure 3.3 depicts topography of Nairobi County as sloping from the high altitude western areas towards the low lying eastern parts of the County.

a) NAIROBI COUNTY SLOPE MAP

Nairobi City County Slope map was extracted from DEM raster of the study area. This was achieved using Raster Terrain Analysis tool in QGIS using Nairobi DEM as our input raster. Topography has been considered as one of the major contributing factors to soil deterioration.

Steep areas experience soil erosion removing fertile top soil that settle in less steep areas making the latter areas most suitable for crop farming. The output raster is as illustrated below with slope values expressed in percentage (%) rise:

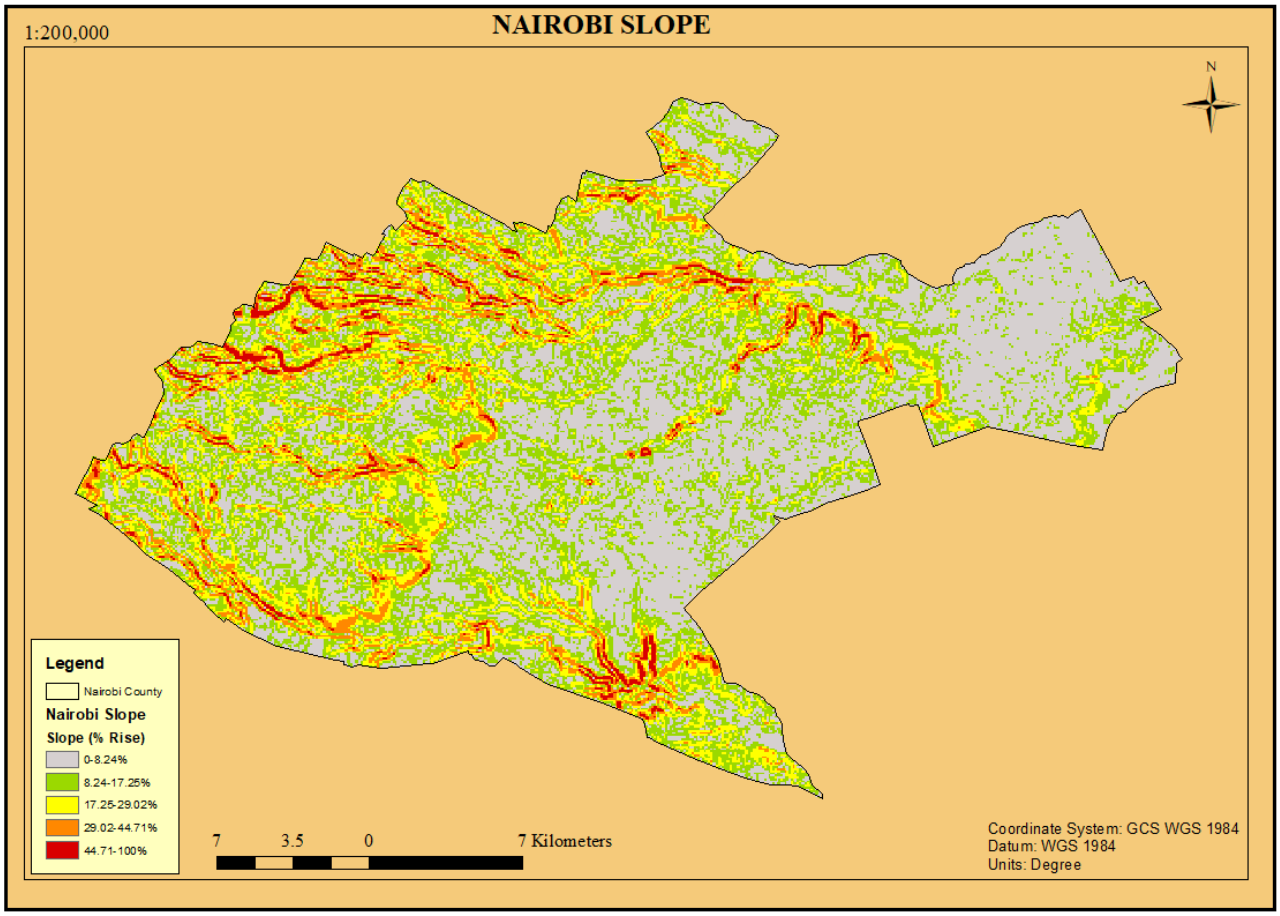

Figure 3:4: Nairobi City County Slope Map

3.5.2 SOIL ANALYSIS

Soil data used in this project was obtained from KALRO, a government agency mandated to conduct research on agriculture and livestock farming.

Soil properties that were considered vital in delineating arable lands are soil texture, Soil PHAQ and soil drainage. It will however be noted that soil data within Nairobi Central Business District is missing as most of these areas have concrete and tarmac as their land cover.

Discussed hereafter are the soil properties layers used in the arable land delineation process:

a) SOIL TEXTURE

This is a description of soil particle size. Soil texture usually influence soil drainage properties and its ability to store water for shorter or longer durations.

Nairobi County is comprised of loamy, clayey and very clayey soil textures with the most dominant one being clayey as can be visualized below. Loamy soils are considered most suitable for a wide variety of agricultural practices, followed by clayey due to their drainage and water holding properties. Very Clayey soils have poor drainage characteristics and are usually water logged making the unsuitable for most crop cultivation whereas sandy soils have poor water retention capacities. The *Figure 3.5* illustrates soil texture distribution in Nairobi City County:

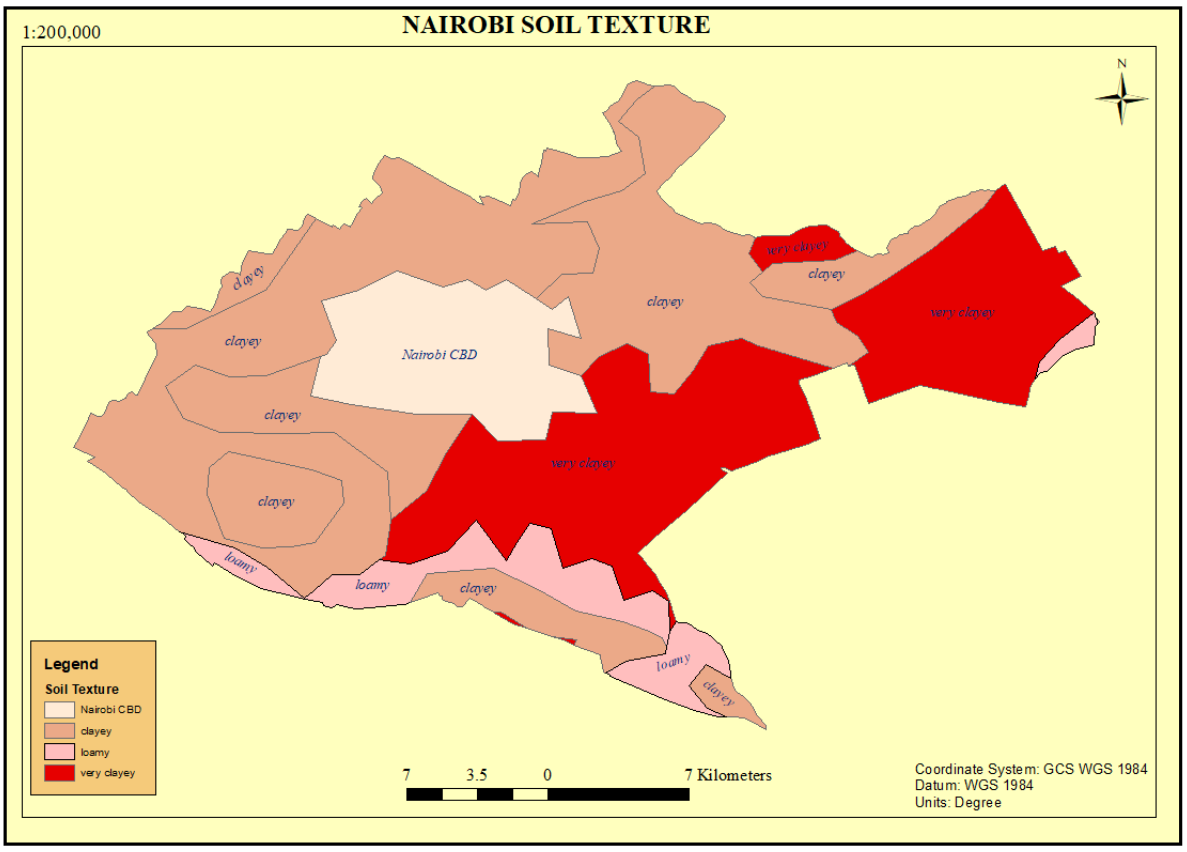

Figure 3:5: Nairobi City County Soil Texture Map

b) SOIL DRAINAGE

Soil drainage is a property of soil texture. It is usually the ability of soil to hold water after rainfall precipitation. Areas with "excessively drained" characteristics lose water rapidly and as such are not considered suitable for crop farming whereas those areas classified as "very poorly drained" have soils remaining wet for long durations and are not considered suitable for cultivation of most crops except rice, sugarcane among others.

The *Figure 3.6* illustrates soil drainage properties for Nairobi City County:

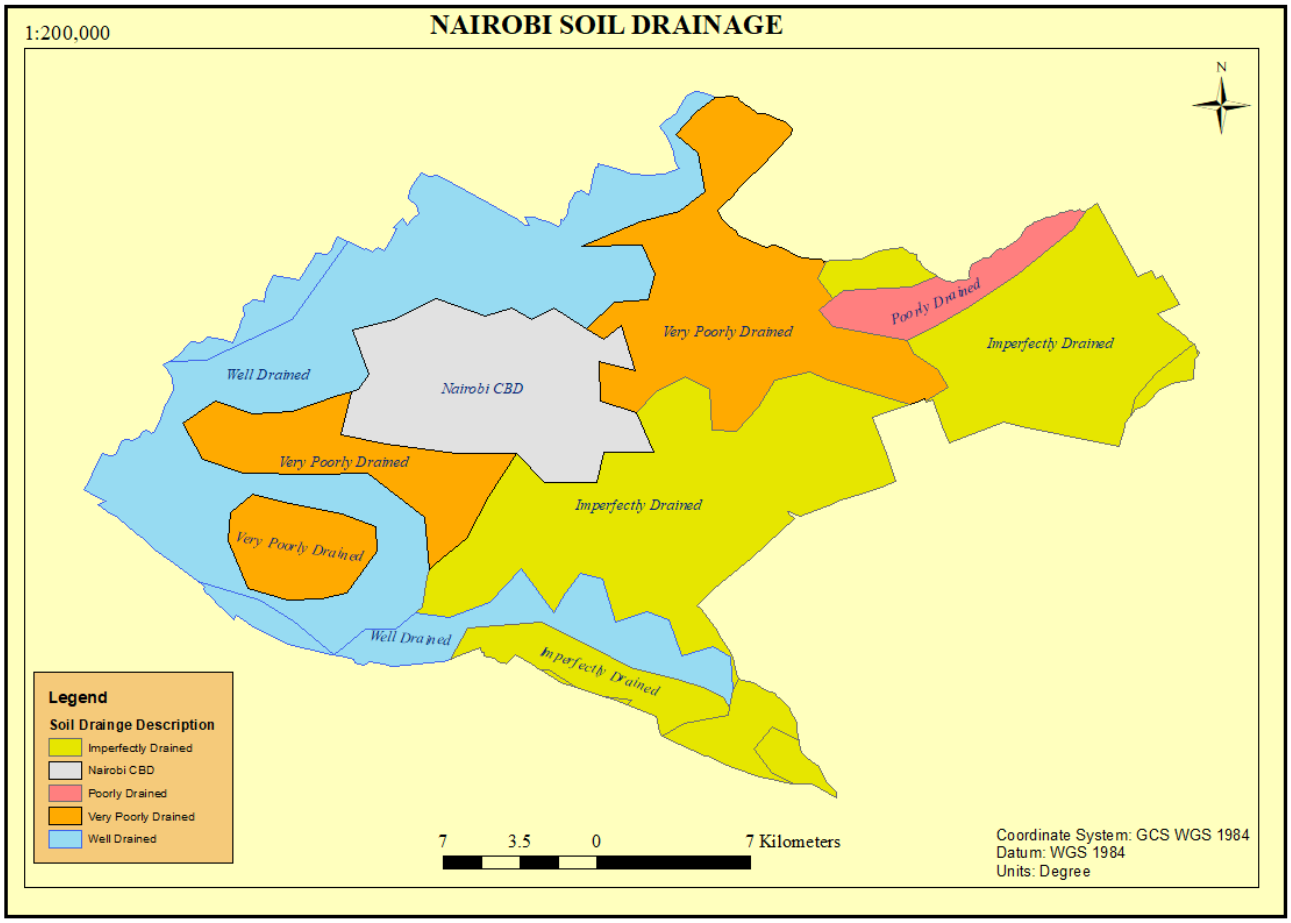

Figure 3:6: Nairobi City County Soil Drainage

c) SOIL PHAQ

Soil PHAQ is the PH of soil in water. It has been used overtime to establish suitability of soil for crops and vegetation in general. A PH range of 4.5 to 5.5 is considered to be low and it does

reduce crop yields. The same applies with PH of 8.0 and above. The optimal PH of soil in water for a huge majority of crops lies within the range of 6.5 to 7.5.

The *Figure 3.7* is a map indicating PHAQ values of soil in Nairobi City County:

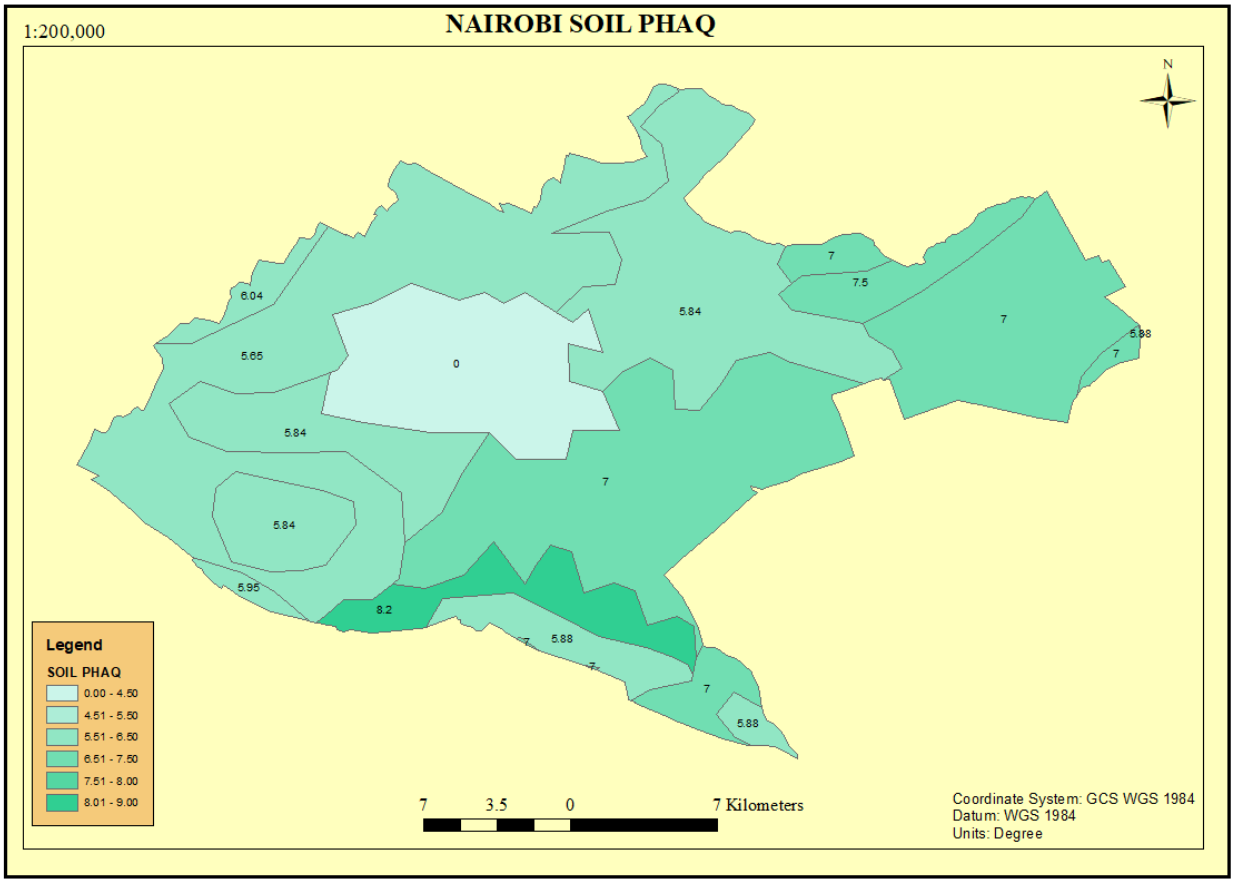

Figure 3:7: Nairobi City County Soil PH in Water

3.5.3 CLIMATE SURFACE

The three major climatic factors that influence the ability of parcels of land to be used for productive agricultural activity are temperature, humidity and rainfall precipitation.

a) RAINFALL PRECIPITATION

Since the Kenyan Agricultural Sector is mostly rain-fed, the amounts of rain received annually and its distribution throughout the year in a particular area directly influences crop productivity.

The *Figure 3.8* shows the distribution of annual amounts of rainfall precipitation in millimeters in Nairobi City County:

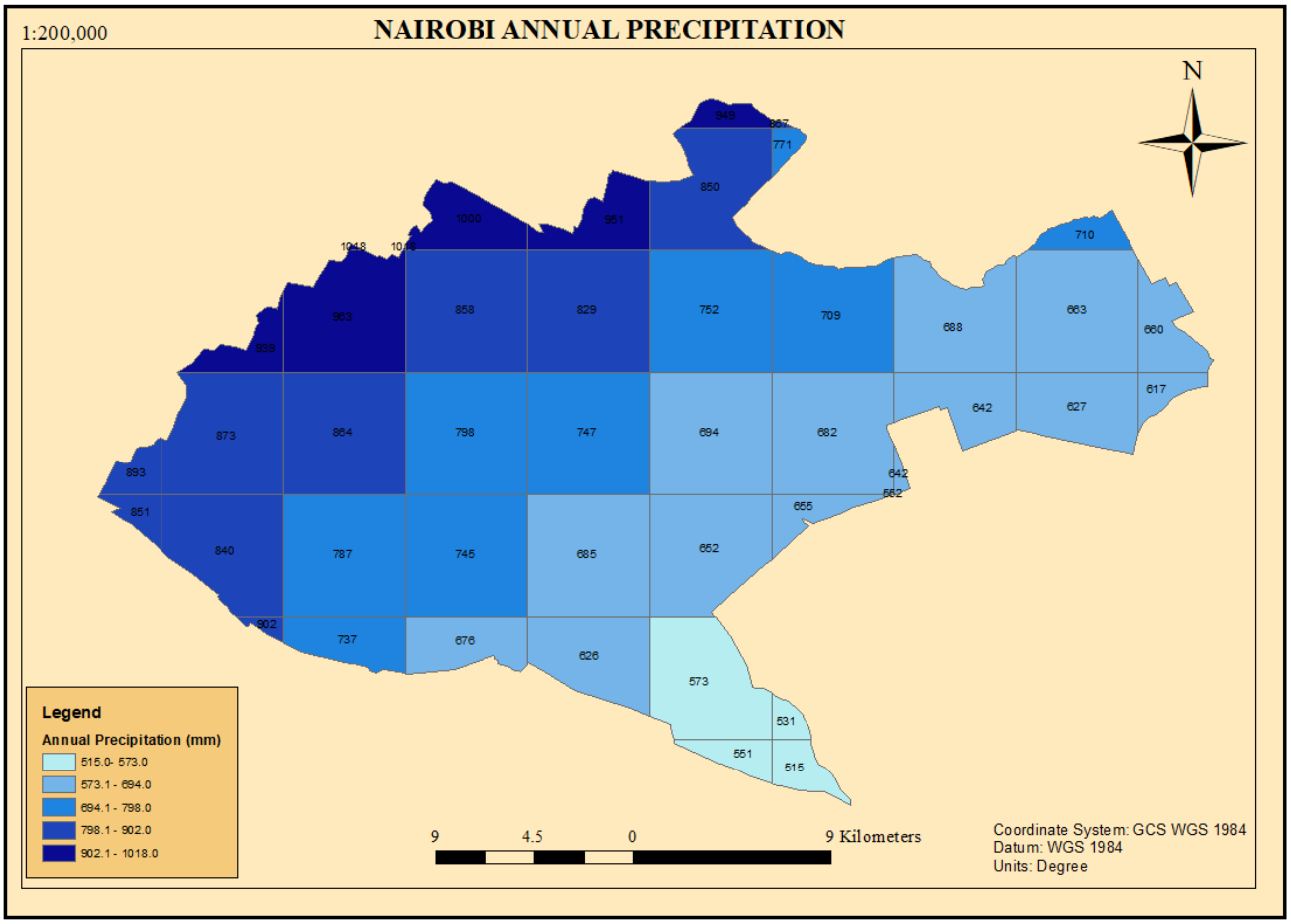

Figure 3:8: Nairobi City County Rainfall Precipitation Map

Areas that experience high amounts of rainfall are considered very highly suitable for agriculture whereas those that receive the least amount of rainfall are considered least suitable.

b) HUMIDITY

This is the availability of moisture content in the atmosphere. Humidity facilitates the photosynthesis process for vegetation. The amount of water vapor in the atmosphere influences rates of plant evapotranspiration which in the other hand influences intake of carbon dioxide (CO_2) by plants for photosynthesis.

The humidity layer for Nairobi was extracted from Kenya Climate Surface data obtained from KALRO.

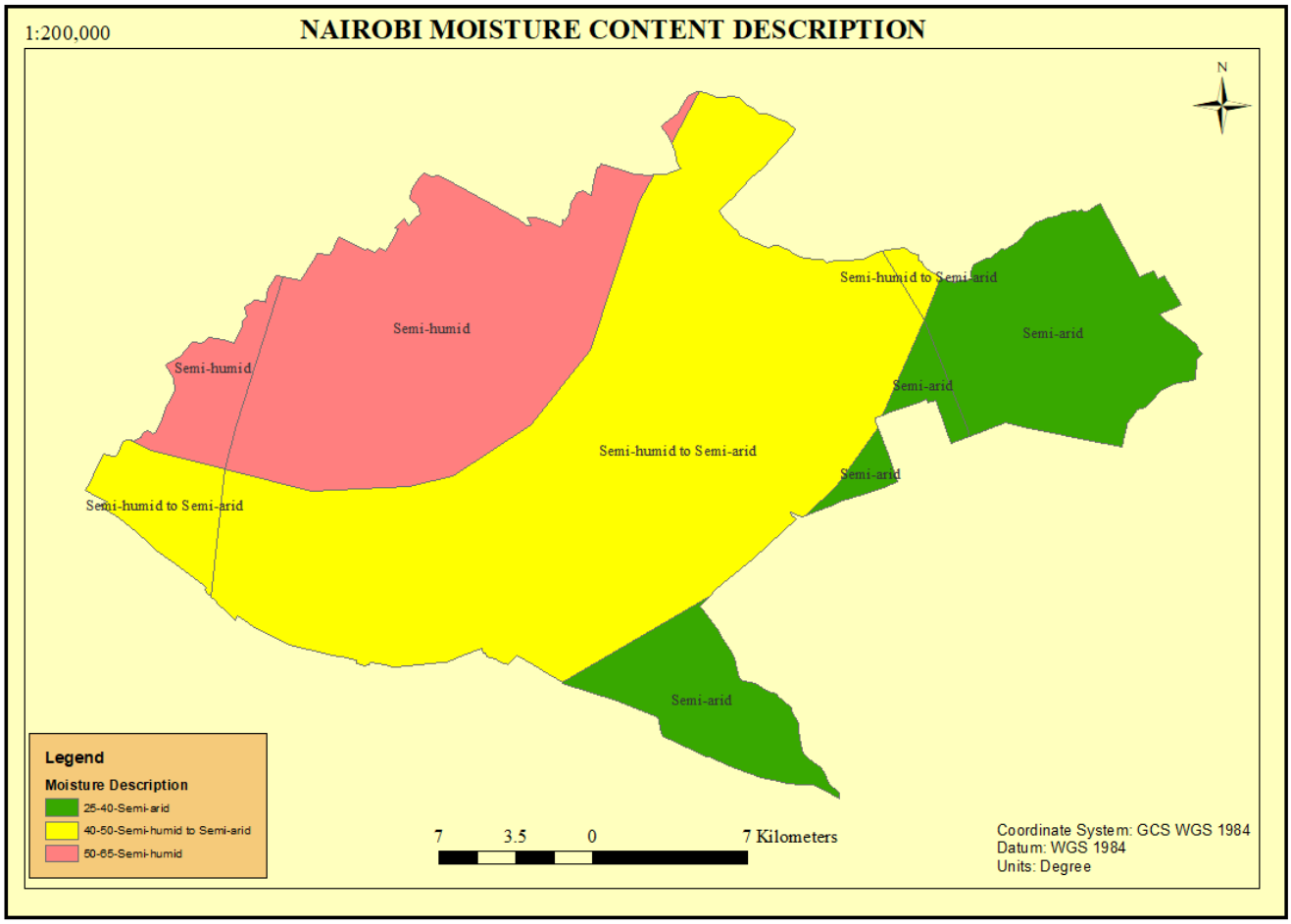

Figure 3:9: Nairobi City County Moisture Content Description Map

For Nairobi City County, areas classified as semi-humid are the most suitable for crop cultivation with the semi-arid areas being the least suitable for farming

c) TEMPERATURE

Mean annual temperature layer was extracted from Kenya Climate Surface data. The optimum temperature for a wide variety of vegetation for photosynthetic activities falls within a range on 18 to 25 degrees Celsius.

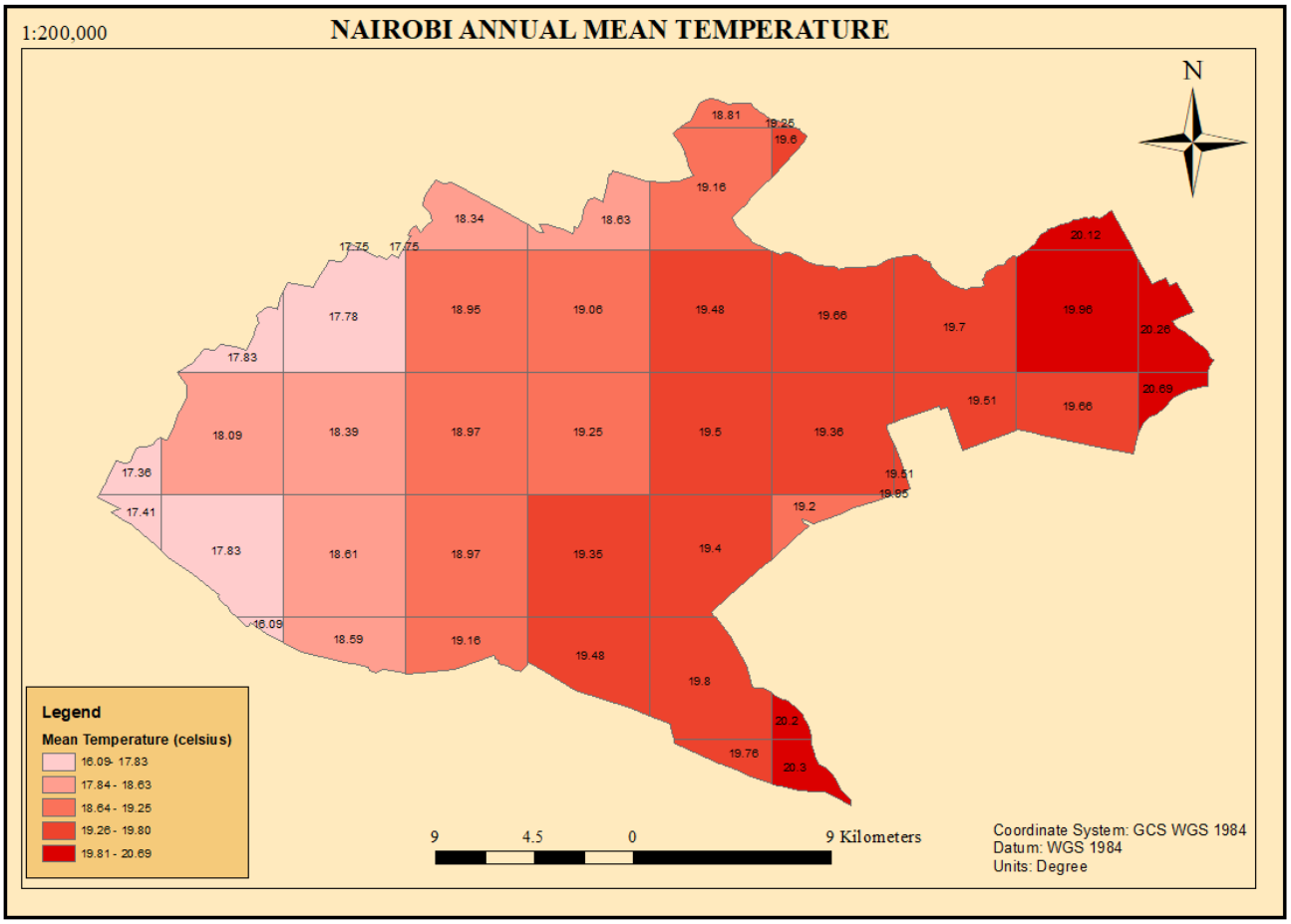

Figure 3:10: Mean Temperature Map for Nairobi City County

It will be observed that nearly all areas in Nairobi City County fall within the range of 18-25 degrees Celsius based on the mean temperature distribution and are thus considered suitable for crop farming.

3.5.4 ASSIGNING WEIGHT OF FACTORS AND MULTI CRITERIA EVALUATION

The raster layers extracted from topography, soil and climate datasets were reclassified and assigned scale based on the level of significance of each sub-class to growth rate and crop yields as indicated in *Table 3.2*.

Analytical Hierarchy Process (AHP) which is considered to be one of the multi criteria decision making tool was used to conduct pair wise comparison of factors and establish factors weights as illustrated in *Table 3.4* and *3.5*. Review of literature from previous research together with those recommended by FAO played a pivotal role in establishing factors weights.

The example scale for comparison used was the one developed by Saaty & Vargas (1991).

Table 3:2: Saaty & Vargas Scale of Comparison Adopted for the Project

Scale	Degree of Preference
1	Equal importance
3	Moderate importance of one factor over another
5	Strong or essential importance
7	Very strong importance
9	Extreme importance
2, 4, 6 and 8	Values for inverse comparison

The datasets were converted from vector to raster and reclassified based on scale value as indicated in the *Table 3.3*:

Table 3:3: Weighted Overlay Analysis Assigned Weights

No.	Datasets	Properties	Sub-Classes	Reclassification Scale	Scale Value
1.	**Topography**	Slope	0-8.24%	Very Highly Suitable	5
			8.24-17.25%	Highly Suitable	4
			17.25-29.02%	Suitable	3
			29.02-44.71%	Low Suitability	2
			44.71-100%	Very Low Suitability	1
		Soil Texture	Loamy	Very Highly Suitable	5
			Clayey	Highly Suitable	4
			Very Clayey	Low Suitability	2
			Sandy	Suitable	3
			Very Sandy	Very Low Suitability	1
			Nairobi CBD (Unclassified)	Very Low Suitability	1

2.	**Soil**	Soil Drainage	Well Drained Moderately Well Drained Imperfectly Drained Poorly Drained Very Poorly Drained Nairobi CBD (unclassified)	Very Highly Suitable Highly Suitable Suitable Low Suitability Very Low Suitability Very Low Suitability	5 4 3 2 1 1
		Soil PHAQ	0.0-4.5 4.5-5.5 5.5-6.5 6.5-7.5 7.5-8.5	Very Low Suitability Low Suitability Highly Suitable Very Highly Suitable Suitable	1 2 3 5 4
3.	**Climate Surface**	Rainfall	515-627 627-710 710-798 798-902 902-1018	Very Low Suitability Low Suitability Suitable Highly Suitable Very Highly Suitable	1 2 3 4 5
		Humidity	>80-Humid 65-80-Sub-humid 50-65 Semi Humid 40-50 Semi Humid to Semi-Arid 25-40 Semi-Arid	Very Highly Suitable Highly Suitable Suitable Low Suitability Very Low Suitability	5 4 3 2 1
		Temperature	16.09-18.09 18.09-18.63 18.63-19.25 19.25-19.76 19.76-20.69	Very Highly Suitable Highly Suitable Suitable Low Suitability Very Low Suitability	5 4 3 2 1

A pairwise comparison of input layers was conducted based on level of significance of one factor vis-à-vis the other using Saaty and Vargas scale of comparison as highlighted in *Table 3.2*.

Table 3:4: Pairwise Comparison Table

Scale	Slope	Soil PH	Soil Texture	Soil Drainage	Humidity	Rainfall	Temperature
Slope	1	3	1/3	3	3	1/3	1/3
Soil PH	1/3	1	1/3	1	1	1/3	1/3
Soil Text	3	3	1	3	3	1	1/3
Soil Drain	1/3	1	1/3	1	1	1/3	1/3
Humidity	1/3	1	1/5	1	1	1/3	1/3
Rainfall	3	3	1	3	3	1	3
Temperature	3	3	3	3	3	1/3	1

Synthesis judgement table was used to come up with level of influence (weight) of each factor that will be used in the weighted overlay analysis for purposes of generating arable land suitability map.

Table 3:5: Synthesis Judgement Table

Scale	Slope	Soil PH	Soil Texture	Soil Drainage	Humidity	Rainfall	Temperature	Influence
Slope	0.09	0.20	0.05	0.20	0.20	0.09	0.06	0.13
Soil PH	0.03	0.07	0.05	0.07	0.07	0.09	0.06	0.06
Soil Text	0.27	0.20	0.16	0.20	0.20	0.27	0.06	0.20
Soil Drain	0.03	0.07	0.05	0.07	0.07	0.09	0.06	0.06
Humidity	0.03	0.07	0.03	0.07	0.07	0.09	0.06	0.06
Rainfall	0.27	0.20	0.16	0.20	0.20	0.27	0.53	0.26
Temperature	0.27	0.20	0.48	0.20	0.20	0.09	0.18	0.23
CR=0.06								1.00

The resultant output of weighted overlay analysis process conducted in ArcGIS 10.5 is as illustrated in the *Figure 3.11*:

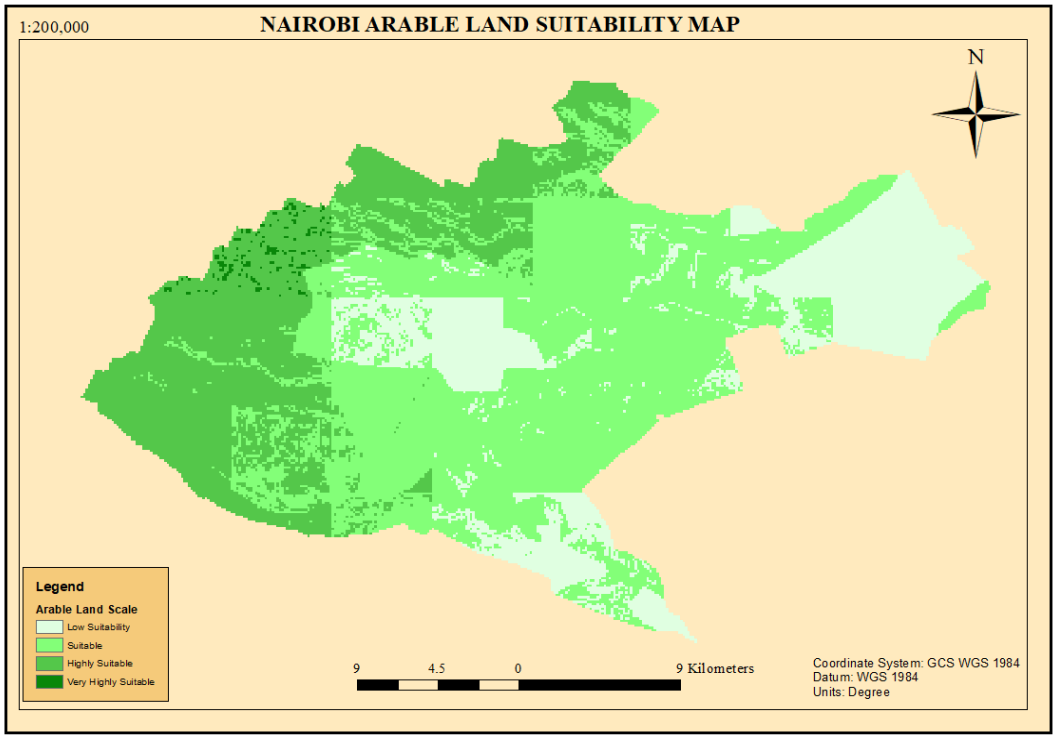

Figure 3:11: Arable Land Suitability Map for Nairobi City County

3.6 LANDCOVER CLASSIFICATION AND CHANGE DETECTION ANALYSIS

Landsat Satellite images of path 168 and row 061 were used for this research, as our area of interest falls within this region. The images used were of Landsat 7, Landsat SLC-OFF and Landsat 8 ETM+ of the year 2000, 2012 and 2018 respectively from USGS Portal. The images were selectively chosen to ensure there was minimum or no cloud cover at all that would obscure details save for 2012 that had gaps.

Table 3:6: Landsat Image Specifications

LANDSAT IMAGES SPECIFICATION					
Sensor	**Spatial Resolution (meters)**	**Datum**	**UTM Zone**	**Band Combination**	**Acquisition Date**
Landsat 7_ETM	30	WGS 1984	37 North	1,2,3,4,5,6 VCID-1,6 VCID-2,7,8	February 2000
Landsat 7 SLC-OFF	30	WGS 1984	37 North	1,2,3,4,5,6 VCID-1,6 VCID-2,7,8	January 2012
LANDSAT_8 OLI_TIRS	30	WGS 1984	37 North	1,2,3,4,5,6,7,8,9,10,11	February 2018

3.6.1 IMAGE PRE-PROCESSING

1. Data downloaded from USGS Portal was compressed and in *.tar* format. Thus, using WinRAR software, the data was extracted to obtain band images in TIF file format.
2. Using ArcMap 10.5 *Composite Band,* raster processing tool, a single image file was formed from bands 5, 4 and 3 (false color) of Landsat 7 and saved locally as in *Figure 3.12*.
3. For Landsat 7 SLC-OFF 2012 imageries that come with gaps, using QGIS 2.18 Raster Analysis, '*Fill No Data'* tool, the gaps were first filled using the corresponding bands in gap mask raster collection and using composite band raster processing tool in ArcMap 10.5, a single image was formed from bands 5, 4 and 3 as in *Figure 3.13*.
4. The first two steps were repeated for Landsat 8 data. The band combination for a composite raster was 6, 5 and 4 (false color) as in *Figure 3.14.*
5. Using the *compute pan-sharpen weights,* raster processing tool in ArcMap 10.5, band 8 (panchromatic band) for Landsat 7 and 8 were used to improve spatial resolution of the three output files of layer stacking process.
6. A vector layer of Nairobi City County administrative boundary was loaded into ArcMap 10.5. Using the *raster clip tool,* the pan-sharpened images were clipped to our area of interest.

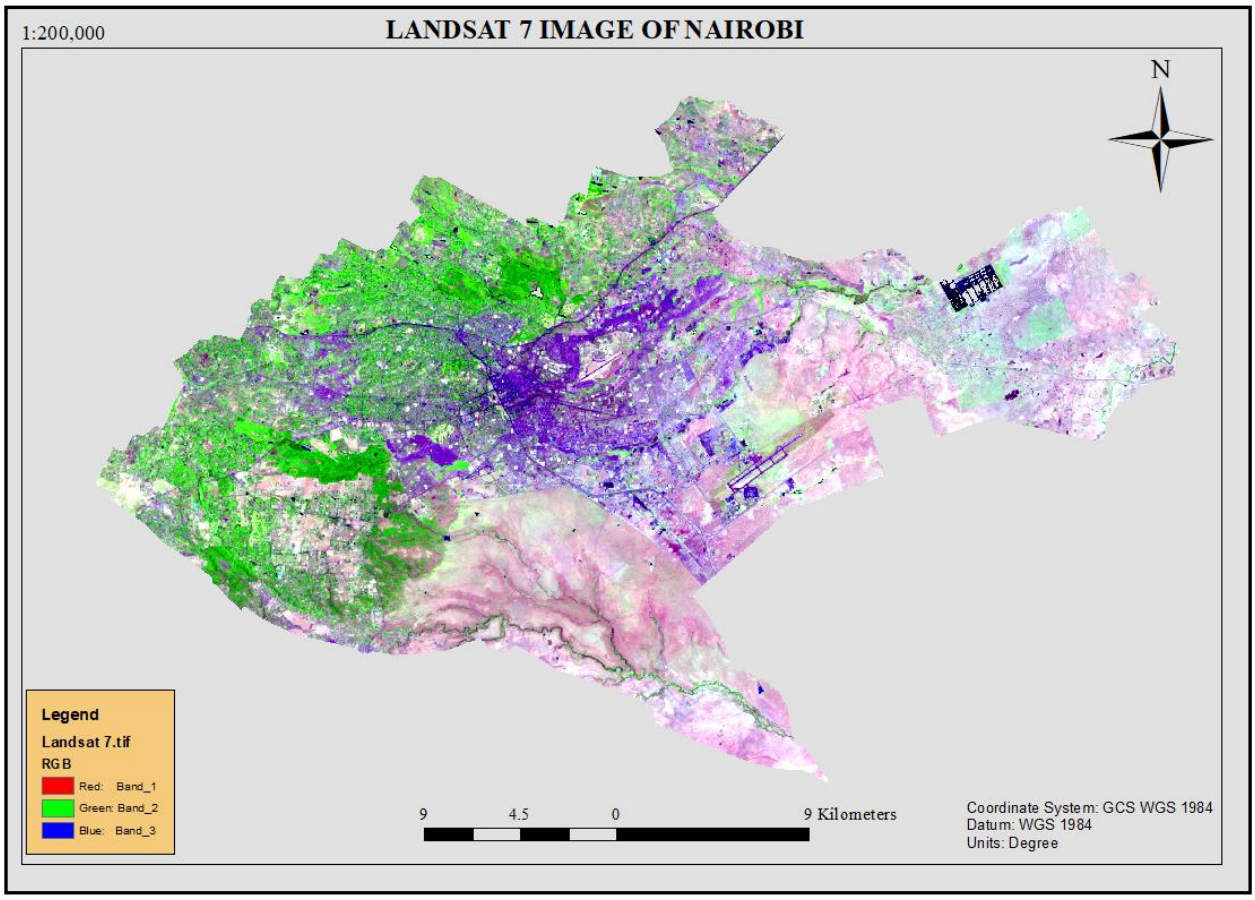

Figure 3:12: Landsat 7 (2000) false color (5, 4 and 3) composite band image of Nairobi City County

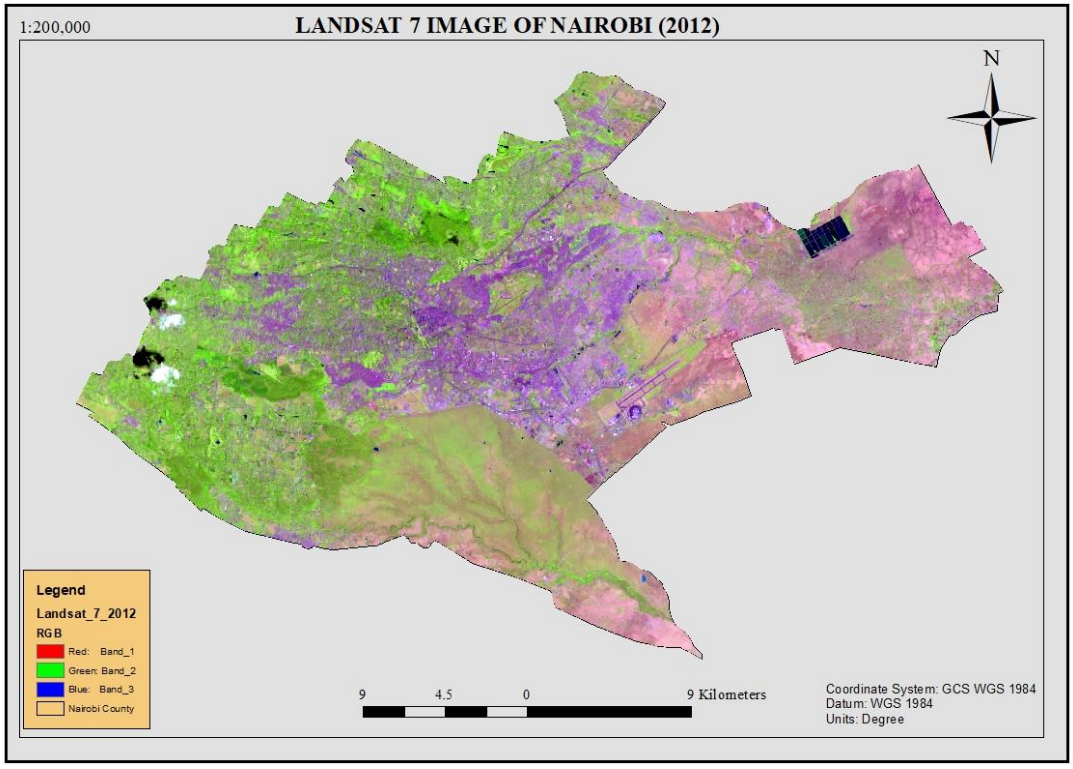

Figure 3:13: Landsat 7 (2012) false color (5, 4 and 3) composite band image of Nairobi County

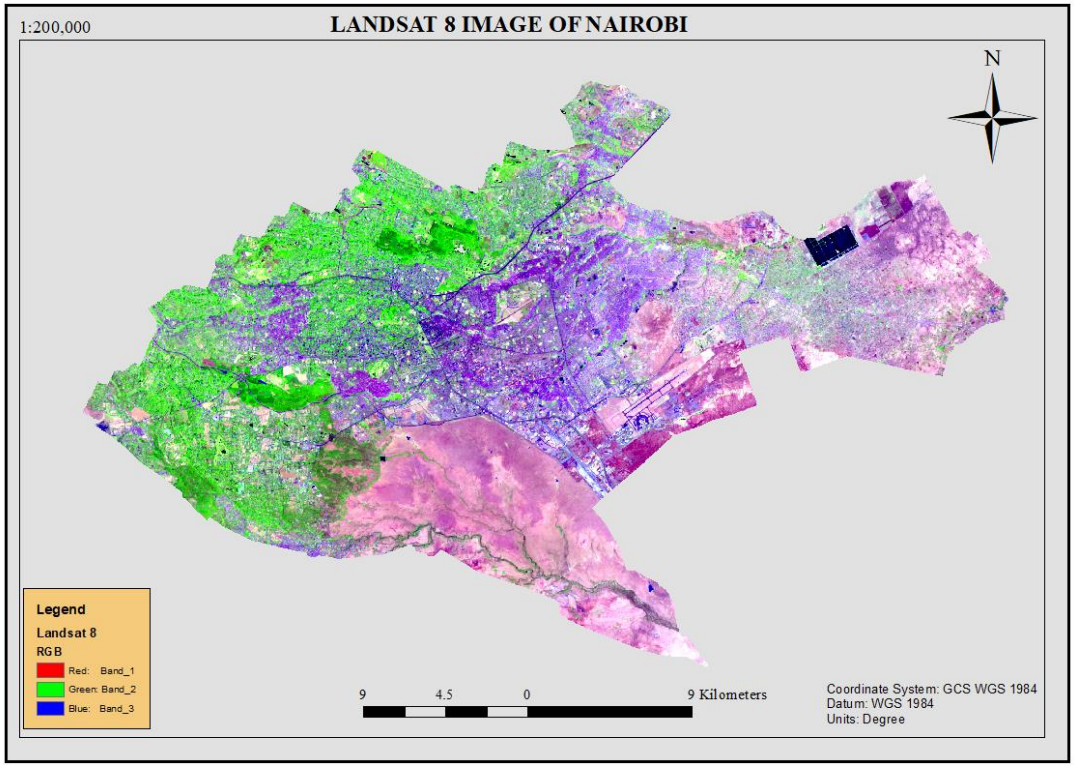

Figure 3:14: Landsat 8 (2018) false color (6, 5 and 4) composite band Image of Nairobi County

3.6.2 NDVI ANALYSIS

Using the *Image Analysis* tool in ArcMap 10.5, layer stacked images of Landsat 7, Landsat 7 SLC-OFF and Landsat 8 were selected independently and NDVI tool selected to run NDVI Analysis.

NDVI= (NIR-RED) ÷ (NIR+RED)

NDVI Landsat 7= (Band 4-Band 3) ÷ (Band 4+Band 3)

NDVI Landsat 8= (Band 5-Band 4) ÷ (Band 5+Band 4)

Equation 1:NDVI Analysis formula

A point shapefile layer was then created and sample points within the resultant NDVI raster output chosen selectively to represent every land cover, helped in extraction of NDVI values.

Using *Extract Values to Points* tool in ArcMap 10.5 Spatial Analyst tools, NDVI values were extracted to help in clearly defining class range of each land cover which were then used to generate land cover maps of Nairobi City County. The *Figure 3.15* illustrates how sample points were chosen to help extract NDVI values.

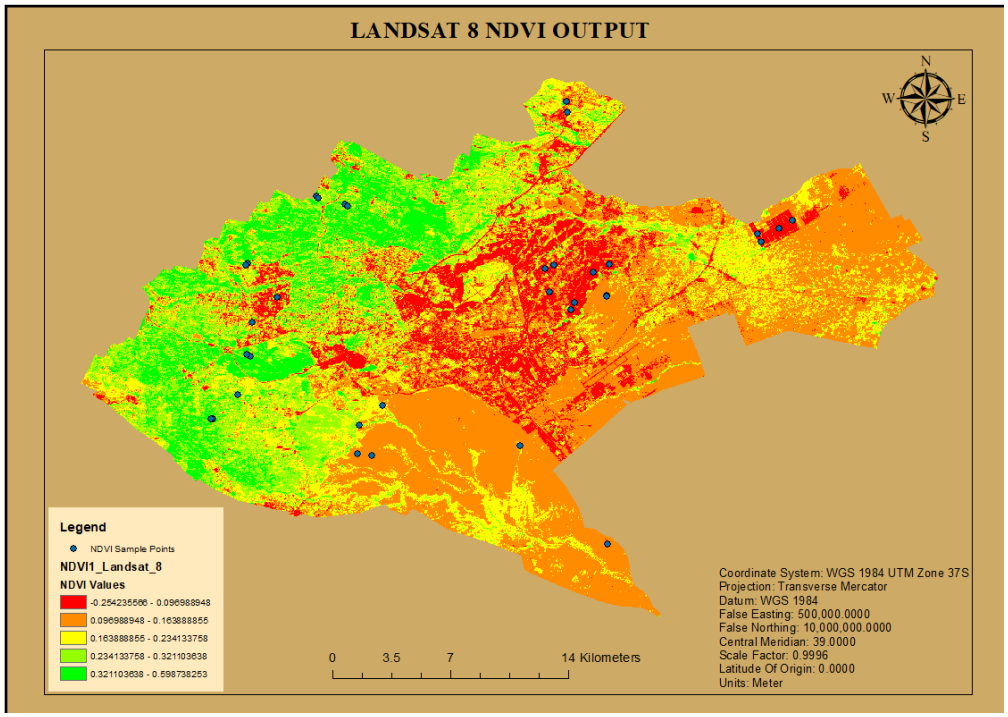

Figure 3:15: NDVI Analysis output for Landsat 8 with points created to extract NDVI values

The *Table 3.7* shows NDVI values extracted and the Land Covers the point represents.

Table 3:7: NDVI Values Extracted and Land Cover Class Represented for Landsat 8 NDVI Analysis

LANDSAT 8 EXTRACTED NDVI VALUES		
OBJECTID	**NDVI Value**	**Land Cover**
1	-0.037665326	Water Bodies
2	-0.003134796	Water Bodies
3	0.012909078	Water Bodies
4	-0.014624307	Water Bodies
5	-0.02403914	Water Bodies
21	-0.010997644	Water Bodies
23	0.035853613	Built-up Areas
24	0.090656012	Built-up Areas
25	0.105186753	Built-up Areas
30	0.102921672	Built-up Areas
31	0.084366061	Built-up Areas
32	0.070147678	Built-up Areas
33	0.055205178	Built-up Areas
34	0.134869859	Bare Land
35	0.13411808	Bare Land
36	0.130823895	Bare Land
37	0.11383602	Bare Land

It was noted that values lying between -1 to 0 represent water bodies, 0 to 0.10 represent Built-Up Areas whereas 0.11 to 0.20 represent Bare Land and values above 0.20 represent vegetation cover at different densities as illustrated in *Table 3.7*.

The values extracted were used to define class range of NDVI values for different land cover. The raster was then reclassified using the *Reclassify Spatial Analyst* tool and converted to vector form. The layer converted to vector was exported as *.csv* file to help in acreage extraction of each land cover.

3.7 INTERSECTION ANALYSIS

The Built-Up Areas land cover classes for the year 2000, 2012 and 2018 were extracted and saved as separate layers.

Using Arable Land Suitability layer and Built-Up Areas as inputs, intersection analysis was conducted with the help of *Intersect Analysis tool* of ArcMap 10.5 and the outputs saved locally.

The resultant outputs were exported as .csv files and area information extracted to help in analyzing the amounts of arable lands lost to urbanization overtime.

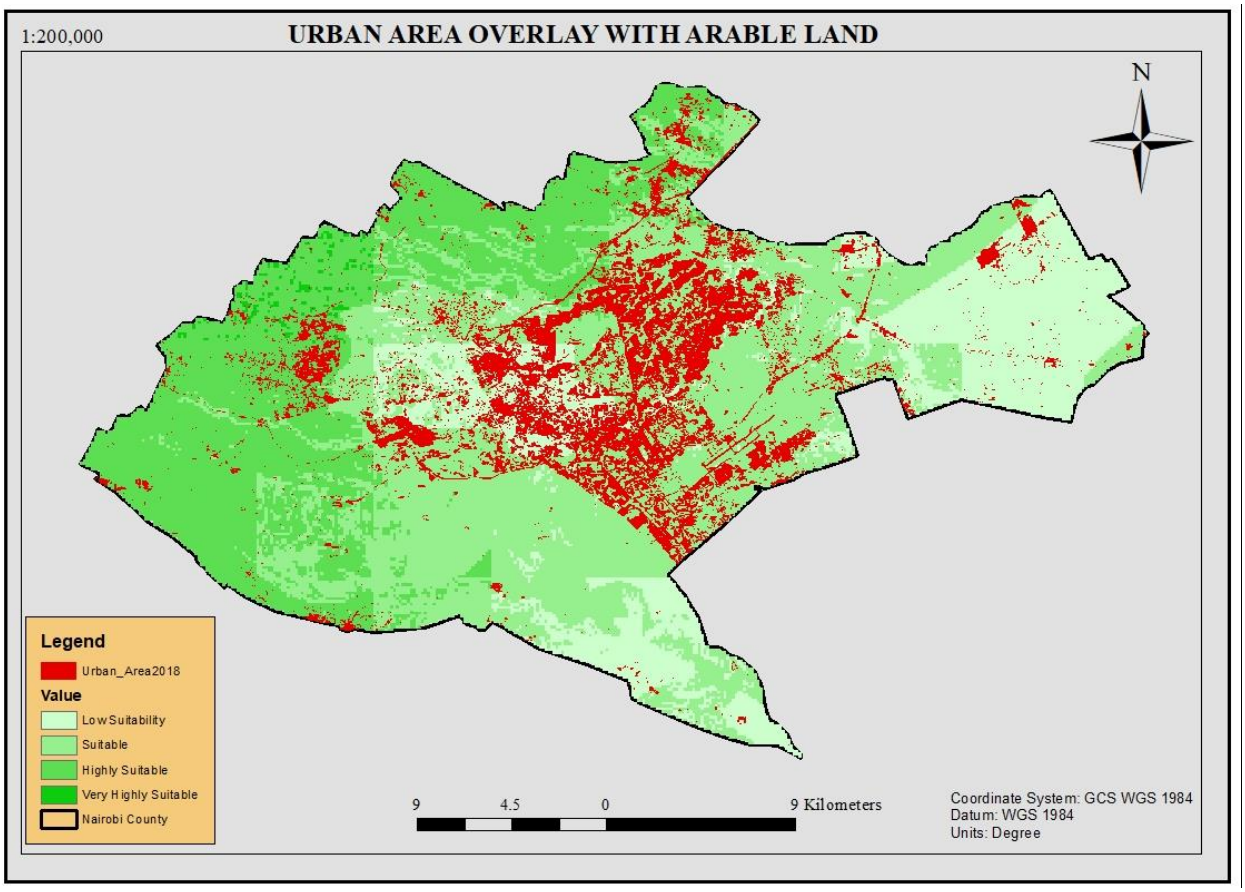

Figure 3:16: Overlay of Built-Up Areas with Arable Land Suitability Map

CHAPTER 4: RESULTS AND DISCUSSIONS

This chapter deals with analysis of results obtained from processed data and how these findings contributed towards achieving the main objective this study is made.

4.1 POPULATION AND HOUSING AS INDICATORS OF URBANIZATION

Population and housing data obtained from KNBS were graphically represented to help in statistical analysis of the population and housing trends of Nairobi City County over the years. The data was also mapped to help in visualization of spatial distribution of population and housing at sub-county level as illustrated in the *Figures 4.2 and 4.4*:

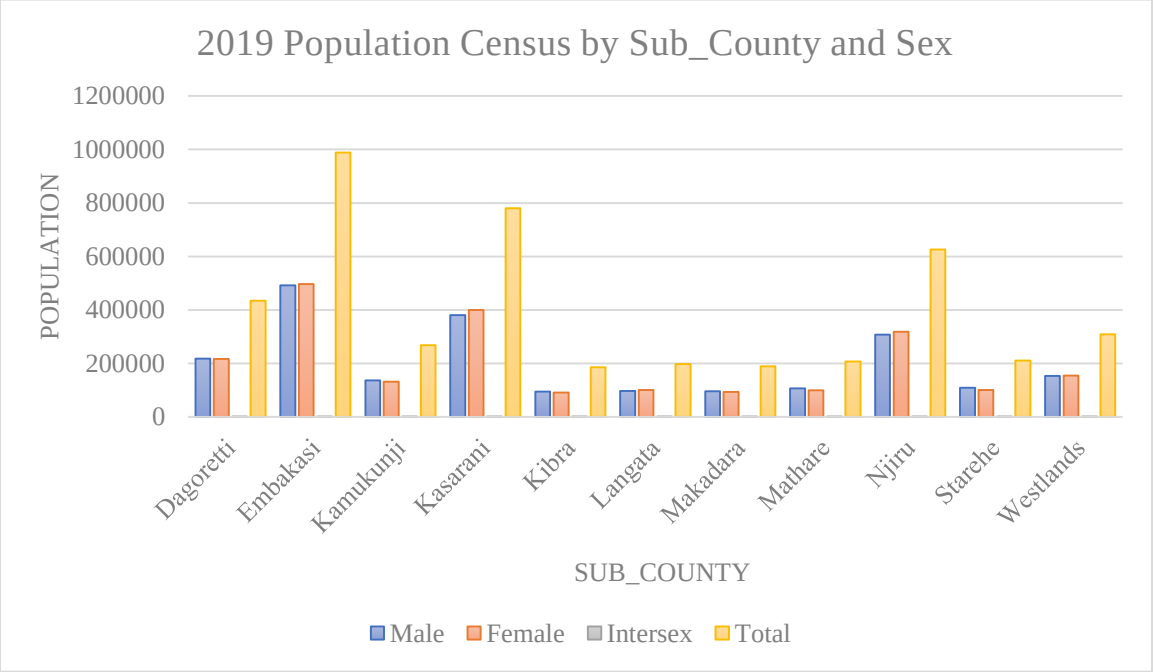

Figure 4:1: Graphical representation of 2019 Population Census by Sub-County and Gender

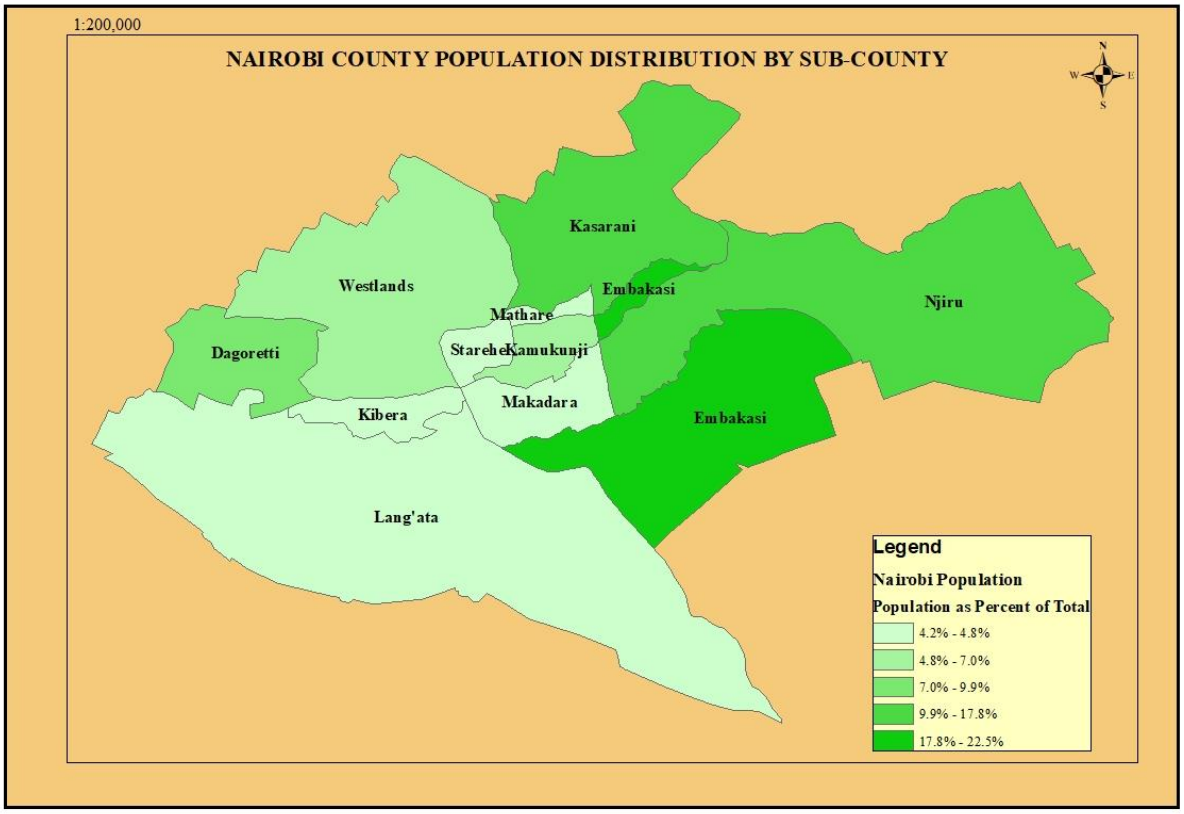

Figure 4:2: Map of 2019 Census Population Distribution by Sub-County in Nairobi City County

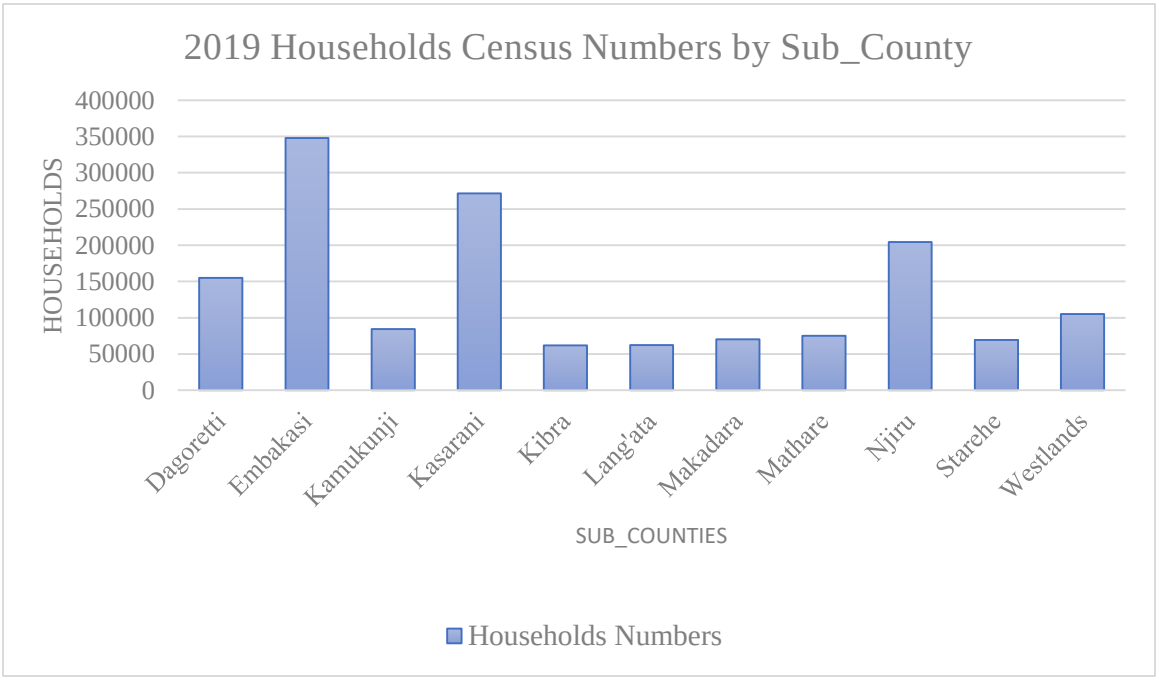

Figure 4:3: Graphical representation of 2019 Households Census by Sub-County

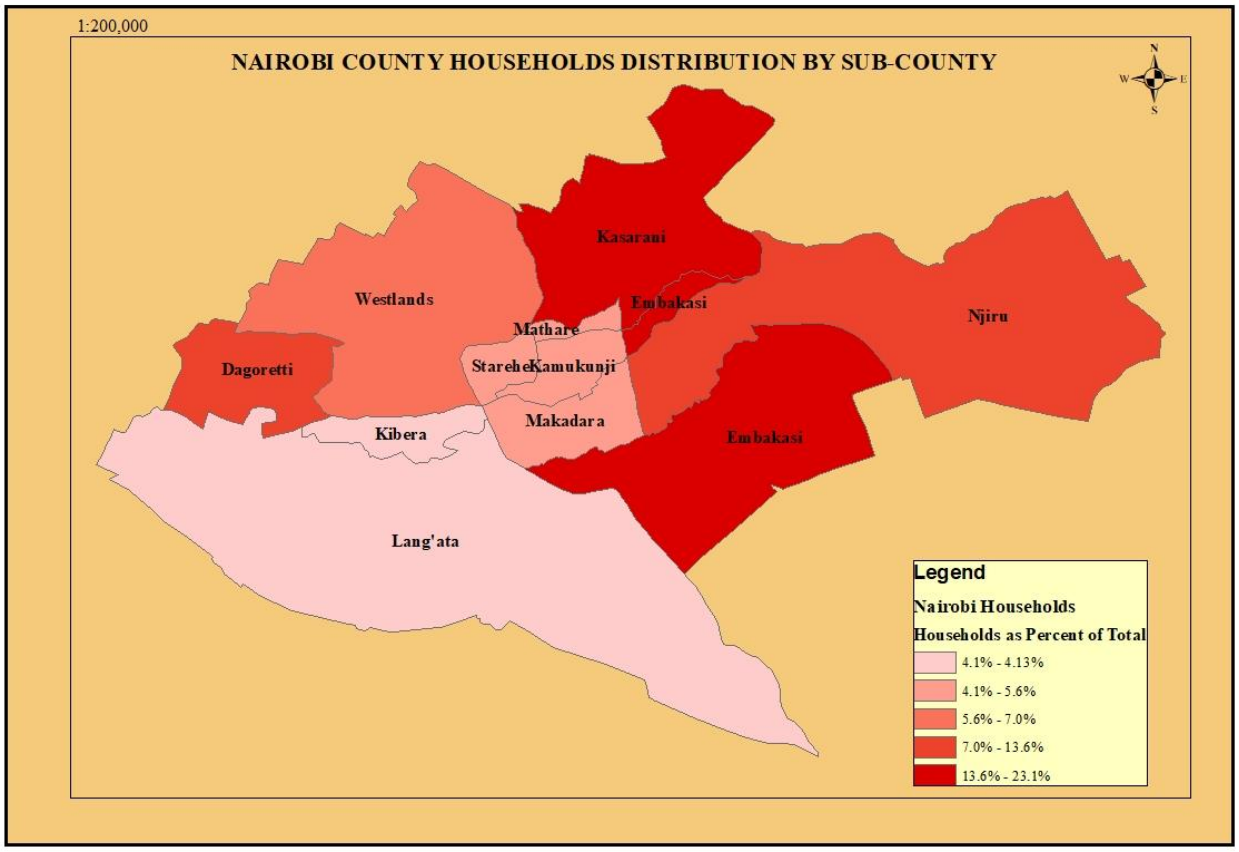

Figure 4:4: Map of 2019 Census Households Distribution by Sub-County in Nairobi County

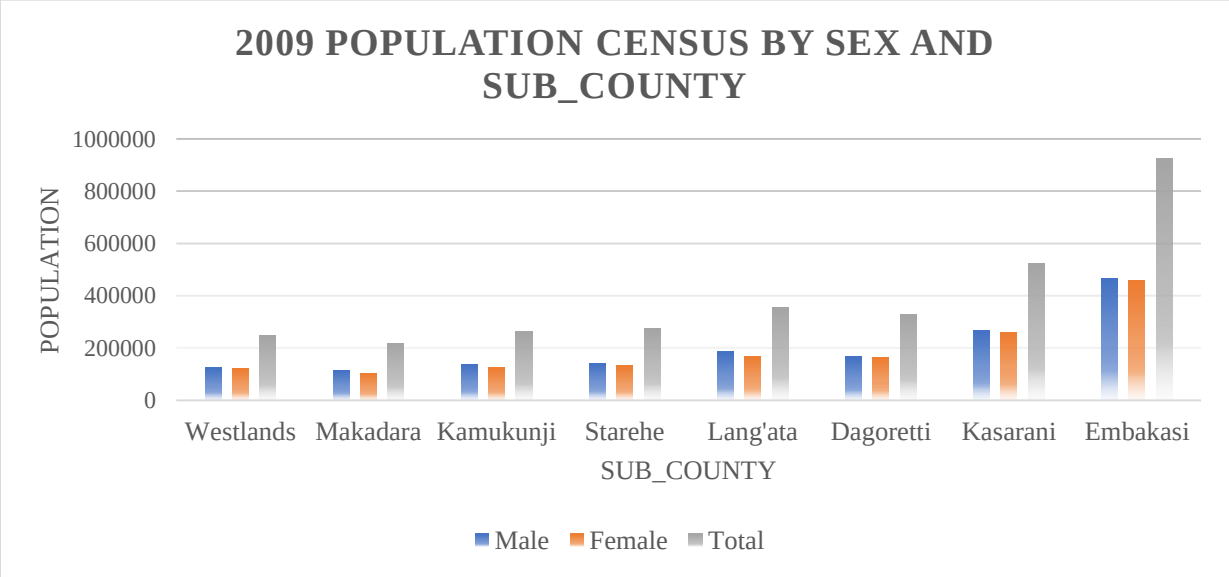

Figure 4:5: Graphical representation of 2009 Population Census by Sex and Sub-County

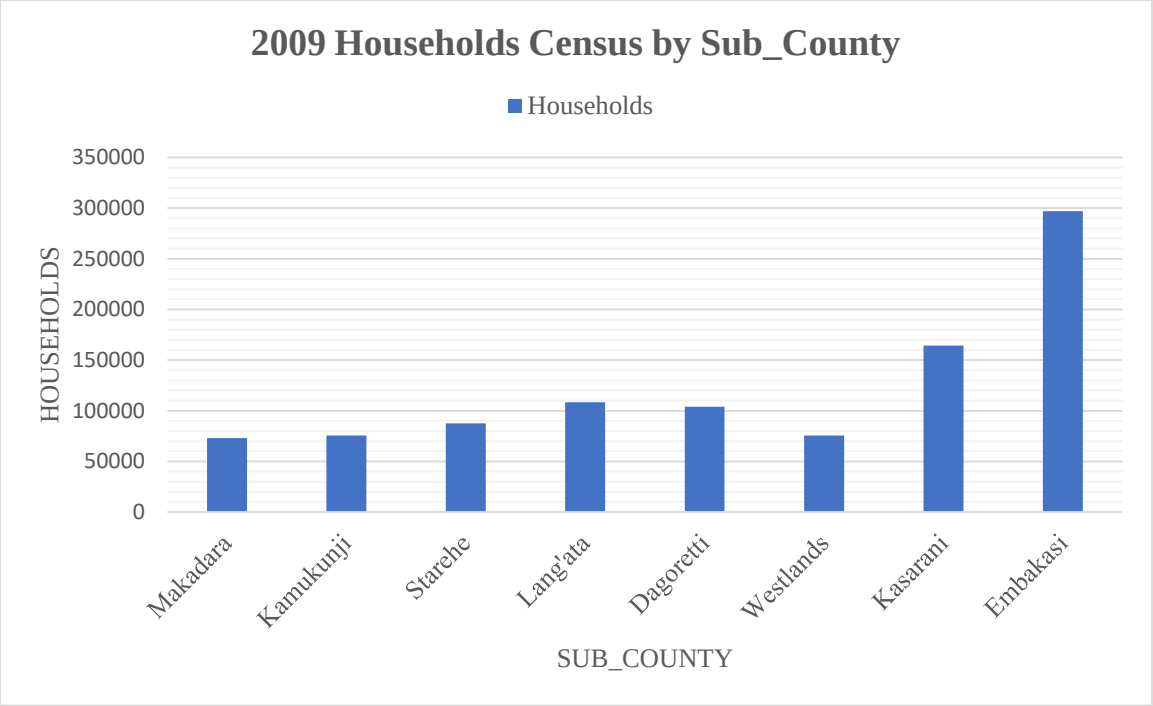

Figure 4:6: Graphical representation of 2009 Households Census by Sub-County

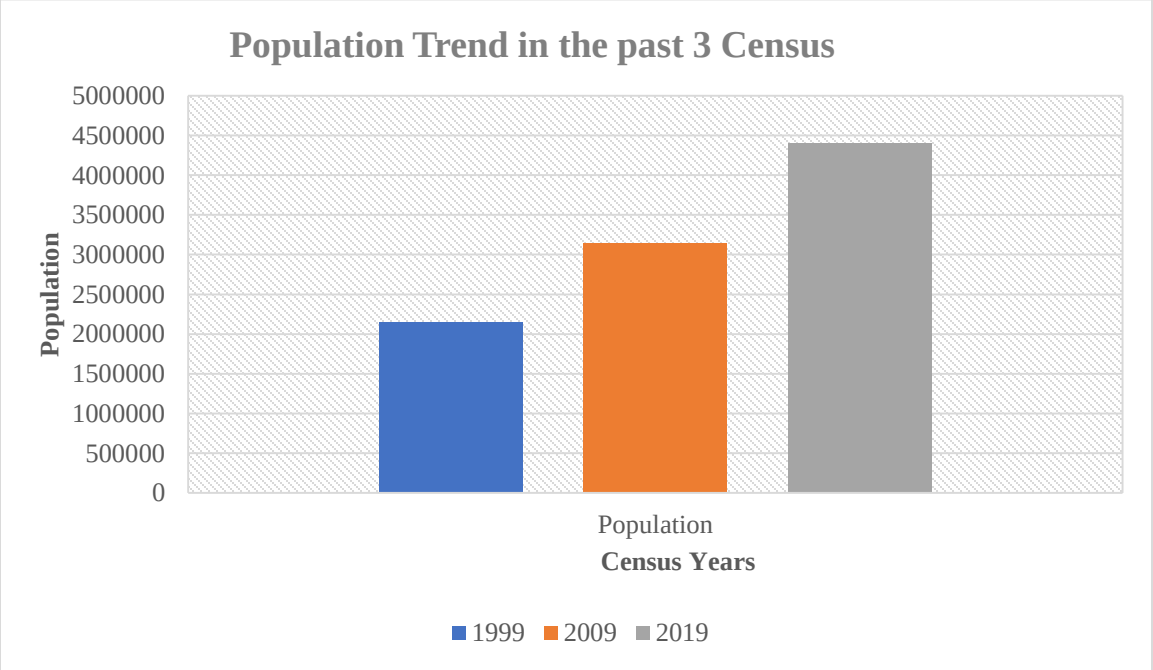

Figure 4:7: Graphical Representation of Population Trend

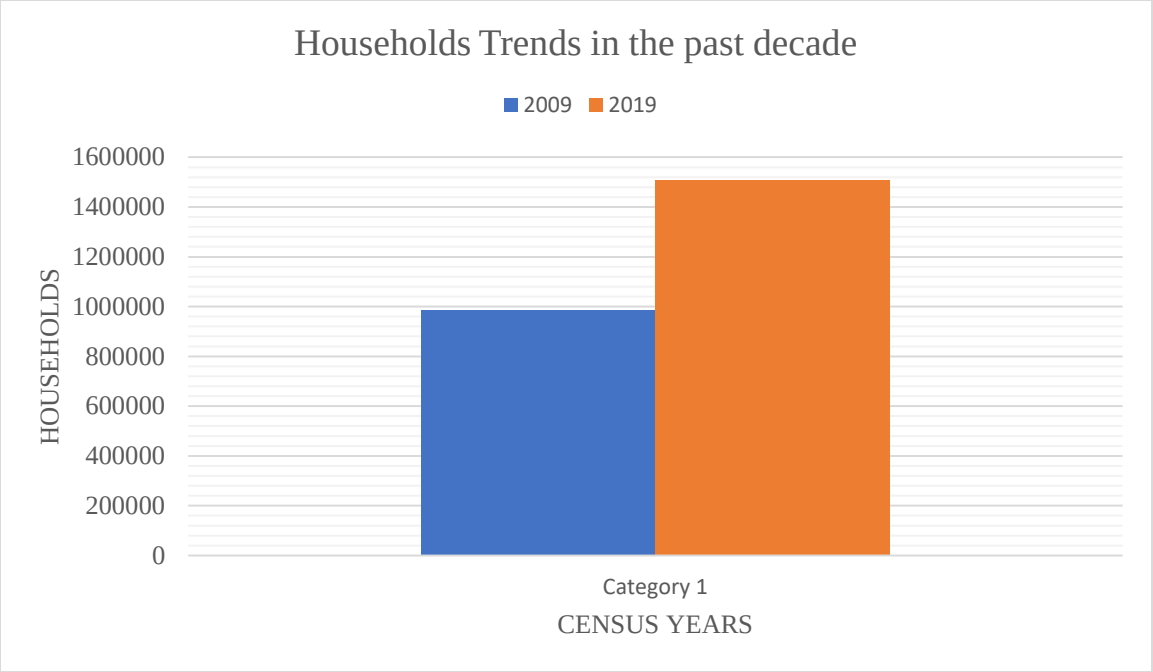

Figure 4:8: Graphical representation of Households Trends

Urban population is considered as one of the key drivers of urban areas development. From *Figure 4.1 and 4.3,* it is clear that the most populous sub-counties with the largest numbers of households within the county are Embakasi, Kasarani and Njiru whereas sub-counties with the least inhabitants were Makadara, Lang'ata and Kibra. *Figure 4.2 and 4.4* show spatial distribution of population and household data by sub-county. From *Figures 4.2 and 4.4,* it is clear that the eastern parts of Nairobi City County which hosts majority of the middle class and the urban poor is the most populated whereas central, parts of western and southern areas of the district are among the least populated regions in the county and this can be attributed to presence of Nairobi National Park in the southern parts, Central Business District in the central region and the leafy suburbs in the Western side. This would therefore imply that a majority of land cover changes are prone to have occurred in the eastern and parts of the western areas of the county so as to pave way for housing and infrastructural developments in these areas.

Figure 4.5 and 4.1 clearly show that the most populated sub-counties in 2019 were still the same most populated sub-counties in 2009. This would therefore imply that the level of housing and social amenities strain in these areas is high and as such attracting more housing and social amenities developments in these to offset the deficit.

Based on the 2009 census data from KNBS, Nairobi County inhabitants accounted for 8.13% percent of the total population of Kenya with the number of households within the same administrative area accounting for 11.23% of total households in the country. As at 2019, the total number of households in Nairobi City County equated to 12.41% of the total households countrywide whereas the county's population was equal to 9.24% of Kenya's total population. This would therefore imply that in the past decade (2009-2019), Nairobi County was the biggest gainer in population and housing developments increase despite being the smallest county. This would therefore imply that during this duration, there was huge loss of potential farm lands so as to pave way for housing developments to shelter the additional populace.

Figure 4.7 and 4.8 clearly illustrates population and household trends in the county for the past few decades based on KNBS data. The county experienced a surge in household unit numbers by 521,872 (five hundred and twenty-one thousand, eight hundred and seventy-two) units in the past decade inferring a 52.98% increase in households in the last decade which implies an annual growth rate of approximately 5.30%.

Between the years 1999 and 2009, the county experienced an increase in number of residents by 995,115 (nine hundred and ninety-five thousand, one hundred and fifteen) people, which is equated to 46.43% increase in population in ten years i.e. annual population growth rate of approximately 4.64%. In the past decade however, 2009-2019, the number of city inhabitants rose by 1,258,704 (one million, two hundred and fifty-eight thousand, seven hundred and four) persons amounting to 40.11% increase in population inferring an approximate 4.01% annual population growth rate.

It is significant that there was a decrease in annual population growth rate in the past decade (2009-2019) which stood at 4.01% vis-à-vis the previous one (1999-2009) at 4.64%. This can be attributed to devolution of government services to county level that commenced after the 2013 general election following the promulgation of the new constitution in 2010. County governments have created jobs and attracted investors who have created employment opportunities for the rural youth thus deterring rural to urban migration which is one of the drivers of urban population growth.

In conclusion based on the analysis drawn from population and household data, it is clear how rapid increase in urban population stimulates urbanization.

4.2 ARABLE LAND DELINEATION

Arable Land Suitability Map was obtained by weighted overlay analysis of datasets as indicated in *Table 3.5.*

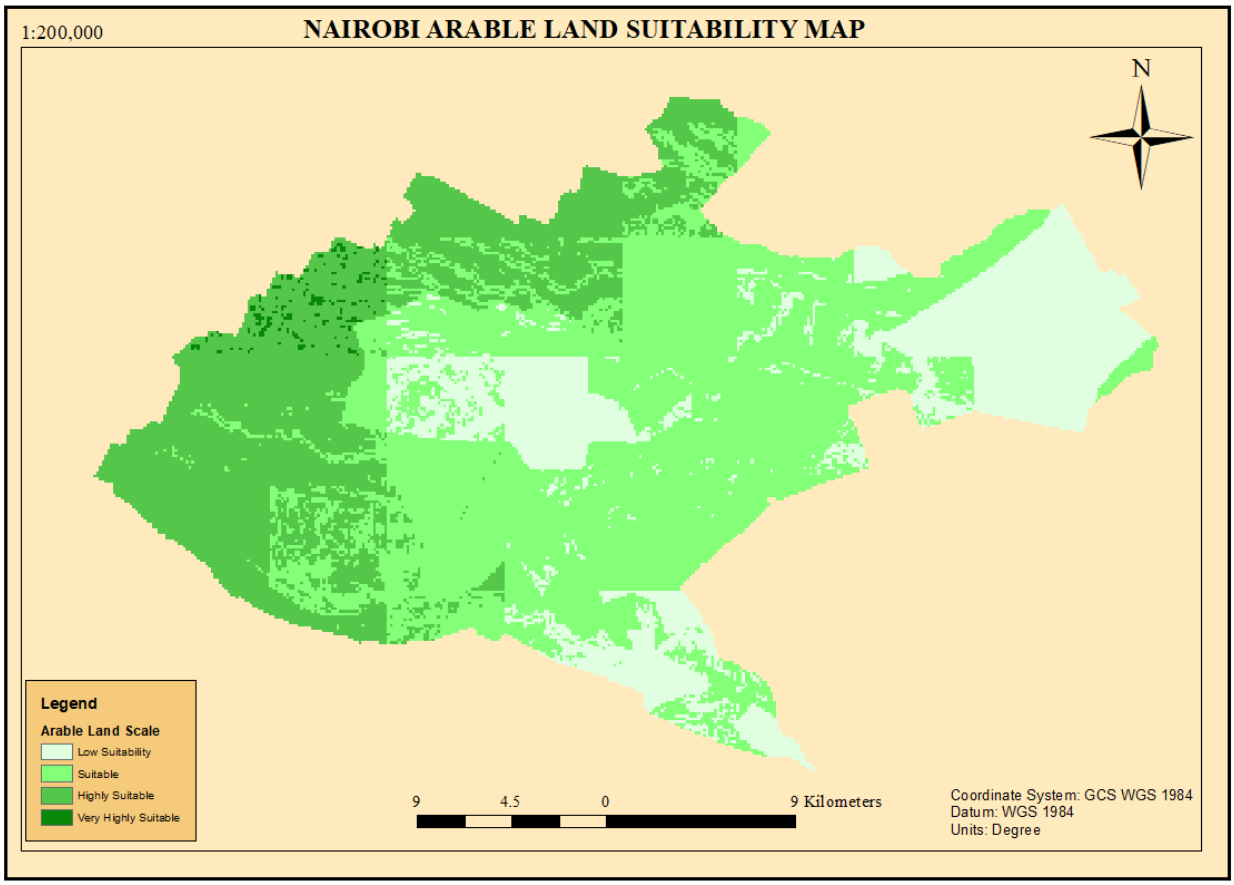

Figure 4:9: Arable Land Suitability Map of Nairobi County

From the *Figure 4.9,* parcels of land within Nairobi County were categorized as Very Highly Suitable, Highly Suitable, Suitable and Lowly Suitable based on their appropriateness for agricultural practices.

Area information of parcels of land was extracted using the help of calculate geometry tool in ArcMap 10.5 after conversion of the arable land suitability layer from raster to vector as illustrated in the table below:

Table 4:1: Arable Land Suitability Output

Class	**Area (Ha)**	**Percentage Area (%)**
Lowly Suitable	16087	22.1
Suitable	36010	49.3
Highly Suitable	20619	28.2
Very Highly Suitable	285	0.4
Total Sum	**73001**	**100**

From the *Figure 4.9,* it is clear that most of the areas classified as highly suitable for crop cultivation are found within the Western and the North-Western parts of Nairobi whereas those classified as least suitable areas are within the Eastern and the southern parts of the county. Based on *Table 4.1,* approximately 78% of lands within the county are suitable for crop cultivation with only 22% being lowly suitable for agriculture. Areas within the central parts of the county were classified as unsuitable more so because of missing soil data which is speculated to be as a result of built-up areas within the same region.

4.3 LAND COVER CLASSIFICATION

Land cover maps for the years 2000, 2012 and 2018 were generated after conducting classification through NDVI analysis. The resultant NDVI raster outputs were reclassified and converted to vector format to facilitate extraction of areas.

Five land cover classes were used to categorize land cover within Nairobi City County. This comprised of water bodies, bare land, built-up areas, thin vegetation cover and dense vegetation cover. The tables and figures below illustrate generated land cover maps for Nairobi County for the years 2000, 2012 and 2018 and the areas of the land cover classes.

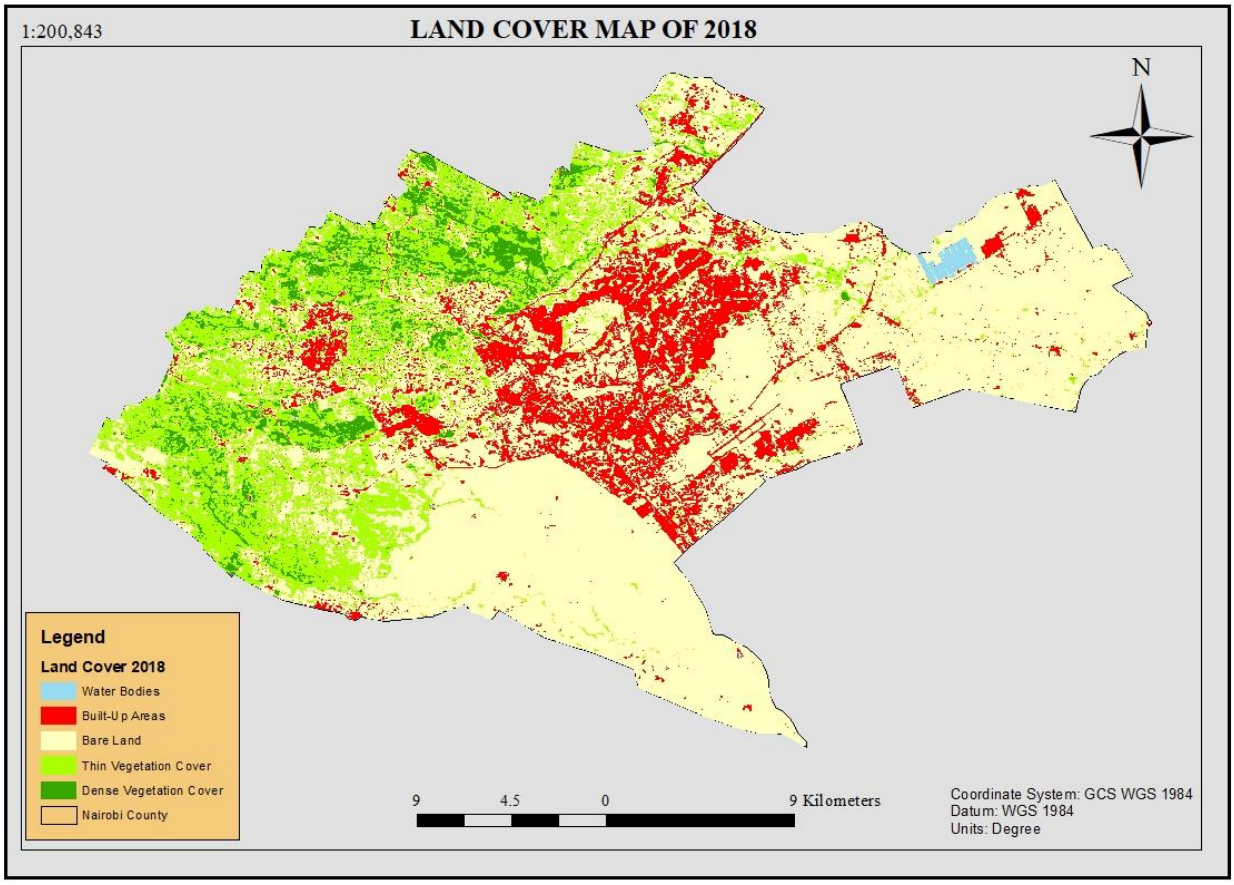

Figure 4:10: 2018 Land Cover Map of Nairobi County

Table 4:2: 2018 Land Cover Classes and their Areas in Hectares

ID No.	Land Cover	Area (Hectares)	% Area
1.	Built-Up Area	11,095	15.1
2.	Bare Land	43,371	58.9
3.	Water Bodies	324	0.4
4.	Thin Vegetation Cover	14937	20.3
5.	Dense Vegetation Cover	3906	5.3
TOTAL AREA		**73633**	**100**

Figure 4.10 is a Land Cover Map of Nairobi City County for the year 2018. From the area information extracted as in *Table 4.2*, the most dominant land cover was Bare Land whereas the least was Water Bodies. Built-Up Areas ranked third in land area coverage at an average of 15.1% of total land mass of Nairobi County.

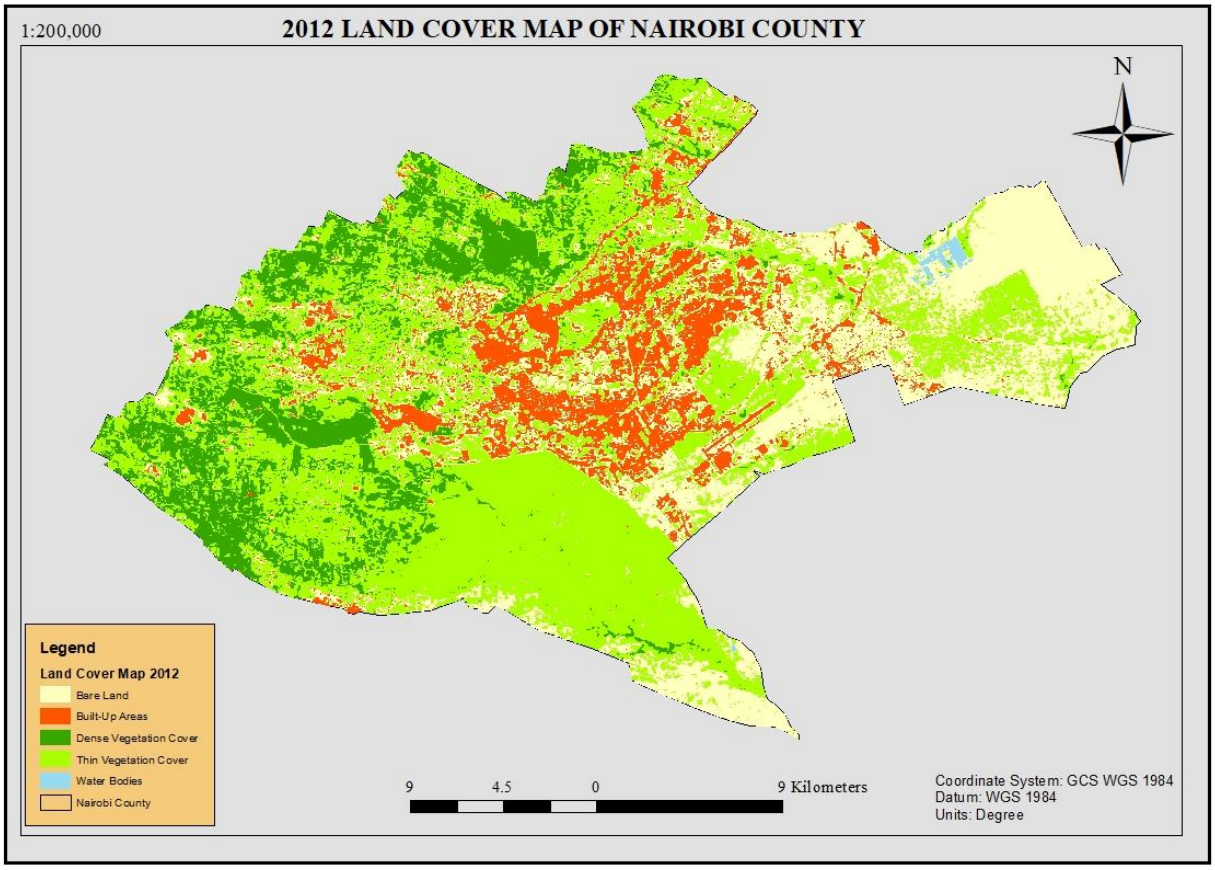

Figure 4:11: 2012 Land Cover Map of Nairobi City County

Table 4:3: 2012 Land Cover Map Classes and their Areas in Hectares

ID No.	Land Cover	Area (Hectares)	% Area
1.	Built-Up Area	9346	12.7
2.	Bare Land	19635	26.7
3.	Water Bodies	222	0.3
4.	Thin Vegetation Cover	33351	45.3
5.	Dense Vegetation Cover	11116	15.0
TOTAL AREA		**73670**	**100**

Figure 4.11 illustrates land cover map of Nairobi City County for the year 2012. From the *Table 4.3*, it is evident that the most dominant land cover is Thin Vegetation Cover followed by Bare Land with the least dominant being water bodies. Built-Up Areas rank second last with an average of 12.7% area coverage of the total land mass of Nairobi City County.

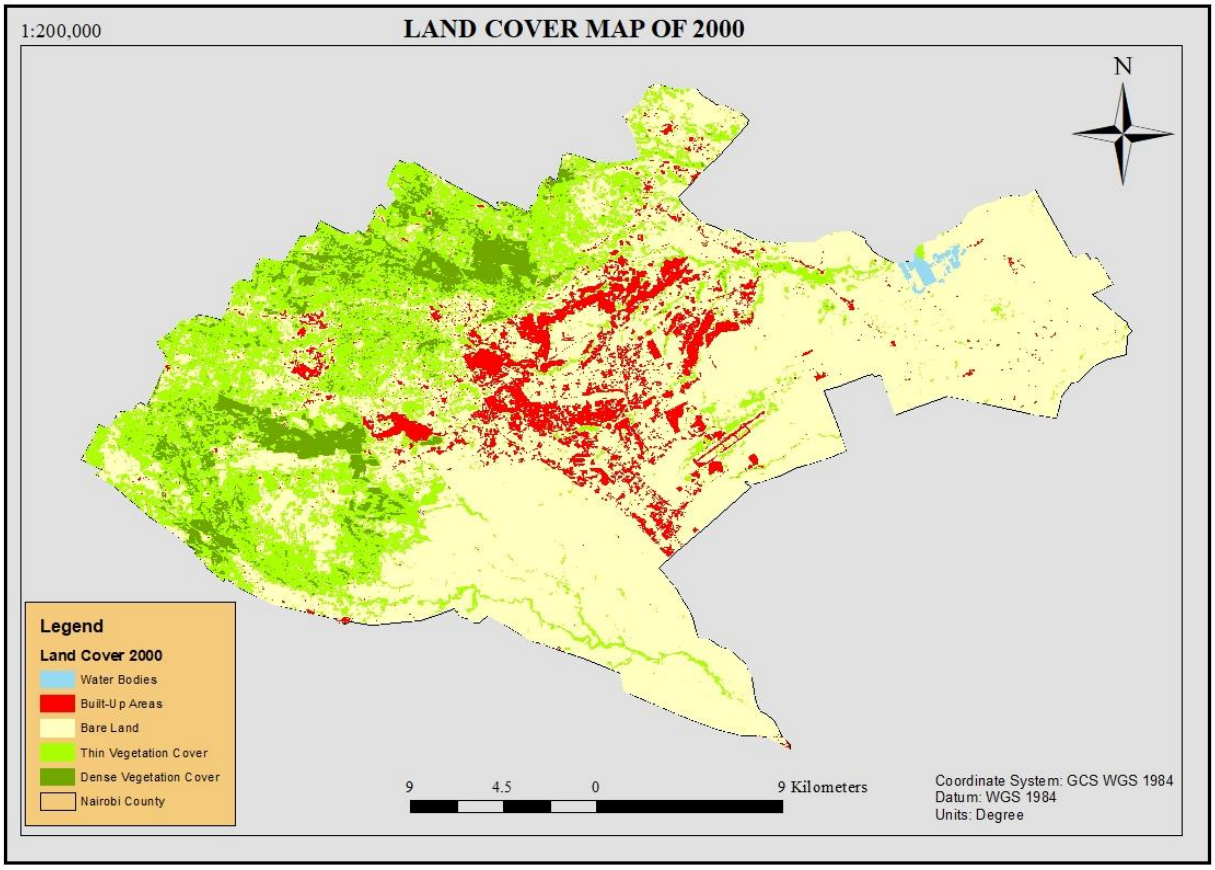

Figure 4:12: Land Cover Map of Nairobi County for the year 2000

Table 4:4: 2000 Land Cover Map Classes and their Areas in Hectares

ID No.	Land Cover	Area (Hectares)	% Area
1.	Built-Up Area	5825	7.9
2.	Bare Land	45059	61.2
3.	Water Bodies	248	0.3
4.	Thin Vegetation Cover	17897	24.3
5.	Dense Vegetation Cover	4606	6.3
TOTAL AREA		**73635**	**100**

Figure 4.12 is a land cover map of Nairobi City County for the year 2000. The *Table 4.4* shows the land cover area information extracted from the land cover vector map. From the table above, it is clear that the most dominant land cover was Bare Land with the least being water bodies. Built-Up Areas land cover was the third most dominant at an approximate value of 7.9% of total land cover of Nairobi

Table 4:5: Land Cover %Area Comparison for 2000 and 2018 Land Cover Maps

ID No.	**Land Cover**	**% Area 2000**	**% Area 2012**	**% Area 2018**
1.	Built-Up Area	7.9	12.7	15.1
2.	Bare Land	61.2	26.7	58.9
3.	Water Bodies	0.3	0.3	0.4
4.	Thin Vegetation Cover	24.3	45.3	20.3
5.	Dense Vegetation Cover	6.3	15.0	5.3
TOTAL AREA		**100**	**100**	**100**

The *Tables 4.2, 4.3 and 4.4* indicate areas of different land covers for different years. It will be noted that for the past 18 years, nearly all land covers lost huge chunks of land spaces except built-up areas that nearly doubled its area coverage within the same time span as highlighted in *Table 4.5*. This can be attributed to rapid urbanization due to increased housing pressure resulting from population outburst and increased demand for office spaces for the past two decades due to Nairobi's strategic position as a regional hub for technological and entrepreneurship development and being gateway to East Africa. Built-Up areas experienced an average annual growth rate of approximately 5.02% within this duration of 18 years, which nearly tallies with the annual growth rate recorded by the number of households in the past decade that stood at 5.30%. Water Bodies had a very insignificant gain in area coverage for the past two decades and this can be attributed to regeneration processes undertaken by the government.

The *Figure 4.13* helps to illustrate land cover area trend for the past two decades:

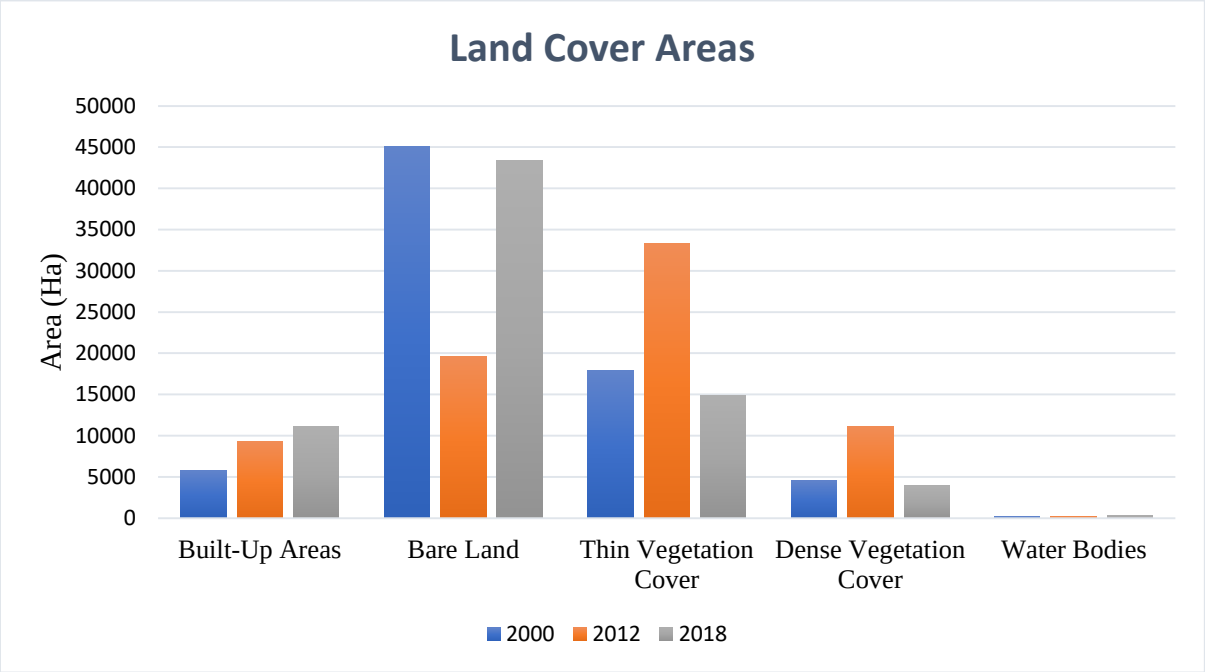

Figure 4:13: Graphical representation of percentage land cover areas for the years 2000 and 2018

4.4 INTERSECTION ANALYSIS OUTPUT

Built-up areas land covers were extracted after conducting classification and saved independently as separate layers. After which they were overlaid with Arable Land Suitability layer as indicated in *Figure 4.14, 4.15 and 4.16* and intersection analysis conducted using the intersection analysis tool in ArcGIS 10.5. The resultant output shapefile were exported as .csv files to help in extraction of areas for statistical analysis.

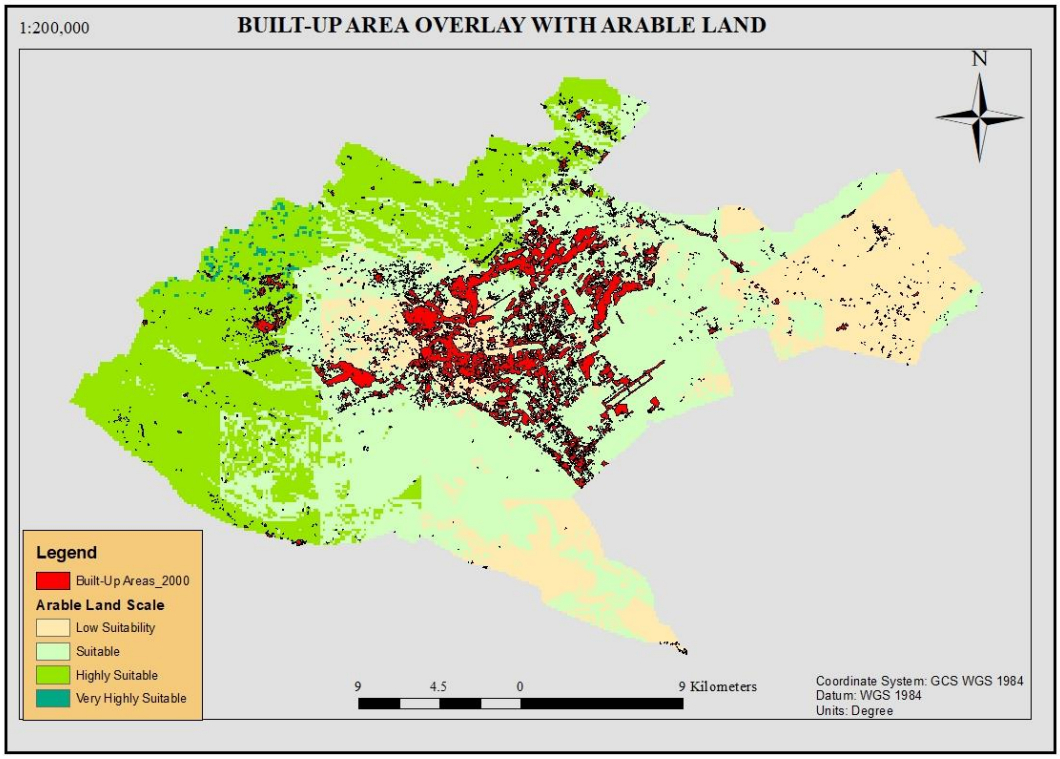

Figure 4:14: Overlay of Built-Up Areas Land Cover for the year 2000 and Arable Land Suitability Layer

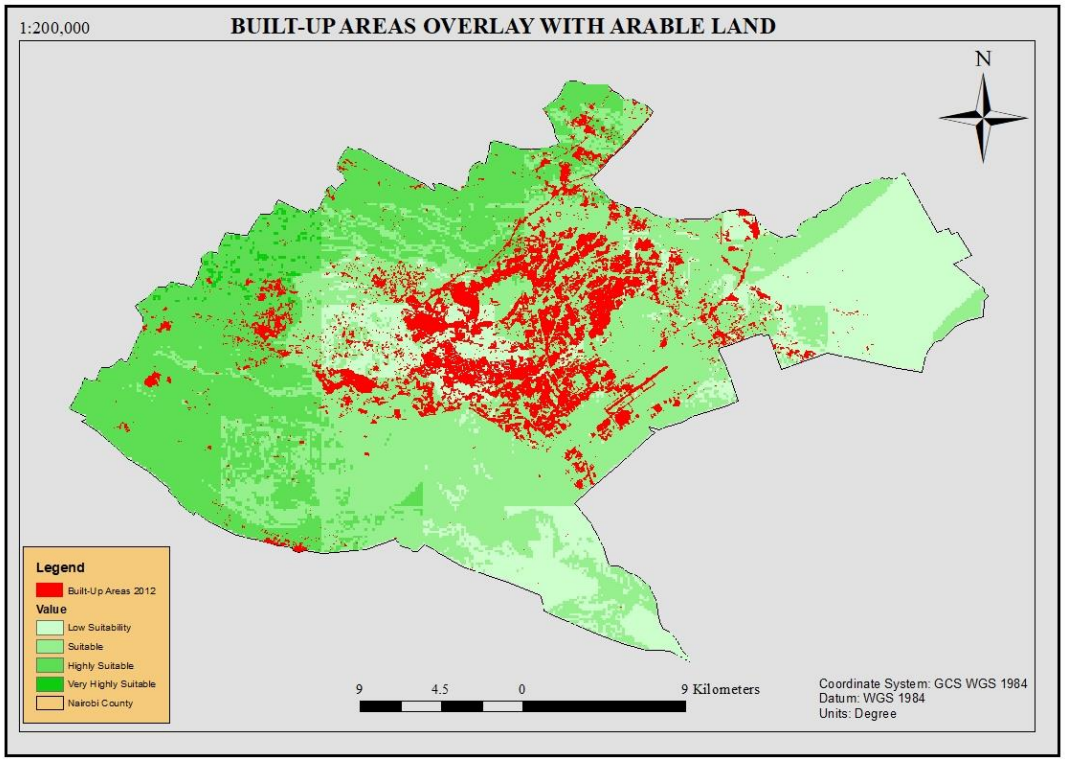

Figure 4:15: Overlay of Built-Up Areas Land Cover for the year 2012 and Arable Land Suitability Layer

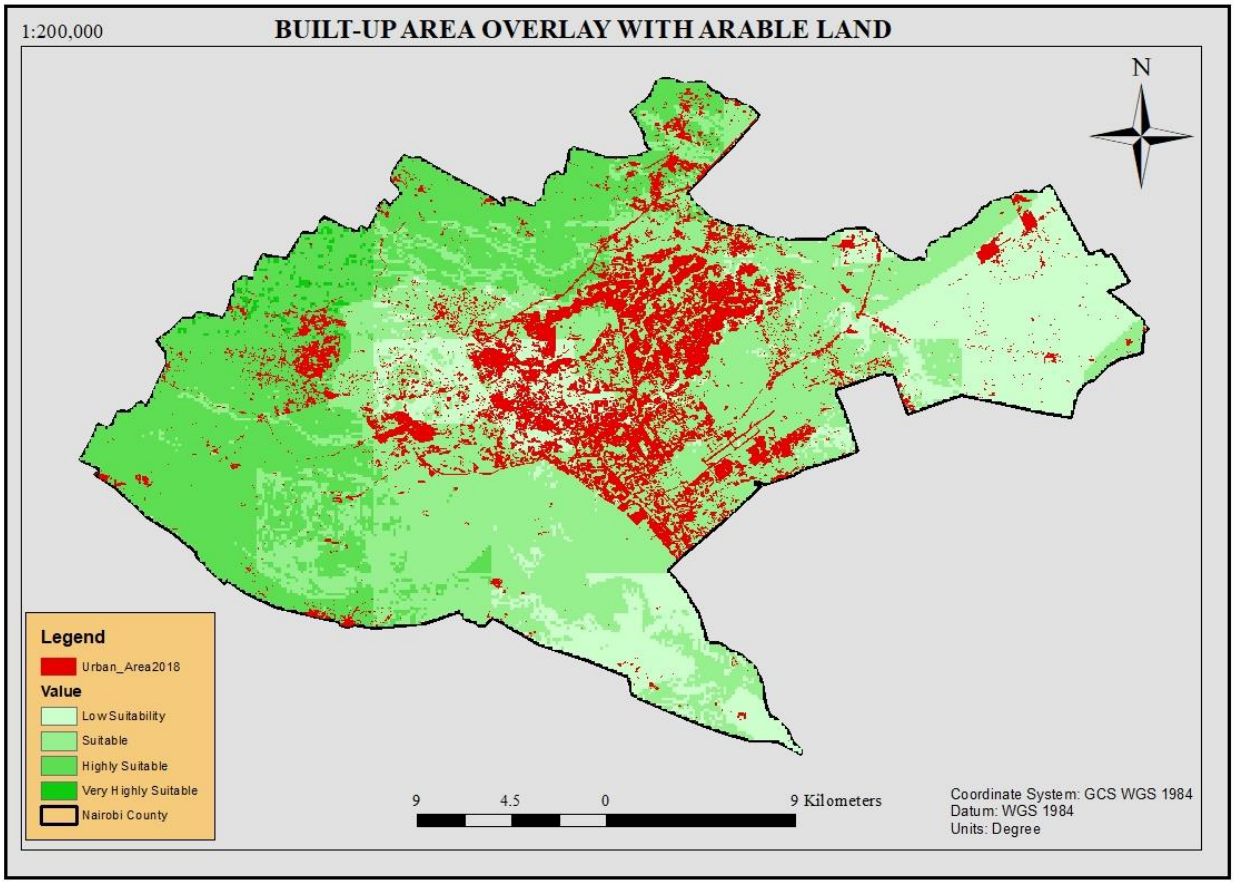

Figure 4:16: Overlay of Built-Up Areas Land Cover for the year 2018 and Arable Land Suitability Layer

The *Tables 4.6, 4.7 and 4.8* summarize area statistics extracted from the csv files:

Table 4:6: Areas of Arable Land that fall within Built-Up Areas Land Cover for the year 2000

ID No.	Arable Land Suitability	Area (Hectares)	% Area
1.	Very Highly Suitable	3	0.1
2.	Highly Suitable	458	7.9
3.	Suitable	3826	65.8
4.	Low Suitability	1528	26.2
TOTAL AREA		**5815**	**100**

Table 4:7: Areas of Arable Land that fall within Built-Up Areas Land Cover for the year 2012

ID No.	Arable Land Suitability	Area (Hectares)	% Area
1.	Very Highly Suitable	5	0.1
2.	Highly Suitable	1047	11.2
3.	Suitable	6303	67.7
4.	Low Suitability	1960	21.0
TOTAL AREA		**9315**	**100**

Table 4:8: Areas of Arable Land that fall within Built-Up Areas Land Cover for the year 2018

ID No.	Arable Land Suitability	Area (Hectares)	% Area
1.	Very Highly Suitable	9	0.1
2.	Highly Suitable	1386	12.6
3.	Suitable	7406	67.1
4.	Low Suitability	2232	20.2
TOTAL AREA		**11033**	**100**

The *Tables 4.6, 4.7 and 4.8* summarize areas in hectares of arable land that urban areas occupied based on the land cover maps for the years' 2000, 2012 and 2018. From *Tables 4.6, 4.7 and 4.8,* it is evident that most of the arable lands occupied by built-up areas are classified as suitable for crop farming followed by areas classified as low suitability, then highly suitable and lastly very highly suitable. An average of 77% of areas whose Land Cover is Built-Up Areas are considered suitable for crop farming.

Table 4:9: Comparison of Areas of Arable Land Occupied with Built-Up Spaces for the year 2000, 2012 and 2018

ID No.	Arable Land Suitability	2000 Urban Areas (Hectares)	2012 Urban Areas (Hectares)	2018 Urban Areas (Hectares)
1.	Very Highly Suitable	3	5	9
2.	Highly Suitable	458	1047	1386
3.	Suitable	3826	6303	7406
4.	Low Suitability	1528	1960	2232
TOTAL AREA		**5815**	**9315**	**11033**

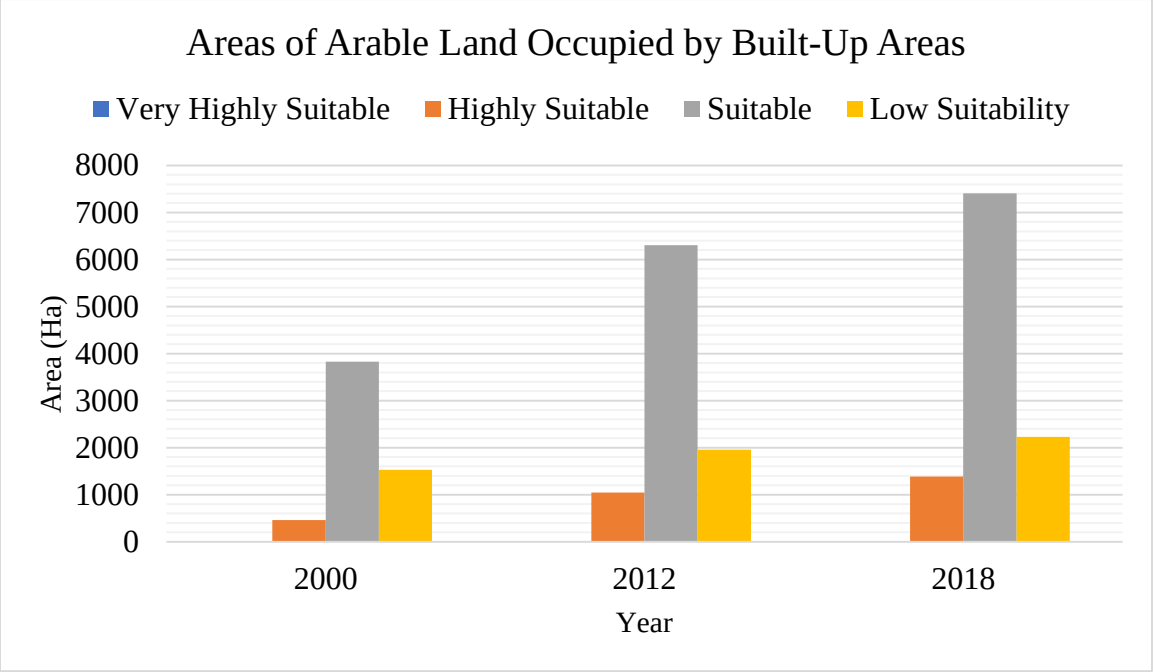

Figure 4:17: Graphical Representation depicting Built-Up Areas and Arable Land Relationship Trend

The *Figure 4.17 and Table 4.9* illustrates the relationship between arable lands and built-up areas overtime. From *Figure 4.17 and Table 4.9,* it is clear that huge chunks of land suitable for agricultural practice have been lost so as to pave way for housing and infrastructural development. A total of 4,514 hectares of land suitable for crop cultivation has been lost to Built-Up spaces in a duration of 18 years i.e. from 2000 to 2018. This illuminates a dark future for urban crop farming if this trend persists. With insufficient policies and regulations to safeguard

potential agricultural land within Nairobi City County, then the county risks losing all arable lands to urbanization if the growth trend observed persists. This puts us vulnerable to food shortages and starvation due to insufficient crop production and makes Kenya's aspiration of being food secure a dream.

4.5 DISCUSSION OF THE RESULTS

Nairobi City County has always been considered urbanized with no room for crop cultivation but the study was in a position to clearly show that more than 70% of the total land mass of Nairobi City County is suitable for conducting farming activities. A majority of the areas considered as highly suitable for crop farming are in the western and north western parts of the county which are still agrarian.

From the findings drawn from the study, it is clear that urban areas development in Nairobi City County, placed at an average of 5.02% annual growth rate as from 2000 to 2018, has had massive impact on the quantity of arable lands in the county. With a total of 4,514 hectares of land considered fit for crop farming lost to urban areas, this clearly paints a grim picture on the future of urban agricultural practice and food security in general. It also highlights weaknesses and inefficiencies in statutory authorities charged with ensuring sustainable urban development and that land use policies and zoning controls are adhered to. From the insights drawn from the study, urban population growth emerged as a major driver of urbanization and housing trends as indicators of urbanization.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This study has shed up some light on the significant role that GIS and Remote Sensing Technologies play when it comes to monitoring urbanization trend and identifying the adverse effects such trends have on urban agricultural practice and food security in general.

The use of spatial analysis proved pivotal when it came to delineation of arable lands within Nairobi City County. Results obtained have illustrated how powerful the use of AHP Multi-Criteria decision-making tool together with GIS Systems can be when it comes to conducting spatial analysis in the agricultural sector more so suitability analysis. It is noted that most of the suitability analysis research conducted in Kenya have been crop specific but this study centred on identifying areas suitable for a wide variety of crop cultivation based on climatic conditions, soil properties and area topography. The arable land suitability map generated illustrates spatial distribution of masses of lands based on their fitness for crop cultivation.

Remote Sensing technologies played a major role in data collection and analysis in this research. Land Cover Maps for Nairobi City County were generated by conducting classification of Landsat 7 and 8 imageries and the trends observed. NDVI Analysis was adopted for classification, this was preferred against Supervised Maximum Likelihood classification due to complexity and inaccuracies of the latter. From the change detection analysis conducted, it is clear that in the past two decades, the county underwent rapid urbanization and this can be attributed to uncontrolled development due to laxity and corruption by relevant authorities, together with population outburst as discussed herein resulting to housing pressure.

From the study, the direct impact of rapid urbanization on urban agricultural practice was evident. Masses of prime lands for crop cultivation (4,514 Hectares of land considered suitable for agriculture) have been lost to pave way for concrete structures and road infrastructures and the trend doesn't seem to reverse anytime soon. This puts the county residents at risk of hunger due to insufficient and overpriced food crop supplies, increasing their vulnerability to unscrupulous traders who import sub-standard food products to offset the deficit. It also reduces the country's GDP as the sector accounts for 31% of the same and it also makes the vision of the country being food secure by 2030, as spelt out in Vision 2030 difficult.

Lastly, it is noted that the accuracy of the results and analysis performed is dependent on accuracies and resolution of data used which depends on data collection techniques employed by the relevant agencies. The study achieved the objectives set out at the start of the research.

5.2 RECOMMENDATIONS

Based on the findings of this report, it is evident that is there is need to revamp the practice of sustainable urban development within the county with an aim of preserving potential farm lands and flora. This can be achieved through strictly enforcing of existing zoning controls and land use planning policies.

There is also need to support and entrench devolution of governance at county level as spelt out in our constitution in our social fabric. This would play a significant role in shifting development to rural areas thus creating job opportunities for the rural youth which would help deter rural-urban migration thus easing housing pressure in urban areas hence reducing the rate of urbanization.

Lastly, there is need for relevant stakeholders including the legislative assemblies to formulate land use policies, regulations and legislations that would seek to delineate, safeguard and protect agricultural land in urban areas. A good example is “The Prime Land Protection Regulation” law in China enacted in 1994 and reviewed in 1998 that seeks to integrate measures on how to protect farm land in all land use plans and ensure clear demarcation of their boundaries.

5.3 AREAS FOR FURTHER RESEARCH

Despite the fact that the study managed to highlight clearly the negative effect of urbanization on quantity of lands suitable for agriculture, it failed to demonstrate how loss of such lands has affected the practice of urban agriculture, food production and food security in general. This thus opens up opportunities for future research on the same subject matters.

While delineating arable land suitability map, the study mainly focussed on rain-fed agriculture leaving out irrigation agricultural practice. This implies therefore that the study might not have painted the true picture of masses of lands in the Eastern and Southern parts of the county, a majority of which were classified as lowly suitable for crop farming. This therefore opens up another avenue for generating arable land suitability map considering both rain-fed and irrigation crop farming to be used as input in the intersection analysis.

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APPENDIX

Table A1: Distribution of Households by Sub-County, 2019 Census/ (courtesy of KNBS)

S No.	Sub-County	Households
1.	Dagoretti	155089
2.	Embakasi	347955
3.	Kamukunji	84365
4.	Kasarani	271290
5.	Kibra	61690
6.	Lang'ata	62239
7.	Makadara	70361
8.	Mathare	74967
9.	Njiru	204563
10.	Starehe	69389
11.	Westlands	104980
	TOTAL	**1,506,888**

Table A2: Distribution of Population Data by sex and sub-county, 2009 Census (courtesy of KNBS)

S No.	Sub-County	Male	Female	Total
1.	Dagoretti	166391	163186	329577
2.	Embakasi	468097	457678	925775
3.	Kamukunji	136920	124935	261855
4.	Kasarani	266684	258940	525624
5.	Lang'ata	185836	169352	355188
6.	Makadara	114457	104184	218641
7.	Starehe	142097	132510	274607
8.	Westlands	124748	122354	247102
	TOTAL			**3,138,369**

Table A3: Distribution of Households by Sub-County, 2009 Census (courtesy of KNBS)

S No.	Sub-County	Households
1.	Dagoretti	103818
2.	Embakasi	296942
3.	Kamukunji	75555
4.	Kasarani	164354
6.	Lang'ata	108477
7.	Makadara	72924
10.	Starehe	87519
11.	Westlands	75427
	TOTAL	**985,016**
	KENYA	**8,767,954**

Table A4: 1999 Census Population Data (courtesy of KNBS)

S No.	County	Population
1.	Nairobi	**2,143,254**