UNIVERSITY OF NAIROBI

EFFECT OF URBANIZATION ON URBAN FORESTRY AND AIR QUALITY;

A CASE STUDY OF NGONG ROAD FOREST NAIROBI, KENYA

By

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DECLARATION

Candidate Declaration

I, **Anis Yussuf Ibrahim** (Reg.no: A60/12282/2018), hereby declare that this thesis is my original work and has not been submitted to any other university or institution of higher learning for academic credential.

Signature:  Date: 6th July 2021

Supervisor's Declaration

This thesis has been submitted for examination with our approval as university supervisors

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Signature……  ……Date……8th July 2021…….

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List of Abbreviations

AOI:	Area of Interest
ArcGIS:	Aeronautical Reconnaissance Coverage Geographic Information System
CBD:	Central Business District
CFA:	Community Forest Associations.
COVID 19:	Corona Virus Disease 2019
EMCA:	Environmental Management & Coordination Act
ENVI:	Environment for Visualizing for Images
ERDAS:	Earth Resources Data Analysis System
FAO:	Food Agricultural Organization
FGD:	Focus Group Discussion
FMA:	Forest Management Act
GEO:	Global Environmental Outlook
GIS:	Geographical Information System
IFF:	Intergovernmental Forum on Forest
IPF:	Intergovernmental Panel on Forest
KeFRI:	Kenya Forest Research Institute
KFS:	Kenya Forest Services
KWTA:	Kenya Water Tower Agency
KWS:	Kenya Wildlife Service
LDCs:	Less Developed Countries
LPG:	Liquified Petroleum Gas
LULC:	Land Use Land Cover
MDGs:	Millennium Development Goals
NDVI:	Normalized Difference on Vegetation Index

NEMA:	National Environment Management Authority
NGOs:	Non-Governmental Organizations
NRFA:	Ngong Road Forest Association
ODK:	Open Data Kit
PFM:	Participatory Forest Management
PM:	Particulate Matter
SQL:	Structured Query Language
SSA:	Sub-Saharan Africa
UN:	United Nation
UNCED:	United Nation Conference on Environment & Development
UNDP:	United Nation Development Program
UNEP:	United Nation Environmental Program
UNSDG:	United Nation Sustainable Development Goals
USGS:	United State Geological Survey.
WHO:	World Health Organization.

Abstract

Urban forest though playing a vital role in sequestering air pollutants in cities, they have been on the verge of depletion due to rapid urbanization of cities in Sub-Saharan Africa including Kenya. The research aimed on studying the effect of urbanization on the Ngong Road Forest cover and air quality. The study employed household survey for collecting primary data from communities living within around the forest, within a distance of 5km. Past imageries of four scenes 1988, 1999,2008, and 2019 were analyzed using ArcGIS, ENVI and Google earth engine. A total of 219 respondents were interviewed using household survey, key informant and FGD. Correlation analysis was subject to the data.

Generally, 37% of the forest cover was converted to other land uses, where built-up areas accounted for 74%. The statistical analysis shows that there was strong negative correlation between the expansion of the city and forest cover (R; 0.903, R2;0.810). Between 1988-2019, urbanization has led to significant deforestation, this will potentially reduce the forest ecosystem services. By the year 2030, if no stringent actions are taken, the forest cover will reduce to as low as 600 ha, thus will contribute to poor air quality. The study found this significant deforestation was mainly due to illegal logging, as the need for wood for construction and fuel increased. 49.8% of the respondents indicated that illegal logging as the main factor that led to deforestation. Others attributed it to land grabbing (22.4%), infrastructural development (13.7%) and poor forest governance (7.8%).

In regards to forest governance and practices, the study found that there is a relation between gender and level of community involvement in decision making process (*p-value less than alpha value, 0.01<0.05*). Women were not effectively involved in forest decision making process. This might be due to cultural norms as well inadequate measures taken by CFA and KFS in regards to gender mainstreaming on matters related to forest governance and management. The local communities plant trees for various reasons, majority did plant for

domestic use (68%), while other did so during reforestation programs (17.8%), for commercial (13.2%) and medicinal purpose (0.9%). Majority of the households near the forest rely on non-forest businesses (71.7%). While the rest rely on farming (15.5%), livestock (2.7%), charcoal businesses (2.7%), tree nursey business (6.4 %) and timber business (0.9%). In regards to source of energy for cooking, majority rely on LPG (45.7%), while others rely on firewood and charcoal (19.2%) as well on electricity (14.6%). The study further found that household's average income and their level of access to forest products are related (p-value less than alpha value, 0.01< 0.05) though majority had no access. In regards to air quality, 82.6% of the respondent indicated that the air quality has declined in the last 30 years, where majority of them (54.8%) attribute this to deforestation, 19.6% and 5.9 % of them attribute this to excessive pollutions from motor vehicles and pollution from factories respectively. Stateline data revealed an increasing trend of Sulphur dioxide concentration between 1988 to 2019. The study recommends that the government must effectively enforce the implementation of Forest Act 2005, EMCA1999 and other related policies. All the relevant government ministries and relevant institutions must act affirmatively to combat illegal logging and reclaim forest land that have been grabbed/ or illegally taken over to restore the forest ecosystem as well protect the remaining forest cover. The government must promote sustainable urban growth and ensure the urban forest is protected at all means. KFS must engage the effectively engage the CFAs and promote the women inclusivity in making all forms of decisions related to the forest. Due to fragile nature of the forest and its location, the study affirmatively recommends all the forest blocks to be fenced to deter illegal loggers and protect the forest. Lastly, KeFRI must collaborate with public and private academic institutions in conducting research on urban forestry governance and management to provide innovative solutions to govern and protect the urban forest that fragile but however plays a vital role in sequestering air pollutants.

CHAPTER ONE

1.1 Introduction

Urbanization is the most rapid form of land use in developing countries (Paul and Meyer, 2008) By 2030, over 60% of the world's populace will reside in cities (UN 1997). According to Mundia and Aniya (2006), population growth and rapid economic development are drivers of land-use change (Mundia and Aniya, 2006). The industrial revolution, among other factors, has resulted in a rapid congregation of populations in the urban centers (Harley, 2018). According to a report released by the UN in the year 2014, the biggest population growth in the future will be in cities. Most of cities in the globe have a population of above 10 million people. Research has it that most of these cities have a surprisingly low quality of air. Pollution has been dominant thus triggered the United Nations to release the maximum threshold of certain pollutants that can be accommodated in the atmosphere, especially regarding pollutants like particulate matter and gases like nitrogen dioxide (UN, 2014).

Air pollution in these cities, cities with a high number of people, often have deleterious results. Bell and Davis (2001) record remarkable results of air pollution in cities, which included the high levels of sulfurous smog, which killed thousands and many others sick in Penn, 1948, and London in the year 1952. These results could still be witnessed elsewhere if appropriate measures are not taken. It would be vital to ensure the air quality in cities, like Nairobi, and prevent atmospheric pollution. One of the factors that could help ensure that the air quality reaches the minimum acceptable levels is the presence of forests (She *et al.,* 2017). Global forest cover is estimated to be 30% of global land (4million hectares) though the world lost 3% of this between 1990 and 2005, with Africa alone losing 9% of its forest cover between 2000 and 2005 (Butler, 2005).

Forests bring a certain level of balance since leaves take in considerable amounts of these pollutants and also release oxygen during photosynthesis (She *et al*., 2017). As such, an urban

center with a forest around is likely to have an environment that will sufficiently cater to the needs of the population in the city. Unfortunately, urban forests have been on the verge of depletion following the high dependence on the forest products and due to infrastructural development. Urban forest terminology has evolved as an interdisciplinary approach that responds to issues related to trees and forests in cities (Konijnendijk van den Bosch *et. al*., 2006). In this 21st century, the concept of urban forestry has been practically applied in Countries such as China, where reforestation projects and forest compensation schemes were implemented (FAO, 2016b). Urban forest is defined as tress growing in non-rural areas (Konijnendijk *et al.* 2006). Urban forest are trees and its related biotic and abiotic component in an urban area (Miller 1997; Kenney *et al*. 2011).

The benefits of forests, especially in urban cities are immeasurable. They ecological and socio-economic benefits (Roy *et al.* 2012). Growing urban populations, especially in developing countries, put more pressure on the natural green spaces, especially urban forestry and their potentiality in providing ecosystem services to the population. Urban land uses intensify due to the demand for land, therefore, sustaining and managing the urban forest to continuously provide ecosystem service and benefits becomes imperative (Young 2011, Nilon *et al*. 2017, Hölscher et al. 2019). Urban forest appraisals are the premise upon which the importance of the forest, the approach is decided, and its administration is executed (Brack 2002, Cowett and Bassuk 2017). Thus, urban forestry needs a sustainable, integrated, and participatory approach, where the urban community is an essential part of the decision-making process concerning the in regards to forest conservation and protection.

According to the Brundtland Commission Report (21), sustainable forestry is managing forest by practicing land stewardship ethic that incorporates tree plantation, sustaining and collection of forest products, i.e non-timber products, with the conservation of soil, air, water quality, as

well as wildlife and aquatic habitats. Forest is an essential component of urban environment, purifying air pollutants, moderating storm water runoffs, reduce energy consumption, provide physiological wellbeing, and provide habitat for wildlife. A study in Finland shows that majority of people in urban areas attribute positive benefits to Urban forests and are ready to pay for the re-creation and half willing to deter any construction or development of infrastructures in an urban forest (L.Tyrväinen 2001). UN outlined 17 Sustainable Development Goals that replaced MDGs in 2015, with an aim to make strides the quality of life in the globe (UN, 2015b). SDG 15 promotes sustainable use of terrestrial ecosystems, including forests and promote fights against desertification., thus environmental solutions i.e promotion of urban forest conservation can address these laid out objectives. Past work related to conservation of natural resources are solutions to meet the UN SDG (Sharrock and Jackson, 2017, Vlek *et. al*, 2017). However, deforestation and degradation of urban forests, such as Ngong Forest, as a result of proximate anthropogenic activities fueled by an underlying socio-economic, political and technological process in urban areas or away from the city may have both negative and positive impacts. These adverse anthropogenic impacts can be reduced through urban planning, reforestation and sustainable management, with common commitment and vision. Urban forest management requires consistent management since the net benefit accrued from forest management can only occur when adequate and fair treatment is given. It also requires forest authorities to involve the community living near the forest in decision making and actions related to the forest (Clark *et al*. 1997). Long term existence of urban forest requires proper planning and sustainable management. Therefore, it is important to protect and sustainably manage urban forest through an ecosystem approach, policy reforms, and participatory management by involving and sensitizing the communities surrounding it and other urbanites.

However, there is a need to get a precise data on urban forest cover so as to understand the trends of deforestation of the forest through temporal and spatial scales. Scanty information is available in regard to the importance of urban trees and forestry. An accurate data on the extent of deforestation of urban forests that quantifies the effect of city expansion will be a foundation for sustainable management and governance of the forest. The benefits of urban forest are immeasurable, especially abiotic factors. It enhances the city environment by improving the quality of air and regulating the ambient temperature, thus has significant implications on the well-being of urbanites (Rowan *et al.,* 1992). The attitudes and awareness of residents in cities about the importance of urban forest are essential to ensure the mutual co-existence of the forest and the urban resident.

Geographic Information System (GIS) techniques was largely used to track LULC over a time period (Butt *et al.,* 2015; Dadras *et al*., 2015) since its effective, realistic and cheap (Haack and Rafter, 2006). LULC mapping is one of the major important applications of land sat data, with new modern remote sensing platforms providing detailed topographical data in the hard-to-reach areas (Malgorzata *et al*. 2012). Therefore, the study aims to quantify Ngong forest cover changes and its likely related to urban growth, using GIS and remote sensing software by analyzing the prehistoric satellite imageries, the demographic data of the neighboring communities for the last two decades, and collect information on the Attitude and Perception on the air quality and on forest governance and management.

1.2 Statement of Research Problem

Most cities in developing countries, including Nairobi, are undergoing rapid urbanization and population increase, which is attributed to environmental degradation and pollution, thus the need to promote a sustainable city (Okumu *et al.*, 2017). According to Berenguer *et al.* (2015), pollution and environmental degradation in urban areas have led to several challenges such as air pollution, housing problems, food insecurity, and put pressure on green spaces. Kenya has realized a rapid increase in population in the last three decades, with current population being 47,564,296 (KNBS, 2019). In Nairobi, the population grew from, 1,324,570 people in 1989 to 4.3 million in 2019 (KNBS, 2019). The increased population have threated forests, especially the urban forests. The forest ecosystem in the country have been degraded and deforest, for instance Kenya's prime water towers lost 500 km^2 between the 1970s and 2010 alone due to deforestation (Kiringe J. *et al.*, 2015).

Urban forestry in Kenya, particularly Ngong Road Forest in Nairobi, faces unique problems due to the complexity and nature of urban sprawl and its consequences. The expansion of Nairobi city is a threat to the forest, that lies 6km from the CBD (Boiyo *et.al*, 2019), mainly due to increased demand for land. Increasing population in the city, demands more houses and increased road networks to ease the traffic. Thus, the expansion of the city has become a threat to natural habits that have ecologically value and areas that are protected, such as the forest. This will reduce the potentiality for the forest to provide good air quality to the urban dwellers. The built-up areas in Nairobi increased from 41km^2 in 1988 to 62km, with a projection of an average annual rate of 1.49km^2 per year from 2014 to 2020 (Mundia and Aniya, 2007). The city's growth and expansion have led to loss of urban forest such as Karura and Ngong Road Forest.

On the other side, the country has also experienced a significant level of air pollution, especially in urban centers. In Nairobi, most of the air pollution is caused by motor vehicle emission (Odhiambo *et al.*, 2010; Malla *et al.*, 2011). The industrial waste release has also contributed to air pollution significantly (Omanga *et al.*, 2014). The increased population growth in Nairobi city may have led to increased economic growth, thus led to increased acquisition of motor vehicles by significant portions of the population. Most of these motor vehicles rely on leaded fuel and release considerable number of pollutants to the air (Odhiambo *et al*., 2010). Therefore, there has been a need to find a remedy to the issue brought about by air pollution and one of the suggested effective remedies lies in the protection of urban forests. However, there is no accurate data on urban forest cover dynamics in Nairobi, especially for Ngong Road Forest, that face significant threats due to urban expansion, thus study will address the gap and will highlight emerging pressures of urbanization on an urban forest that are critical in providing good air quality and other ecosystem services to urban residents.

1.2 Research questions

a) What is the temporal pattern of forest cover dynamics between 1988 and 2019?
b) What is the perception and the current practices of the local community about urban forest governance and air quality dynamics?
c) How did the local community contribute to Ngong Road Forest's cover and air quality dynamics?

1.3 Research Objectives

1.3.1 General Objectives

The General objective of the study is to analyze the effect of Urbanization on Ngong Forest cover and its implications on air quality as an ecosystem service.

1.3.2 Specific Objectives

The specific objectives are to:

a) Analyze the spatial and temporal forest cover dynamics between 1988 and 2019.
b) Appraise the perception of the local communities on urban forest governance and air quality dynamics.
c) Assess the practices of the local communities in regards to urban forest governance. Evaluate the contribution of the local community to Ngong Road Forest's cover and dynamics.

1.4 Justification

The bigger part of the global population lives in cities. This scenario has majorly been caused by the industrial revolution that led to urban growth, which has influenced rural-urban migration, with most of them seeking better-paying jobs. Coffee *et al.* (2016) explains that more 50% of the current population in the globe resides in towns. In some circumstances, some cities have a population of over 10 million people. According to a report issued by the United Nations, the cities with a population exceeding 10 million people have been referred to as megacities, and there are more than 30 such cities. In as much economic growth is associated with the heavily increasing urban population, there are many other repercussions of the ever-growing urban population. An increase in population, as explained to Bagan and Yamagata (2015), results in an increased population density and a consequential need for more resources to cater for the increased population. Some of the resources that may be required include room for settlement and a source of energy, among other things. At the same time, the increase in urban population results in more activities in the industries and factories, which ultimately leads to greater production of goods and services and, at the same time, emission of more pollutants.

The effects of pollution are more deleterious in places with a higher population. Unfortunately, high population in cities is attributed to high pollution. Gariazzo *et al*. (2016) explain that high population density both contributes to an immense release of pollutants and experiences the direst results of pollution. High urban population demand that more room for settlement is created and that more jobs and goods be produced. As such, there is a higher demand for cheap energy, and fuelwood serves, especially in developing countries. The demands rendered by the urban population lead to immense construction of roads and houses, buying of motorcars in high numbers, and construction of factories at an alarming rate (Gariazzo *et al.*, 2016). Consequently, there is a massive emission of pollutants that mostly comprise particulate matter from the construction, nitrogen dioxide from the motor vehicles, and Sulphur dioxide from the factories and industries, among other pollutants. Simultaneously, there is a rapid reduction of forested areas as the required area for settlement increases. The need for a cheap source of energy to cater to the needs of the informal settlements in developing countries like Kenya leads to illegal logging of trees. All these factors contribute to deforestation, endangering the urban forests like Ngong Forest. These will have impact to the lives of around 4 million residents in Nairobi City.

The United Nations released a maximum threshold of pollutants, particularly the particulate matter that should be in any environment. This was after a massive number of people in megacities lost their lives while many others were left sick, resulting from atmospheric pollution in the towns. Some of these scenarios are as recorded by Bell and Davis (2001) happened in Penn, 1948, and London in the year 1952. High levels of sulfurous smog led to the deaths and the sickening.

Urban forest and green spaces provide some of the solutions to the problems faced by urban residents (Endreny *et al*., 2017). The benefits of trees in are vast (Hirons and Thomas, 2018),

and many researchers have focused on urban residents (Jennings and Johnson Gaither, 2015). According to Nowak *et. al* (2015) each year trees in urban areas of US sequester an estimated amount of 711,000 metric tons of air pollutants. Plant's accumulation capacity of $PM_{2.5}$ depend on the species diversity and its maturity (Chen, Liu, Zhang, Zou, and Zhang, 2017). In addition to this, Mo *et al.* (2015) found that the woody species have high accumulation to store $PM_{2.5}$. Despite the vital role played by urban forests, it is unfortunate that they are on the verge of depletion if necessary urgent measures are not taken to protect them. The urban population has been eating into the forests and consequently eating into themselves. With increasing population in cities Kenya, urban forest will definitely face much pressures, especially in Nairobi city where the current population is at 4.3 million (KNBS 2019). Ngong Forest would play a vital role in sequestering pollutants, protect over 4 million lives since it's one of the only two forests around Nairobi. It is, therefore, vital to study the forest cover and understand its trends. There is no recent analysis examining the effect of urbanization on the Ngong road forest cover that is located 6km from the city center. Understanding trends of urbanization is especially important to sustainably protect and govern urban forest in Nairobi, a fast-growing city. Though many studies of urbanization and its consequences were conducted focusing on the LDCs (Pauchard *et al.,* 2006) and few studies in developing countries with a disconnect between the nexus of urbanization and urban forestry, especially the studies conducted on the forests in Kenya. Therefore, this study endeavors to provide accurate spatial and primary data of the effect of the city's expansion on Ngong forest cover, the consequences of this on forest ability to provide air quality and contribute to both research and policy domains.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This section highlights relevant research topics; it comprises of nexus between urbanization, urban forest and air quality, forest governance in Kenya, air pollution in developing countries and its causes, and lastly, population and economic growth in developing countries.

2.2: Nexus between urbanization, urban forest, and air quality

According to UN-Habitat (2014), in sub-Saharan Africa, urban metamorphosis somewhat a recent issue, with cities growth rate considered to be highest in the globe compared to other continents. This is a result of city expansion to adjacent peri-urban areas and towns growing to cities. A study shows that settlements in urban areas of less than 300,000 residents account for only 58% of urban growth between the years 2000 and 2010 (UNDP, 2016). The demand for land for housing, and infrastructural developments such as roads and social amenities, have increased in cities around the world. Urbanization poses unique challenges to urban forests in both developed and developing countries; that, however, supplies quality air and sequesters CO_2 and particulate matters. Urban trees influence local air quality in that it reduces or increases building energy consumption by shading buildings, modifying air flows, and reducing air temperature, thus in turn changes building energy use that affects pollutant emissions from factories (Heisler, 1986). The decrease of air quality in urban areas is attributed to urban growth, since urbanization in LDCs has led to land-use change and mode of transportation thus worsening the current state of air pollution (She *et al.*, 2017; Fang *et al.*, 2015).

Kenya's forest ecosystem, though valued by many due to its ecosystem services and resource provision the country, lost 500 km2 of its prime water towers between the 1970s and 2010 alone due to deforestation (Kiringe J. *et al.*, 2015). Nairobi City is not different than the other, rapidly growing African cities that face multiple environmental challenges. Suitable execution

of urban planning that will acknowledge the role of urban green spaces such as parks, urban trees, and forest will have remarkable impact on the quality of air. Relevant studies have shown that land use land cover have a close interlink with the air quality. The studies point out that green spaces such as urban forests and parks improve air quality. Cities with blend types of land use provide better-quality air than the ones with low population density (Borrego *et al.,* 2006). A study carried out in Shenzhen, southern China, found that vegetation may significantly decrease the concentration for $PM_{2.5}$ in the air (Xie & Wu, 2017). Green spaces were conversely corelated with air pollution, greener spaces lead to reduction in air pollution (Xie & Wu, 2017). Trees also affect O_3 photochemistry and formation (Cardelino & Chameides, 1990). The environmental challenges that are faced by Nairobi city residents is attributed to its growing population as a result of rural-urban migration. However, inappropriate city planning is also contributing to the degradation of the city's air quality (Tabiajuka, 2017) yet it is among the growing cities in developing countries that lack effective framework and systems that to measure and monitor air pollution. Nairobi is rank to be among the twenty poorest developing countries in regards to their capacity to manage and control air pollution (UNEP & WHO, 1996).

Most African cities, especially Nairobi city, rely on biomass for cooking using a low-efficiency stoves, resulting high emissions in the context of poor emissions controls, especially in slums. This have contributed to increased levels of particulate matter ($PM_{2.5}$) in the city, which was above the levels prescribed by WHO (Muindi, 2017). The reason the level of pollution was this high was that the sources of energy used included kerosene and biomass like wood and charcoal in rooms that did not have sufficient ventilation. Muindi (2017) also mentioned that the dwellers of the two regions under study considered the indoor environment to be less polluted than the outdoor environment. This was related to the fact there are vehicles and factory emissions in the region. As such, the levels of pollution in the two slums in overall were above

the levels recommended by the United Nations. The highly populated areas, like the Nairobi slums, are a likely source of pollution. Muindi (2017) further explained that most of the communities in the slums in Nairobi depend on biomass for energy. As such, there is a high possibility that the population could be getting illegal firewood from the surrounding forests for their energy requirements. This insinuates that there would be a chance that Ngong road forest is used to supplying energy needs to a significant portion of the population in these slums. In Nairobi, the concentration of TSP is high that recommended levels by WHO (Mulaku & Kariuki, 2001). Outflows from motor vehicles are among the main sources of air pollutions in the city. Thus, it is very important to understand the nexus between the urbanization, air quality and the role of urban forestry. It was necessary to conduct studies that will help people understand the impact of urbanization on urban forestry cover and its implications on air quality.

2.3 Air pollution in Developing Countries

United Nations Environmental Programs has held several annual workshops that have been able to compile some of the reports collected by all sorts of environmentalists. Two such scenarios are the 2016 and the 2018 Global Environmental Outlook. In the Global Environmental Outlook (2019), the role of youths in and to the environment was considered. GEO (2019) held it that youth could reduce unemployment by considering the available natural resources, like forests and rivers, and using them well, to their benefit. GEO (2019) had a number of scholars contributing to the program and who held diverse opinions on the use of natural resources by the youths for their benefit.

The majority of the African population lies in the bracket of youths (GEO, 2019), meaning that the high population in urban centers of developing countries like Kenya is mainly comprised of youths. This shows that the pollution that has been as a result of population increase can be

checked and regulated if all the youths in developing countries like Kenya are sensitized about pollution and the protection of the Environment. Geo (2019) stressed on protecting the natural resources and sited the fact that natural resources like forest could make life in developing countries and Africa in general sustainable.

For Africa to be able to sustainably develop economically, it needs to have employment for its youths in green economy since green economy aims to mitigate environmental risks and promote sustainable development (GEO, 2019). Green economy aims to achieve sustainable growth, minimizes environmental risks and ecological scarcities (Loiseau *et al.*, 2016). As such, Kenya should also strive towards attaining and using a green economy. Kenya's environment has been adversely affected by the economic activities that are carried out, especially in urban centers. Most of the economic activities here do not add any value to the environment but rather degrade the environment through deforestation, dumping, and other forms of air pollution.

As countries develop throughout the world, there are major changes that occur. These changes include industrialization and urbanization (Gollin *et al.*, 2016). Both industrialization and urbanization have a range of benefits to the society and the involved nations but still cause milestones of havoc to the atmosphere. Air pollution in the third word, is a common problem since massive numbers of industries, and factories get constructed. As such, these countries experience enormous air pollution from dust, aerosols, and factory wastes, among other pollutants. At the same time, these countries do not have measures sophisticated enough to control the emissions let into the atmosphere (Golin *et al.*, 2016). Apart from industrialization and urbanization, air pollutions have also been attributed to indoor sources of pollution. In this case, the levels of pollution keep rising on a daily basis. There is, therefore, a dire need to

investigate what has been found before in relation to air pollution and put it into consideration when seeking the remedy to the problem.

A study that embarked on a research to study the effects air pollution found that health is a vital aspect of human life, which must be protected with all it takes (Mannucci & Franchini, 2017). However, this aspect of life has been endangered by the daily path taken by the atmosphere, among other key aspects. The atmosphere provides the most significant support for life, air. They are polluting the air that all living things, plants, and animals depend on, places the globe at a huge risk. Mannucci and Franchini (2017) main objective in their study was to synthesize policy-relevant knowledge that would be critical in the endeavors of developing strategies to curb the highly growing pollution and its effects.

Developing countries are the most affected by air pollution. These countries are also middle-income countries and have high urban concentrations of health-damaging pollutants (Mannucci & Franchini, 2017). However, the countries' war against air pollution, although it has been staged, is still on the younger end and needs to be stepped up if it is to sufficiently deal with the catastrophe being created by air pollution hazard. As such, the whole world has staged a war to fight and control the looming disaster, which has the potential to cause an insurmountable effect on life. Various countries have gone ahead and ventured in the endeavors to stop the daily-increasing levels of air pollution, to ensure lives of people, animals, and plants in their countries remain safe (Mannucci & Franchini, 2017). However, the methods employed by various nations across the globe have had a significant difference based on their level of growth and development. For instance, developed countries have established sophisticated measures to stop air pollution both national and international levels.

The developing countries are also doing fairly well in their endeavors to curb the disaster. However, the underdeveloped countries are still facing challenges in devising ways to fight

and stop the increasing rate of air pollution, which is endangering life in all scopes despite the fact that they have launched local ways and methods of dealing with the disaster (Mannucci & Franchini, 2017). According to Mannucci and Franchini (2017), all these strategies that have been launched by countries on the various scale of growth can be improved if all effects of air pollution are investigated and a collaboration employed to ensure that the whole globe employs the strategies to curb air pollution since it is a global menace. The effects of air pollution on life have been deleterious. The study reveals that the world records about 7 million deaths every year, deaths which are attributed to air pollution (Mannucci & Franchini, 2017). As such, health has been mightily affected by air pollution peril. Some of the health problems that have been recorded and attributed to air pollution include asthma, bronchitis, emphysema, deadly cancer, aging of lungs, and loss of lung capacity and decreased function, among other effects (Mannucci & Franchini, 2017).

All the above challenges have placed people in various countries in unusual levels of strain in all aspects. Social life, as well as economic life, has been affected by air pollution. The most affected sick people economically are the sick people from middle- and low-income nations, the developing, and the undeveloped nations (Mannucci & Franchini, 2017). These people experience a high level of strain since it is difficult for them to undergo proper treatment due to the financial strain they experience. In addition, it has been recorded that the air pollution is great in these nations. Air pollution in the developing countries that affect health is mainly caused by compounds i.e Nitrogen Oxide and Sulphur dioxide (Mannucci & Franchini, 2017). These pollutants are emitted into the atmosphere both by natural causes and by human activities. Regardless of the source of these pollutants, the effect has been devastating and continues to worsen as urbanization and industrialization get to develop.

The accelerated population growth in Sub-Saharan Africa (SSA), has contributed to air pollution in cities (Amegah & Agyei-Mensah, 2017). The situations worsen by increased vehicle ownership, industrial expansion, high consumption of solid fuels and poor waste management practices in these cities (Amegah & Agyei-Mensah, 2017). According to Amegah and Agyei-Mensah (2017), the number of deaths in SSA that have been related and attributed to air pollution is 176,000 and is likely to be higher owing to the fact that there is scanty data related to ambient air pollution. For this reason, UN resolutions on health, air pollution and Sustainable Development Goals are key strengths added to the fight against this problem in Sub-Saharan Africa (SSA). Therefore, all the developing countries need to embrace and implement the strategies outlined and suggested by World Health Assembly and Sustainable Development Goals for them to be able to fight and control the air pollution in urban centers. Among these strategies is the protection of the environment by planting trees and avoiding deforestation, especially in urban forests. As such, Kenya has the mandate to protect Karura Forest and Ngong Forest since these are the urban forests around the capital city. Protecting these two forests will mitigate the impacts of air pollutants.

Kenya has also experienced a significant level of air pollution, especially in urban centers. Most of the air pollution in Kenya is caused by motor vehicle emission and domestic use of bio-mass (Odhiambo *et al.*, 2010; Malla *et al.*, 2011). The industrial waste release has also contributed to air pollution significantly (Omanga *et al.*, 2014). The country has realized a rapid increase in population in the last three decades, with current population being 47,564,296 (KNBS, 2019). As such, there has been an equally enormous economic growth that has seen a significant portion of the population to acquire motor vehicles. The acquired motor vehicles have been used to make economic growth even more rapid but have had its share of environmental impacts (Odhiambo *et al.*, 2010). Most of the vehicles have been using leaded fuel until the lead was declared a hazard to the environment. Still, the exhaust fumes from the

vehicles still have considerable amounts of pollutants that are hazardous to the environment (Odhiambo *et al*., 2010).

In other circumstances, Malla *et al.* (2011) explained that indoor use of biomass majorly contributes to air pollution. The majority of the people living in Kenya rely on biomass that includes firewood, charcoal, and biogas, among others for energy. As such, there has been an enormous release of pollutants into the atmosphere, a situation that has caused an alarming condition of pollution, a condition that endangers the ever-increasing Kenyan population (Malla *et al.,* 2011). Therefore, there has been a need to find a remedy to the issue brought about by air pollution. One of the suggested effective remedies lies in the protection of forests. As such, there is a dire need to protect the Kenyan forests, especially those within the urban centers such as Ngong Road Forest, which are likely to be victims of urbanization that is coupled with a rapid increase of urban population, a population that may rely on biomass for energy.

2.4 Air Pollution and Urbanization

Developing countries have a rapidly increasing pace for industrialization and urbanization. Consequently, air pollution has also been increasing rapidly and so has the effects of air pollution, especially in the health sector. Decision-makers have had to rely on the scanty data in their endeavors to make a decision regarding saving the population from the overlooking calamity (Schirnding, 2012). Occasionally, there may arise a need to make a rapid response concerning a certain health effect of air pollution. For instance, there may be a surge in the number of people affected by an unexpected spillage of air pollutants, or there may be people getting respiratory problems resulting from air pollution emanating from industry in a certain geographic location. These aspects, among others, are aspects that would need a rapid response in order for the effects to be contained. In other circumstances, cases may arise that not only

rapid solutions and the response would be required but long-term solutions as well. For instance, in the cases of forest fires, there may be a rapid change in the environmental conditions, which may be associated with a rapid surge in the number of asthma cases. On the other and, correct or right environmental conditions would help deal with the effects of air pollution. These environmental conditions would include having the right forest cover, which enhances the quality of life. Environmental epidemiology is one of the important aspects of public health and should be considered since it specifically concerned with the environmental determinants of diseases and health effects (Schirnding, 2012). It helps in the understanding of health situations and consequently helps in establishing correct a result of environmental hazards (Ladd-Acosta *et al.*, 2016).

Katsouyanni *et al.* (2019) found that the level of pollutants in Europe and in the United States cause varying types of results. For hospitalization, results were different without a variation among the data sets used. Also, the pattern of modification of the effect of particulate matter (PM_{10}) was not entirely between the centers where the research studies were done. Therefore, it can be seen that there has been a difference in the effect of various pollutants, including particulate matter and the polluting gas in the developed nations. Katsyoumi *et al*. (2019) report can be used to conclude that the patters in the rest of the world are expected to be different since the various parts of the globe have varying topographies and distribution of the air pollution factors. As such, it is important to conduct studies in all developing countries like Kenya and establish the distribution and patterns of the air polluting parameters and the effects they have on the population in the countries.

Sub-Saharan Africa has witnessed a rapid pace of industrialization and urbanization. Research studies have been conducted, and it has been shown that the rate of urbanization and industrialization exceeds the level of environmental protection. One such research that was

conducted was the study done by Tomlinson (2017). A study on effect of urbanization and industrialization on LULC in SSA within a period of 23 years, found out that in 2017, lands exceeding 500,000 hectares had been cleared with the purposes of urbanization and industrialization (Tomlinson, 2017). The cleared land was used for the construction of houses and loads (Tomlinson, 2017). Having in mind that construction is one of the most abundant sources of particulate matter and that clearing land leads to eating up of forests, which positively modify the environment, it can be concluded that air pollution must have increased significantly during that period. However, not much study has been done in South Africa to evaluate the amount of pollution that has been caused by the changes and the effect it has had on the ever-changing population structure.

In other circumstances, most developing countries lack adequate systems of managing air quality due to ineffective polices and poor governance and balancing between economic development and sustainable development is difficult since short terms benefits is favored (Omanga *et al.,* 2014). As such, there is no adequate data that can be used to address the problem of air pollution in most developing countries, including Kenya. Therefore, lack of data has made many developing nations get the perception that there is no problem while in the real case, air pollution is slowly eating up their environment (Omanga *et al.*, 2014). Use of improved stoves have been proved to be effective in reducing indoor air pollution in Western Kenya. Yip *et al.* (2017) found out that the improved stoves have brought a significant reduction in the concentrations of the particulate matter, although the concentrations were still higher than the standards laid by the World health organization.

The fact that the concentration of $PM_{2.5}$ in the rural areas was more than the WHO standards causes a worrying situation (Yit *et al*., 2020). It is likely that urban centers have more concentrations of particulate matter. For instance, a study found that the mean daytime

concentrations of $PM_{2.5}$ ranged from 10.7 μg/m^3 to 98.1 μg/m^3, thus exposing many residences to elevated levels of concentrations air pollutants, with long-term health implications (Kinney *et al.,* 2011). Therefore, it is vital to look into the available ways of modifying the environment such that the concentration levels would reduce. One of the suggested ways of improving the environmental conditions is by having sufficient forest cover and a good number of trees for the case of a city like Nairobi. The forests that are near to Nairobi and which could bring relief to the escalating levels of air pollution are Karura Forest and Ngong Forest. Any eating up of the forest space would mean that the city residents continue to be placed in ultimate danger.

2.5 Urbanization and Population Growth

Lee *et. al* (2017) emphasized that the population structure is an imperative definitive of the level of exposure to air population and other health determinants. Most of the developing countries have a population that has been on an increasing trend. As the population increases, there is always an expected change in terms of economic development. Also, population density gets to determine the level of exposure and some of the factors that shape the environment. When the population increases, there is a tendency to get forests cleared to accommodate both the settlement of the population and their economic activities. Additionally, an increased population leads to more ventures into the economic world, which would mean additional industries, factories, and motor vehicles, among others. This addition in the pollutant emitting sources translates to an addition in the level of contaminants. Therefore, scholars and researchers have ventured into studies to analyze and determine the role of population in matters to do with air pollution.

One such research was conducted in India by Coole and Hoover (2015) on population growth and economic development. The study aimed at elucidating the patterns of economic development as well as the pattern of population growth. Coole and Hoover (2015) argued that

economic growth has effects on the population, and the population has effects on economic growth. For instance, as the population increases, there is a need for more room for agriculture since more food will be required. Additionally, an increase in population leads to innovative ways to cater to the economic requirements of the population. It leads to an increase in the number of industries and vehicles and at the same time, reduces forest cover since there is a need for more room for agriculture and settlement, to feed and accommodated the growing population in cities (Coole & Hoover, 2015). Rapid population increase has led to economic growth. For instance, India has a bigger portion of its vast population that depends on combustible sources of energy (Coole & Hoover, 2015). The country developed and created many manufacturing industries to acter for the economic needs of its increasing population (Coole & Hoover, 2015). However, it has been noted that the level of pollution in India has been on an increasing trend. Venkataraman *et al.* (2018) explain that there has been an increasing trend in noise and air pollution, specifically the particulate matter ($PM_{2.5}$). There has been a consequential increase in air pollution-related health effects. It has been noted by Gupta *et al.* (2017) that the cases of respiratory problems have also been on the rise. Therefore, it is essential to examine the trend in population growth in all developing countries and determine the effects they have on economic development and the consequent effects on the environment. This is because most of the developing nations have a rapidly increasing population based on the high number of births and comparatively low number of deaths.

Population growth and population density cannot be treated separately since an increase in population leads to a need for more room that might not be their Urbanization worsens the matter as far as population density and air pollution is concerned. Urbanization also results to rapid population growth in cities, thus lead to increased demand of land and forest resources. Research conducted in China found that urbanization leads to an increase in population in the urban centers resulting from the rural-urban migration (Liu *et al.*, 2017). There has always been

a debate about the interlink between population growth and economic development (Obere *et al.*, 2013). One side of the debate holds the opinion that population growth leads to economic growth while the other holds the opinion that population growth retards economic development. At the same time, there is a theory that holds the opinion that population growth has no effect on economic development (Obere *et al.,* 2013).

Obere *et al.* (2013) embarked on a study to evaluate the relationship between population growth and economic development in Kenya. The study found that population growth in Kenya promotes economic development. The economic development is brought about by the need to have a satisfying source of living to the ever-growing population. As such, there has been an enormous increase in the number of vehicles purchased, enormous industries constructed, and massive residential areas build, among others (Obere *et al.,* 2013). Economic development has, in turn, affected several aspects. There has been a need for more land for the construction of residential areas as well as enough land for cultivation for enough food to cater for the increasing urban population. The population increase has mostly been in the urban centers, specifically the capital city Nairobi, which has become a center for industries and other economic activities. As such, there has been a need for land for the construction of amenities that support the population. This has, in turn, led to the clearing of forested areas in the endeavors to create enough land for the needs (Obere *et al.,* 2013). For this reason, urbanization has rapidly developed and led to the eating up of forest areas. Karura forest and Ngong forest are the affected forests. Therefore, there is a need to evaluate the extent to which urban forests have been eaten up by urbanization and take necessary measures.

2.6 Use of GIS and Remote land use land cover change

Land use analysis can either be done through field surveys and analysis of remotely sensed imagery. Human health and deterioration of the environment are some of the factors that make

a natural urban environment and human-induced environmental changes to become major concerns (Mullupatu P. & Reddy J., 2013). As such, there is a need to track land cover changes since the changes are vital informants of the proper planning decisions that should be taken. Mullupatu and Reddy (2013) found that there was a significant increase in the built-up area in India during, the period between the year 1976 and the year 2003. It was also noted that a significant amount of dense forest area had been cleared during the period of study, which may have been due to the rapid urbanization of the study area (Mullupatu P. & Reddy J., 2013). GIS and remote sensing technology will therefore be instrumental in the study on urbanization and the effects it has had on Ngong Forest. GIS and remote sensing will help analyze LULC. The obtained information is crucial in making conclusions regarding the effects of urbanization on Ngong Road Forest.

2.7 Legal framework related to forest

2.7.1 International policies and frameworks

Successive conferences have culminated in a new global agenda for forests. Forest related development is now incorporated into sustainable development and is considered part of it. The Among the most important international events is UNCED, which took place in Rio de Janeiro-Brazil, is that it stressed the importance of protection and conservation of forest, which is element in achieving sustainable development. The result of the conference was a worldwide appreciation of the interconnected complexities of sustainable development and forests. 27 guiding principles, agendas (known as agenda 21) and non-legal declarations of principles are included in the items of this conference. The 27 principles outlined guide nations' conduct towards more environmentally sound development patterns. Non-mandatory agreement known as Agenda 21, has also been adopted by UNCED, which reflects consensus building on a "national workplan" for the United Nations' economic, social and environmental tasks as they develop over time. A "non-legally binding authoritative declaration of principles for a global

agreement on the management, protection and sustainable growth of all types of forests" was the third official product of UNCED.

However, it was difficult for the parties to for a legally binding convention on forests. Analyst highlighted that parties were unhappy with the final outcome from UNCED, an aim to ensure further talks on establish a framework on forests (The World Forestry Institute, 2006). Agenda 21 (chapter 11 of Agenda 21) and later the forest principles, set guiding principles for Sustainable Forest Management. Some countries' attempts to a binding agreement on forests, known as legally binding instrument during post-Rio process, have been aimed at creating a a uniform structure for forest regime. "The" missing Rio convention "or the" fourth convention "is sometimes referred to as an international binding convention on forests," which include Framework Convention on Climate Change (FCCC, the Convention to Combat Desertification (CCD) and the Convention on Biological Diversity (CBD), and The United Nations Commission on Sustainable Development (CSD) – that is obliged to implement Agenda 21. This followed the initiation of Intergovernmental Panel on Forests (IPF) in 1995, succeeded by the Intergovernmental Forum on Forests (IFF) in 1997, to implement the Forest Principles and Chapter 11 of Agenda 21.

The IPF/IFF processes (1995-2000) discussed on financial support and technology transfer to ensure sustainable forest management. The IPF / IFF processes have analyzed and studied on forest related topics and developed a non-binding 270 proposals for action on SFM, known as proposal for actions. However, there is a political duty for participants in these processes to adopt the negotiated proposals for action. In 2000, United Nations Forum on Forests was established as a subsidiary of United Nations Economic and Social Council (ECOSOC), to promote conservation of forest and sustainable development.

Other important forest related policy development includes MDGs and SDGs. In 2000, MDGs were adopted by the United Nations General Assembly. Specifically, forestry growth was connected to Millennium Development Goal 7: Maintaining Environmental Stability. In 2002, World summit on sustainable development accepted Sustainable Development as a key pillar to end deforestation and over-extraction of natural resources. Subsequently, in May 2007, Forest Instrument, a biding legal that consists of policies and initiatives to enhance the involvement of stakeholders and four global forest objectives were developed by UNFF (FAO, 2013b). The Four Global Forest Objectives focuses on reduction of forest loss, to increase the socio-economic and ecological benefits of forests; to sustainably manage forests, increase benefits accrued from sustainably managed forest and increase financial support towards forest management.

The Sustainable Development Goals which succeeded the MGDs in 2015 also emphasizes on sustainable forest management directly and indirectly. For instance; SDG 6, 14 and 15. SDG 6 promotes accessibility and available of water for all human kind, while SDG14 promotes sustainable use of natural aquatic resources, including mangroves forests and lastly SDG 15, promotes the sustainable use of terrestrial ecosystems and promote the fight against on desertification and land degradation.

2.7.2 National frameworks

2.7.2.1 Kenya's 2010 constitution

Chapter 4: Provides every citizen the right to an environment free of pollutants, protected and sustaibly managed natural resources for the benefits of the current and future generations, through reforms in policies as indicated in article 69. The constitution distinguishes land as community, public and private land (Chapter 5, 2010 constitution). The constitution also emphasizes on sustainable utilization and equitable use of forest resources, maintaining 10%

forest cover, enhancing indigenous knowledge and promotion of public participation in matters related to forest {(Article 69(1), Article 71(1)}.

The constitution also defines clear roles of both national and county levels of government, devolving some functions to county governments (Article 174). It also guides the establishment of new legislations governing the management of urban areas and cities (Chapter 11).

2.7.2.2 Forest Act 2005

The act provisions include the establishment of KFS and forest board. The function of the institution is to manage and protect all forests in the country through policy reforms and setting guidelines for the management and sustainable utilization of forest resources in the country. It's also mandated to create partnership with private and public institutions to promote forestry research and education. The institution is mandates to in setting up management plans for all indigenous forest and plantations. The Board carryout management services and its members include the Permanent Secretaries for forestry, Water, finance, local authorities or a designated representative (directors) of KFS, KWS, NEMA, KFRI and eight other persons appointed by the ministry, that are not civil servants.

However, the Act faced a number of challenges in implementation since the forest management had to be adjusted to be able to cope with the newly established regulations. Kinyanjui (2009) conducted a study on the effects of encroachment on Mau Forest in the period between the year 2003 and the year 2007, a period within which the Forests Act (2005) was passed. In his study, Kinyanjui (2009) aimed to study the impacts of anthropogenic activities on the forest and establish its resilience by comparing forest aspects at three levels of disturbance. Forest cover was analyzed using satellite image data by supervised classification at two-year intervals. Five forest cover types were identified; closed-canopy forest, plantation forests, bamboo dominated forest, forest bush, and grassland. From this study, Kinyanjui (2009) found out that human

encroachment and human activities had affected the forests to a level that it would be hard to recover. Trees had been cut, and the area was used in the cultivation of maize and settlement. Trees were fell daily for the purpose of domestic use. Kinyanjui (2009) records that the residents of the places occupied by the forests ventured into agriculture and realized that the soil was quite fertile. As such, they fell more trees and reduced the forest area even more. According to his statistics, Kinyanjui (2009) indicates that forests area had decreased by about 40% as compared to data collected in various ways ten years earlier. The total land that was deforested included the land that was used for farming and settlement, the land that was left without forest cover, and the land that had reduced forest cover. As such, Kinyanjui recommended that stringent measures needed to be taken to ensure that Kenya does not take the path it was taking. Kenya would land into a dangerous position environmentally if the measures to conserve the forest were not taken. This is where the Forest Act of 2009 came in, that promotes sustainable forest management where the local communities are involved.

The forest Act (2005) then provided for clauses that protected the Kenyan forests. This was achieved through prohibiting tree felling, empowering the Kenya Forest Service, and declaring forests as areas not for human settlement, among other regulations. However, the Kenya Forest Service has had a challenge in enacting the laid-out regulations. The challenge, especially for the forests situated near cities, was caused by the fact that cities have kept noticing a high influx of residents who require settlement areas and a source of energy. Additionally, the forests have been endangered by the ever-rising pollution (Kinyanjui, 2009). The Forest Act was again revised in 2016 which promotes good governance and access to public information. Additionally, the act promotes the cooperation of both level of governments in the management and conservation of forests. Besides, it provides for collaboration amongst key relevant stakeholders in ensuring that 10% tree cover all over the country is achieved.

According to Boiyo *et al.* (2019), CFA at Ngong road forest, known Ngong Road Forest Association was established in 2008after which it applied for official registration in December 2008. The main objective behind the application was to protect and conserve the forest and at the same time try to improve the living standards of the local communities around the forest. This was to be achieved through promoting utilization of forest resource that would be attainable. The study found out that the members of the CFAs represent diverse communities with different level of interest in protecting and use of forest resources. The CFAs were established under the constitution to play a role in forest management and protection of the forest, as well promote sustainable use of the forest products by its own members to enhance their livelihood (GoK, 2016).

2.7.3 Other national policies related to forestry

2.7.3.1 Environmental Management and Coordination Act, 1999 (amended 2015)

Conservation and management of environment is guided by this national framework. Environmental Management and Coordination Act established National Environmental Management Authority (NEMA) to ease the governing of the environment. This was to be done through environmental policies enforcement and coordination of issues related to environment. It is the authority to establish regulations, standardize and set measures consultation of lead agencies and county government, to manage and conserve the natural resources sustainably, through seeing to it that Environment Impact Assessment (EIA) and Environmental Audits are carried out for all projects concerning development, to eradicate its effect on natural resources. In 2012 and 2015, EMCA 1999 was amended to realign it with the 2010 constitution. The act also established Public Complaints Committee, National Environment Tribunal, National Environment Action Plan Committees, and County Environment Committees.

2.7.3.2 The Energy Act, Cap 314, 2006(amended 2019)

It is a legislative framework law that promotes the development of energy by ensuring efficient and sustainable use renewable energy sources. It provides the establishment of Rural electrification and renewable cooperation mandated to carry out research and dissemination of findings on new technologies for the development of renewable energy. It also mandated the cooperation to establish a framework that ensures efficient and sustainable production, transformation, supply, marketing and efficient use of renewable energy sources such biomass, solar and wind. It mandates the cooperation to promote uses of fast maturing trees for energy production for commercial purposes, for instance urban plantations in consultation with KFS.

2.7.3.3 The Land Act, 2012

This act provides the establishment of National Land Commission, that is mandated land, whether public or private on behave of the national government of Kenya. The commission carry out studies related to land use and recommends appropriate measures to be taken by relevant authorities. The act also provides establishment of court tribunal to resolves land-based conflicts and complaints and ensures forested lands are not occupied by any entity or individual (Article 67 of Kenya's constitution).

2.7.3.4 The Water Act, 2002

The act was revised in 2016, to clearly guide the aspect of devolution, giving clear define roles to national and county governments. It has provisions that establishes authorities with different roles and functions in conservation of water sources and control of water uses. This include water user's associations and Basin Water Resource Committees (BWRCs), that is mandated to conserve and protect water catchments areas i.e forests to ensure water is available to the communities.

2.7.3.5 The Timber Act, Cap. 386, 1972 (revised 2012)
The act provides guidelines to effectively control the sale and export of timber. It sets measures and standards i.e gradings and marking.

2.7.3.6 Mining Act, 2015
Proposes plans that ensure substantiable extractions of mineral resources and guides by setting standards in mining activities that may have impacts on forest ecosystems.

2.7.3.7 County Government Act, 2012 (revised 2013)
Mandates counties to play a critical role, in supervising and controlling developmental projects to ensure the environment is protected and interest of minority groups are considered through meaningful participations

2.8 Theoretical framework

2.8.1 Sustainable Development and System Theory

Sustainability has been an important concepts and goals for many societies and even science. Sustainable development promotes economic growth that ensures the needs current and future generations are catered for. The concept was widely recognized in the globe as a balance between development and conservation of natural resources, thus created a platform where these issues is discussed (Ling, 2005). Series of international conferences such as, UN conference on the Human Environment held in Stockholm and Nairobi, proposed an integrated approach in solving many environmental problems most cities are facing. Sustainable development seems to be the ideal approach to protecting the environment and improving the quality of human life, the reality is however not so straight forward. The challenge can be better understood by looking at Maslow's hierarchy of human needs. Sustainability is human and biodiversity centered. For sustainable development to be achievement, human being should be a central key actor in ensure the natural resources are utilized appropriately without jeopardizing the ability of the ecosystem to regenerate. ''Sustainability' may be centered on an environment or the status of biodiversity, for case − with or without express consideration

to human well-being or can be inclined towards a particular human interest, i.e monetary wellbeing (Waas *et al.*, 2011). Hence, interest of maintainability is situated toward long period treatment of characteristic assets, social frameworks, and individuals in ways that are reliable with human well-being. In any case, as placed by Bettencourt and Kaur (2011), the "concept of economic advancement", presently plagues the plans of governments and enterprises as well as the mission of instructive and inquire about programs around the world." The intertwined concepts of sustainability and development are linked to concerns about the health of social-ecological systems and the increasingly evident human dimensions of global change (Vitousek *et al.*, 1997; MA 2005; Kareiva *et al.*, 2007; Steffen, Crutzen, and McNeill 2007; Steffen *et al.*, 2015a, 2015b). With rising concerns about the capacity of Earth systems and human technologies to maintain ecosystem services and provide for human needs, sustainability science emerged at the beginning of the 21st century, with attention to both basic and applied research (Kates *et al.*, 2001; Clark 2007; Elsevier and SciDev.net 2015). Therefore, the study adopts system theory that states there is a relationship between structures and behavior (Zhang 2013). Cities are created by social systems that rely on complex network of human-made systems to supply. A city, which is a place a in which the numerous subsystems of an urban region interact, is taken to be like an ecosystem which belongs to a bigger system. Analyzing the interactions between human and the environment systematically would make it possible for the one to capture the complexity of urban systems, thereby making it possible to understand how cities process matter or energy in relation to their surroundings as explained by Broto *et al*. (2012). It is therefore imperative for one to focus and understand the temporally and spatially dependent changes between systems (Nelson 2005, Carpenter *et al.*, 2006, Liu *et al*., 2017, Reid *et al.*, 2010, Bettencourt and Kaur 2011, Costanza *et al*, 2013)

2.8.2 Cities and protected areas

The disconnection that exists between the protected areas and the cities is an obvious issue that brings out the tension that reflects on the conservation-urbanization (Tryzna, 2005). Beatley, (2004) Mitlin and Satterthwaite, (1996) also mention about the conservation-growth dispute, and the second argument is the separation of urban citizens from nature (Tryzna, 2007; Wang, 2007) are two theories that may justify this situation. Beatley (2004) states that contradictions between the conservation of species and urban growth occur. Biodiversity security will also be in competition with housing and economic growth demands. Such disputes are more frequent and serious where there is a larger number of rare and endangered species or where there are the most serious population and development pressures.

The above view is also acknowledged by Mitlin and Satterthwaite (1996) and they speak about the wide gulf between those whose primary concern is conservation and those whose primary concern is meeting human needs. This suggests that one of the key strategies for resolving protected area concerns will be to build a bridge between conservation and growth interest. The second problem is that urban residents are disconnected from nature (Wang, 2007); they have less and less interaction with nature. There are numerous explanations for this: there may be no access or opportunity for the urban poor, while wealthy people prefer other electronic technology-driven leisure activities or entertainment (Tryzna, 2005). This is a conservation downside because broad public support is crucial to have. It is important that individuals have an understanding of what is at stake and that they also become involved (Tryzna, 2005). Therefore, public support can only be achieved if urban citizens understand the vital position that protected areas play.

2.8.3 Sustainable development of cities

Sustainable development is considered a panacea as a solution to the dispute between biodiversity conservation and the development of urban areas. The reason is that "sustainable

growth has been used to highlight the simultaneous achievement of environmental and development targets" (Mitlin and Satterthwaite, 1996). The interdependence between protected areas and cities must first be recognized in order for cities to grow sustainably. Cities benefit greatly from protected areas: environmental services, such as natural control of water flow, water quality, microclimate alteration and waste assimilation. This is in addition to economic benefits such as tourism, jobs and profits for businesses and social benefits such as good health, leisure, education, and protection of historical and cultural heritage.

Safe areas, on the other hand, rely on cities for political support, financial support and tourist support, so it is a relationship that is mutually dependent (Tryzna, 2005; Connor, 2005). Menezes (2005) notes that "the fight for conservation will be fought in the cities" to highlight this interdependence. This is in recognition that opinion makers, leaders, lobbyists and main organizations are more likely to be located in metropolitan areas. How sustainable development can be extended to cities and protected areas is an essential issue, then. First, the significance and value of protected areas needs to be understood by city planners. Jowsey and Kellet (1996) point out that while urban planners might be environmentally conscious, this does not guarantee that the policies adopted and enforced are successful in protecting the environment. As Tryzna (2005) states, the challenges are primarily political, more so when one assumes that accountability for environmental problems is divided between different government agencies. Institutional solutions are important to address the challenges mentioned. The job is not only for the conservationists, but for all the town planners. The Rio Declaration on Environment and Development of 1992 acknowledges local authorities' central position in achieving sustainable development. Sustainability must also be consciously integrated into the planning agenda in order for a city to be sustainable (Ling, 2005). In order to incorporate these many cities, projects have been undertaken whereby the notion of sustainable development is put into

practice in their policies and development programs. Both international and local are these programs.

2.9 Conceptual framework

2.9.1 Urban Forest Disturbances

Urban forest disturbances influences are related with the adjoining frameworks (Trowbridge and Bassuk 2004) and the thickness of buildings and other urban structures influences the radiations such as daylight accessible for photosynthesis and microclimate of urban zones (Jutras *et al.*, 2010). Besides, the degree of impenetrable surfaces (e.g., concrete and black-top) confines the arrive region accessible for urban woodland foundation (Tratalos *et al.,* 2007). Tree nearness to, and potential strife with, framework (e.g., overhead wires) can moreover be a roundabout source of unsettling influences are due to administration hones related with evacuating clashes (Trowbridge and Bassuk 2004). Arrive utilize has too been found to be exceedingly compelling on both tree mortality and environment structure (Nowak et al. 2004), particularly those with more noteworthy escalated of utilize and higher thickness (e.g., commercial and mechanical arrive uses. Exposure to social stressors related to both land-use intensity and land administration hones too cause purposefulness and inadvertent physical harm to trees (Lu *et al.,* 2010). Biology of trees and the ecological processes of urban forests are negatively affected by environmental contaminants and pollution.

In spite of the trees' amelioration of urban air pollution (Nowak and Dwyer 2007), airborne pollutants simultaneously degrade tree physiology. For instance, besides hindering of biomass accumulation by the ground level or tropospheric ozone, plant photosynthetic rates are also reduced. (Sitch *et al.,* 2007). The urban soils' chemical properties are often widely modified in cities to varying degrees. The most prevalent urban stresses of trees include but not limited to heavy metals soil contamination, leaf-litter-removal-resulting low nutrient availability, alterations of the acidity or alkalinity of the (Zimmerman *et al.,* 2005). Soils are important for

the conservation of urban trees and soil structure loss can lead to limited root growth and degraded water infiltration, impeding the overall condition and growth of the tree (Hanks and Lewandowski, 2013). A typical phenomenon in land uses with an excess of construction and impermeable surfaces is often inadequate soil volumes to support proper root growth (Trowbridge and Bassuk 2004). The primary biological threats to urban trees are from insects and pathogens outside of the human population of a town (Konijnendijk *et al.*, 2005; Lac'an and McBride 2008). Insects and diseases are the focus of both urban and hinterland forests. However, trees that are stressed are more vulnerable to infestation and decline, as many are in the urban setting (Armstrong and Ives 1995). In addition, invasive forest pests and diseases that have been introduced as a result of global trade and the changing environment are frequently subject to urban areas (Dukes *et al.*, 2009). The Dutch elm disease (Ophiostoma novo-ulmi) and, more recently, the emerald ash borer, which currently affects ash populations in Canada and the United States (Herms and McCullough 2014), are a well-known example of decimated urban tree populations. It is also predicted that the frequency and intensity of these biological invasions in urban areas will increase in the near future.

2.9.2 Good urban governance and policies

Introduction of appropriate forest policies that specifically focus on resolving the complexity of the disturbances that urban forests are facing, especially those that are located in a rapidly growing cities in developing countries such as Nairobi, that provide services to competing interest to the urban populace. Effective implementation of forest policies and good governance of forest resources will be the success of achieving sustainable forest management, contribute to the reduction of air pollution and enhance socio-economic well-being of human beings. In addition to this, urban forest governance will contribute to the success of achieving of Reducing Emissions from Deforestation and Forest Degradation (REDD+) which will promote incentives and minimize negative social impacts, promote structures of service deliver that is geared

towards sustainable development and poverty reduction. Though governance challenges including corruption, lack of political will, lack of inclusivity in decision making process related to urban forests and uncoordinated mechanisms, it can be resolved through coordinated, cross-sectoral development strategies that ensures accountability, inclusivity and transparency.

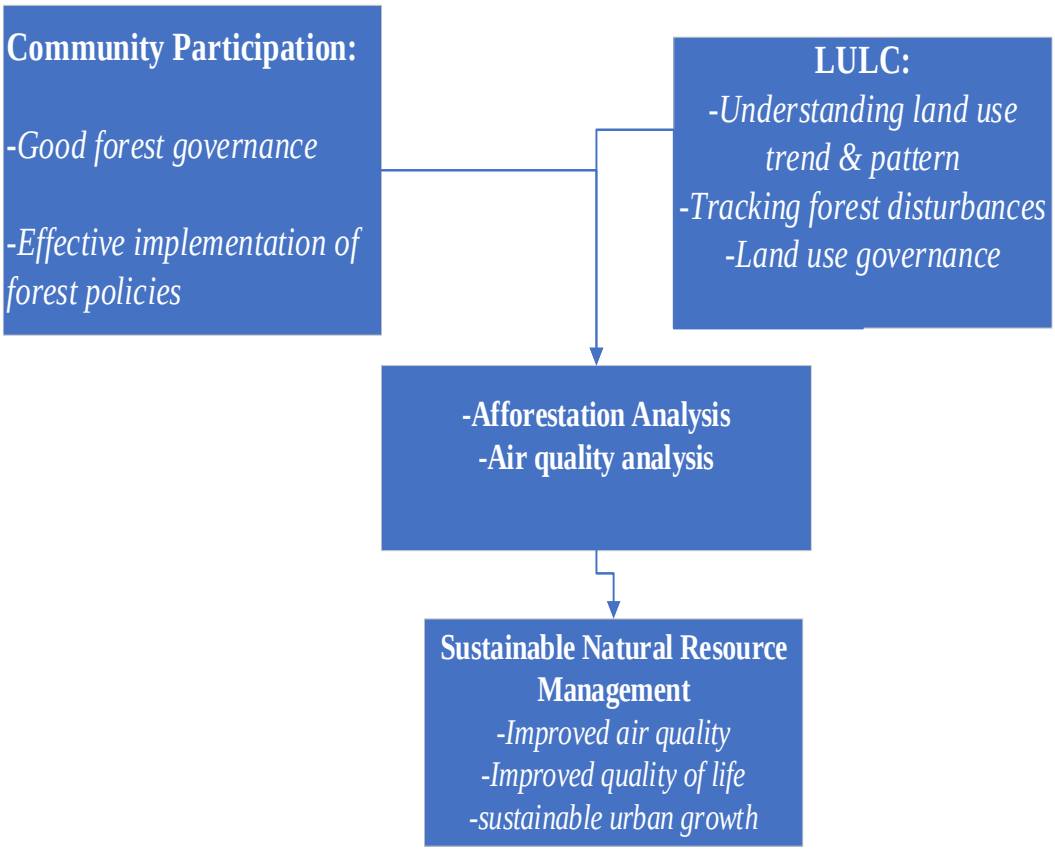


Figure 1: Conceptual Framework Source: Author

CHAPTER THREE: DATA AND METHODS

3.1 Introduction

This chapter discusses about the research area, research design, target population, sample size, and sampling procedure, data collection method and data analysis.

3.2 Study area

This section describes the location where the study was carried, climate, land use and socio-economic activities.

3.2.1 Description of the area

Ngong Road Forest is situated along the boundaries of three constituencies; Kibra, Dagoreti, and Langata in Nairobi County. It lies 6km from the Nairobi Central Business District (Boiyo *et al.*, 2019). The indigenous urban forest was gazetted in 1932 and it has an altitude of 1670m above sea level with a latitude of 36^0 50' and longitude 1^0 17' south (Boiyo *et al.*,2019). The study focusses on the Ngong road forest and its surrounding administrative areas within Nairobi County (as shown in figure 1). The city serves regional and international headquarters for several public and private institutions that include United Nation Agencies (Ottichilo, 2010)

3.2.2 Population and Land Use

The population in Nairobi City have grown from 118 000 in 1948 and 343 500 people in 1962 (Rakodi 1997, CBS 2001). The population of the city grew from, 1,324,570 people in 1989 to 2,143,254 in 1999, 3,138,369 in 2009 to 4.3 million in 2019 (CBS, 1989; CBS, 1999; KNBS, 2009; KNBS, 2019). Rural-Urban migration have fueled Nairobi's early growth with explosion happening between 1979 and 1989. The driving force of rural-urban migration being search of economic prospects and opportunities for higher education among others (NEMA 2003). The current population of Nairobi County is 4.3 million (KNBS 2019) with an area of about $700km^2$. It is rapidly growing, and this have "cause and effect" implications on climatological

and the physical conditions of the city. Satterthwaite (2008), revealed that the outcomes of the increased population growth are increased built-up area that alters the surface albedo hence increases emissions of greenhouse gases. The built-up areas have increased due to economic accelerated economic growth due to urbanization. The built-up areas in Nairobi increased from 41km^2 in 1988 to 62km (Mundia and Aniya, 2007). The city's growth and expansion have led to loss of urban forest such as Karura and Ngong Road Forest. Mundia and Aniya, 2007 noted that these changes reveal that there was a rapid development.

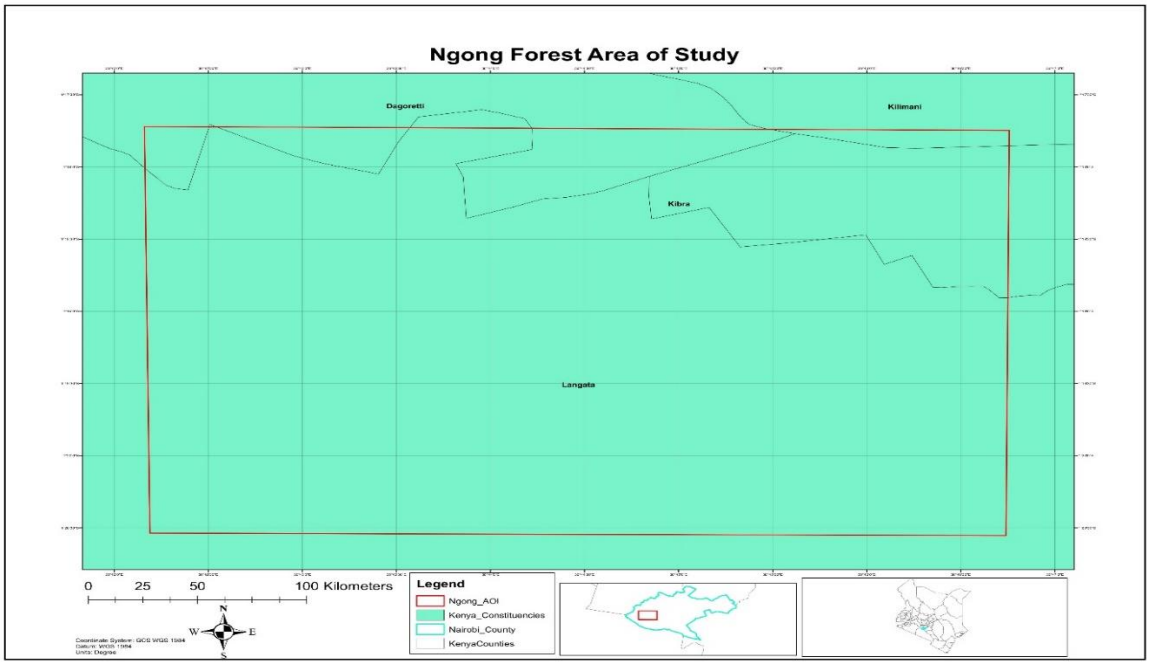


Figure 2: Ngong Road Forest Map

Source: Author

3.2.3 Climate

The area has tropical climate with two rainy seasons, receiving high amount of rainfall on March-April and short rainfall on November-December. The area is dry and cold on July-August while on January-February is hot and dry with a mean relative humidity between 36% and 55% (CBS, 2003).

3.2.4 Urbanization

Nairobi once called ‘’Green City in the sun’’ due to its landscape that has indigenous forests, riverine ecosystem and wetlands, with abundant wildlife. The rapid growth of the city has degraded the forest and loss of other greenspaces. UNEP (2017) reported that demand for food by the rapid growing population of the city resulted transformation of peri urban areas to other agricultural uses, which led transformed to built-up areas.

3.3 Research Design

This study used descriptive research design which is concerned with determining the frequency of occurrence or the relationship between variables (Bryman and Bell, 2011). This approach is, therefore, suitable for this specific study, for it endeavors to collect comprehensive information through household survey. Bryman and Bell (2011) confirm that this approach seeks to get information that describes a phenomenon by asking questions relating to individual perception and attitudes.

3.4 Target Population and sample frame

Sekaran and Bougie (2010) explain that a population is the total collection of elements about which we wish to make inferences. The target population for this study is individuals who are residents who live within the administrative boundaries where the forest lies. The general population of Nairobi County is 4,397,073 (KNBS 2019). The administrative boundaries where Ngong Road Forest lies are in Langata, Dagoreti South and Kibra sub-counties with a population of 197,489, 434,208 and 185,777 respectively (KNBS 2019). The number of households in Dagoreti, Langata and Kibra are 155,089, 62,239 and 61,690 respectively (KNBS 2019). Thus, the target population is 650, 274 with 279,018 number of households. The sample frame was drawn from the sum of the number of households of all the sublocations within the administrative wards that lies within 5km radius around the forest. These villages were focused purposely to understand the communities’ interaction with the forest, their access

to forest products and how they contribute to forest cover dynamics. Ngando, Muituni and Muteego sublocations under Dagoreti constituency with a population of 47,019 with 23,998 households (KNBS 2019). The Sarangombe sublocation under Kibra with a population of 55,303 with 16,860 households and lastly Karen and Bomas under Langata constituency with a population of 36,723 with 11,758 households (KNBS 2019). Thus, the sampling frame was 52, 616 households.

3.5 Sample Size

The sample size is a subset of the population that is taken to be representatives of the entire population (Kumar, 2011). To get a representative sample size, the study used The Cochran formula which allows to calculate an ideal sample size from a larger population, with a given precision and confidence level and estimated proportion of the attribute in population.

The Cochran formula is:

$$n_0 = \frac{Z^2 pq}{e^2}$$

Where:

n0 is the desired sample size (for a larger population)

e is the desired level of precision i.e the margin of error.

p is the estimated proportion of the population which has the attribute in question

q is 1-p

Thus, with a margin of error of plus-minus 5, hence p will be 0.5 and A 95 % confidence level gives us Z values of 1.96, per the normal tables, thus we get;

$((1.96)^2 (0.5) (0.5)) / (0.05)^2 = 385.$

Therefore, the study adopted 385 as a sample size (as shown in table 1). However, due to some households being restrictive as a result of COVID 19 pandemics they were not accessible. Only 219 respondents were reached through both physical and remote means across the sample frame.

Table 1: Distribution of the samples selected across the sampling frame.

Constituency	**Sub-location**	**No. of households**	**Proportions (%)**	**No. of samples**
Kibra	Sarangombe	16,860	32	123
Dagoreti	Ngando	18,784	35.7	138
	Muituni	2815	5.4	21
	Muteego	2399	4.5	17
Langata	Bomas	8524	16.2	62
	Karen	3234	6.2	24
Total		***52,616***	***100***	***385***

3.6 Data Collection Methodology

3.6.1 Steps taken to establish temporal pattern of forest cover dynamics of 1988-2019

The study used are Arc GIS 10.7 and ENVI 5.3 to carry out change detection (as shown in figure 3), as indicated in the following steps;

a) Identification and selection of Ngong Forest, as an Area of interest (AOI)

i. KMZ file was used and uploaded to earth explorer to search for the images, since area of interest was already defined.

ii. Landsat images for the area of interest was downloaded using the earth explorer platform, for the year 1988, 1999 (Landsat 7), 2009 (Landsat 5) and 2019 (Landsat 8).

b) Pre-processing

i. This procedure involves layer stacking and application of corrections and clipping of the Ngong road forest area of interest. Layer stacking include choosing the right band combination to use for land use land cover change, based on specific band properties,

thus in this study false color images of band combination was used. Notably, Landsat images has band 1 to 5 and band 7 are layer stacked this is because they have the same spatial resolution of 30 meters. While 6 and band 8 have 60 meter and 15meters resolution respectively.

ii. For visualization in GIS platform, band 6, 4 and 2 was used as the combination.

iii. Preprocessing was done using the Impact toolbox. The impact tool is very useful for atmospheric and geometric corrections. Atmospheric corrections were done by TOA (Top of atmosphere) reflectance conversion, this is the calibration of the data collected by the sensors to alleviate effects of sun, elevation and acquisition time.

iv. Clipping of the Region/Area of interest was done using Arc GIS extraction by mask tool (Jun *et.al,* 2017).

c) Classification

Google earth engine code editor was used for classification. The following steps were followed:

i. The image was loaded into Arc GIS and using the image to create random points, these points was coded, where each number represents a class. A shapefile was created using Arc GIS and the attribute table was used to code the features with their respective numbers (as shown in table 2).

ii. After creation of all the random points for all of the above classes, the shapefile was then uploaded into google earth engine code editor.

iii. The next step was to run the classification code and input the area of interest and the shapefile with the random points.

iv. The image type (Landsat), period for the four scenes of AOI and classifier type was chosen (as shown in table 1), in this case random forest classifier was used. For the four scenes random points was generated, and classification run for each.

v. The classified image of each scene was then downloaded.

Table 2: LULC classes

Code	***Class***
1	*Forest*
2	*Grassland*
3	*Cropland*
4	*Built-up area*
5	*Wetland (water*

d) Post classification

In this process decision tree was used to make the image identifiable by ENVI Software. A decision tree was created and run for the four scenes of the AOI. Post classification in ENVI provides for change detection and Statistics. Alternatively, Arc GIS was used for additional comparison of post classification. The visualized images of change detection were visualized using Arc GIS, and make maps using the same software. The descriptive statistics was analyzed, using Excel and the data was displayed using graphs.

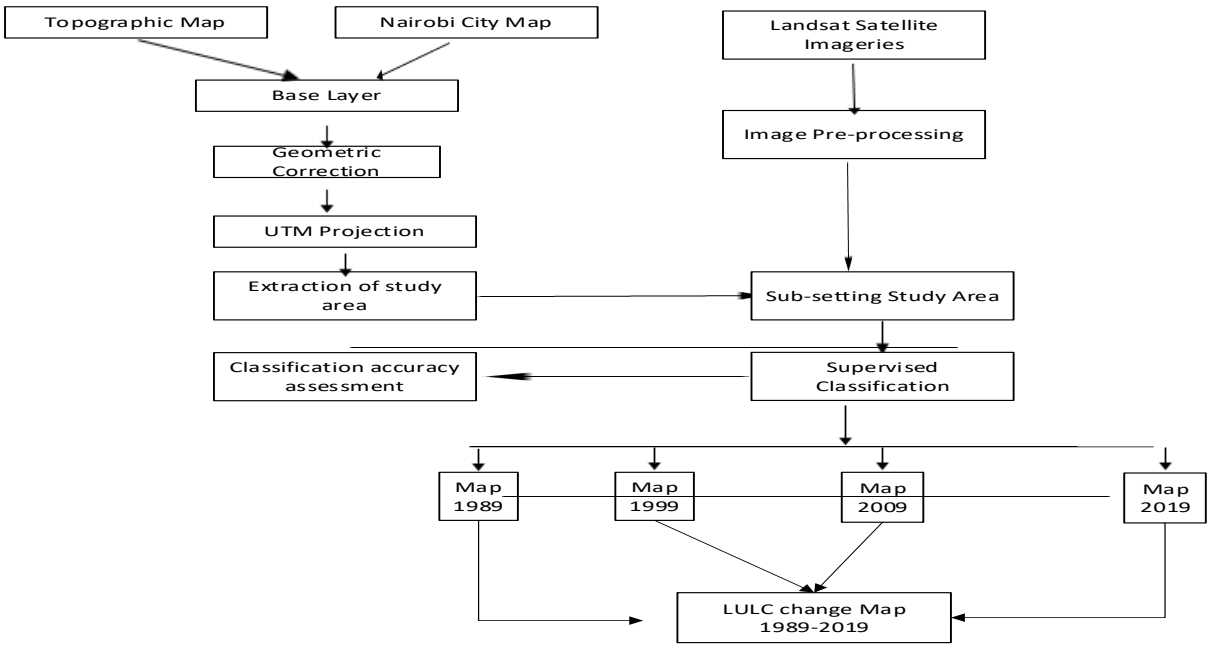


Figure 3: Chart flow for LULC Mapping

3.6.2 Steps taken to collect primary data for the study objectives

a) **Transect walk-** transact was done at villages and residential areas near and along Ngong Road Forest to observe, discuss and register the endowments and problems of the area (Mikkelsen, 2005). By using this method in the first stages of our research, it made clear and gave an insight into the areas surrounding the forest. It is furthermore a useful tool for describing and showing the location and distribution of resources, features, landscape, main land uses along a given transect (CARE, 2002).

b) **Global Position System and Online Data Collection-** Global Position System (GPS) is a global navigation satellite system that provides geo-location and time information to a GPS receiver anywhere on the Earth (Hoffman-Wellenh of *et al.,* 2001). GPS locations of each respondent was recorded through Online Data Collect (ODK) platform. The study used GPS to map the households in the villages while administering the questionnaire.

c) **Semi structured questionnaire-**A structured household questionnaire was developed to gather information from respondents using questionnaire identified (as shown in appendices 2) in regards to the study. Some of the response of the questionnaire was ranked using Likert scale which is a response scale that is used in questionnaires to obtain participants preferences or degree of agreement with statements or set of statements. Respondents are asked to indicate their level of agreement with a given statement by way of an ordinal scale (Bertram D, 2014)

d) The total respondents interviewed were 219, through systemic randomly sampling of the households around the forest. The questionnaire was coded in excel format (as shown in appendices 1), that can be accepted by the online data kit (ODK), through ONA platform personal account (See section 3.5.3). The feedback from the respondents were then captured using a smart phone, thus minimizing the use of printed papers. The interviews were conducted by maintaining social distancing and wearing facemasks thus the measures

set by the ministry of health, to avoid any risk of contracting COVID 19, were compiled during the entire period of the field work.

After the data was captured from the field using the ODK app, the forms for each respondent were reviewed and sent to the ONA platform for each specific day the interview was conducted, for analysis.

e) **Participant Observation-** this enables the researcher be present and carefully observe practices, activities, relationships or interactions that occur in the everyday life of their research subjects (Brockington and Sullivan, 2003). Detailed notes were taken in relation to the observations made, either on the spot, or in the evening of the same day. Summarized reports were written about the general view and the observations made in every day. Photos of objects or scenes related to the study was taken. The general observations focused on the nature of the infrastructural and settlement expansion, forest deforestation and degradation. It also focused on the socio-economic conditions of the respondent especially the communities living around the forest. Specific practices in relation to the use of firewood, timber and other forest resources was focused during interviews.

f) **Focused Group Discussion-**Focus Group Discussions (FGD) was used to explore the condition of the forest and its importance, the extent of urban growth and its implications to the forest cover. It was used to reveal the residents' perspective of past and present conditions of the air quality and the link between the forest and air quality. Gender, age and period of residence was used as key selection criteria of the participants in random manner. However, due to restrictions in regards to having an assemblage of people and residents' concerns as a result of COVID 19, only one group of 7 respondents were willing and later selected to participate in the discussion. SWOT analysis and Venn diagram was used during the FGD; this enabled the researcher to deeply investigate the residents' perspective on the impact of urban growth on forest cover and its implication on air quality both past and

present. The seating arrangement of the group compiled with the social distancing rule, of 1.5 meters.

3.5.2 Remote Data collection and quality assurance

3.5.2.1 Use of ODK Collect

Online Data Kit (ODK) Collect app was used to collect the primary data using a mobile phone. The following steps was followed;

a) The ODK collect app was first downloaded from google play store and installed in the mobile.

b) ONA account was created, with username and password, using the *https://ona.io/join*

c) Using ONA form builder, all the questions in household survey was added, skip pattern was considered as well those questions with either single or multiple options. The form was named as *HH survey*.

d) After created the form, the form was reviewed, to ensure no errors exist in all the questions.

e) Then the ODK collect app with ONA account, to access the form using the url; https://odk.ona.io using below procedure;

Open the app → click general settings → change server to https://odk.ona.io

f) Under the general settings, ONA username and password was entered.

g) On the main menu, ***Get Blank form*** was clicked. The form was then download into the app.

h) To access and administer the tool, ***fill blank*** form was clicked.

i) Lastly, every time an interview is finalized. Internet connectivity was confirmed then, the form was sent to the server using below steps;

Open the app → send finalized form → select the form send

3.5.2.2 Data quality assurance

The At the end of each day, quantitative data was reviewed and checked for accuracy and consistency before it was sent to the server, it was reviewed to ensure. The raw primary from the household survey, was retrieved from ONA server in excel format for analysis.

3.7 Data Analysis

3.7.1 Qualitative Data Analysis

Qualitative data from key informant interviews and FGD was analyzed thematically based on the objectives of the study. The qualitative data was also presented in prose**.**

3.7.2 Quantitative Data Analysis

3.7.2.1 LULC change analysis

For objective one, ArcGIS Structured Query Language (SQL) code was used to run LULC statistics. The data was downloaded as an excel format for analysis.

a) Attribute table was opened,
b) Two fields, LULC_1988 and LULC_1999 was added,
c) Select by attribute was chosen
d) In the select by attribute dialog box, value was selected and then "*Get unique values'* was clicked. Note; each value [1,3,4,5 & 6) has specific class assigned to.
e) To assign the Land use type to their respective value, the value is doubled clicked. For instance; *Select from>[Value]=1. Then click, apply.*
f) Attribute table was clicked again, then LULC_1988 was double clicked.
g) Field calculator was selected, then "Forest" was inserted.
h) Step a- to-e was repeated for other values (3,4,5 & 6)
i) Step f to g was repeated for LULC_1999
j) Another field was added, "Change_area_1988_1999

k) Above field was right clicked, the statement, [value]*30*30/1000 was selected.

Note; the value 30 denotes pixel value & the division of 1000 is to make into hectares.

l) Another field was added, for changes, then right clicked

m) Field calculator was added & following statement issued; [LULC_1988] "to" [LULC_1999]

n) For non-change areas, this command *"No Change in" + [LULC_1999]* was issued.

o) The entire above steps were repeated for scenes 1999, 2009 and 2019.

p) Then the statistics for changes between LULC 1988-1999, 1999-2009, 2009-2019 and lastly for 1988-2019 was generated and downloaded in an excel format.

The excel data was later used to generate graphs and charts, to show the changes in land use and land cover for different classes or land use type as well the trend of deforestation. T-test was conducted using excel, to know the significance of the changes.

3.6.2.2 Descriptive and inferential analysis of the primary data

The primary data collected retrieved from ONA account in excel format was cleaned and exported into Statistical Package for the Social Sciences (SPSS) version 22.0 for analysis. Descriptive statistics, with frequencies and percentages, was used for analysis. For inferential analysis, Pearson's Chi-square test at 95% Confidence Intervals (CI) was conducted to test for associations, for the categorical data, using cross tabulation. Results was later presented in tables, graphs, and charts. Further verification and cleaning were done to check for missing values and outliers, misplaced skip logics and coding.

CHAPTER FOUR: RESULT AND DISCUSSION

4.1 Temporal pattern of Ngong Road Forest cover dynamics between 1988 and 2019

4.1.1 LULC dynamics of 1988-1999

Nairobi's urban growth have significantly impacted the forest morphology, with expansion of infrastructural and housing development to illegal logging, that have greatly degraded the forest ecosystem. Prehistoric image of 1988 show (figure 4) that the forest was densely populated with less disturbances from anthropogenic interferences of infrastructural development such as roads and housing development within and around the forest environ compared to the forest cover in 1999(figure 5).

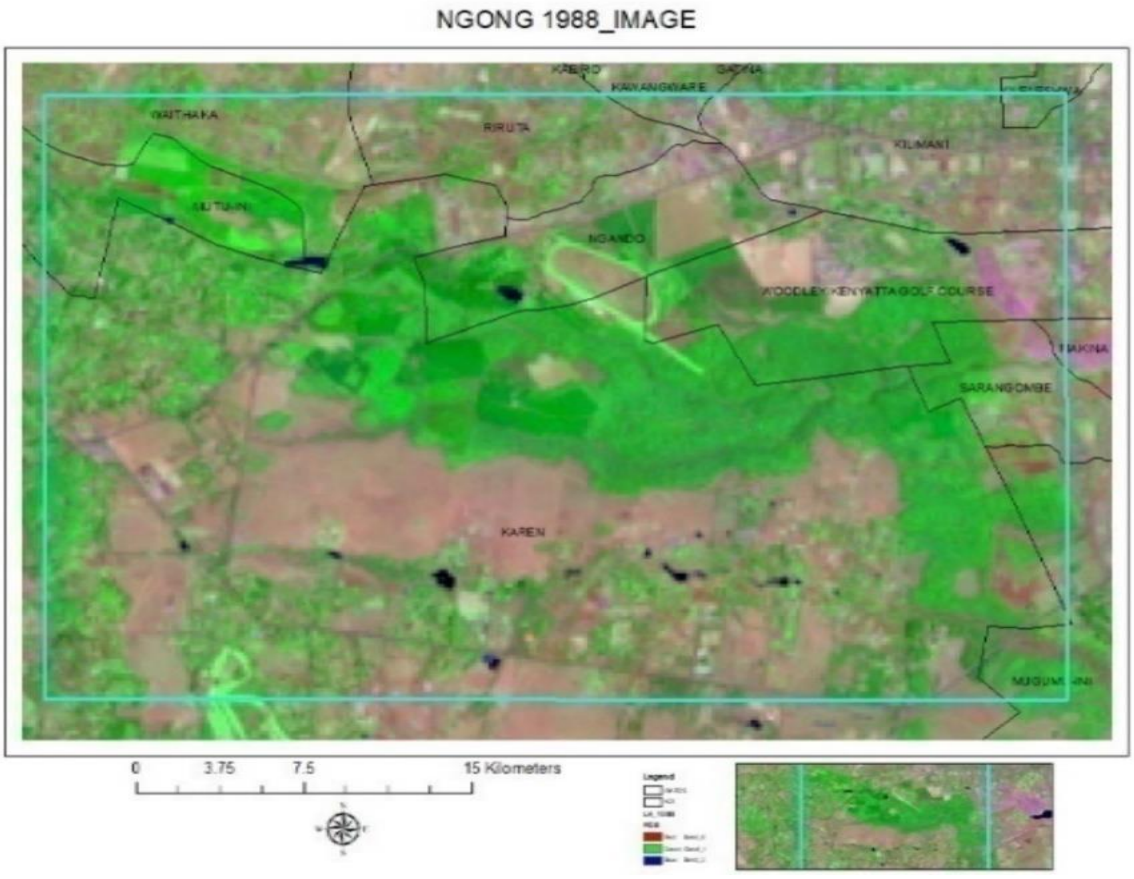


Figure 4: Ngong Road Forest Map 1988; Source: Author.

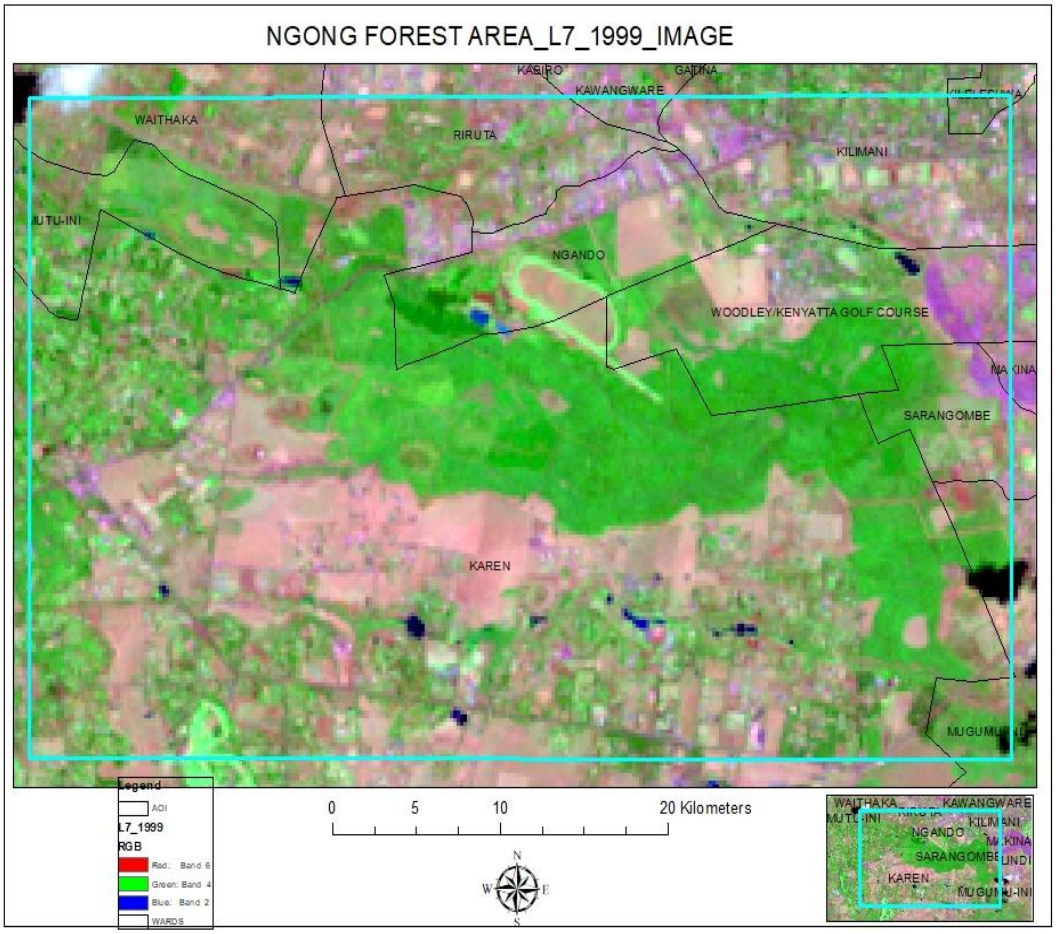


Figure 5: Ngong Road Forest Map, 1999. Source: Author.

Natural regeneration of forest or reafforestation was observed, covering positive increase of forest cover of 273 ha, where there was a change of other classes; grassland(47ha), water(0.99ha) and cropland (225 ha) to forest cover, as shown in figure 6. The forest area that are undisturbed was found to be 1443 ha.

The total deforested area for the ten-year period was 193 ha, with the highest percentage of the conversion was accounted for grassland (87%), built-up areas (8%), cropland (4%) and water

(1%). 193 ha of forest cover were converted to other land uses, largely to grasslands (167ha), followed by built up areas(14.54ha), cropland(9.18ha), and 1.8 hectares of water body (figure 6 and 7). In addition to this, 322 ha of grassland within the study area was converted to built-up areas, revealing an expansion of settlements around the forest, as the city's population grew. The population of the capital, Nairobi, has increased from 897,000 in 1980 to an estimated 1,324,570 in 1988. This increase can be attributed in large part to rural-urban migration (Central Bureau of Statistics, 1989).

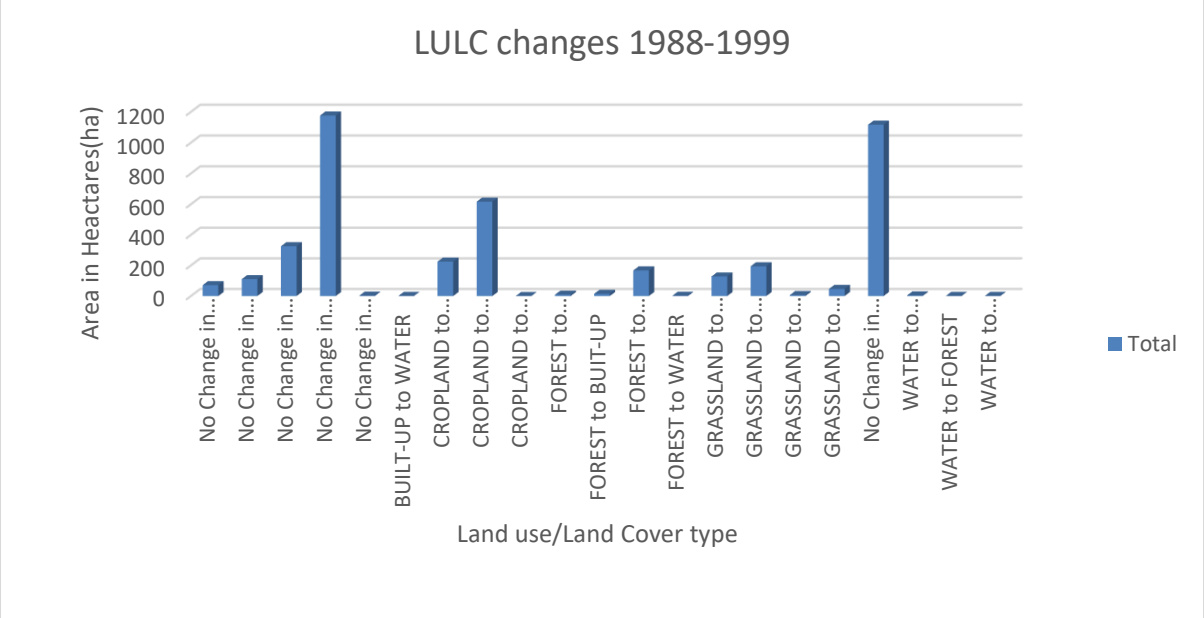


Figure 6: LULC changes, 1988-1999

Discussions with the deputy chair of the Ngong Road Forest Association revealed that the forest cover was approximately 2927 ha in 1932 when it was gazetted and it supplied the railway with timber and fuel. However, by 1978 the areas reduced after series of legal excisions. The respondent noted that approximately 150ha of forest land were degazetted and transferred to public schools, churches, hospitals and private entities. The statistical test revealed that there were no significant changes in forest cover. The p-value for was 0.2 greater than alpha (0.05). However, the LULC analysis between 1988-1999, revealed that the forest

cover was reduced from 1575ha to 1389.5 ha (table 3) According to IUCN report (1999), the government have excision forest lands to Kenya Broadcasting Commission (KBC) and transferred lands to senior cabinet ministers, business individuals and political elites. In 1997, 82 ha was excised for unspecified purposes, (with ref. gazette 6/6/96).

TABLE 3: LULC AREA_1988-1999

Class_LULC type	**Area** 1988	**Area 1999_ha**	**Change 1999**
Forest	1575.09	1389.51	-185.58
Grassland	1424.07	2134.51	710.44
Cropland	996.21	383.22	-612.99
Built-up area	300.42	403.2	102.78
Wetland	45	30.35	-14.65

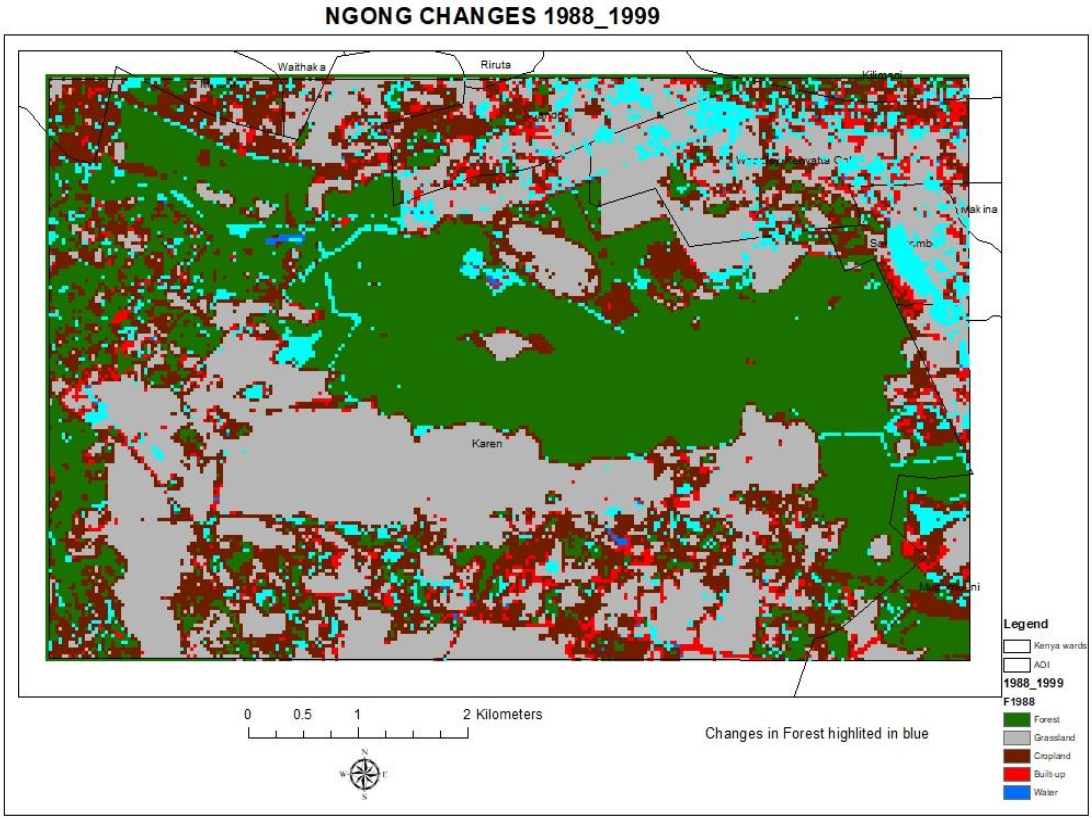


Figure 7: LULC change map, 1988-1999; Source: Author

4.1.2 LULC dynamics of 1999-2009

In the period between 1999-2009, there was significant changes in land use land cover. The forest was significantly transformed into other land uses due to deforestation that took place. A forest cover of 1493 ha was converted to other land uses, with highest conversion was accounted for grassland 76%, built-up areas 23%, cropland 0.3% and water 0.2%, (as shown in figure 8 and 9). Though efforts of reforestation were observed, where 1211 ha of grassland and 20 ha of built-up areas were reconverted back of forest cover, statistical analysis shows that there was a significant deforestation during the 1999 and 2009 period, with p-value of 0.04. Interestingly, the analysis show that there was no significant increase in built-up area & grassland, p-value, 0.17 and 0.2 but also found a negative correlation between forest and built-up area (as shown in table 5).

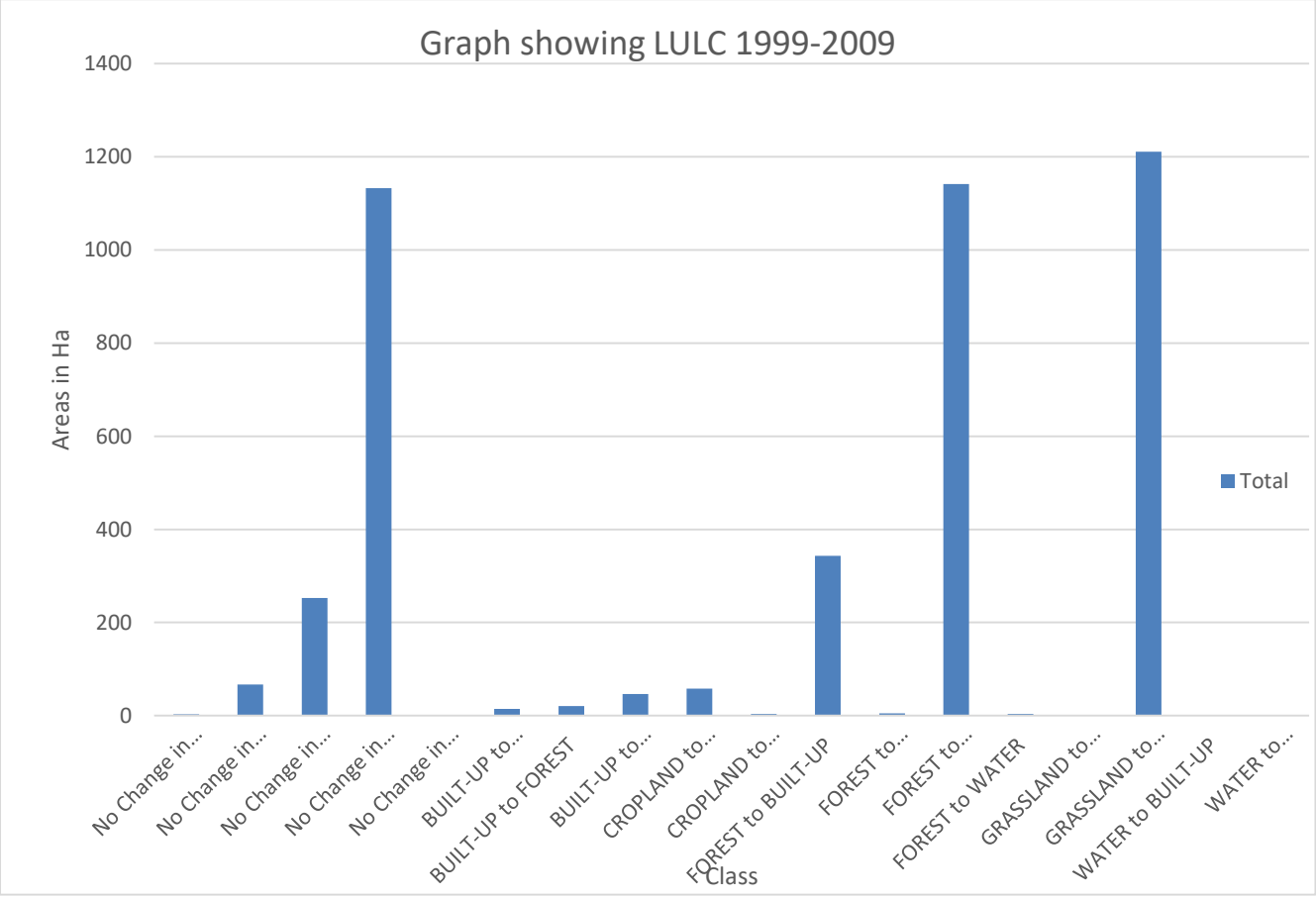


Figure 8: LULC change data, 1988-1999

In the same period, a significant increase of cropland was observed. This might be due to increase the population in Nairobi. The population have increased from 2,143,254 in 1999 to 3,138,369 in 2009(CBS 1999, KNBS 2009). The statistical analysis conducted shows that there was a strong negative correlation between forest cover and built-up areas, with correlation co-efficient(r) of -0.693 (R^2 of 0.480). On the other side, increased built-up areas also had a subsequent negative impact on grassland, cropland and wetland, with correlation co-efficient(r) of -0.414, 0.763 and -0.85 respectively. (See table 4). This shows that increased settlement expansion and infrastructural development due to urbanization had led to decline in forest cover on the forest cover.

Table 4: Correlation result, 1999-2009

	Forest	Grassland	Cropland	Wetland	Built-up area
Forest	1	-0.369	0.995	0.966	-0.693
Grassland	-0.369	1	-0.273	-0.116	-0.414
Cropland	0.995	-0.273	1	0.987	-0.763
Wetland	0.966	-0.116	0.987	1	-0.856
Built-up Area	-0.693	-0.414	-0.763	-0.856	1

The regeneration of forest cover might be a natural phenomenon or might be attributed conservation efforts that was promoted through the promotion of community participatory approach that was introduced through forest 2005 forest Act. Despite this effort, 23% of the forest land has been converted, showing that urbanization have much pressure and causing the

forested areas to shrink in size as observed (as shown in figure 9, 10 and 11). The forest cover in 2009 was 1353ha, a loss of 37 ha (as shown in table 6).

49.8% of the respondents believe that 2000-2009 period was the period that forest cover loss was observed, attributing this to the infrastructural development that they observed (as shown in figure 9). One of the residents in Muteego village, in Dagoreti South noted, *"when I come here in Nairobi more than 30 years ago, there was no houses in this area and all over this place was forested"*

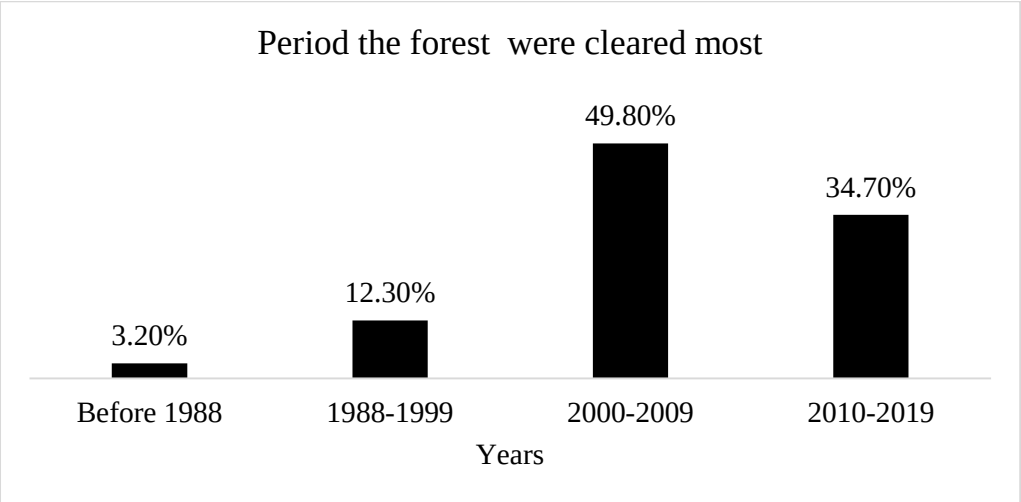
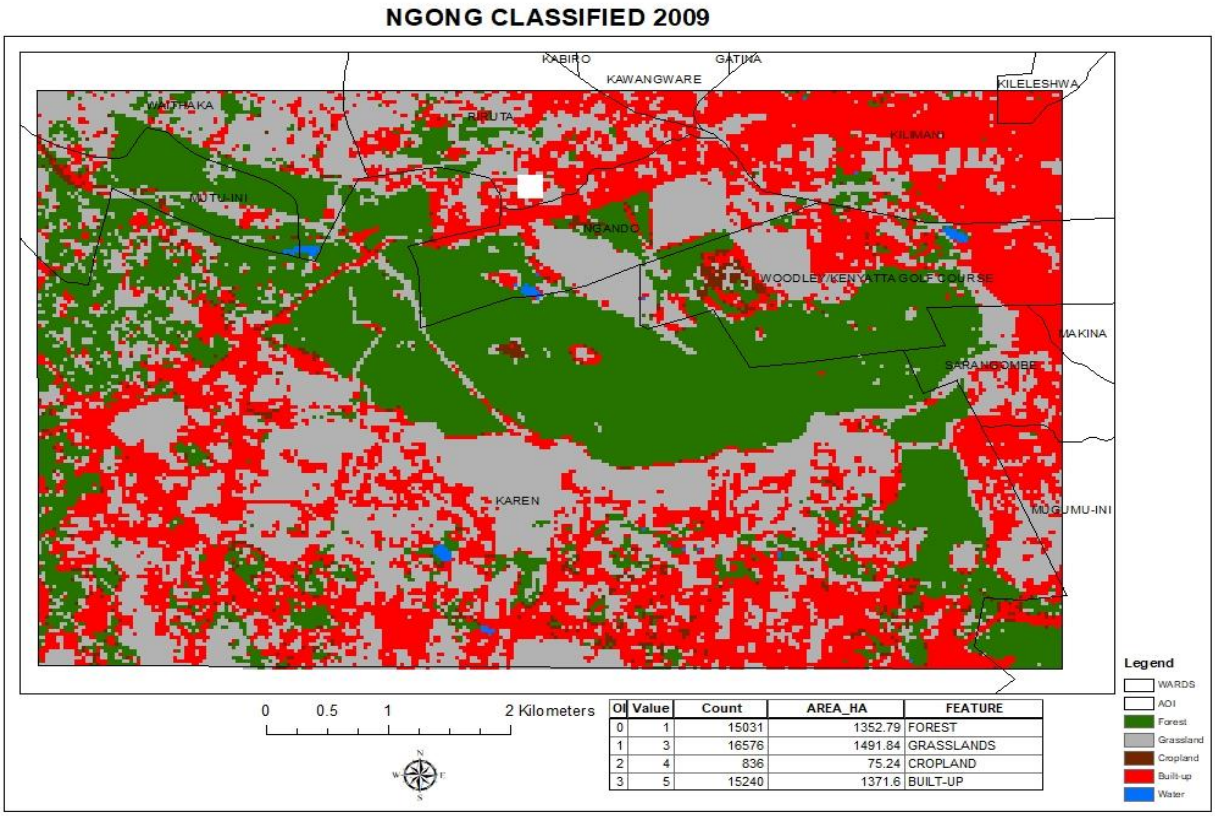


Figure 9: Perception of respondents about the period the forest was cleared mostly.

Table 5: Table 6: LULC area, 1999-2009

Class_LULC type	**Area 1999_ha**	**Area 2009**	**Change 2009**
Forest	1389.51	1352.79	-36.72
Grassland	2134.51	1431.86	-702.65
Cropland	383.22	164.25	-218.97
Built-up area	403.2	1371.6	968.4
Water	30.35	20.29	-10.06



OI	Value	Count	AREA_HA	FEATURE
0	1	15031	1352.79	FOREST
1	3	16576	1491.84	GRASSLANDS
2	4	836	75.24	CROPLAND
3	5	15240	1371.6	BUILT-UP

Figure 10: LULC change map, 2009. Source: Author

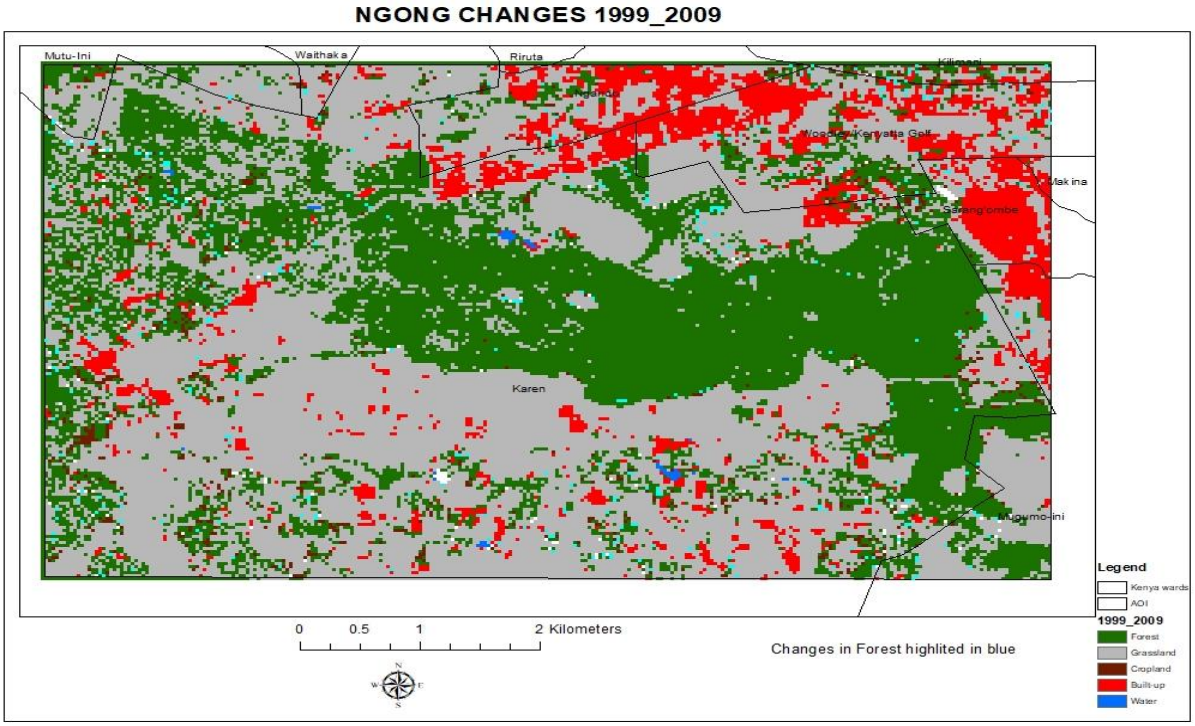


Figure 11: LULC change map, 1999-2009. Source; Author

4.1.3 LULC dynamics of 2009-2019

The LULC change analyses shows that there were no changes observed in 2711 hectares (63%) of land within and surrounding the forest area. However, 338 hectares (7.8%) of areas with tree cover was changed to other land uses, the highest, 214 hectares, accounting for built up areas, followed by cropland and grassland with 105 and 19 hectares respectively. In addition to this, 20% of grassland cover was converted to built-up area, showing that their infrastructural expansion or development is still felt despite strict management of the forest by local communities and Kenya Forest Services. A positive conversion of other land use type to forest or grassland was noted include, 190 ha of built-up area was converted to cropland, forest and grassland with 0.7%,1.4% and 2.4% respectively. Another 14 ha (0.3%) of cropland was converted to forest, showing an efforts of forest land recovery. In addition to this, 38.4 hectares of grassland was converted to cropland as well 2 hectares of cropland was also converted to grassland, this shows that there were agricultural activities that was carried around the forest, where there is an interconversion of grassland to cropland being noted (as shown in figure 12,13 and 14). Generally, there was an increase of 978 ha of built-up areas in the expense of a loss of 179 ha of forest cover and 807 ha grassland cover (as shown in table 7).

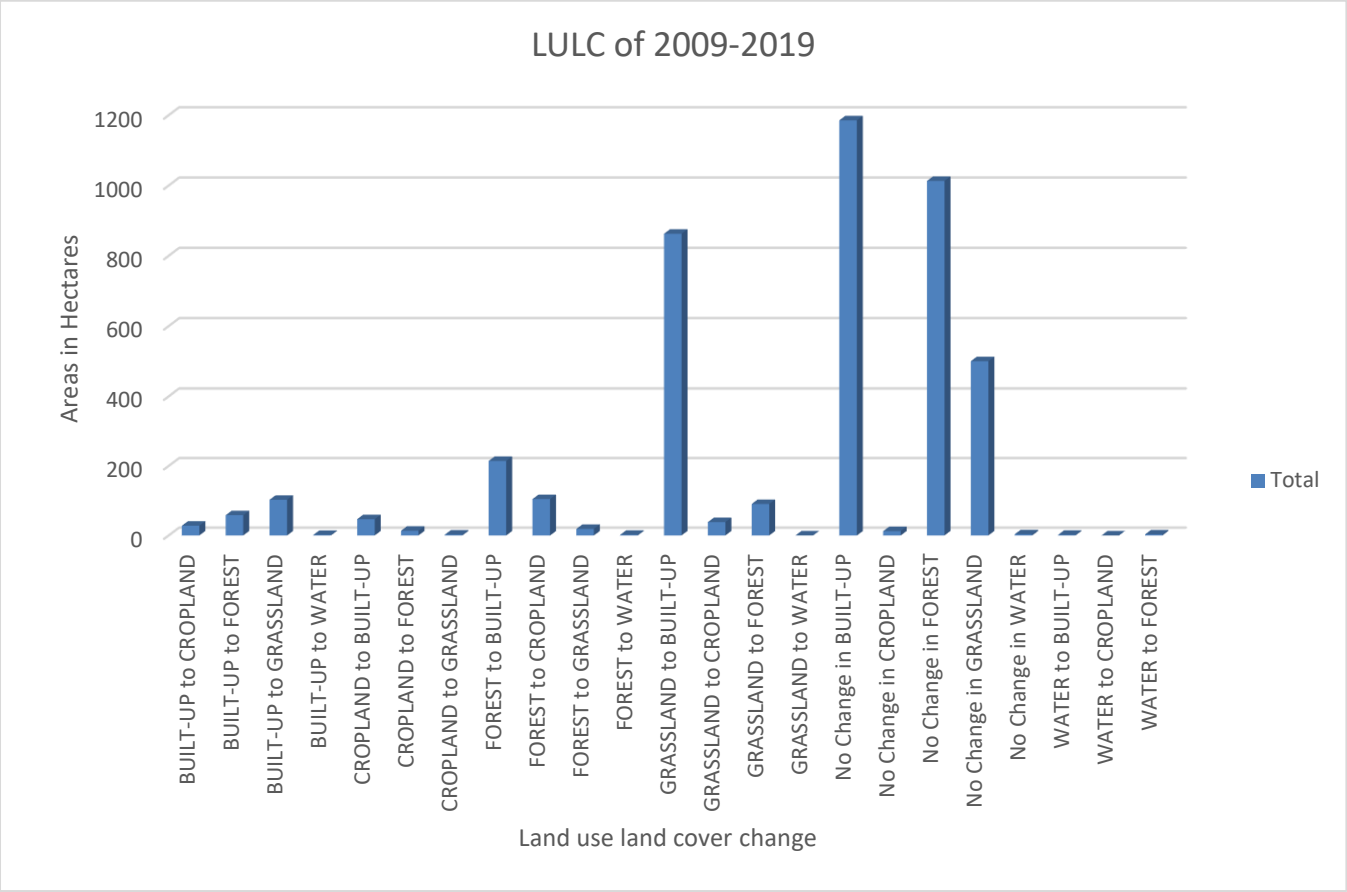


Figure 12: Graph showing LULC change data, 2009-2019

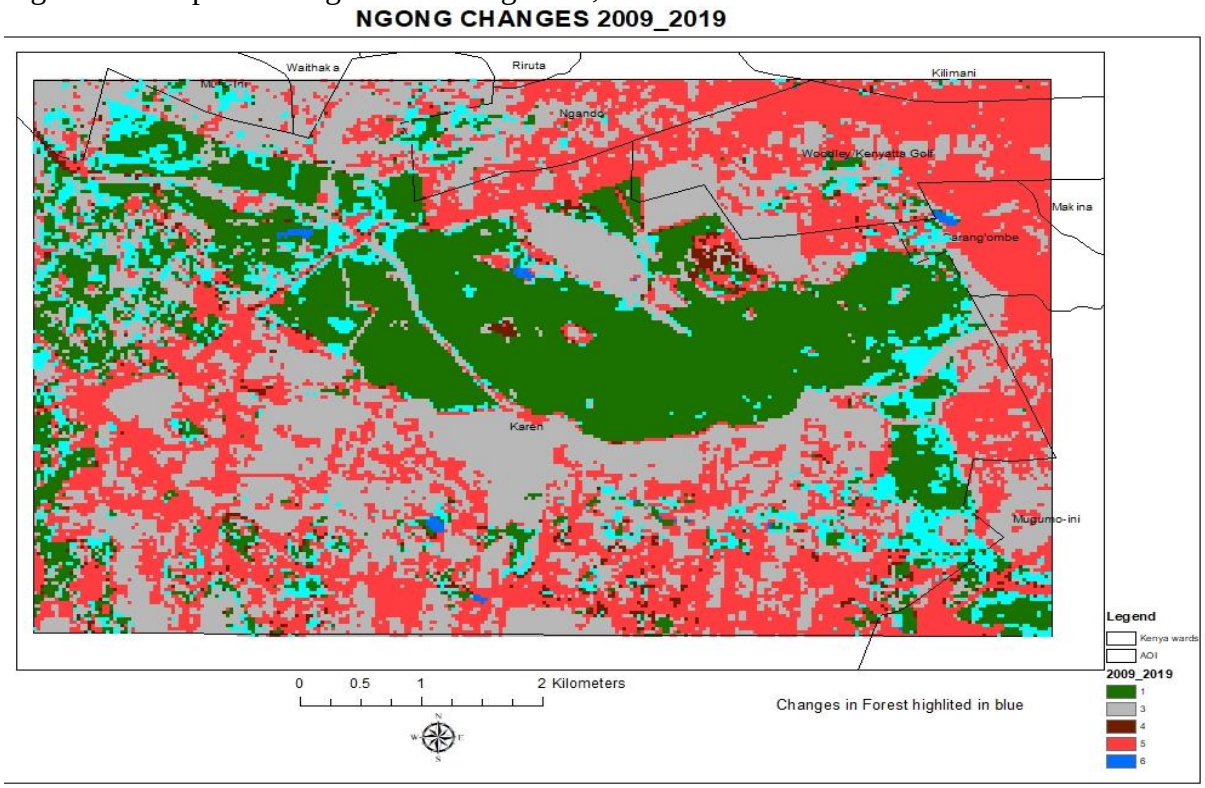


Figure 13: LULC change map, 2009-2019. Source; Author.

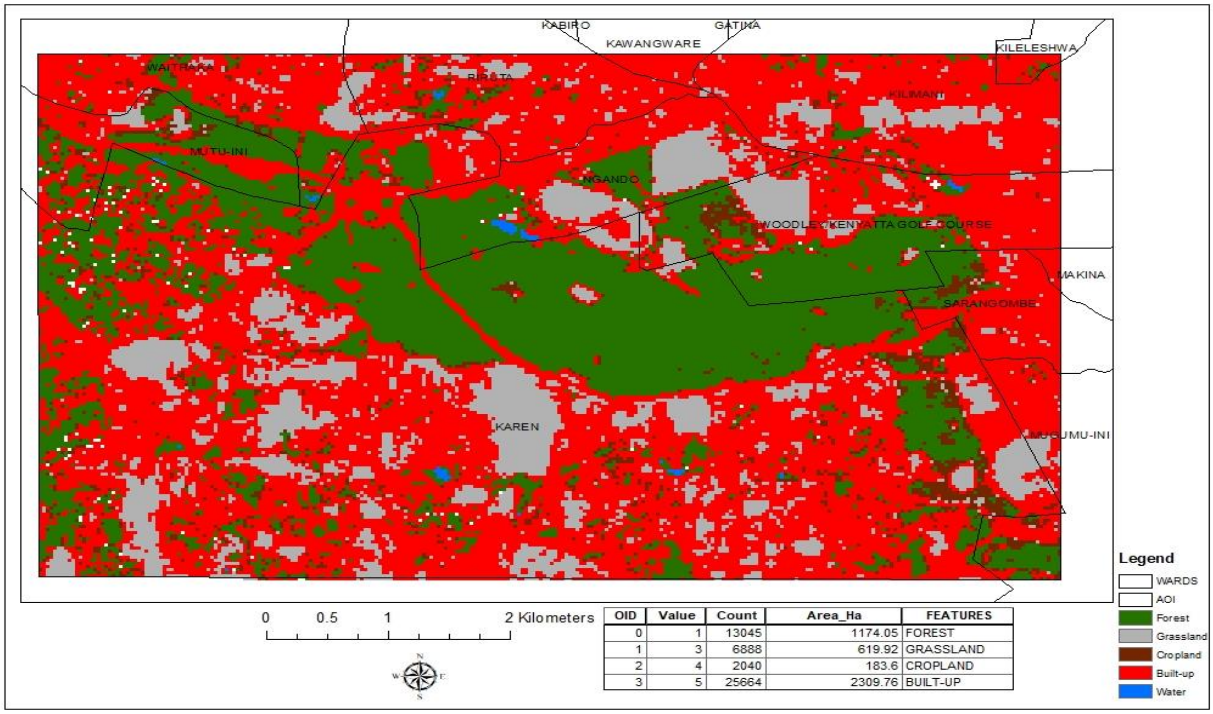


Figure 14: LULC change map 2019. Source: Author.

Table 6: LULC area change, 2009-2019

Code Class	Area 2009	Area 2019	Change 2019
Forest	1352.79	1174.05	-178.74
Grassland	1431.86	624.74	-807.12
Cropland	164.25	183.6	19.35
Built-up area	1371.6	2349.76	978.16
Wetland (water bodies)	20.29	8.64	-11.65

4.1.4 LULC dynamics 1988-2019

There was a significant clearance of forest cover, for the entire period between 1988 to 2019. Urbanization had a major significant impact on the forest cover, as demand for land for housing and expansion of infrastructures such as roads and social amenities have increased, to accommodate the increasing population in Nairobi city. Generally, 579 ha of forest land was converted to built-up, cropland, grassland and water, that account for 427ha, 106ha, 41ha and 5 ha respectively. However, 11% of the deforested land was reforested during the period, where

highest land use type reforested was cropland which accounted for 72% and followed by grassland (22%), built up areas accounted for 5% and wetland for 1% (as shown in figure 15 and 16). The forest cover in 1988 was 1575 ha and it was reduced to 1174 ha by the year 2019 (as shown in table 8). However, there was a positive transition of 177 ha other land uses to forest. 128 ha cropland was converted to forest, while grassland, built up area and water, accounted for 38 ha, 9 ha and 2 ha respectively. The result of the t-test indicated there was enough statistical evidence to show that there were significant changes that have occurred in LULC during the entire period, in that forest cover, grassland and cropland have been converted to built-up area (as shown in table 8). The forest cover was significantly cleared in the expenses of expanding infrastructural and housing development. The analysis found that there is a strong negative correlation between forest cover and built-up area with an increasing negative trend in the forest cover as year goes. These is due to demand for more space for infrastructural and housing development. Illegal forest excisions that happened in late 90's and early 2000 also contributed to forest cover loss. The road networks within the city expanded, for instance the southern by-pass splits the forest into four sections, further exposing the forest to more disturbance. The forest became more fragile. By the year 2030, if the protection and conservation of forest has not improved between and without introduction and robust enforcement of the existing policies, the forest cover may reduce as low as 600 ha (as shown in figure 16).

Table **7**: LULC change area, 1988-2019

Code Class	**Area 1988**	**Area 1999_ha**	**Change 1999**	**Area 2009**	**Change 2009**	**Area 2019**	**Change 2019**
Forest	1575.09	1389.51	-185.58	1352.79	-36.72	1174.05	-178.74
Grassland	1424.07	2134.51	710.44	1431.86	-702.65	624.74	-807.12
Cropland	996.21	383.22	-612.99	164.25	-218.97	183.6	19.35
Built-up area	300.42	403.2	102.78	1371.6	968.4	2349.76	978.16
Water	45	30.35	-14.65	20.29	-10.06	8.64	-11.65

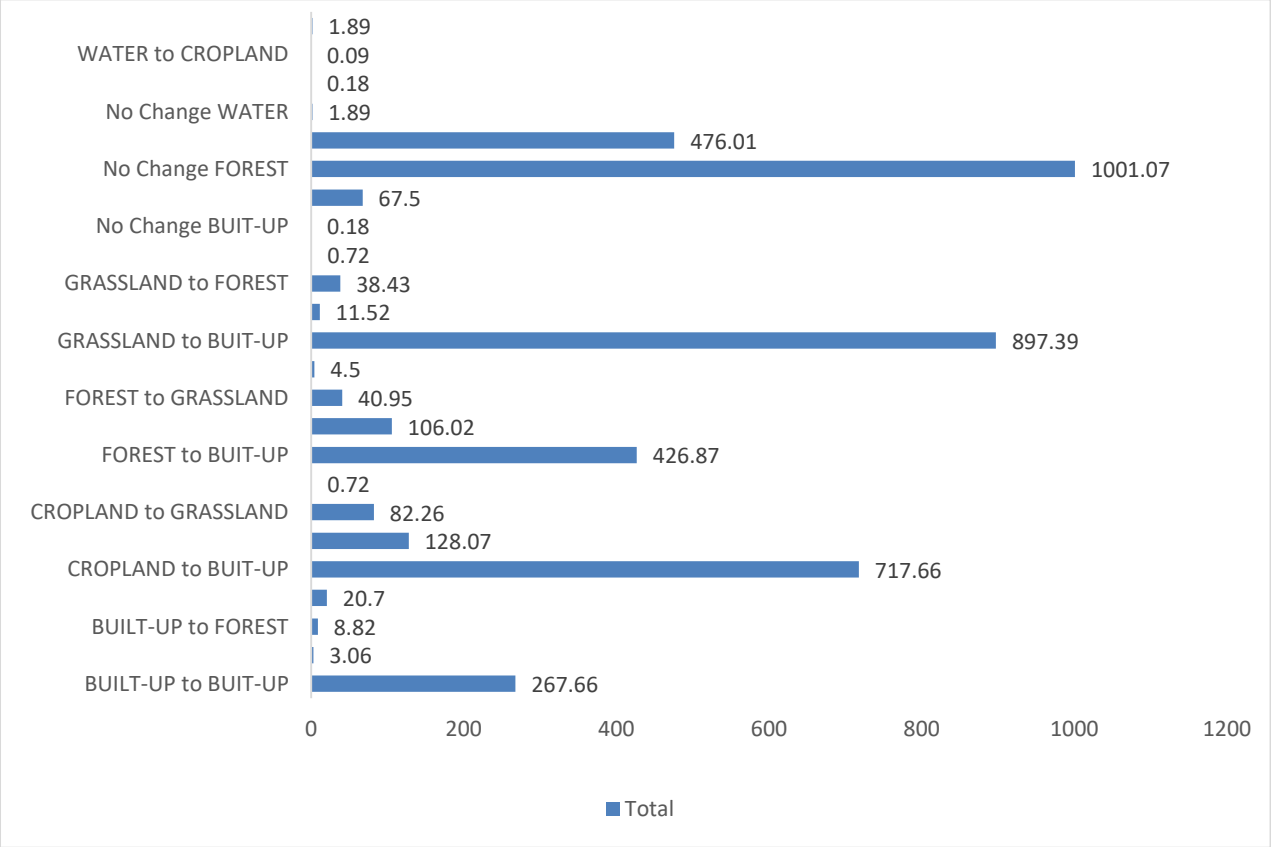


Figure 15: LULC change data, 1988-2019

The statistical analysis shows that there is strong negative correlation between the expansion of the city and forest cover, with co-efficient R value of -0.903 and R^2 value of 0.815 (as shown in table 8). During the period under study, the growth of the city has led to significant deforestation, this will potentially have consequential impact on forest ability to provide

ecosystem services. The air quality service due to the existence of the forest will diminishes as the forest will be completely destroyed if corrective measures are not taken into place.

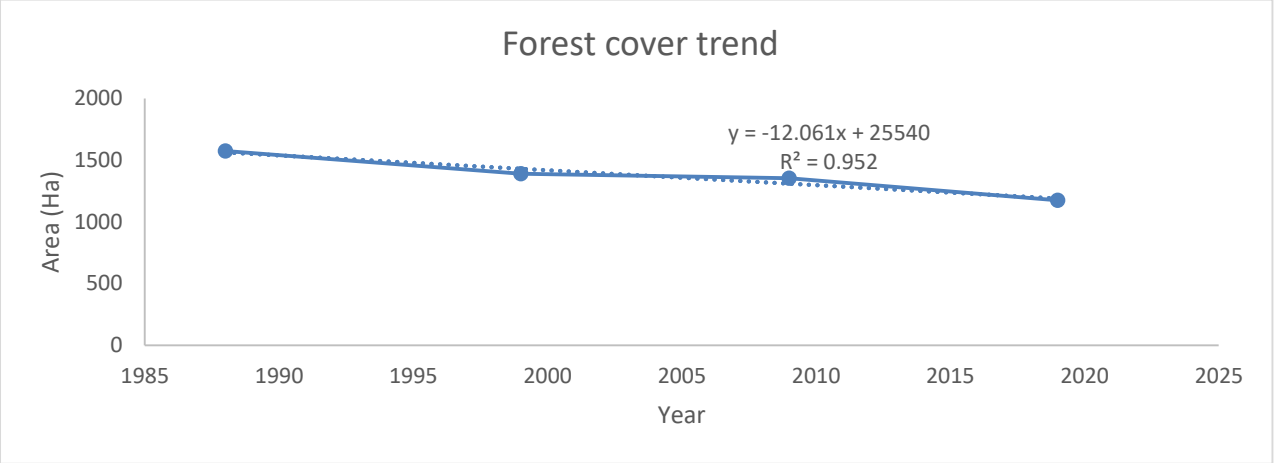


Figure 16: Ngong road forest cover trend

TABLE 8: CORRELATION CO-EFFICIENT; LULC 1988-2019

	Forest	Grassland	Cropland	Wetland	Built-up area
Forest	1	0.561	0.876	-0.376	-0.903
Grassland	0.561	1	0.225	-0.745	-0.840
Cropland	0.876	0.225	1	0.118	-0.715
Wetland	-0.376	-0.745	0.118	1	0.501
Built-up Area	-0.903	-0.840	-0.715	0.501	1

Similar findings were achieved by Mullupatu and Reddy (2013), who analyzed LULC changes in Tirupati in India Using Remote Sensing Data and GIS at an Urban Area between 1976 and 2003. Their study found that there was a significant increase in built-up area and substantial amount of agriculture land, water spread area, and dense forest area was degraded and deforested during the period of study which may be due to rapid urbanization of the study area.

In northern part of Ethiopia, the built-up area has shown a steady increase due to population growth and its need for infrastructure development (Gebiaw *et. al* 2017).

Urbanization has significant impacts on forests that not only purifies the air but also act as a watershed. Mwaura *et. al* (2016) revealed that there was a significant impact of LULC dynamics on Chyulu watershed in Makueni-Kajiado counties, Kenya. The findings showed a major increase in the built environment (96.1%) and the land cover change in the Chyulu watershed ecosystem was quite similar to other watershed ecosystems in the country and will eventually affect the role of the watershed as a critical dryland water tower. Increased built up areas also effect the weather pattern of an area. For instance, Ndolo *et. al* (2017) found out that rainfall occurrence in recent years has been above normal than previous years with extreme rainfall occurrences across four stations in Nairobi city. The study related to increasing influence of the changing density of built- up area around Moi airbase station. It was also found that built up areas also affect river channel and run off. Krhoda and Kwambuka (2015) examined the relation between growth of built-up surfaces and channel morphology at four representative sampling points along Motoine and Ngong River channel for the period 1976 and 2013. The findings indicate a steady spatial increase of the built-up surfaces by 50.9% during the period thus reduced infiltration capacity, simultaneously increasing surface runoff and stream flow and seasonal flow variability. The increased discharge caused bank erosion.

The local community believe that the main reason of forest cover change in the last 30years, was a result of illegal logging. This is according to 49.8% of majority of the respondent. However, 22.4% of them related the forest clearance to land grabbing, while 13.7% say it’s due to infrastructural development. The rest, linked this to poor forest governance (7.8%), climate change/natural disasters (4.1%), change of land tenure (1.4%) and 0.9% of the noted that its lack of pollical will (as shown in figure 17).

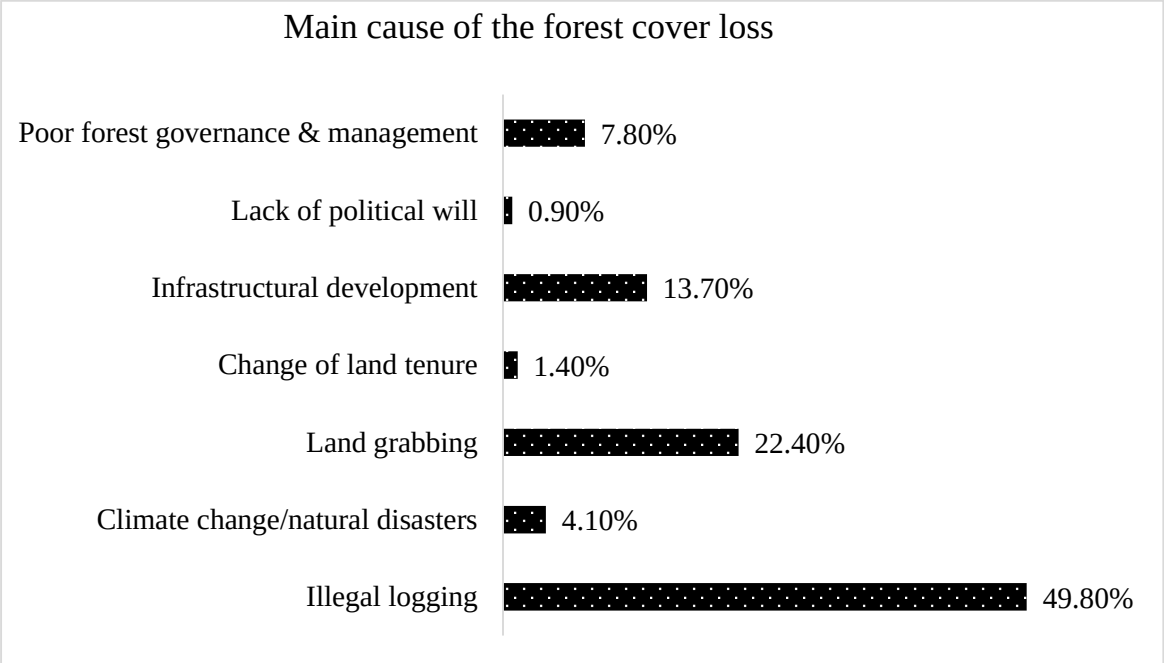


Figure 17: Causes of forest cover loss in the last 30 years

Satellite data from NASA show that there was constant trend in NDVI in the study area for December, January and February between 2000 and 2019 (as shown in figure 18).

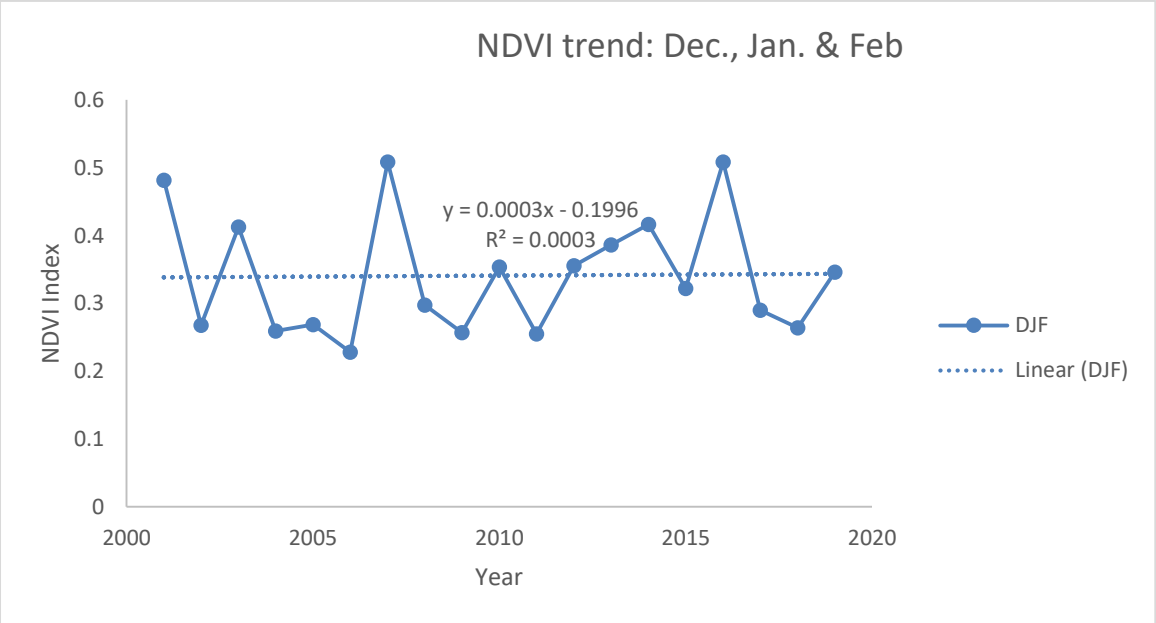


Figure 18: NDVI trend for Dec, Jan and Feb in 2000-2019

For March, April and May, increasing trend of NDVI was observed, with highest of 0.59. This typical shows the influence of urbanization due to increased pavements attributed to development in the city (as shown in figure 19).

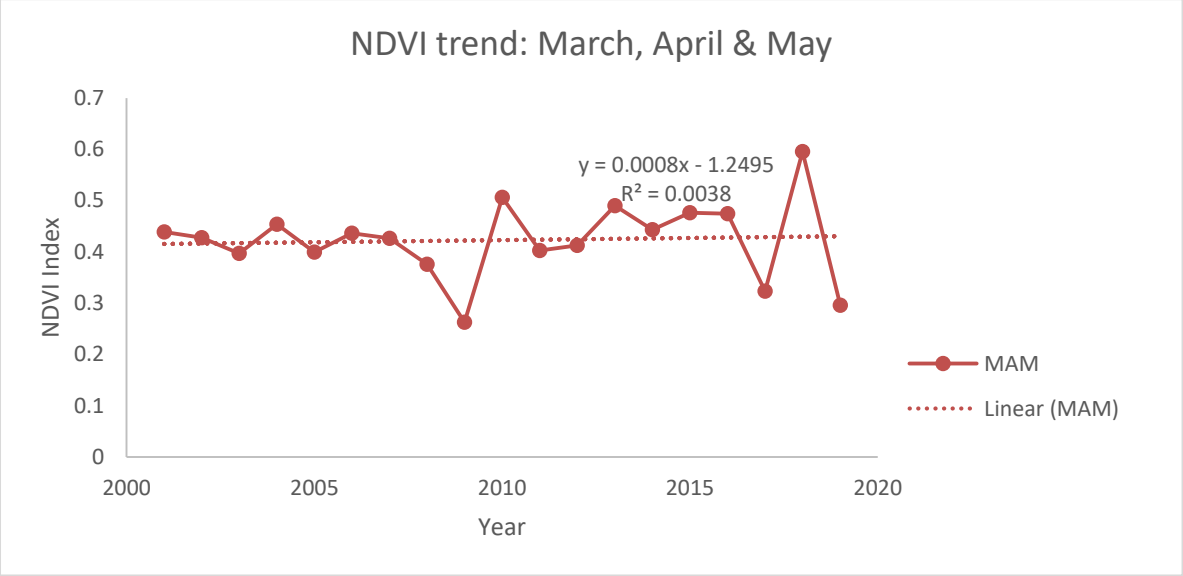


Figure 19: NDVI trend for March, April and May in 2000-2019

Within the same period, the trend was increasing with seasonal changes for JJA and SON with the highest recorded index was 0.54 and 0.38 (as shown in figure 20 and 21)

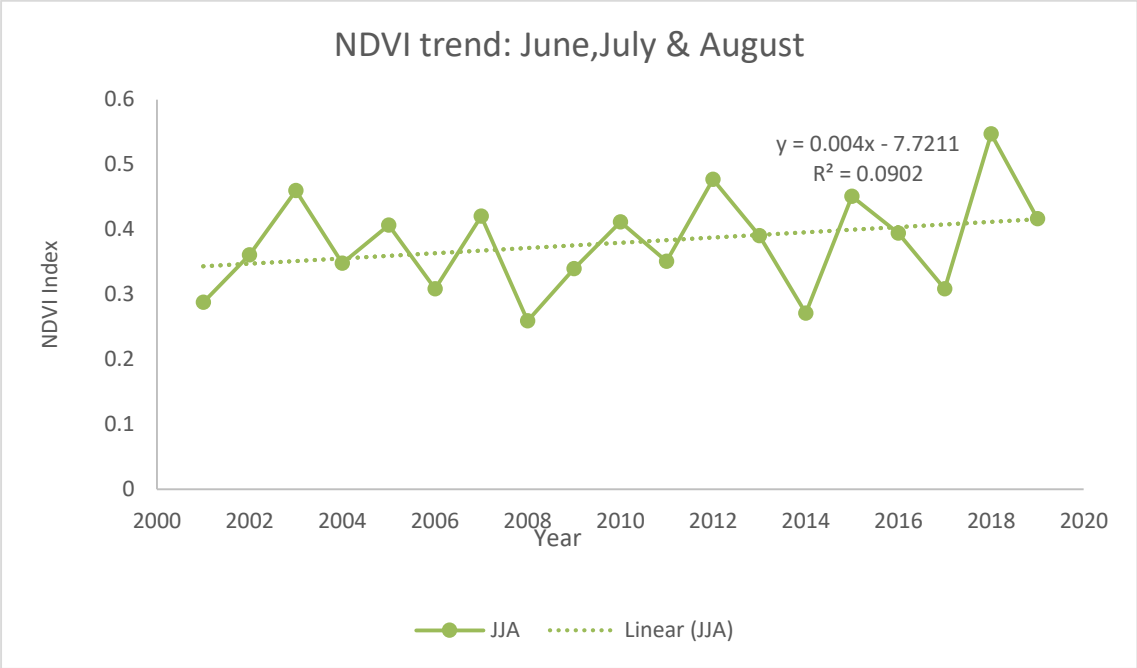


Figure 20: Figure 20: NDVI trend for June, July and August in 2000-2019

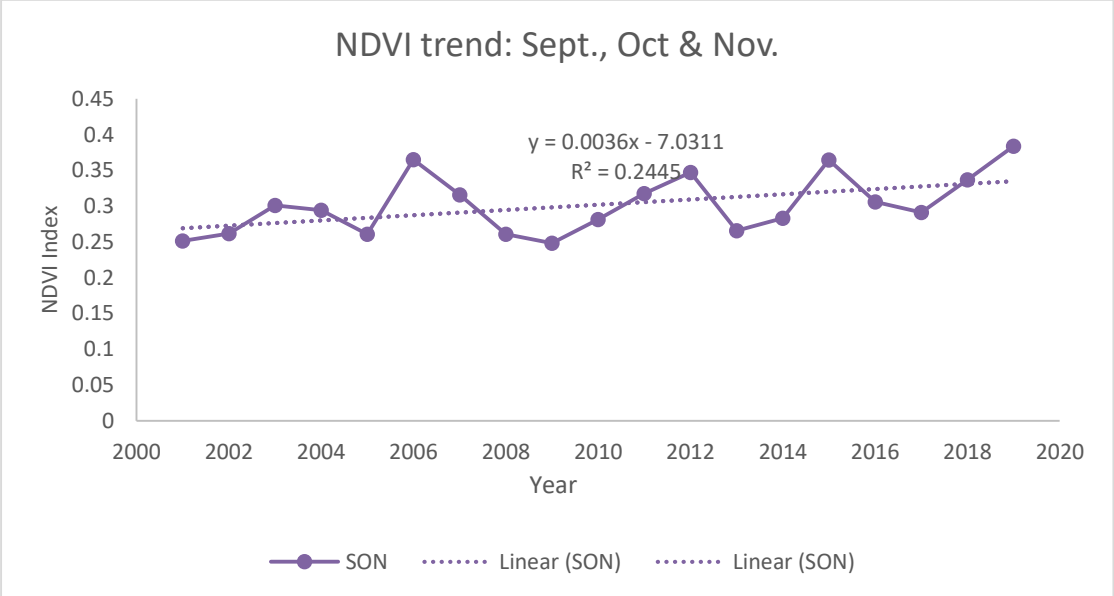


Figure 21: NDVI trend for Sept, Oct and Nov in 2000-2019

4.1 Perception and current practices of the local community about forest governance and Air Quality

4.2.1 Involvement of the local community in forest management decision making

The Forest Act 2005 of Kenya, was to envisage the establishment, development and sustainable management of the forest resources through participatory forest management where the locally community are actively engaged in the decision-making process. However, majority 61.2% of the local community indicated that they are not involved in decision making process. Few 4.6% strongly agree and 20.5% of the local community agree that they engaged in decision making related to forest management and conservation. The rest 13.7% neither agreed nor disagreed (as shown in figure 22). On contrary opinion, interview with a staff at KFS, revealed that there is an effective community engagement that resulted to reduced pressure on the forest. However, the informant noted that lack of political will and political interference derails the effective implementation of the forest act 2005 that was revised in 2015. Boiyo et al, (2019) found out that the membership Ngong Road Forest Association (NRFA) was constituted by heterogeneous membership of individual members from the community, NGOs and corporate organization and noted the key role in implementing forest conservation activities. The study however didn't report on the effectiveness of the engagement but further recommends the uniqueness of the forest and the surrounding community should to be considered during planning for forest management.

A study done by Chisika *et. al* (2020) on Gathiuru and Karima forests substantiate that FMA is a reasonably robust, multi-objective-win-win tool that promotes equity in PFM but the implementation process has been slow. Focus group discussion with the members of the community forest association revealed that they have few staffs in manning all the four forest blocks. NRFA has several user groups who together with KFS managed all the forest blocks.

According to them, they have done magnificent efforts to protect and conserve the forest, to an extent they have mobilized the local communities and contributed money to fence block 1, which is now full fenced and managed by KFS. However, they lamented that they are not given the benefits accrued through the revenues collected from the tourist who visit the forest, especially the part they fenced. Despite this, they recommend fencing the remaining three forest blocks

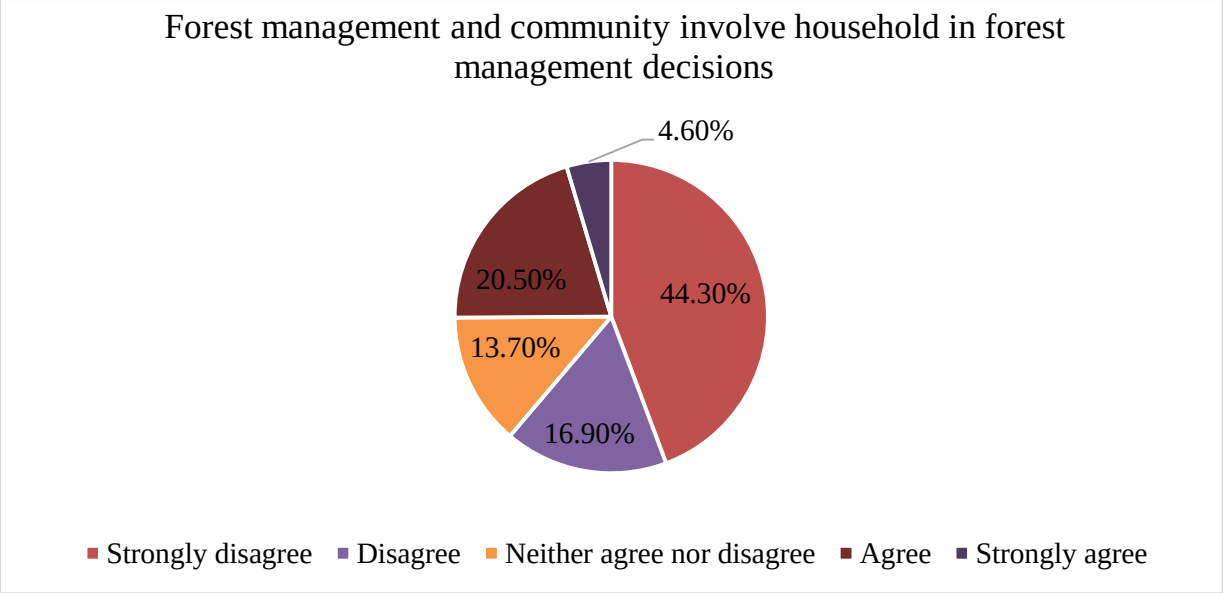


Figure 22: Community involvement in decision making process related to forest

The statistical analysis shows that there is enough evidence to conclude beyond a reasonable doubt that gender and level of involvement in decision making process related to forest management are corelated (as shown in table 11). Women felt that the forest management authorities and community associations don't effectively involve them in decision making process related to forest management and conservation, as compared to their male counterpart. Though generally, both male and female feel that they are not effectively involvement in decision making process, women tend to be feeling much of neglect as compared to their male counterpart. 65% of female respondents disagree that forest managers and community associations involve them in decision making process related to forest management. On the

other hand, 56% of male respondents disagree on the same. However, an equal percentage (25%) of male and female agree that they are involved in decision making process. 10% of female and 19% of male interviewed neither agreed nor disagreed (as shown in table 10).

Table 10: Level of community involvement in decision making process, gender segregated.

Count		Level of community involvement in decision making				
		Strongly dis agree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Gender of respondent	Female,128	64	19	13	30	2
	Male, 91	33	18	17	15	8
Total	219	97	37	30	45	10

Table 9: Result of the co-relation between gender and level of community of involvement in decision making.

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	13.193[a]	4	.010
Likelihood Ratio	13.316	4	.010
Linear-by-Linear Association	2.723	1	.099
N of Valid Cases	219		

4.2.2 Community involvement in tree plantation

The study reveals that 48.4% of the local communities living around the forest planted less than 500 trees in the last 12 months, in the forest or at their homes. While 1.4% of them planted between 501-1000 trees. The remaining 50.2% of them didn't planted trees within the same period (as shown in figure 23). However, majority of the respondent (68%) indicated that they planted trees for domestic use, while 17.8%, 9.1%, 4.1% and 0.9% of them said the main purpose they planted trees was reforestation, tree products for sale, tree nursery for sale and medicinal purposes (as shown in figure 24).

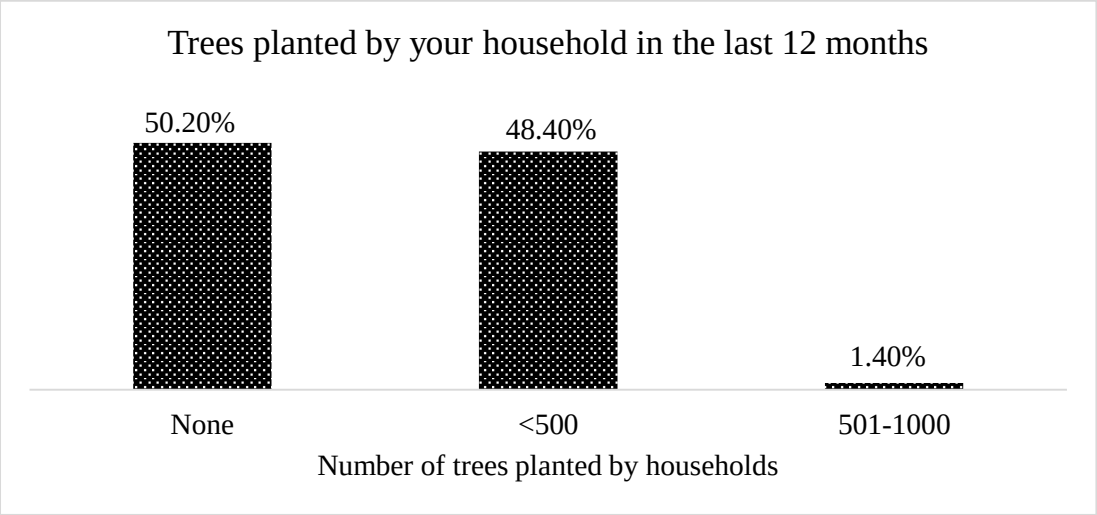


Figure 23: Percentage of households planting trees in the last 12 months

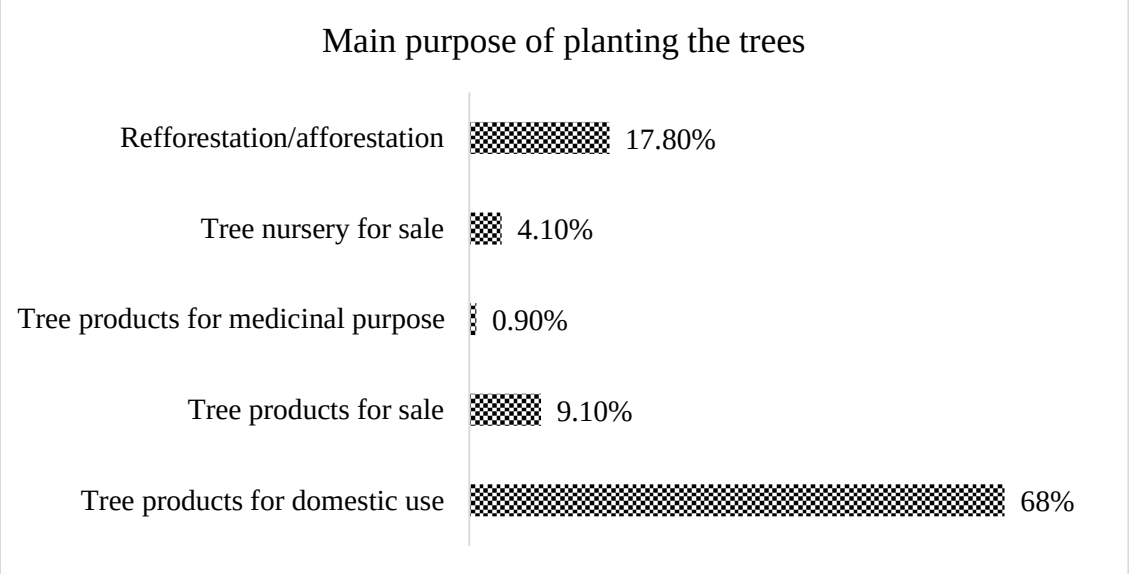


Figure 24: Purpose HHs planted trees in the last 12 months

4.2.3 Perception of the community about forest conservation

81.2% of the respondent believe that the protect and conservation of the forest is very important, while 17.4% of them indicate that its moderately important and 1.4% of them saying its slightly important (as shown in figure 25).

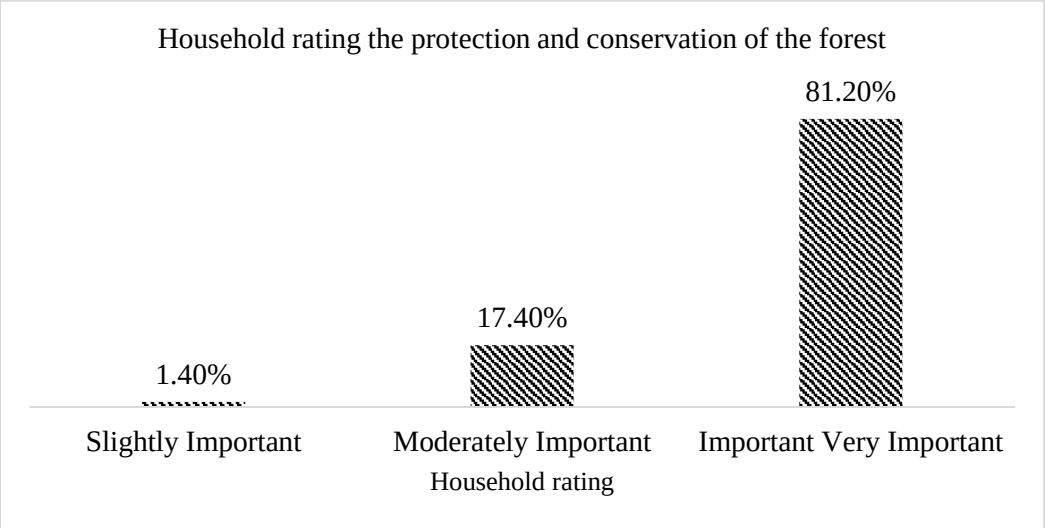


Figure 25: HHs rating of importance of Ngong Road Forest conservation.

4.2.4 Perception about benefits of urban forest and changes in air quality

Though all the respondents value the protection and conservation of the forest, 58.4% of them value the forest due to its provision of good air quality and 15.1% of them value it since it acts as water catchment. 12.3% said the main benefits of the forest is due its aesthetic beauty and their usage for recreation. 9.6% of the respondents value the forest because it is source of income to them while only 2.3% value the forest due its spiritual and cultural importance (as shown in figure 26).

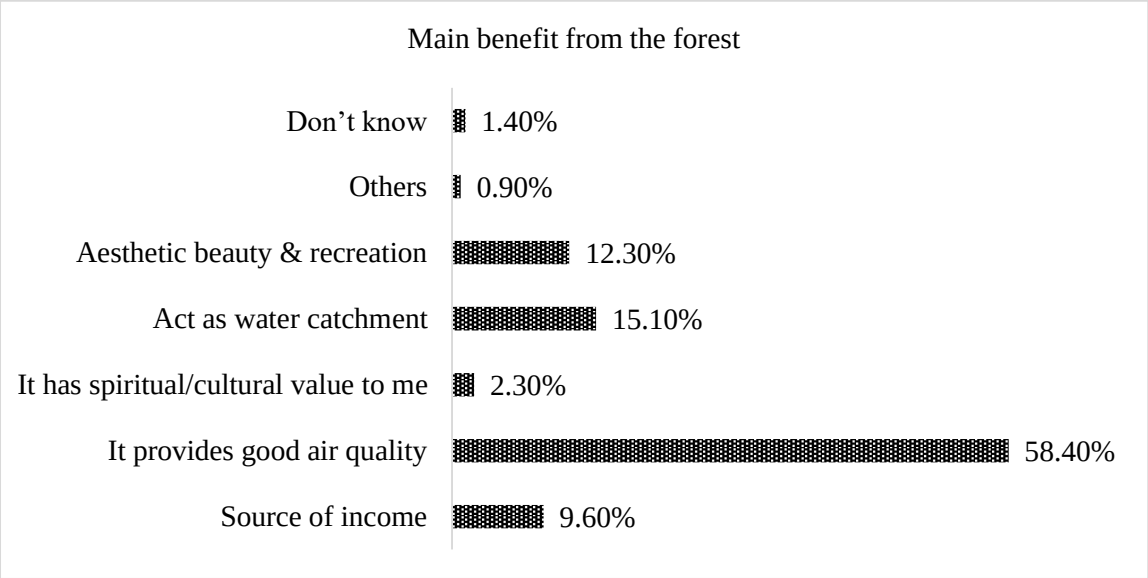


Figure 26: HHs rating main benefits of Ngong Road Forest conservation.

In addition to the above, 58.4% of the respondents strongly agreed that the forest purifies the air around where they work or live, 27.9% agreed and 9.1% neither agreed nor disagreed. However, 2.3% of them disagreed and another 2.3% strongly disagreed the fact the forest purifies the air around where they live or work (as shown in figure 27). Bearing in mind the majority have either agreed or strongly agreed that the forest purifies the air, 82.6% of them believe that the air quality around them have changed compared to 30 years ago, that the air was high quality (as shown in figure 30).

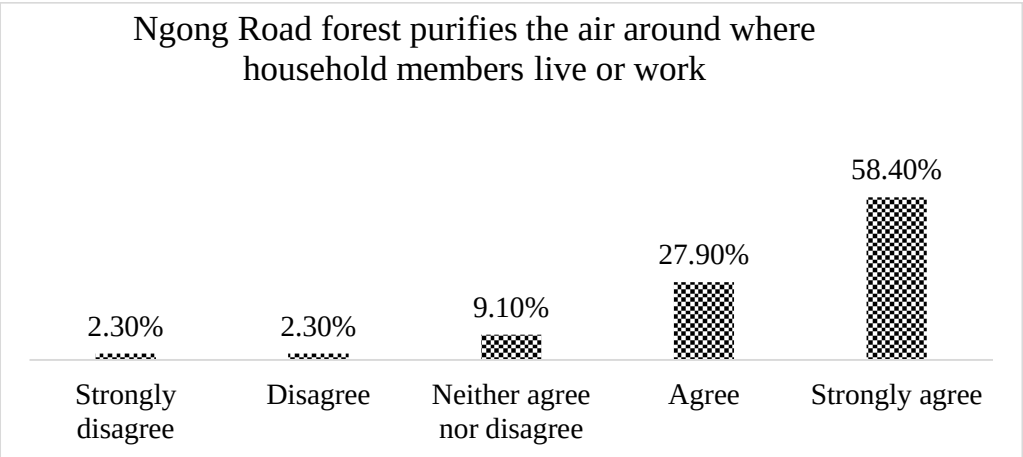


Figure 27: HHs perception about the role of the forest in air purification

4.2.5 Perceived air quality changes

Majority of the respondent (54.8%) attribute the changes in air quality to cutting down of trees, while 19.6% of them attribute it to excessive pollutions from motor vehicles and 15.5% said it is due to pollution from factories. 5.9% and 4.1% of the respondent attribute the changes of air quality to smokes from dumpsites and indoor pollution respectively (as shown in figure 28 and 29)

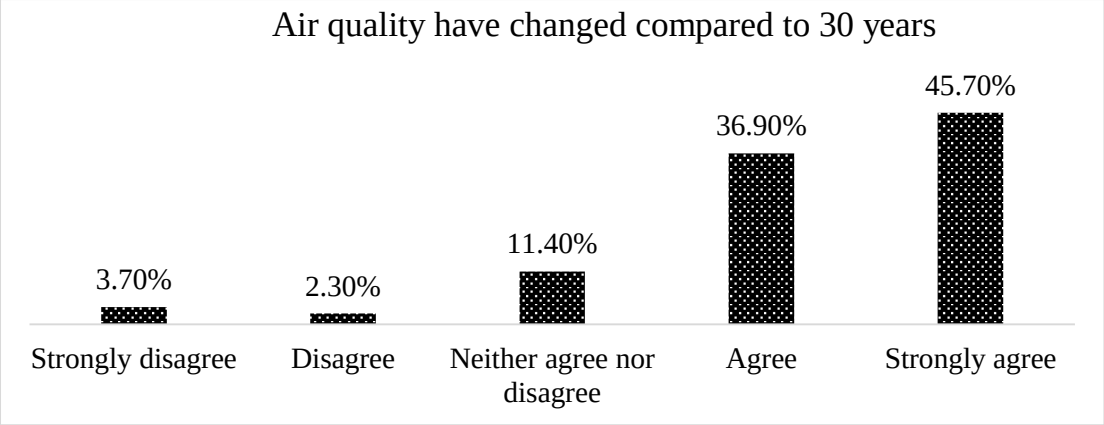


Figure 28: Perception on air quality change

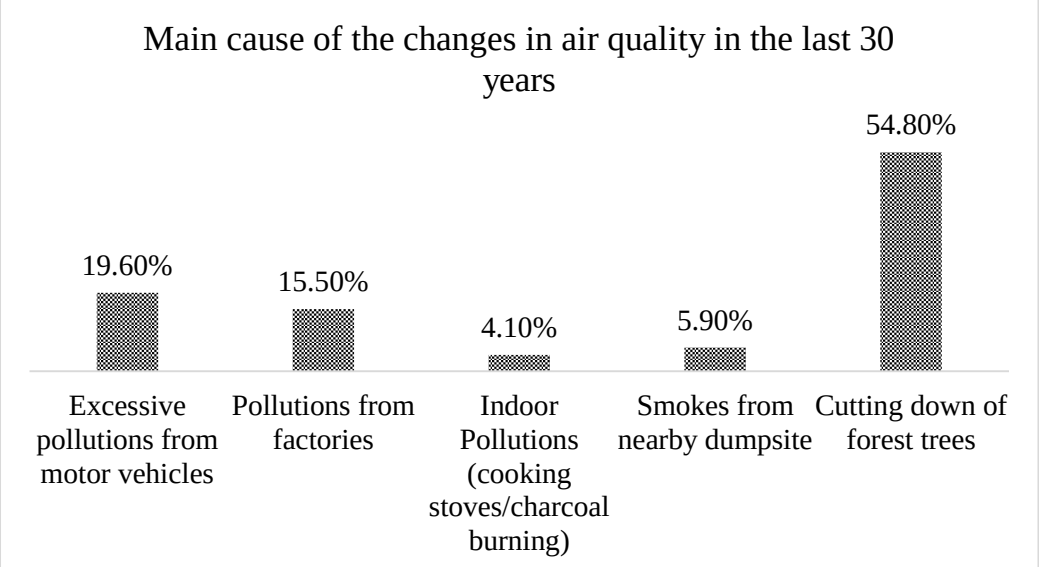


Figure 29: HHs view on the cause of air quality

There was an increasing trend of concentration of air pollutants (as per the data retrieved from NASA Giovanni) such as Sulphur dioxide in different seasons for the period between 1988 to 2019, in the study area. During the Months December, January and February characterized with short rainy season, the highest amount of SO_2 recorded was 4.08E-10 and the minimum amount of 2.02E-10 (as shown in figure 30).

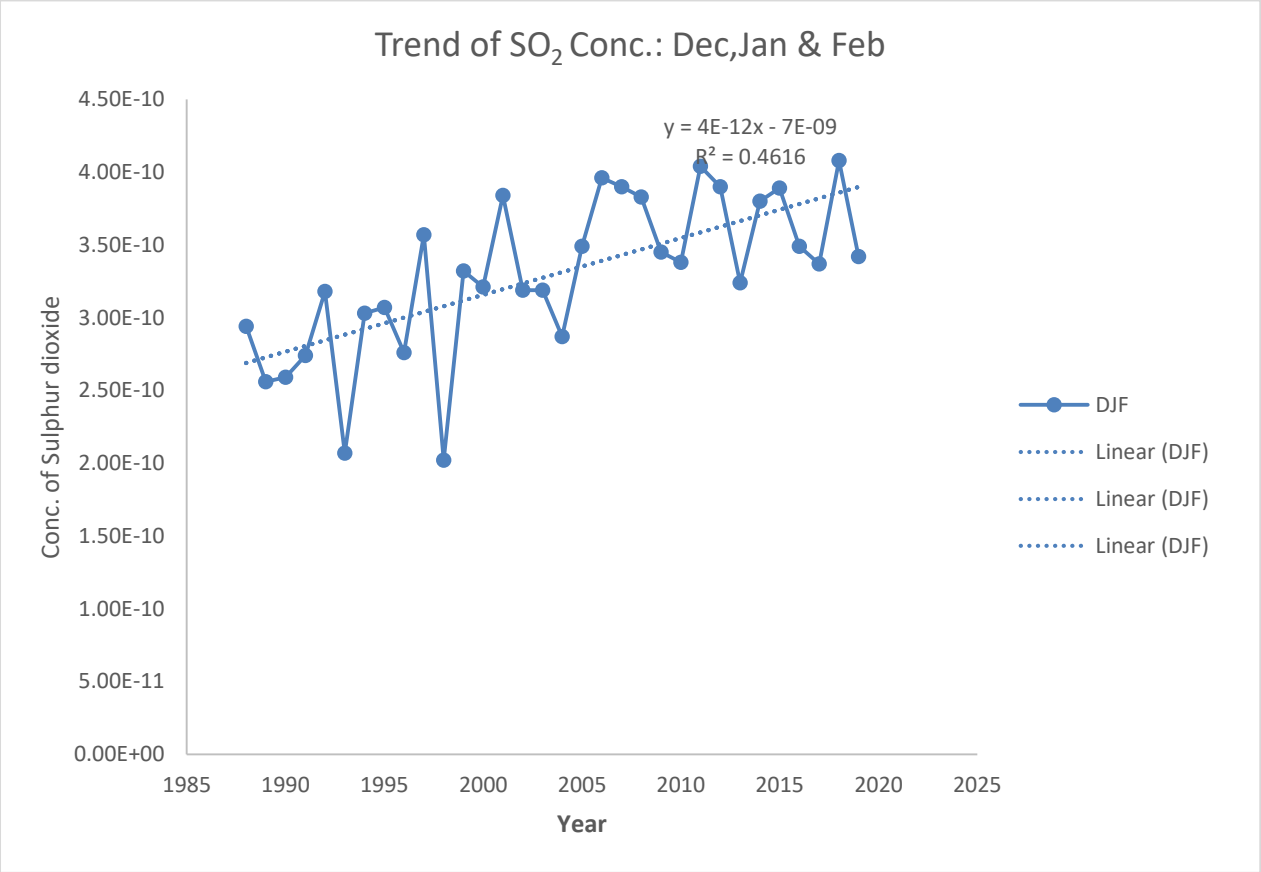


Figure 30: Trend of Sulphur Dioxide concentration (Dec, January and Feb.) in Nairobi County

During the months of March, April and May, the trend continued to increase and the highest amount of SO_2 recorded was 3.908E-10 and with the least recorded being 1.87E-10 (as shown in figure 31)

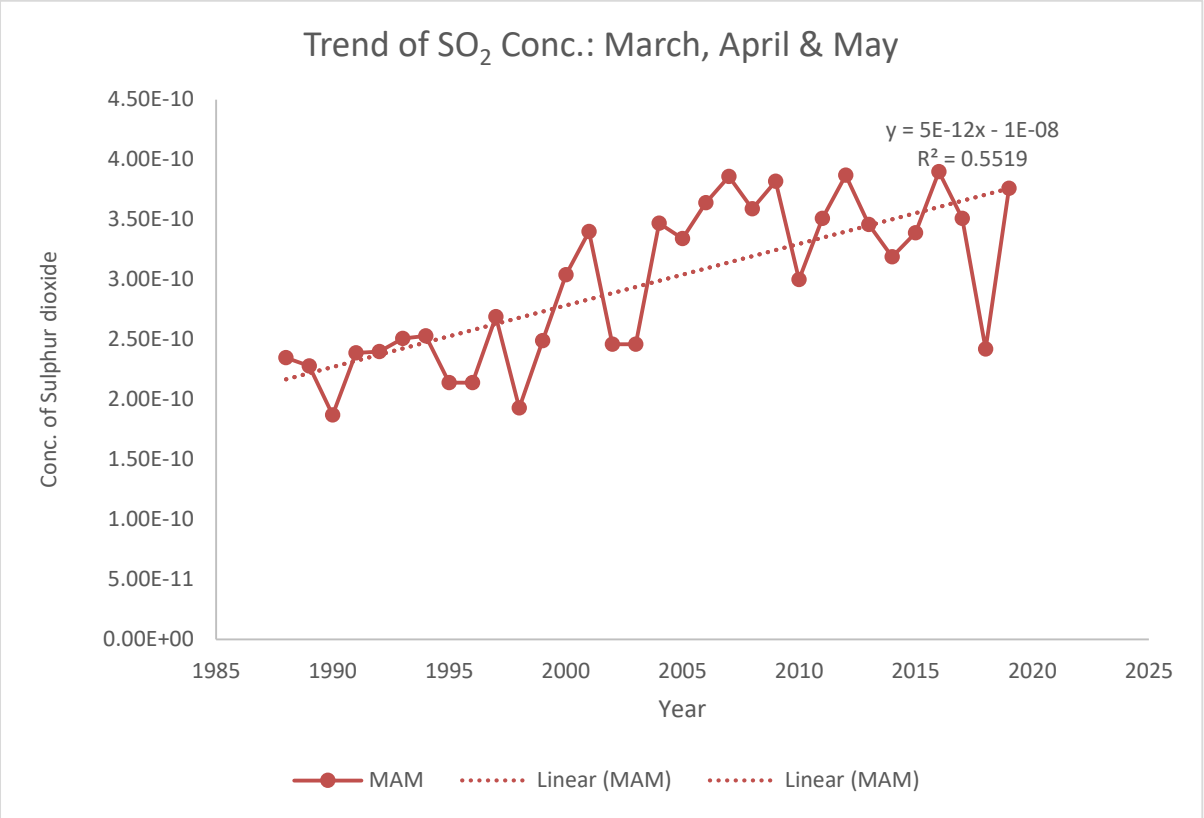


Figure 31: Trend of Sulphur dioxide concentration (March, April and May) in Nairobi County

During the months of June, July and August, the trend continued to increase and the highest amount of SO_2 recorded being 5.338E-10 and with the least recorded being 2.13E-10 (as shown in figure 32)

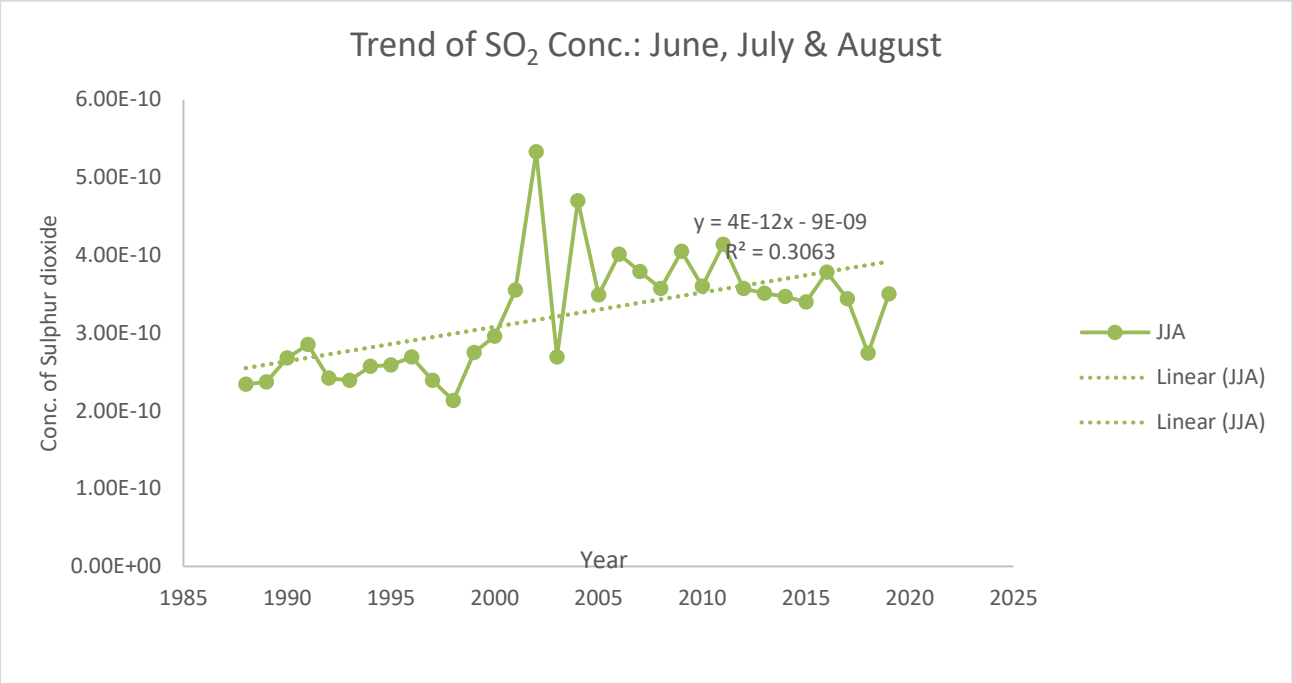


Figure 32: Trend of Sulphur dioxide concentration (June, July and August) in Nairobi County.

During the months of September, October and November the trend continued to increase and the highest amount of SO_2 recorded being 4.12E-10 and with the least recorded being 2.06E-10 (as shown in figure 33).

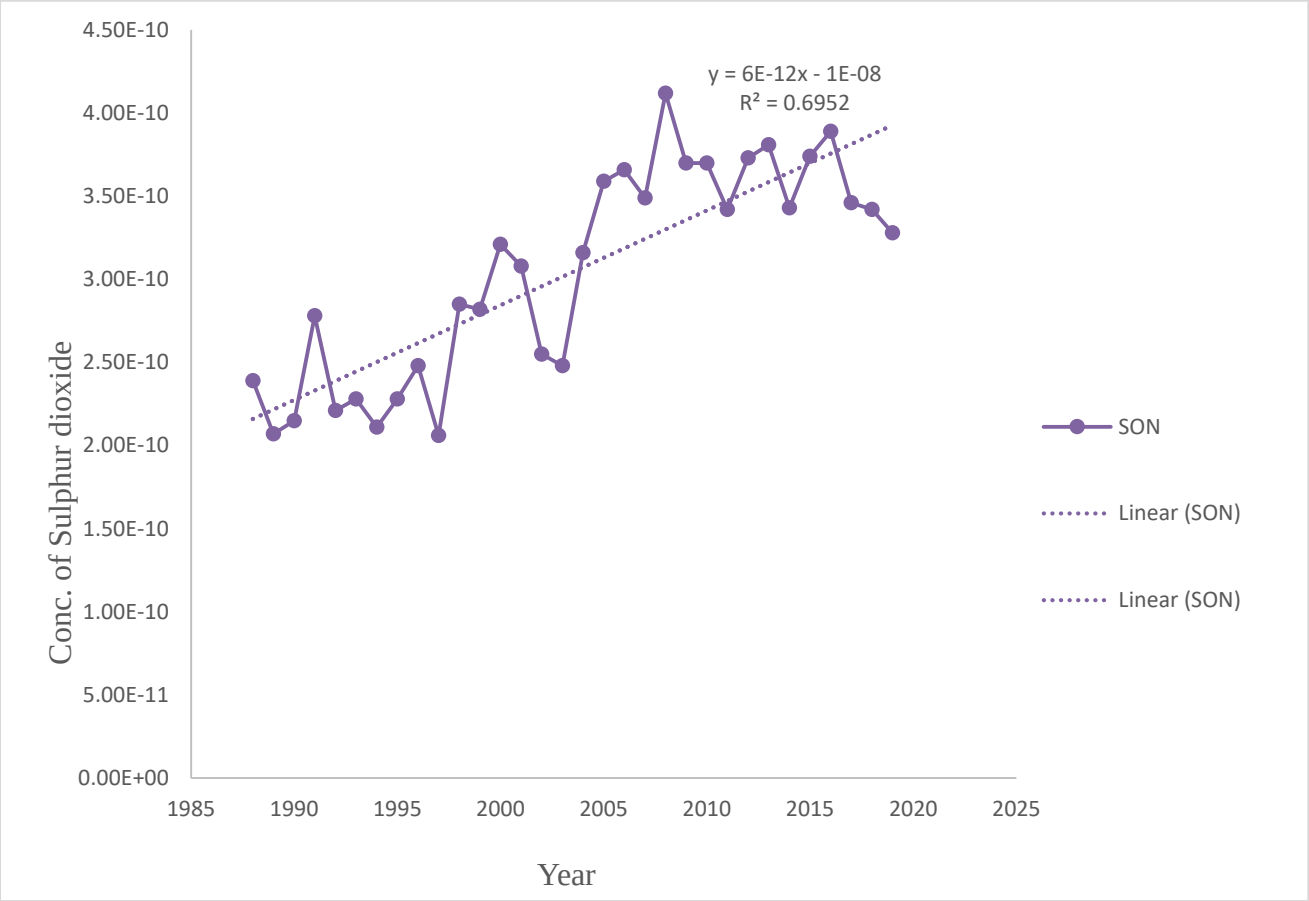


Figure 33: Trends of Sulphur Concentration (September, October and November) in Nairobi County.

4.3 Contribution of Ngong road forest resources to local community

4.3.1 Source of income of the local community

The majority of the people living around the forest don't directly depend on forest products as source of livelihood. The study showed that 71.7% of the people depend on non-forest businesses as source of income and 15.5% of them depend on farming. An equal number of them (each 2.7%) depend on livestock and charcoal businesses. 6.4 % of the people rely on tree nursey business and only 0.9% rely on timber business (as shown in figure 34).

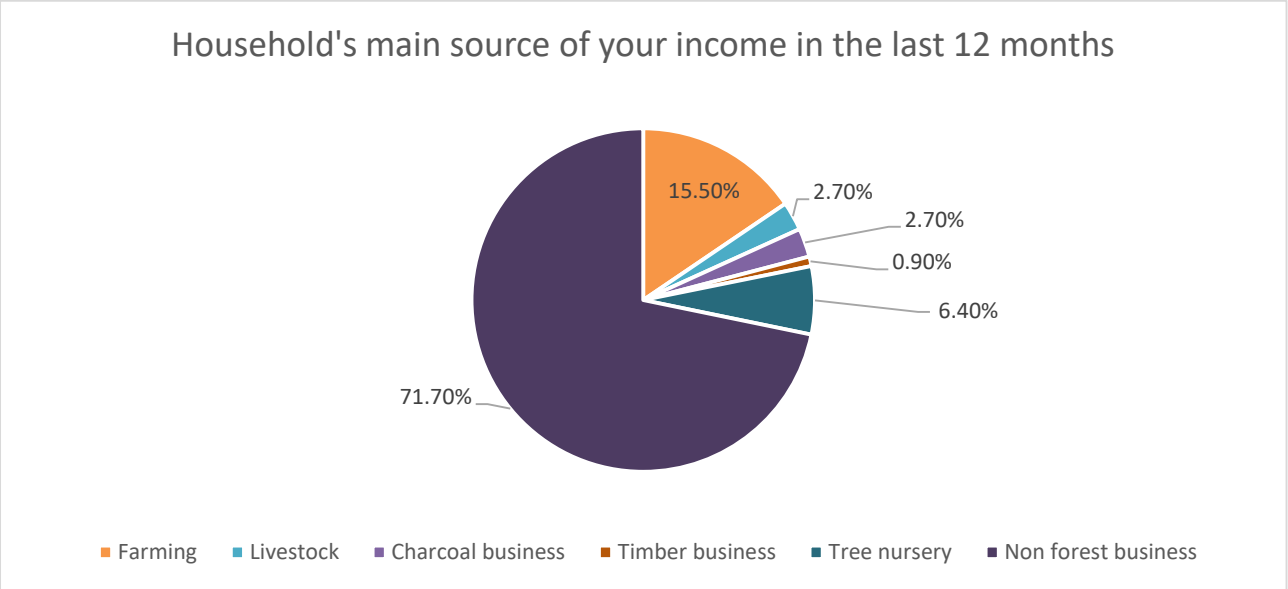


Figure 34: Pie chart showing main source of respondent's income in the last 12 months.

4.3.2 Source of energy for cooking

In regards to households' source of energy for cooking, majority (45.7%) of the households rely on Liquified Petroleum Gas (LPG), while charcoal and firewood were used by 19.2% of households each. Other source of energy used by households were kerosene (14.6%) and electricity (1.4%), (as shown in table 12).

Table 11: Household's main source of energy for cooking

Household's Main source of cooking energy	*Frequency*	*Percent*
Charcoal	*42*	*19.2*
Firewood	*42*	*19.2*
Kerosene	*32*	*14.6*
Electricity	*3*	*1.4*
Gas (LPG)	*100*	*45.7*
Total	*219*	*100*

The households use charcoal and firewood alternately, for some occasions despite majority households rely on LPG as main source of energy for cooking. In addition to this, majority spending less than ksh.100 in a day to purchase either charcoal or firewood while 28.8%, 4.1% and 3.2% of them spend an average of ksh 150, ksh 250 and ksh 350 per day (as shown in

figure 35). In terms of quantity of charcoal/firewood used per day, majority (47.9 %) used less than 3kg, while 27.4% and 0.9% consume an average of 4.5 and 8.5 kg respectively. 1.8% of the households consume more than 10kg of charcoal or firewood in a day while 21.9% permanently don't rely on both sources of energy (as shown in figure 36).

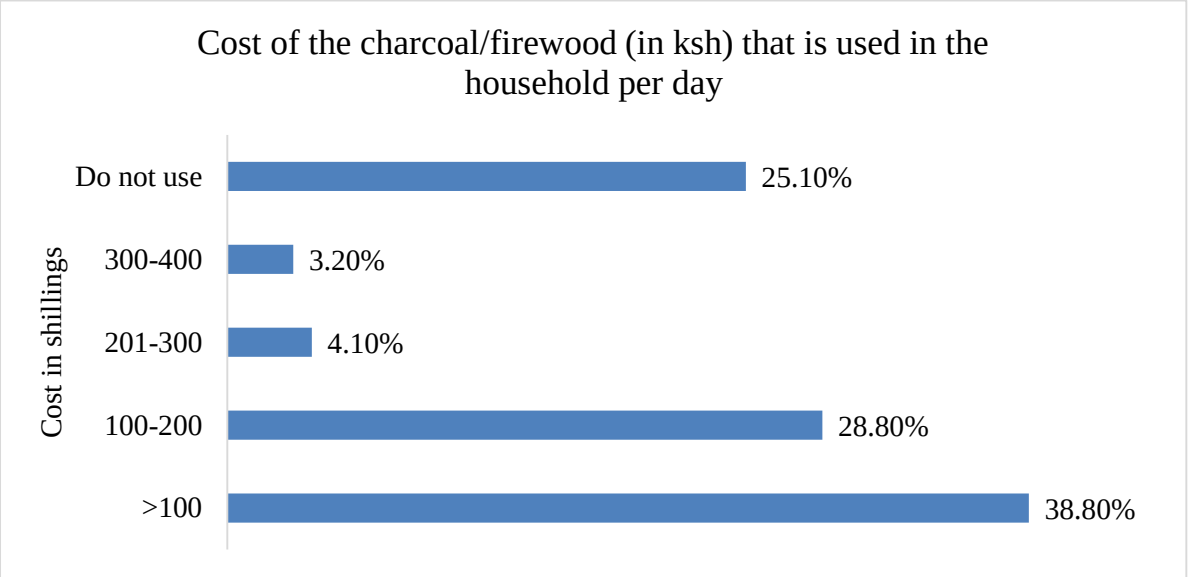


Figure 35: Cost of charcoal and firewood used by household per day

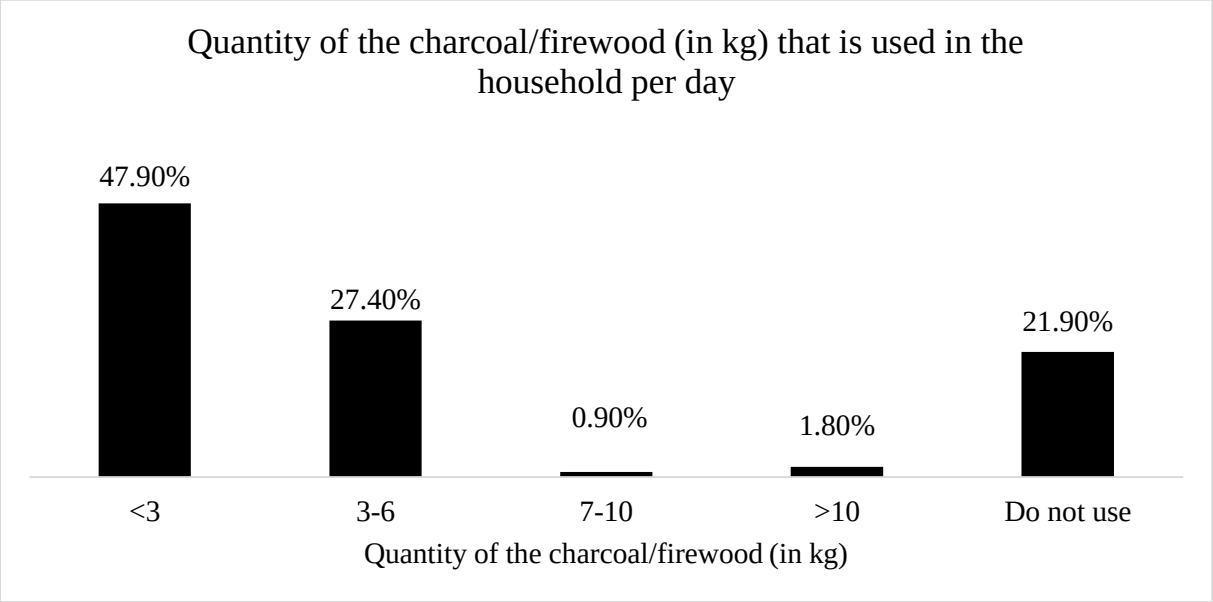


Figure 36: Quantity of charcoal/firewood (kg) used by household per day

Interestingly, the statistical test show that there is no relationship between the average household income in the last 12 months and the source of energy household use (as shown in table 12 and 13). Meaning, income level didn't have an impact, in terms of which the type of energy the household use for cooking, however, typically due to the majority of the household being a middle class that depend on non-forest business, i.e employees of private or government institutions or self-employed people, thus majority can afford to purchase LPGs to cook.

Table 12: Cross-tabulation of Household average income and source of energy for cooking

Count		Household MAIN source of energy for cooking in					
		Charcoal	**Firewood**	**Kerosene**	**Electricity**	**LPG**	Total
Average HHs monthly income(ksh) last 12 months	None	1	4	0	1	7	13
	<10,000	12	13	11	0	18	54
	10,000-20,000	14	9	11	0	24	58
	20,001-30,000	7	12	7	2	21	49
	30,001-40,000	5	3	1	0	15	24
	40,001-50,000	1	0	0	0	7	8
	>50,000	2	1	2	0	8	13
Total		42	42	32	3	100	219

Table 12: Chi-square test result

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	31.529[a]	24	.139
Likelihood Ratio	35.600	24	.060
Linear-by-Linear Association	5.127	1	.024
N of Valid Cases	219		

4.3.3 Level of household access to forest products

In terms of accessibility to forest products, only 1.8% of the local community had access without fear of penalties. Almost half of the households (49.8%) didn't have access to the forest products in the last 12 months. However, 30.6% and 3.7% of the respondents had access to forest products with fear of penalties, and 14.2% had little access without fear of penalties (as shown in figure 37).

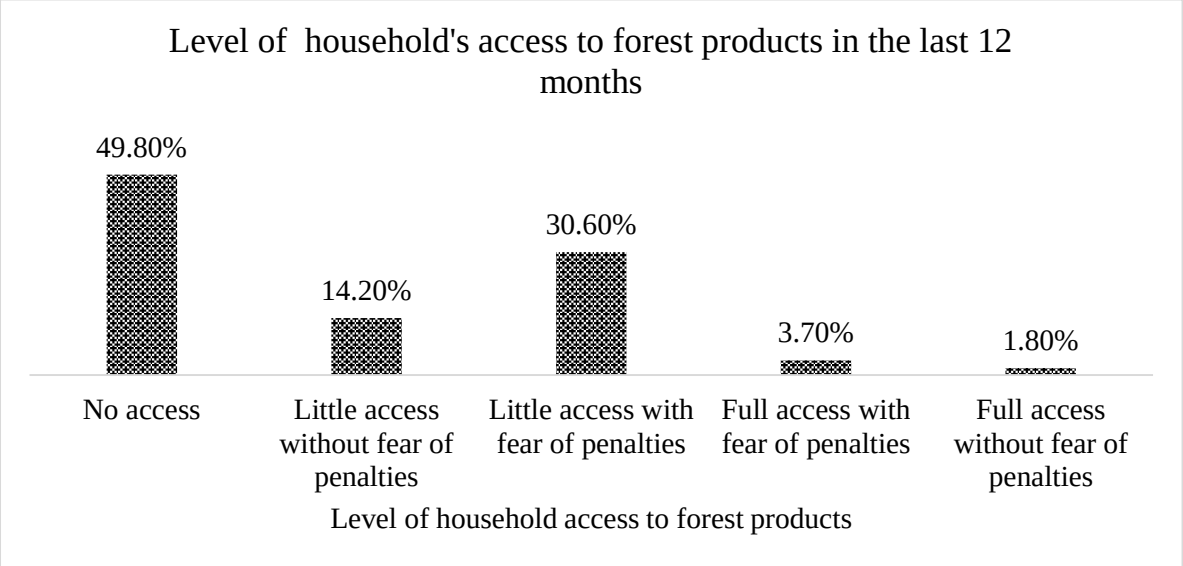


Figure 37: Level of household access to forest products in the last 12 months.

Statistical test shows that there is a relationship between the household's average income and their level of access to forest products, though majority had no access (as shown in table 14 and 15). The findings show that low middle class, earning ksh 30,000 and less, had little access with or without fear of penalty.

Table 13: Cross-tabulation of HHs income and level of access to forest products

		HHs level of access to forest products in the last 12 months					
		No access	*Little access without fear of penalties*	*Little access with fear of penalties*	*Full access with fear of penalties*	*Full access without fear of penalties*	*Total*
HHs average monthly income(ksh) in12 months	*None*	*10*	*0*	*2*	*0*	*1*	*13*
	<10,000	*22*	*14*	*17*	*1*	*0*	*54*
	10,000-20,000	*25*	*6*	*24*	*3*	*0*	*58*
	20,001-30,000	*29*	*6*	*13*	*0*	*1*	*49*
	30,001-40,000	*11*	*4*	*4*	*3*	*2*	*24*
	40,001-50,000	*6*	*0*	*1*	*1*	*0*	*8*
	>50,000	*6*	*1*	*6*	*0*	*0*	*13*
Total		*109*	*31*	*67*	*8*	*4*	*219*

Table 14: Chi-square result, showing p-value

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	42.572[a]	24	.011
Likelihood Ratio	43.518	24	.009
Linear-by-Linear Association	.088	1	.767
N of Valid Cases	219		

4.3.4 Forest products processed by the local communities

Amongst those who had access with or without fear of penalties, majority (19.6%) of the household processed firewood from the forest in the last 12 months, while 13.2%,3.7%,2.7%,1.8%,1.4%,1.4% and 0.9% processed charcoal, wooden furniture, timber, resin and honey, vegetable, medicinal plants and seeds respectively. However, the majority of the household (47.9%) indicated that they had not processed any products (as shown in figure 38)

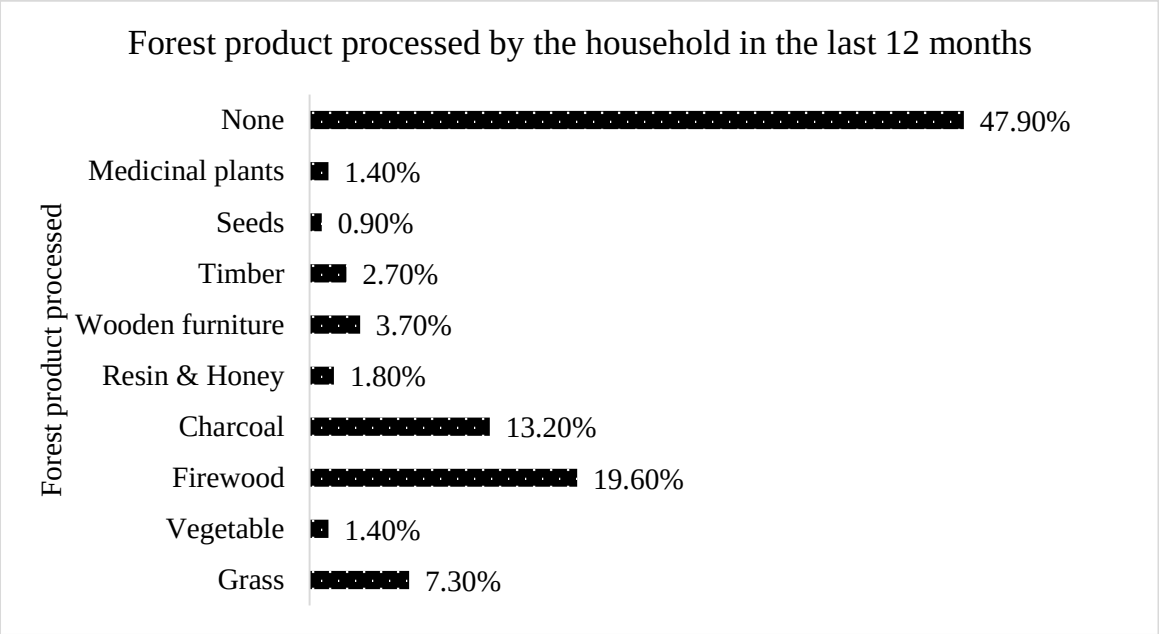


Figure 38: Forest products processed in the last 12 months

4.3.5 Purpose of forest products processed by the local community

Majority of the household process forest products for domestic use. 82.6% of the household indicated that they don't sale any forest products that are processed while 6.4% reported that they often sale the processed forest products. 4.6% of the households indicated that they sometimes sale the products. However, 2.3 % of the respondents said they always sale the processed products and 4.1% rarely sale the products (as shown in figure 39).

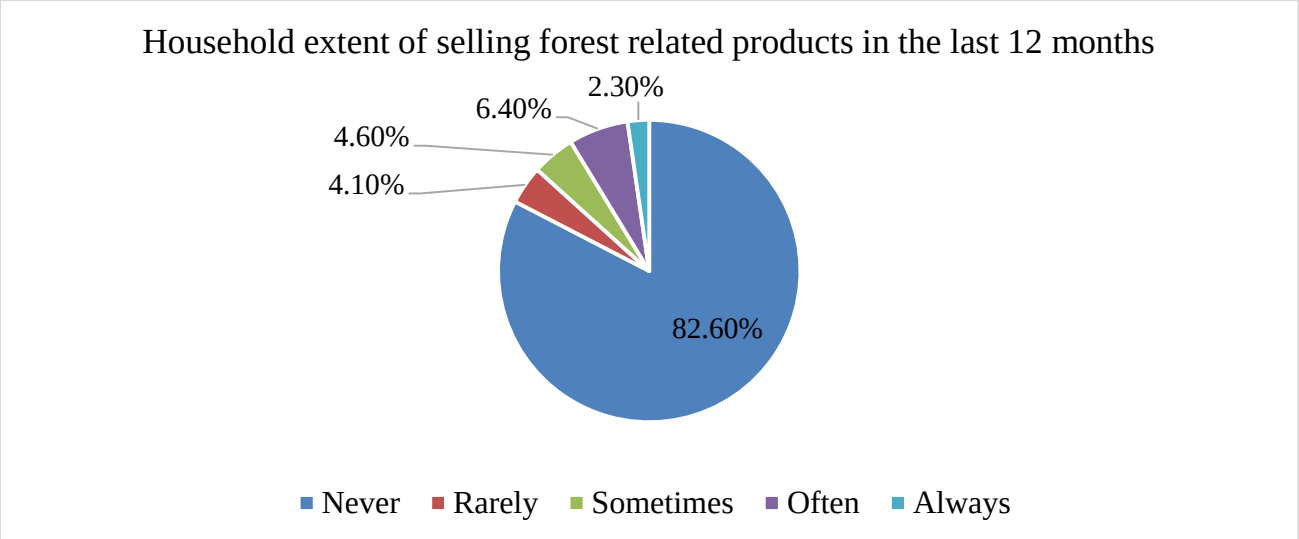


Figure 39: Chart showing HHs selling forest products.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In a nut shell, the rapid growth of Nairobi city has affected Ngong road forest cover that lies at the edges of southern bypass highway, making the forest the most vulnerable to disturbances. The forest is significantly degraded, due to urban growth. Lu *et al* (2010), found that exposure of trees to social stressors due to land use intensity and management practices, causes physical damages to the trees. The study showed that there were less disturbances to the forest in 1988, however much disturbances were observed with the highest of forest to built-up area conversion realized towards 1999. This was as a result of legal excision of the forest land that happened in between 1988 and 1999, with the then government allocating forest land to public schools, churches and to private entities. Though little efforts of reforestation were observed during the period of 1999-2009, there was significant forest degradation.

A forest cover of 1493 ha was converted to other land uses, with highest conversion accounted for grasslands (76%) followed by built-up areas (23%). The household survey revealed that much of the forest land was cleared during this period. The urban expansion remained a threat to the forest cover even towards 21st century despite having an appropriate policy. The expansion of existing Ngong road to a super four-lane highway, divided the forest into four sections, thus contributing to habitat fragmentation that will significantly make the forest more vulnerable. The forest cover was significantly cleared in the expenses of expanding infrastructural and housing development despite the Forest Act 2005 started its full implementation in 2007, with subsequent revision in 2009 and 2015, its effective implementation is in question. The local community were not effectively involved in decision making related to forest management and conservation. Women felt more sideline compared to men. The forest management authorities and community associations didn't effectively

involve them in decision making. This can be attributed to cultural norms, where women are left to play a domestic role. This shows that KFS are not robustly engaging the local community and thus it is against the spirit of Kenya's 2010 constitution that calls for participatory approach in sustainable management of natural resources.

The satellite data revealed that there was an increasing trend of concentration of air pollutants such as Sulphur dioxide in different seasons between 1988 to 2019 for the period. The local community believe that the air quality has decline during this period, and they attribute this to cutting down of trees coupled with increasing levels of pollutant released from motor vehicles. 82.6% of the respondent indicated that the air quality has declined in the last 30 years, where majority of them (54.8%) attribute this to deforestation, 19.6% and 5.9 % of them attribute this to excessive pollutions from motor vehicles and pollution from factories respectively. Some of the communities living near the forest, for the last 30 years, might have also contributed to the deforestation since they rely on firewood and charcoal as a source of energy for cooking. Lastly, the study found that there was no relationship between the average household income and the source of energy household use. The 28.4% of respondents use charcoal and firewood alternately, for some occasions despite majority (45.7%) households relying on LPG as main source of energy for cooking. However, there was a relationship between the household's average income and their level of access to forest products, with or without fear of penalty. Low- and middle-income communities, living near the forest have little access to forest products such as firewood. Thus, rapid growth in the city have affected the forest cover that lies at the edges of southern bypass highway, making the forest the most vulnerable to disturbances.

5.2 Recommendations

The study recommends the following;

1. ***Promotion of sustainable urban growth***: the government must establish effective legal and institutional framework to curb, control and monitor air pollutants as well protect Ngong Road Forest to ensure sustainable urban growth. The government must designate specific areas for housing developments, social amenities and ensure the forest are not encroached and deforested for development purposes. The National Environmental Management Authority (NEMA) must effectively enforce Environmental Management Act through monitoring development projects around the forest in order to prevent any further loss of the forest cover. Through NEMA, the government must effectively coordinate all the relevant institutions to reclaim forest land that may have been grabbed/ or illegally taken over to restore the forest ecosystem as well protect the remaining forest cover.
2. ***Establishment appropriate policies and as well strengthening the implementation the existing policies that promote equitable benefit sharing of the forest natural resources;*** the local community especially the CFAs must be given an incentive to conserve and protect the forest resources as well given access to forest products. Policies that promote sharing of benefits accrued from the conservation and management of the forest i.e tourism must be introduced and implemented, to motivate the CFAs for their efforts in preserving and protect the forest to motivate and encourage them further continue their initiatives.
3. ***Effective implementation of existing forest policies:*** the study further recommends the government to strengthened the implementation of the existing forest policies that promote an integrated approach towards conservation, where women must be robustly engaged to play a vital role in the management of the community forest associations.
4. ***Promotion of women inclusivity in decision making process related to forest governance and management; KFS*** should develop gender mainstreaming guidelines for all CFAs

and make women participation mandatory, so that they play a role in decision making process related to the forest. The CFAs and KFS must ensure inclusivity of women, youth and disable people in decisions related to forest management.

5. ***Fencing the forest blocks;*** due to fragile nature of the forest and its location, the study recommends the remaining forest blocks must be fenced to deter illegal loggers and protect the forest. Currently, only block of the forest is secure and fenced, and the other three is not fenced. KFS must work effectively with both other relevant government agencies, local communities and private sector to promote the conservation and protection of the forest. KFS should coordinate and work with other agencies such as NEMA, KWS, KEFRI and KWTA to ensure the forest is protect and conserve to sustain the forest ecosystem services. The KFS must effectively engage the local communities must built trust with the local communities and collaborate with them in preventing illegal logging and access to the forest resources.
6. ***Funding for studies on air quality and urban forest governance;*** government should be open to new ideas and must promote innovative ideas to provide solutions to the problems related to urbanization such as air pollution and deforestation. The government through Kenya Forestry Research Institute (KeFRI) must collaborate with public and private academic institutions in conducting research on urban forestry governance and management to ensure the forest air quality and urban forest protection and conservation through scholars and exchange programs to academicians and scholars. Further studies are needed in relation to effect of air pollution to health and GDP of the country. Studies should focus on urban forestry and help policy makers understand the value of the forest in sequestering air pollutants by measuring the amount of air pollutant the forest sequesters.

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APPENDICES

Appendix 1: Household survey questionnaire

INTRODUCTION

"Good morning/afternoon, my name is **Anis Yussuf Ibrahim**, postgraduate student from University of Nairobi, studying Masters in Environmental Governance. I am undertaking a research on effect of urbanization on Ngong Road Forestry and its implications on air quality, as an ecosystem service. I would like to take few minutes of your time to ask you some questions about Ngong Road Forest. Are you willing to participant in the interview?" I will not share your private information such as name and where you live with anyone and we will only use the information you provide us for our research.

The findings of the research will provide the policy makers and forest stakeholders with accurate data on the state of the forest and will better inform them to make appropriate decision of future conservation and protection of the forest. I appreciate taking your time in filling this form. Thank you.

A. ADMINISTRATIVE DETAILS		
A1	Date of interview	
A2	Location of interview	0. Karen 1. Sarangombe, Kibra 2. Muituni 3. Ngando 4. Other
A3	Name of the Researcher	0. Anis Ibrahim
A4	Names of Respondent	
A5	Gender of respondent	0. Male[ ] 1. Female[ ]
A6	Age bracket of respondent	0. Below 18[ ] 1. 18 – 34[ ] 2. 35 – 49 [ ] 3. 50-65 [ ] 4. Above 60[ ]
A7	Highest level of education	0. None [ ] 1. Primary [ ] 2. Secondary[ ] 3. College [ ] 4. University [ ]
A8	Occupation	0. Farmer[ ] 1. Agro-pastoralist [ ] 2. Entrepreneur[ ] 3. Public Servant[ ] 4. Other (specify)
B. SOCIO-ECONOMIC STATUS OF HOUSEHOELD		

B1	How many members are living in your household?	0. <3[ ] 1. 3-6[ ] 2. 7-10 [ ] 3. >10 [ ]
B2	How many meals do the family consume in a day?	0. 1[ ] 1. 2[ ] 2. 3[ ] 3. >3[ ]
B3	What is the distance(1way) between your home and the forest?	0. <3 km[ ] 1. 3-6 km[ ] 2. 7-10km[ ] 3. >10km[ ]
B4	How long have you lived in here?	0. <3 years[ ] 1. 3-6 years [ ] 2. 7-10 years [ ] 3. >10 years[ ]
B5	What is the **MAIN** source of energy for cooking in your household?	0. Charcoal[ ] 1. Firewood[ ] 2. Kerosene [ ] 3. Electricity [ ] 4. Gas(LPG) [ ] 5. Others [ ]
B6	Where do you get the **MAIN** source of energy that is used in your household from?	0. Nearby market [ ] 1. Nearby forest [ ] 2. Nearby shrubland [ ] 3. Other [ ]
B7	How often do you rely on charcoal/firewood for cooking, or heating compared to alternatives?	0. Not used [ ] 1. Very little [ ] 2. About half of the time [ ] 3. Mostly [ ] 4. Always [ ] 5. Don't know [ ]
B8	What is the quantity of the charcoal/firewood (in kg) that is used in your household?	1. <3[ ] 2. 3-6[ ] 3. 7-10[ ] 4. >10 [ ] 5. N/A[ ]
B9	What is the cost of the charcoal/firewood (in ksh) that is used in your household?	0. >100 [ ] 1. 100-200 [ ] 2. 201-300 [ ] 3. 300-400 [ ] 4. N/A[ ]

B10	What is the source of your income in the last 12 months?	0. Farming [ ] 1. Livestock [ ] 2. Charcoal business [ ] 3. Timber business [ ] 4. Tree nursery[ ] 5. Non forest business[ ] 6. Other [ ]
B11	What is your average monthly income(ksh) in the last 12 months?	0. <10,000[ ] 1. 10,000-20,000[ ] 2. 20,001-30,000[ ] 3. 30,001-40,000[ ] 4. 40,001-50,000[ ] 5. >50,000[ ] 6. None
B12	Do you have an access to the forest products (grass, firewood,charcoal,resin&honey,wooden furniture, timber) in the last 12 months?	0. Yes [ ] 1. No [ ]
B13	What is the level of your household's access to forest products in the last 12 months?(Scale of 1-5; 1;No access, 2; Little access without fear of penalties, 3; Little access with fear of penalties, 4: Full access with fear of penalties, 5: Full access without fear of penalties)?	0. 5[ ] 1. 4[ ] 2. 3[ ] 3. 2[ ] 4. 1[ ]
B14	Which forest product was mostly processed by the household in the last 12 months?	0. Grass [ ] 1. Vegetable [ ] 2. Firewood [ ] 3. Charcoal[ ] 4. Resin & Honey [ ] 5. Wooden furniture [ ] 6. Timber[ ] 7. Seeds[ ] 8. Medicinal plants [ ] 9. None[ ] 10. Other[ ]
B15	How many household members are involved in processing/collection of the above forest product in the last 12 months?	0. <2[ ] 1. 2-4[ ] 2. 4-6[ ] 3. >6[ ] 4. None[ ]
B16	What is the total quantity of the forest products processed(kg)?	5. None[ ] 6. <100[ ]

		7. 101-200[ ] 8. 201-300[ ] 9. 301-400[ ] 10. >400[ ]
B17	Where was the above forest products collected from?	0. Old growth natural forest[ ] 1. Secondary/regenerating forest[ ] 2. Managed plantation forest[ ] 3. Non-forest tree based wild[ ] 4. Non-forest tree based cultivated [ ] 5. Others (specify)[ ]
B18	To what extent did any member of the household sale forest related products, in the last 12 months? (1-5 scale; 1: Never, 2; Rarely; 3: Sometimes, 4: Often, 5: Always) id you or any member of the household that sale forest related products (grass,firewood,charcoal,resin&honey ,wooden furniture,timber)	0. 5[ ] 1. 4[ ] 2. 3[ ] 3. 2[ ] 4. 1[ ]
B19	What is the total quantity of the forest products processed(kg)?	0. <500[ ] 1. 500-1000[ ] 2. 1001-1500[ ] 3. >1500[ ]
B20	To what extent did your household use products harvested(timber) from the forest for construction, in the last 12 months?(scale of 1-5; 1: Never; 2: Rarely; 3:Sometimes, 4: Often, 5: Always)	0. 5[ ] 1. 4[ ] 2. 3[ ] 3. 2[ ] 4. 1[ ]
B21	How easily can your household have access to this land without concern of penalties?	1. Very easy[ ] 2. Somewhat easy[ ] 3. Neither difficult nor easy [ ] 4. Somewhat difficult[ ] 5. Very difficult [ ]
C. FOREST COVER DYNAMICS-DEGRADATION AND DEFFORESTAION		
C1	What is your rating on forest cover change in the last 30 years? (scale of 1: Not at all; 2: Slightly; 3:Moderately; 4: High; 5: Extremely high)	0. 5[ ] 1. 4[ ] 2. 3[ ] 3. 2[ ] 4. 1[ ]

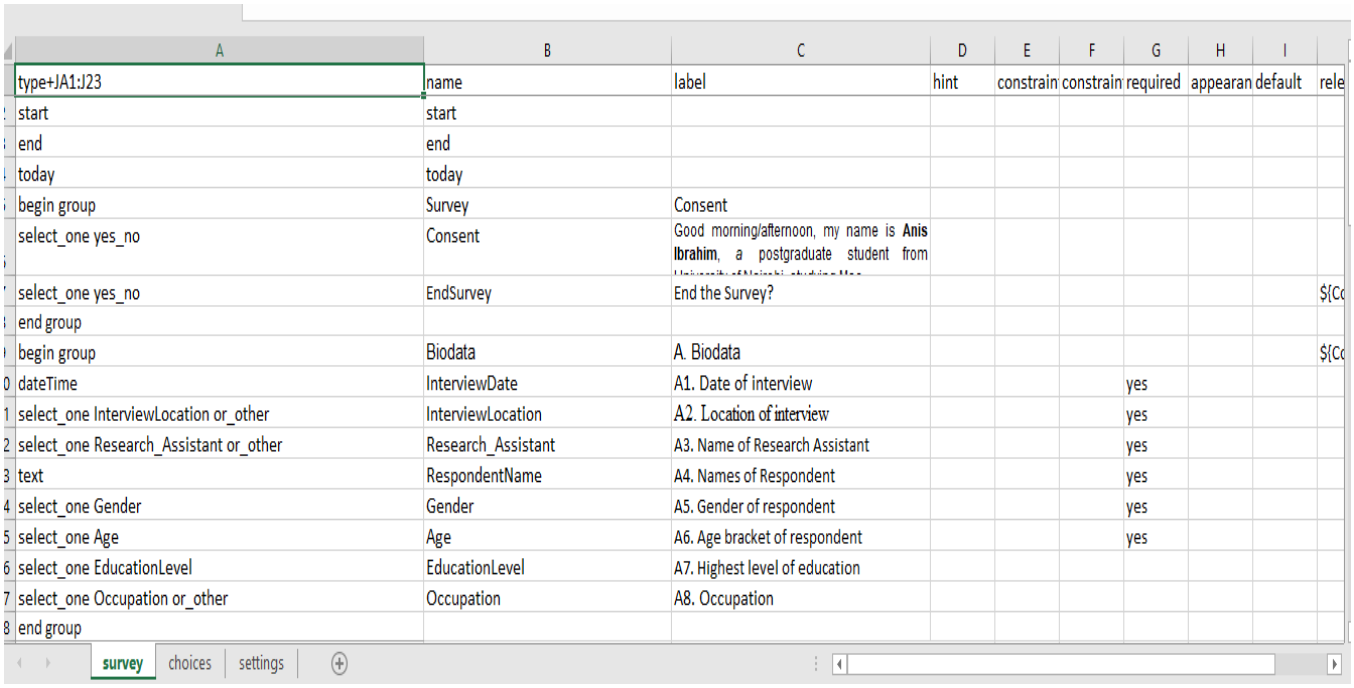
C2	In your opinion, what is the main cause of the forest cover change?	0. Illegal logging [ ] 1. Climate change/natural disasters [ ] 2. Land grabbing [ ] 3. Change of land tenure[ ] 4. Infrastructural development[ ] 5. Lack of political will [ ] 6. Poor forest governance & management 7. Other[ ]
C3	Approximately how many forest land(acres) was cleared during the last 30 years?	0. <500[ ] 1. 500-1000[ ] 2. 1001-1500[ ] 3. 1501-2000[ ] 4. >2000[ ] 5. None[ ]
C4	Which period was the forest land cleared most?	0. Before 1988[ ] 1. 1988-1999[ ] 2. 2000-2009[ ] 3. 2010-2019[ ]
C5	Approximately how many acres of forest land cleared for infrastructural development(i.e road), during the last 10 years?	0. <500[ ] 1. 500-1000[ ] 2. 1001-1500[ ] 3. 1501-2000[ ] 4. >2000[ ] 5. None[ ]
C6	Approximately how acres of forest land was cleared for housing & other development during the last 10 years?	0. <500[ ] 1. 500-1000[ ] 2. 1001-1500[ ] 3. 1501-2000[ ] 4. >2000[ ] 5. None[ ]
C7	How many trees (including trees on farm) have been planted by your household in the last 12 months?	0. >5[ ] 1. 5- 10[ ] 2. 11-15[ ] 3. 16-20[ ] 4. <20[ ]
C8	What was the **MAIN** purpose of the trees planted?	0. Tree products for domestic use[ ] 1. Tree products for sale[ ] 2. Tree products for medicinal purpose[ ] 3. Tree nursery for sale[ ] 4. Refforestation/afforestation[ ] 5. Other[ ]
C9	How do rate/value the protection and conservation of the forest? NB;scale of 1-5 (1: Not Important; 2:Slightly	0. 5[ ] 1. 4[ ] 2. 3[ ] 3. 2[ ]

	Important; 3: Moderately Important; 4: Important; 5:Very Important)	4. 1[ ]
C10	What benefits do you get from the forest?	0. Source of income [ ] 1. It provides good air quality [ ] 2. It has spiritual/cultural value to me [] 3. Act as water catchment [ ] 4. Aesthetic beauty & recreation [ ] 5. Reduce erosion [ ] 6. Other [ ] 7. Don't know [ ]
D. COMMUNITY PERCEPTION ABOUT THE AIR QUALITY & BENEFITS OF URBAN FORESTRY		
D1	Do you believe Ngong Road Forest purifies the air around the area you live or work?	0. Yes[ ] 1. No[ ]
D2	Do you believe the quality air around where you live or work is good for your wellbeing?	0. No[ ] 1. Yes[ ]
D3	Has the air quality changed compared to 30 years?	0. No[ ] 1. Yes[ ]
D4	If yes, what was the course of this changes?	0. Excessive pollutions from motor vehicles [ ] 1. Pollutions from factories [ ] 2. Indoor Pollutions (cooking stoves/charcoal burning) [ ] 3. Smokes from nearby dumpsite [ ] 4. Cutting down of forest trees [ ]
D5	Do you think the air quality now is a concern for you?	0. No [ ] 1. Yes [ ]
D6	How best do you think the above forest service can be improved?	0. Reforestation [ ] 1. Good Urban forest governance [ ] 2. Introduction of New forest policy [ ] 3. Community awareness [ ] 4. Others [ ] 5. Don't know[ ]

FIGURE 40FIGURE 41: APPENDIX 1: HH SURVEY QUESTIONNAIRE

THANK YOU VERY MUCH FOR YOUR TIME
END

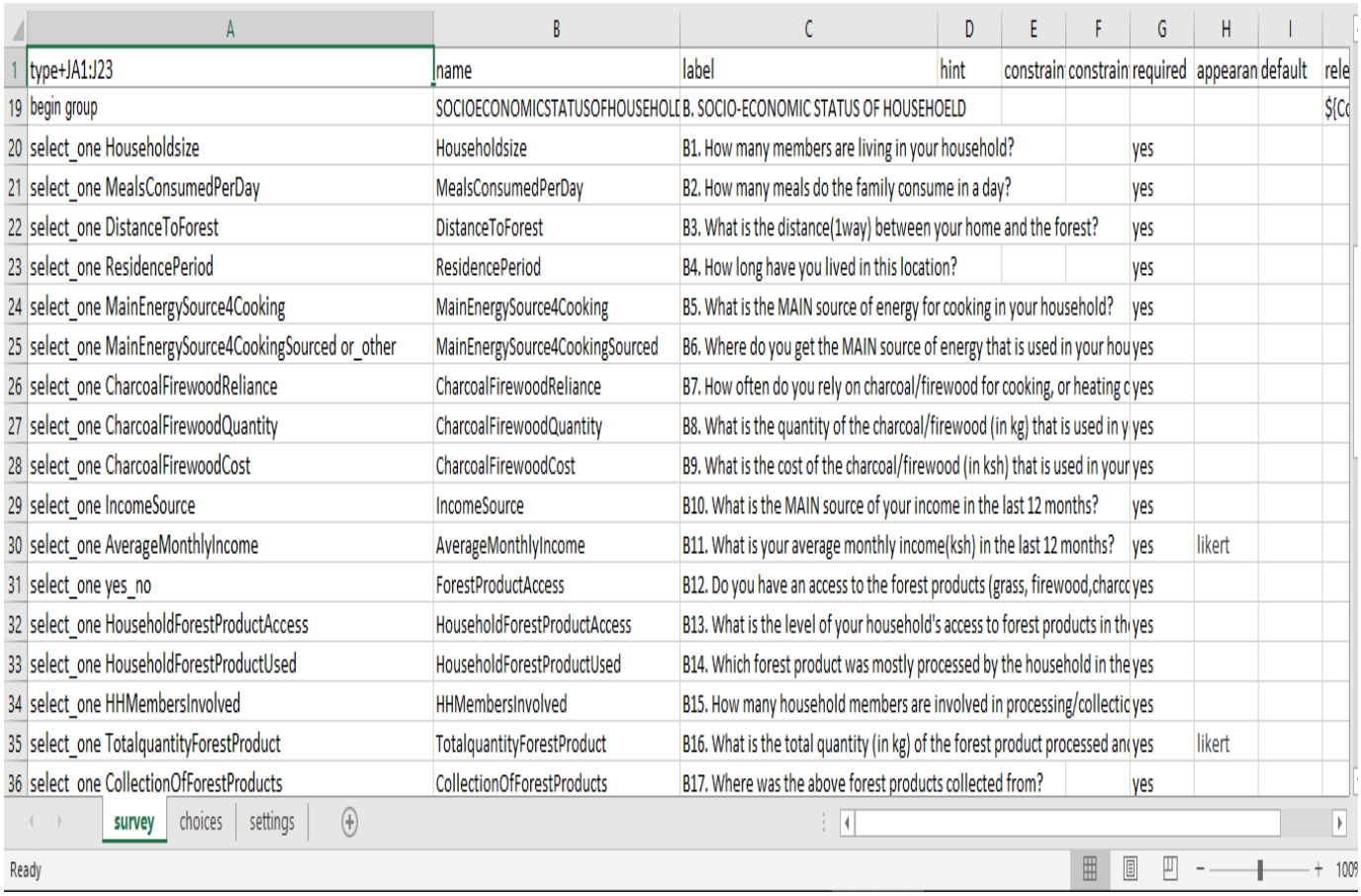
Appendix 2: Coded Household questionnaire in excel (xls) format used in ODK



	A	B	C	D	E	F	G	H	I	
	type+JA1:J23	name	label	hint	constrain	constrain	required	appearan	default	rele
2	start	start								
3	end	end								
4	today	today								
5	begin group	Survey	Consent							
6	select_one yes_no	Consent	Good morning/afternoon, my name is **Anis Ibrahim**, a postgraduate student from							
7	select_one yes_no	EndSurvey	End the Survey?							${Cc
8	end group									
9	begin group	Biodata	A. Biodata							${Cc
10	dateTime	InterviewDate	A1. Date of interview				yes			
11	select_one InterviewLocation or_other	InterviewLocation	A2. Location of interview				yes			
12	select_one Research_Assistant or_other	Research_Assistant	A3. Name of Research Assistant				yes			
13	text	RespondentName	A4. Names of Respondent				yes			
14	select_one Gender	Gender	A5. Gender of respondent				yes			
15	select_one Age	Age	A6. Age bracket of respondent				yes			
16	select_one EducationLevel	EducationLevel	A7. Highest level of education							
17	select_one Occupation or_other	Occupation	A8. Occupation							
18	end group									

survey | choices | settings

42*APPENDIX 2: CODED HH QUESTIONNAIRE(EXCEL)*



	A	B	C	D	E	F	G	H	I	
1	type+JA1:J23	name	label	hint	constrain	constrain	required	appearan	default	rele
19	begin group	SOCIOECONOMICSTATUSOFHOUSEHOLD	B. SOCIO-ECONOMIC STATUS OF HOUSEHOELD							${Cc
20	select_one Householdsize	Householdsize	B1. How many members are living in your household?				yes			
21	select_one MealsConsumedPerDay	MealsConsumedPerDay	B2. How many meals do the family consume in a day?				yes			
22	select_one DistanceToForest	DistanceToForest	B3. What is the distance(1way) between your home and the forest?				yes			
23	select_one ResidencePeriod	ResidencePeriod	B4. How long have you lived in this location?				yes			
24	select_one MainEnergySource4Cooking	MainEnergySource4Cooking	B5. What is the MAIN source of energy for cooking in your household?				yes			
25	select_one MainEnergySource4CookingSourced or_other	MainEnergySource4CookingSourced	B6. Where do you get the MAIN source of energy that is used in your hou				yes			
26	select_one CharcoalFirewoodReliance	CharcoalFirewoodReliance	B7. How often do you rely on charcoal/firewood for cooking, or heating c				yes			
27	select_one CharcoalFirewoodQuantity	CharcoalFirewoodQuantity	B8. What is the quantity of the charcoal/firewood (in kg) that is used in y				yes			
28	select_one CharcoalFirewoodCost	CharcoalFirewoodCost	B9. What is the cost of the charcoal/firewood (in ksh) that is used in your				yes			
29	select_one IncomeSource	IncomeSource	B10. What is the MAIN source of your income in the last 12 months?				yes			
30	select_one AverageMonthlyIncome	AverageMonthlyIncome	B11. What is your average monthly income(ksh) in the last 12 months?				yes	likert		
31	select_one yes_no	ForestProductAccess	B12. Do you have an access to the forest products (grass, firewood,charcc				yes			
32	select_one HouseholdForestProductAccess	HouseholdForestProductAccess	B13. What is the level of your household's access to forest products in th				yes			
33	select_one HouseholdForestProductUsed	HouseholdForestProductUsed	B14. Which forest product was mostly processed by the household in the				yes			
34	select_one HHMembersInvolved	HHMembersInvolved	B15. How many household members are involved in processing/collectic				yes			
35	select_one TotalquantityForestProduct	TotalquantityForestProduct	B16. What is the total quantity (in kg) of the forest product processed an				yes	likert		
36	select_one CollectionOfForestProducts	CollectionOfForestProducts	B17. Where was the above forest products collected from?				yes			

survey | choices | settings

Ready

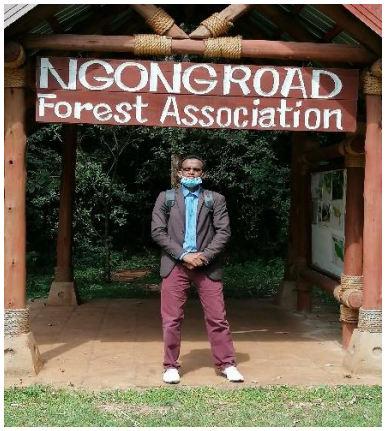
Appendix 3: Photos from the field

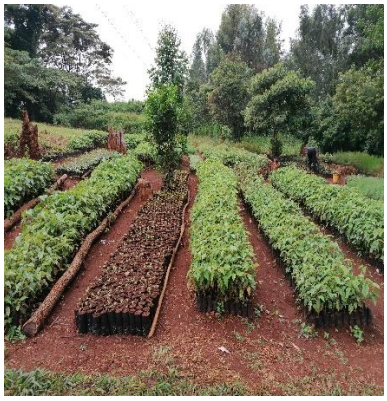










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