ASSESSMENT OF CHANGES IN LAND COVER AND ENVIRONMENTAL IMPACT OF THE STANDARD GAUGE RAILWAY FROM NAIROBI TERMINUS TO KIAMBU COUNTY IN KENYA

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DECLARATION

I declare that this thesis is my original work and has not been submitted or presented for examination, in part or as a whole, for any academic award in any other University.

Signature: **Date:** 26.10.2023

Okoth Augustine Lape Fr

APPROVAL

This thesis has been submitted for examination with our approval as University Supervisors.

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DEDICATION

I dedicate this Thesis to a gentle, stern, and principled man, Captain Nicholas Okoth Mbuya Ademba, who has been my life's main pillar and inspiration. He held my hand and led me to school on my very first day of attendance and as other toddlers cried out their tears I couldn’t because the Captain always taught me that the only fear I should have is the fear of God which is the beginning of pure wisdom. Now that you are no more Captain *N.O.M.A* I draw strength from all that you instilled in me, notably *steering the ship through rough and calm waters, guiding it safely into the port.*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

LC – Land cover

PCA – Principal Components Analysis

CVA – Change Vector Analysis

SGR – Standard Gauge Railway

RS – Remote Sensing

ToA – Top of Atmosphere

DN – Digital Number

NDVI – Normalized Difference Vegetation Index

NIR – Near-Infrared

USGS – United States Geologic Survey

SWAT– Soil and Water Assessment Tool

ABSTRACT

The development of transport infrastructure affects land cover resulting in negative impacts on natural resources over time and space. As such, it is required that due consideration is undertaken to minimize damage to natural and artificial features to a non-reparable degree. This thesis aimed at assessing the magnitude of the environmental impacts of the Standard Gauge Railway (SGR) from the Nairobi Terminus to Nachu Station in Kiambu County. The Specific objectives involved undertaking a detailed GIS and remote sensing (RS) baseline environmental assessment of the developed SGR route; identifying the anticipated social and environmental impacts. The data for this were collected with household surveys, using 100 households as the sample size, proposing mitigation measures to be taken during and after implementation of the SGR project. The assessment results in the thesis area revealed that built areas increased by 3.6%, while grassland, forest, and cropland decreased by 2.5%, 2.6%, and 13%, respectively. The drivers of this change were increased built up areas along the SGR line, urbanization, and land use change. The results also revealed that the SGR has caused negative environmental effects encroaching conservation areas, disrupting human settlement, and diminishing forest and vegetation cover. The noise and air pollution produced due to the SGR construction and operation affected wildlife, vegetation, and human settlement. Recommendations for future SGR projects include wet-spraying of cement and wet drilling to reduce dust emissions during the construction; frequent investigations of the construction sites, afforestation, and recommendation of humane settlement of populations before the execution of such projects as well as suitability analysis using GIS conducted to locate the best SGR routes.

CHAPTER ONE

INTRODUCTION

1.1 Background

Transport infrastructure form an essential component of any built environment by enhancing the rapid movement of goods and services thereby promoting the production processes in any economy (Nistor and Popar, 2014). Many African governments are currently trying to get recognition for acquiring modern transport infrastructure. This is mainly achieved by inviting economic and logistic aid that enables them to meet their vision of attaining a level of development set out by the United Nations (UN). This is carried out to realize a global social and economic development integration that according to the UN, many African countries are still far from attaining (UN, 2009).

In the whole fabric of transport infrastructure, the rail system is considered due to its economic and environmental advantages (Borda et al., 2017). Railway transport can effectively move bulk cargo over long distances at an unmatched cost in addition to connecting ports and land terminals. The rail system has facilitated many economies lower energy costs and spur the growth of container stations and multiple domestic stations to link many towns and cities thus moving people and goods smoothly (Obeng et al, 2022; Yeboa, 2017). The development of railway infrastructures affects both artificial and natural features in space and time. With this in mind, it is then required that these developments are undertaken with due consideration to minimize their negative impacts, particularly their environmental effects whose impacts might be irreversible.

The promotion of harmony between natural and artificial features occupies the background thinking of any government that doesn't want to earn a tag of being insensitive to environment conservation warranted by promoting unchecked infrastructural development. This is in the way of pollution and clearing of vegetation during the construction and development of the railway line, and indirectly as a result of increased human activities along the railway line.

Current statistics, however, indicate that Africa has low railway connectivity and as of the year 2005 it had a total rail network of 90,320 km. When calculated in global parameters, this is considered as having a capacity of moving one percent of global passenger traffic and two percent of goods traffic. This situation means that African countries will continue to invest in the development of railway systems. Kenya for instance aims to have a firmly interconnected state made possible by an ultra-modern network of railways.

The massive increase in imports and exports puts a lot of pressure on Kenya’s transport infrastructure) and thus justifies a heavy investment in improving its infrastructure network (KRC Strategic Plan, 2012). The Kenyan government has built the SGR a railway line that connects Mombasa (at the cost of the Indian Ocean) and Naivasha. The development of this rail system started in 2013 and ended in 2019. The project was envisaged to have positive impacts such as a major influence on economic growth and total factor productivity of the country. Despite the advantages, the impact on the environment with the advancement of the SGR cannot be ignored.

1.2 Problem Statement

The rapid expansion of railway infrastructure can have a detrimental impact on the environment both directly, as an immediate effect of the infrastructure and its construction, or indirectly due to human activities after construction (Laurance et al., 2015; Clauzel et al., 2015). There is a loss of ecosystem integrity with the construction of railway lines by truncation of ecosystems into smaller pockets that are not able to sustain ecological processes.The SGR is not an exception and the same impacts are expected from its construction.

There have been reports of negative ecosystem impacts of the SGR. In this case, disruption of movement and migration of wildlife, behavioral modification among species, bisections of basins and watersheds (Munyao et al., 2020), and the physical disruption of the structure and compositions of ecosystems (Nyumba et al., 2021). Similarly, there has been an increase in water, soil, and air pollution, grassland fires, and alteration of predator-prey relationships (Sang et al., 2022).

Additionally, the construction of the SGR has led to the destruction and loss of natural ecosystems through the clearance and conversion of vast lands of natural forests, water bodies, and grasslands among other biomes (Ambani, 2017). Furthermore, the original characteristics of the natural vegetation have been replaced and/or modified. There is thus a need to understand the effects of SGR on the environment to mitigate its potential impact.

1.3 Justification

So far, research on the ecological impacts of transport infrastructure has focused mainly on roads, even though railway lines have similar ecological impacts on the environment. Additionally, the majority of these studies have been done in developed countries, with a handful of studies done in developing countries, particularly in sub-Saharan Africa (Soares et al., 2004; Dong et al., 2021). This leaves a knowledge gap on the impact of the railway on the ecosystem. There is thus a need to understand how railway line impacts the environment to have effective mitigation measures, to contribute to planning and policy on future infrastructure projects, and finally to contribute to Kenya's obligation to the international bodies on climate change mitigation (DCP Kenya, 2019).

Studies done so far on SGR have been socio-economic studies. For example, Nyumba et al.

(2021), did a reconnaissance thesis to access the ecological impacts of SGR. Likewise, Geographic Information System (GIS) studies done so far have focused on the open/sparse areas such as parks and rural regions. For example, Ambani, (2017) looked at the impact of SGR on the Nairobi National park, while Sang et al. (2022) looked at the landscape dynamics along the SGR.

To the best of knowledge, no thesis has looked at the impact of SGR on Urban and Peri-urban regions. Also, no thesis has made a comprehensive approach incorporating GIS and Remote Sensing with socio-economics This thesis, therefore, sought to provide a spatial-temporal assessment of the impact of SGR on the land cover changes between the Nairobi Terminus to Nachu Station Kiambu County. Additionally, the thesis aimed at assessing the socio-economic impact of the SGR. The finding of this research aids in better understanding the impact of the SGR on the social factors, environment and land cover contributing to mitigation against its impact. The findings are useful to various government agencies and non-governmental organizations in planning environment-aware future railway projects.

1.4 General Objective

To carry out a spatial-temporal assessment of the impact of SGR on the land cover changes between the Nairobi Terminus to Nachu Station Kiambu County.

1.5 Specific Objectives

i. To undertake a baseline environmental impact assessment using GIS along the SGR line.
ii. To identify social and environmental impacts of the SGR project.
iii. To propose mitigation measures to be taken during and after the implementation of the SGR projects.

1.6 Research Questions

i. Are GIS, remote sensing and spatial analysis methods effective in assessing the environmental and social impacts of the SGR Project?

ii. What are the positive and negative impacts of the SGR Project?

iii. What are the possible mitigation measures to be taken during and after the implementation of the SGR project?

1.7 Research scope

This thesis applies both GIS analysis and socio economic analysis. A spatial modeling approach is employed utilizing GIS, and a semi-structured questionnaire is used to collect non-spatial primary data from households. Analysis of land use regulations, master plans, local land use policies, and practices, and interviews with developers, land owners, and local planners are also part of the non-spatial modeling approach.

1.8 Limitations of the Thesis

This thesis made use of free Landsat 8 mission satellite images with pixel sizes of 30 meters. Due to the high costs, very high-resolution images from the satellite platforms such as GeoEye-1, QuickBird and WorldView-2, were not used in this thesis, which could have resulted in more accurate results. Because Landsat satellite images have been widely used in land use/land cover change (LULCC) research, the findings of this thesis were compared to previous LULCC studies, and the use of Landsat imagery in this thesis justified. A household survey was conducted, and 100 respondents were sampled, which is a statistically adequate number, but they were not distributed evenly in the thesis area. The households were divided as follows: 31% lived in Kimuka, 23% in Ngong, 20% in Ongata Rongai, and 8% in the area surrounding the SGR Nairobi Terminus. This could affect the outcome.

CHAPTER TWO

LITERATURE REVIEW

1.1 Introduction

The construction of a railway line is an example of an anthropogenic driver of land use and land cover change that forces a transition from existing land use and land cover to built-up areas. Railways essentially cause the transition of both the land cover as well as land use within the landscape they traverse. Railways being linear structures tend to cut a long streak across a landscape and therefore interact with nearly all the major landscape type within an area. They also draw population clusters leading to an increase in settlements and further land use change in the surrounding areas. Therefore, developments such as the Standard Gauge Railway (SGR) in Kenya, have both a direct impact on the land cover where they pass through, as well as an indirect land use impact on the surrounding areas. This makes an assessment of their impacts a pressing need in the quest for attaining sustainable development. Various studies have looked at the connection between anthropogenic forces such as industrial development, soil exploration, agricultural production, economic development and land cover change. Studies have also looked at the corresponding impact of those changes on both the environmental and socio-economic spheres such as health, education, social action and financial activities. A systematic review of this body of evidence is helpful to answer some of the objectives of this thesis.

1.2 Economic impacts of railway infrastructure

There has been substantial growth in transport infrastructure in sub-Saharan Africa. More than 90% of new infrastructure has been in transport infrastructure mainly railways, roads, and power lines (Alamgri et al., 2017). The development of railway infrastructure has led to a reduction in transport costs, increased cross-boundary trading, and a reduction in environmental pollution. Scholarly studies on the impact of railway infrastructure have been mainly on economic growth, total factor productivity, and agglomeration. Investment in railway infrastructure has a positive impact on economic growth, total factor productivity, and agglomeration effects in cities (Zhang, 2012). Railway carries resources and goods from point of production through to consumption playing a major role in the economies and industrial development by connecting several countries (Obeng, 2022). In Kenya, the railway system is one of the oldest systems, constructed during the colonial period, it has had an immense impact on Kenya's economy mainly through the transportation of natural resources from sources to the ports.

Globally, there has been substantial development in the rail system, for example from steam engine trains to the bullet train. In Kenya, the major change has been from rail line gauges from narrow gauges to standard gauges (Wangai et al., 2020). The importance of the railway to the economy cannot be overemphasized; the investment of SGR has the potential to greatly contribute to Kenya's economic growth and development (World Bank, 2011). However, despite the positive impacts, there is a need to consider the potential impacts of the railway system on the environment and the humans.

1.3 Environmental impacts of railway infrastructure

The rapid expansion of railway infrastructure can impact the environment directly in the way of pollution and clearing of vegetation during the construction and development of the SGR, and indirectly as a result of increased human activities along the railway line (Laurance et al., 2015). The railway infrastructure mainly affects the environment in two ways. First, there is increased land use pressure and encroachment triggered by railway infrastructure development (Sang et al., 2022). Second, railway infrastructure leads to loss of ecosystem integrity through habitat alteration, habitat fragmentation, wildlife–train collision (WTC), and barrier effects. Wildlife deaths occur along railways due to WTC and railway entrapment. In a thesis by Dorsey (2011), railroad impacts have affected a total of 115 species and out of the 115 WTC impact registered death of 84 species therefore, WTC is the common cause of mortality. Habitat alteration occurs when a portion of habitat is broken into smaller pieces through the construction and operation of railways. This leads to loss of biodiversity and bisection of basins and watersheds. Barrier effects limit the movement of wildlife species as they avoid conditions such as sounds and human presence (Munyao et al., 2020). Some species such as turtles are physically unable to climb over the rails, while others avoid crossing the railway line due to risk /perceived risk of predation. Additional impacts of the railway on the environment include air, soil, and water pollution; distortion of natural processes such as hydrology, and competitor and predator-prey relationships among other impacts (Sidle et al., 2004; Catford et al., 2012).

1.4 Effects of anthropogenic activities on Land cover changes

Population growth and agricultural expansion are the major drivers of land use and land cover changes (Munyao et al., 2020). The environmental impacts include forest cover degradation, soil erosion, and soil fertility decline. In addition, there is a drop in ecosystem services such as water volume from streams, firewood, and building materials from forests. The environmental impacts of railways have been reported to increase food insecurity, particularly in low-income households (Sang et al., 2022).

In their thesis on the impacts on hydrology and ecosystem services, Ashaolu et al. (2019) reported anthropogenic fueled change negatively influencing groundwater recharge rates, surface runoff, and incidences of soil erosion, among other ecosystem services. Anthropogenic classes tend to dominate over natural classes as land cover transitions occur within an area, driven by an increase in population (Obeng et al., 2022). There is a need for an urgent management of land cover change necessary to avoid future unsustainability of ecosystem services and the corresponding socioeconomic impacts.

1.5 Analysis of land cover changes using remote sensing and GIS

Remote sensing and GIS have been used to assess the impacts of human interference on the natural landscape from mega-infrastructure investments. For example, Lix et al. (2013) used remote sensing imagery to determine the driving forces in temporal and spatial dynamics of land use and land cover changes in Southern Ethiopia. A land cover change analysis revealed that cropland and build areas classes increased while the other classes, which were majorly natural land cover classes, had declined. Mohan et al. (2011) used RS and GIS techniques to evaluate land use and land cover changes in Delhi, India to determine the impact that drivers such as population and urbanization had on this change. The thesis found that peripheral regions of the thesis area had transitioned from natural classes to anthropogenic classes.

Other studies have examined the sensitivity of land use land cover changes to urban proximity and growth (Gomes et al., 2018; Nyongesa et al., 2022). The authors used geostatistics to examine the influence of change on neighboring areas from the edge of existing urban areas. The thesis found a strong spatial correlation between the proximity of existing artificial surfaces and the emergence of new ones. Essentially, areas close to existing build area classes were more likely to transition from their land use/ land cover classes. Such studies are important for planners and managers of man-made features which cut a long transect through the landscape.

In terms of techniques used in these impact studies, various approaches have been taken to analyze remote sensing data and from it assess environmental impacts and their drivers. In their thesis on land cover changes, Saswata and Prafull, (2015), reported periodic transitions of croplands into fallow land, and that the growth of settlements had a negative impact on ecosystem balancing of such transitions. The researchers used both supervised and unsupervised image classification to map out changes in cropland such as its conversion to fallow land. Similarly, Ingle et al. (2012), used supervised classification of satellite imagery to perform land cover mapping of Jalgaon district in India between two seasons. The change analysis showed inter-season variability strongly occurring in the croplands class and reflected the pre-monsoon and post-monsoon phenological changes.

1.6 Change vector analysis

A Change Vector Analysis (CVA) is used to calculate the angle and magnitude of change vectors in the thesis area. CVA compares two images of the same scene taken at different times to see where spectral changes have occurred over time. Some studies have used change vector analysis (CVA) to examine land cover changes (He et al., 2011). These studies reported some advantages of using CVA to thesis land cover changes compared to traditional spectral-based techniques. For example, a thesis by Özyavuzet al. (2011), used change vector analysis to detect the intensity and dimension of change in the Yildiz Mountains of Turkey. Using Landsat imagery from 1990 and 2009 the thesis successfully applied CVA to quantify the inter-class changes that had occurred during the period.

1.7 Effects of infrastructure development on land cover change in Kenya

Studies of land cover change in Kenya have also found a causal relationship between anthropogenic activities and land cover change. A thesis by Chepkochei and Njoroge (2012) centered on the Menengai area in Nakuru County found that as the population grew, so did land cover change which was exacerbated by development activities such as the construction of geothermal energy stations. Other local studies on the environmental impacts of land cover change have shown that unforeseen consequences such as vector-borne diseases may result. (Similarly, Ikusya et al. (2016) reported noise pollution and cracks on buildings as among the negative impacts occasioned on the communities by the development of SGR. Infrastructure development has also led to the loss of large tracts of forests, for example, Baldyga et al. (2007) reported large forest losses coupled with increases in croplands and pasture grasslands along river Njoro, Nakuru County.

2.8 Chapter Summary

Chapter 2 provides a thorough review of literature pertinent to the impact assessment of the Standard Gauge Railway (SGR) on land cover changes from Nairobi Terminus to Nachu Station in Kiambu County. It emphasizes the transformative effects of railway construction on land use and cover. The economic benefits of railway infrastructure are highlighted, including cost reduction, enhanced trade, and improved productivity. Environmental impacts are discussed, focusing on habitat alteration, fragmentation, and wildlife-train collisions. Population growth and agriculture's role in land cover changes are addressed, emphasizing the need for sustainable management. The chapter introduces remote sensing and GIS techniques, highlighting Change Vector Analysis (CVA) as a valuable tool. Specific impacts of infrastructure development in Kenya, including SGR, are detailed, encompassing population-driven changes, health risks, noise pollution, and habitat loss. This comprehensive literature review forms a strong foundation for the subsequent spatial-temporal assessment of SGR's impact on land cover changes.

CHAPTER THREE

MATERIALS AND METHODS

This thesis comprised of two methodological parts. the first focused on the creation of land cover maps and an analysis of the changes across the years; while the second part focused on the socio-economic analysis of impacts brought about by these changes through a household survey. The hypothesis is that land cover changes have a direct effect on the environment and an indirect effect on the social and economic livelihoods of the dwellers in the thesis area making it important to correlate land cover changes with socio-economic impacts to get a holistic picture of the way the development has affected different paradigms.

1.1 Thesis Area

The thesis was carried out along a section of Kenya's Standard Gauge Railway (SGR), Phase IIA, from Nairobi Terminus in Syokimau to SGR Nachu Station in Kiambu County. To assess the land cover change in the thesis area a buffer zone of 2.5 km covering 290 km^2 along the SGR line was computed.

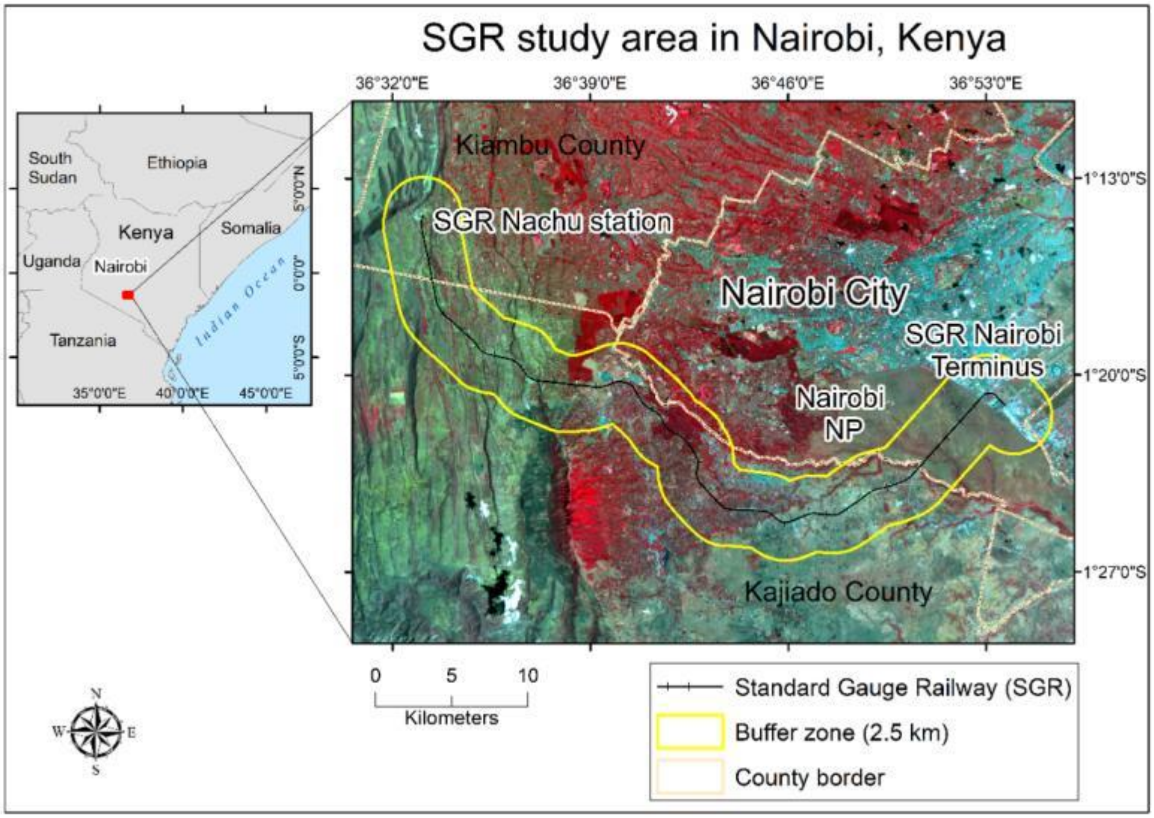


Figure 3. 1: Satellite image outlining SGR track from Syokimau to Kimuka

The thesis applied a hierarchical approach and examined the thesis area from two spatial levels. For direct impacts caused by the SGR track on the landscape, very-high-resolution multi-time imagery from Google Earth Pro (version 7.3.2.5776) was used to on-screen digitize features of interest. For indirect impacts of the SGR development on the thesis region, medium resolution imagery (30 m) Landsat 8 OLI imagery was analyzed. This thesis, therefore, factored both micro and macro land cover change indicators to best capture the complexities of the change.

1.2 Environmental Analysis

1.2.1 Remote Sensing Data

The thesis utilized free and open satellite imagery from the Landsat 8 mission. The Landsat 8 platform collects data across 11 spectral bands and has spatial resolution varying between 15 meters, 30 meters, and 100 meters. Subset of visible and near-infrared wavelength bands was produced and used in this thesis.

1.2.2 Image Pre-processing

Four cloud-free Landsat 8 OLI satellite images were obtained from the U.S. Geological Survey EarthExplorer web portal. Acquisition dates for the images were: 2016/03/28, 2017/01/10, 2018/01/29, and 2019/02/01, respectively. Geometrically corrected satellite images were cropped to the thesis area (2.5 km buffer zone of SGR line) and reprojected to the UTM (Universal Transverse Mercator) projection zone 37 south. Radiometric pre-processing was conducted with the *RStoolbox* R package (https://github.com/bleutner/RStoolbox) to correct for atmospheric scattering of RS radiation and to convert the raw Digital Number (DN) values to Top-of-Atmosphere (TOA) reflectance values. To analyze land cover change using remotely sensed images, the individual bands of Landsat images were stacked, and a subset of visible and near-infrared wavelength bands was produced (bands 1, 2, 3, 4, 5, 6, and 7). Normalized Differential Vegetation Index (NDVI) and Change Vectors (CV) were derived from the final image subset for analysis of the vegetation change across the thesis area.

1.2.3 Supervised Land Cover Classification

This thesis used the Maximum Likelihood Classifier (MLC) in ArcGIS to execute the supervised classification. First, training samples were generated using the Image Classification toolbar within ArcGIS software. Polygons representing the different land cover classes were delineated based on visual interpretation from the Google Earth Pro. Second, Geometric and radiometric pre-processed satellite images for each studied year were imported to the ArcGIS for MLC classification.

Due to high spectral variability in the thesis area, the best results were attained by classifying 10 preliminary classes in the first part of the analysis and then merging these classes to get the desired final 4 land cover classes. Table 3.1 shows the target land cover classes and the pixel values assigned to each from the classification.

Table 3. 1: Designation of classified image pixels in land cover map

Pixel Value	Land Cover Class
10	Built-Up Areas
20	Grasslands / Rangelands
30	Forests and Wooded Areas
40	Croplands and Bare Fields

The final classifications were assessed for accuracy using ground truth data obtained from high-resolution imagery. Assessments points were generated using stratified random sampling with Cohen’s kappa statistic and confusion matrix were generated for quantification of the accuracy (Cohen, 1960).

1.2.4 Land Cover Change Analysis

The thesis examined changes that occurred between the years across the thesis area. One-year epochs were examined, in this case, the changes between 2016–2017, 2017–2018, and 2018–2019. The overall changes between 2016 and 2019 were also examined to see what the aggregate differences across the entire period were.

1.2.5 Normalized Difference Vegetation Index (NDVI) Analysis

Aside from general land cover changes, the thesis specifically sought to determine the impact of changes on vegetation across the thesis area. The NDVI (Tucker, 1979) has become a widely used method for assessing changes in land cover and also to forecast future changes in land cover

(Sahebjalal and Dashtekian, 2013). The NDVI was calculated for the different years and used as a proxy for the vegetation change on the ground over time. The NDVI relates to red and near-infrared bands in a ratio whose formula is in equation I below. The magnitude of the index varies between +1 and -1 and gives a proxy of vegetation biomass in the area by separating green vegetation from other surfaces because the chlorophyll of green vegetation absorbs red light for photosynthesis and reflects the near-infrared (NIR) wavelengths. The formula used to calculate the NDVI is as outlined in equation 1 below.

$$NDVI = \frac{(NIR - \mathrm{Re}\,d)}{(NIR + \mathrm{Re}\,d)}$$ **(Equation 1)**

The *Raster calculator* tool in ArcGIS software was used to compute differences between NDVI values for different years to be able to identify and map the most significant changes in land cover in the thesis area.

1.2.6 Change Vector Analysis

For this task, the *RStoolbox* library in R software was used, with Principal Components Analysis (PCA) performed first to reduce the dimensionality of the data. Because CVA is limited to two dimensions, the Red and Near-Infrared (NIR) bands were considered. In the CVA, the first band serves as the X-axis, while the second serves as the Y-axis. Angles from the Y-axis are calculated and returned in degrees (from 0 to 360), with the magnitude of change given in a metric ranging from 0 to 1. CVA indicates the direction of the greatest change as well as the magnitude of that change. The CVA data was visualized using maps.

1.2.7 Forest Clearance Analysis

High-resolution satellite imagery from the Google Earth Pro was used to map the exact strip of forest cleared for the SGR railway track. The delineation of the railway track through the forest on high-resolution imagery was necessary to get a high precision estimate of the acreage of forest stripped to pave way for the railway track itself. This enhances the analysis of changes in the forested class in satellite image classification, which looked not only at the SGR strip but also at adjacent forested areas.

1.2.8 Excavated Areas Analysis

High-resolution satellite imagery from the Google Earth Pro was also used to delineate excavated areas that were dug during the building of the SGR track. These dug areas were mapped and converted from Google Earth Keyhole Markup language (*.kml) data to vector shapefiles (*.shp) to be able to map and calculate the acreage of the excavated areas. Descriptive statistics were used to describe these excavations along the SGR railway track and define their characteristics.

1.2.9 Demolished Houses Analysis

Within the 2.5 km buffer zone, high-resolution imagery analysis from the Google Earth Pro was used to map out residential dwellings that were demolished to make way for the SGR railway track. The houses were divided into big houses (approximately for four or more people) and small houses (housing 2 or fewer people). All of this was mapped to assess the impact of the SGR development on residential areas and dwellings.

1.3 Accuracy assessment

Land cover accuracy assessment reference points were generated using stratified random sampling, a technique that generates sampling points for each class whose number is based on the size of the class. These assessment points were filled out using ground truthing data from the high-resolution Google Earth imagery and thereafter used to compute accuracy metrics. A confusion matrix, also known as a contingency table, visually represented the difference between predictions from the classification and actual classes on the ground. It quantified how often one class was mislabeled as another and helpful for assessing the accuracy of the results. The Kappa statistic, also known as Cohen's Kappa (Cohen, 1960), is a coefficient that indicated inter-rater agreement, determining the degree of agreement between the observed and actual classes. Two raters, in this case, the classification and ground truth data, classify N number of items into C mutually exclusive categories. It considers the possibility of an agreement between the two raters occurring purely due to chance. It thus provides a more rigorous metric to evaluate the accuracy of the classification. Kappa is given by equation 2.

$$\kappa \equiv \frac{p_0 - p_e}{1 - p_e} = 1 - \frac{1 - p_0}{1 - p_e}$$ **(Equation 2)**

Where;

p_0 Is the relative observed agreement among raters (the accuracy)

p_e Is the hypothetical probability of chance agreement

Kappa is 1 when the raters are in complete agreement and 0 when there is no agreement other than what would be expected from chance. Both the confusion matrix and its associated Kappa statistic were generated for the 2019 land cover map.

1.4 Social Impact Analysis

1.4.1 Household Survey

A household survey was conducted to gather the perspectives of people living in the thesis area. A semi-structured questionnaire was used to collect information from 100 respondents about the various effects of SGR development. The sample size was selected through a combination of convenience and purposive sampling. This sample size was determined based on practical considerations, aiming for a balance between representation and feasibility within the thesis's constraints. The collected data was digitized to database, and tables were created in spreadsheet software to show the various effects of the land cover change on the people who live in the area. Through cross-analysis of the two aspects, the goal was to correlate environmental changes to socioeconomic changes.

1.4.2 Ethical considerations

Ethical guidelines were strictly followed throughout the research process. Informed consent was obtained from all participants in the household survey, ensuring their anonymity and confidentiality. Additionally, permissions were acquired for the use of satellite imagery and GIS data.

CHAPTER FOUR

RESULTS

This section discusses the findings resulting from the analysis described in the methodology section above. Infographics such as maps and graphs are used to visually illustrate the outputs of the thesis, alongside tabular information.

4.1 Land Cover Results for 2016, 2017, 2018 and 2019

Figure 4.1 shows a close-up of the 2019 land cover map highlighting the SGR line cutting through the thesis area. One of the striking features of the land cover maps produced is the visible outline of the SGR track in the latter years which clearly shows the line running through the area of interest.

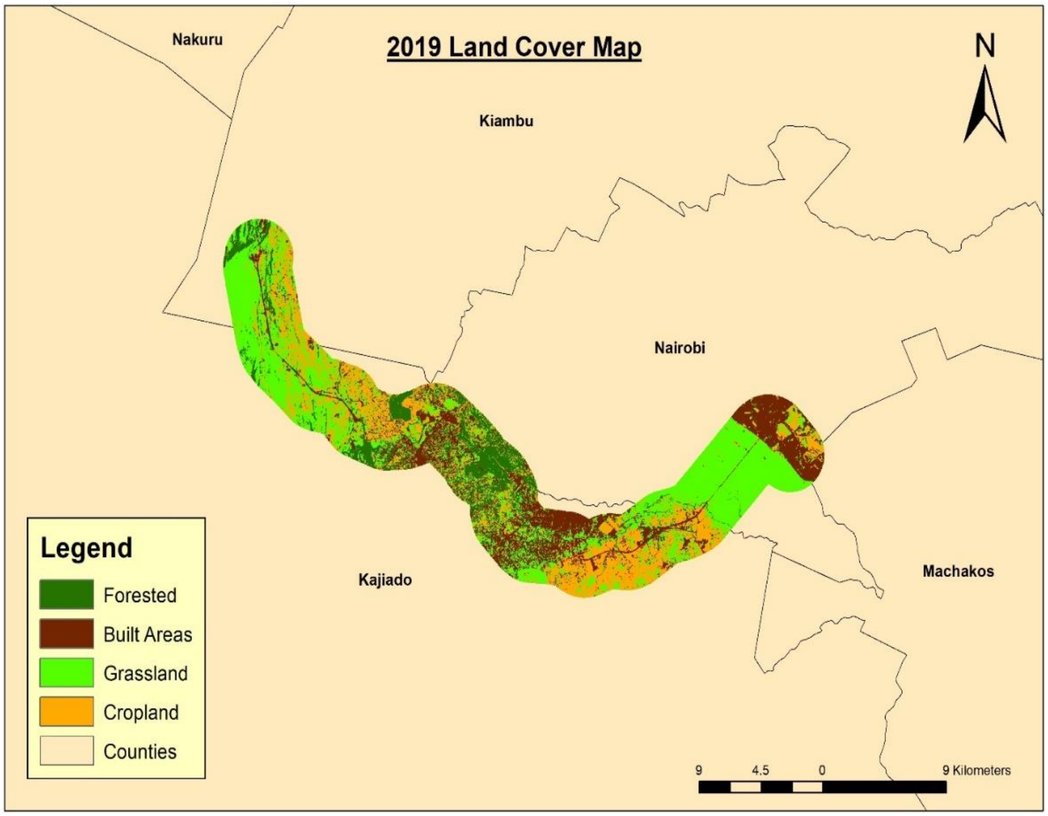


Figure 4. 1: Map of 2019 land cover of the thesis area from supervised classification

The SGR track falls under the class of the built area and can be seen snaking right across the thesis area from east to west. Concentrations of the class of the built area occur to the east of the thesis area and near its center. A significant part of the thesis area is shown to fall under the grassland class with the cropland class interspersed. The forested class is mostly dominant towards the middle of the thesis area with some of it also appearing at the top left of the area.

4.1.1 Accuracy Assessment

Table 4.1 shows the confusion matrix for the 2019 land cover map. From the confusion matrix, type 1 errors also known as user's accuracy are given by the rows of the data and show that classes urban areas and cropland have the highest errors of commission. This represents false positives where pixels were classified into the wrong class. Type 2 errors also known as producer's accuracy are given by the columns of the matrix and show that errors of omission are highest for the forested and grassland classes. This represents errors of omission where pixels that ought to have been classified into a class were left out. The Kappa statistic showing the overall accuracy indicates that the classification achieved close to 82% accuracy.

Table 4. 1: Confusion Matrix for 2019 Land Cover Map

Class	Urban	Grassland	Forested	Cropland	Total	U. Acc
Urban	7	3	0	1	11	0.636364
Grassland	0	20	0	0	20	1
Forested	0	0	10	0	10	1
Cropland	0	3	0	10	13	0.769231
Total	7	26	10	11	54	0
P. Acc	1	0.769231	1	0.909091	0	0.87037

Source: Kappa Statistic: 0.817919

4.1.2 Land Cover Change Analysis Results

Figure 4.2 shows land classification for the period between 2016–2019. Land cover change analysis was conducted for different epochs. The thesis looked at the changes occurring across each year and then cumulatively at the changes that occurred across the entire four-year period. The following findings are broken down by epoch then the cumulative changes across the entire period are presented.

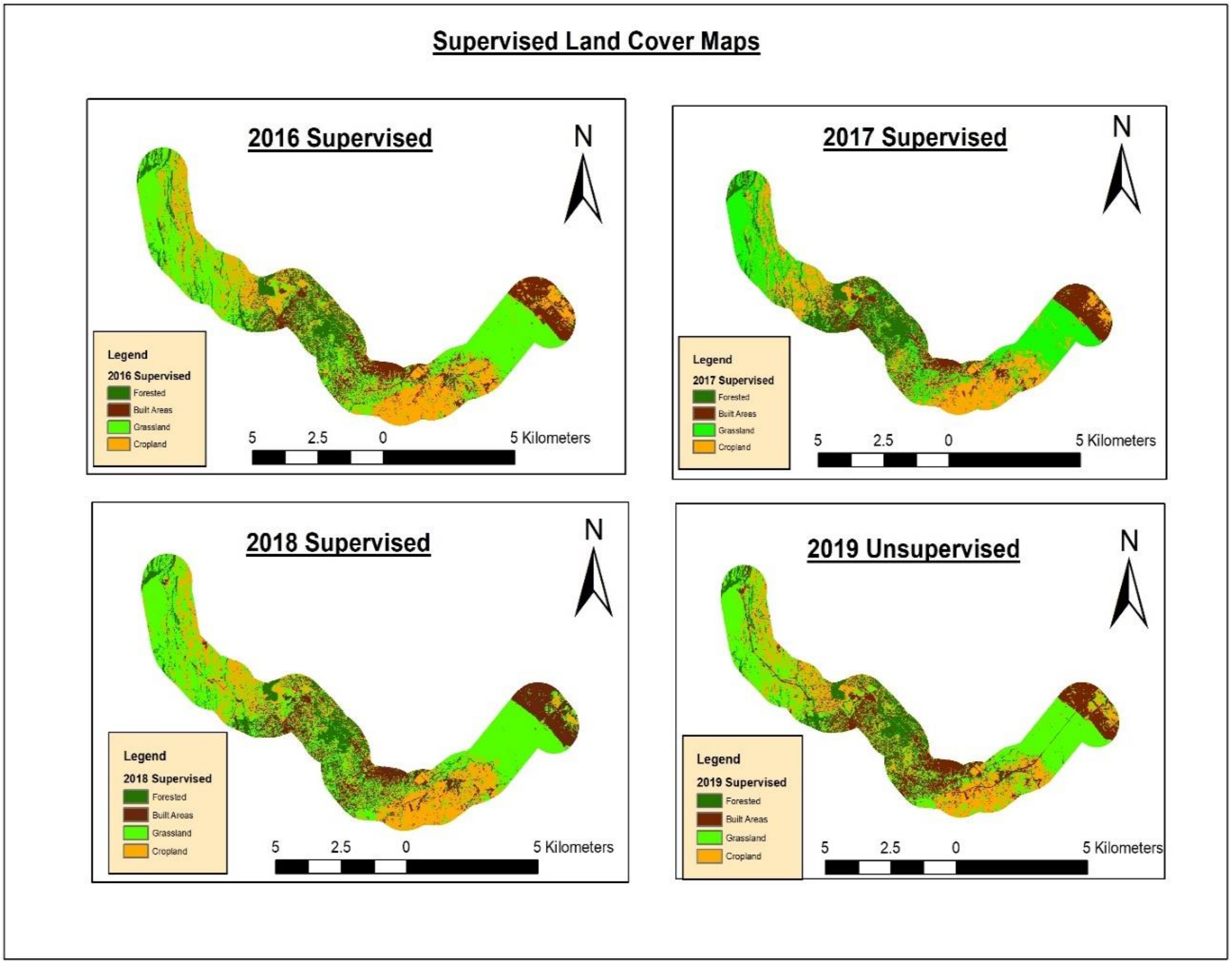


Figure 4. 2: Grid of supervised classification results for 2016-2019

4.1.2.1 Land Cover Change 2016-2017 Epoch

Figure 4.3 shows 2016–2017 land cover changes with gains being indicated to the right of the graph while the left shows losses. Analysis of this epoch shows that the classes that experienced the highest change are grasslands, croplands, and built areas.

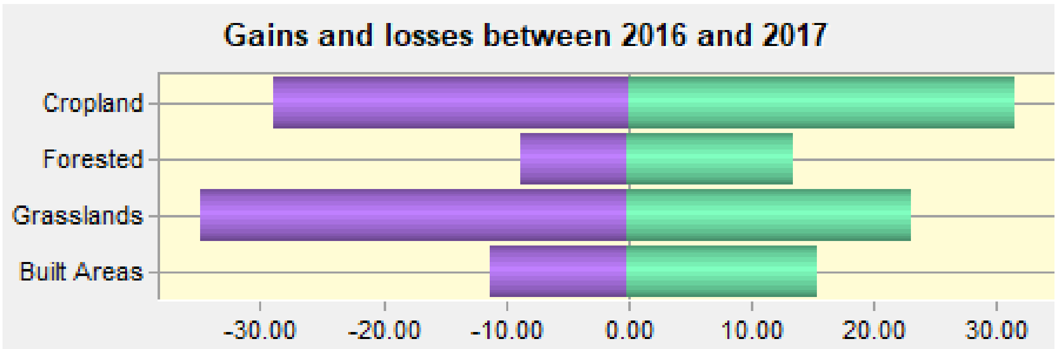


Figure 4. 3: Land cover gains and losses between 2016 and 2017 (in sq. km)

All classes experienced some losses and gains in cover between 2016 and 2017. Croplands had slightly more gains than losses while grasslands had more losses than gains.

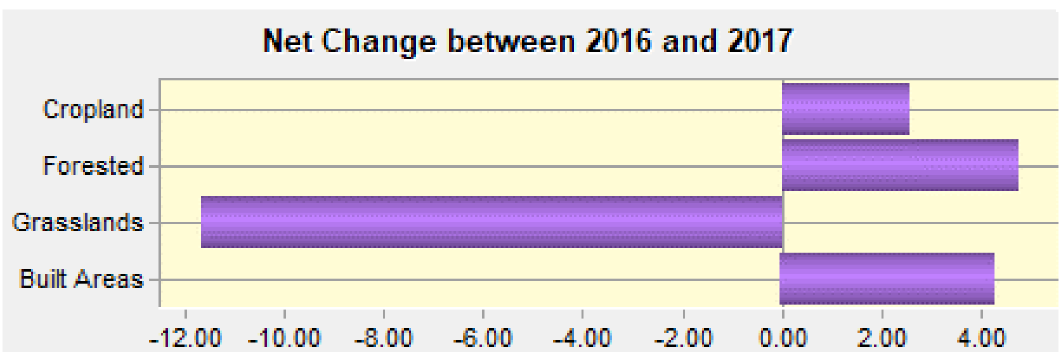


Figure 4. 4: Net change in land cover classes between 2016 and 2017 (in sq. km)

A look at the net changes shows that grasslands reduced significantly while the rest of the classes experienced a net increase during the 2016–2017 epoch (Figure 4.4). This might be indicative of the changes from fallowing land to cropland during a growing season.

4.1.2.2 Land Cover Change 2017–2018 Epoch

Analysis of this epoch shows that all classes again experienced gains and losses with grasslands and croplands showing the highest changes (Figure 4.5). In this epoch, built areas also show a significant change while forested areas experienced the least changes.

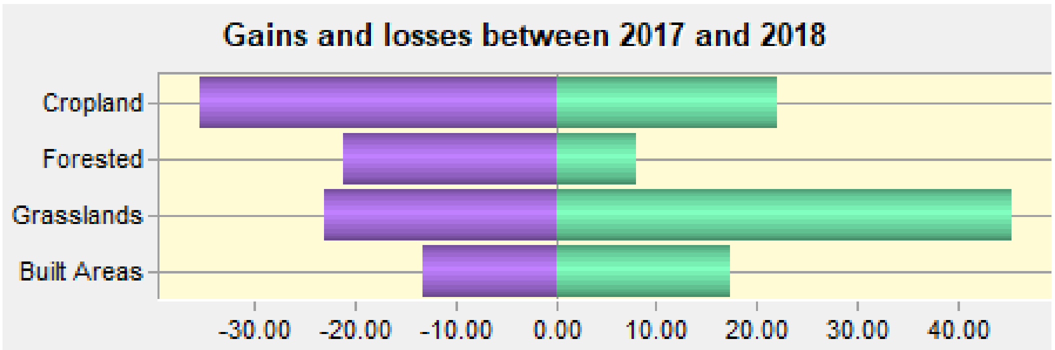


Figure 4. 5: Land cover class gains and losses between 2017 and 2018(in sq. km)

Grasslands gained up to 45 sq. km while they lost around 23 sq. km during this epoch. Croplands on the other hand lost the largest area with close to 35 sq. km being lost while 23 sq. km were gained.

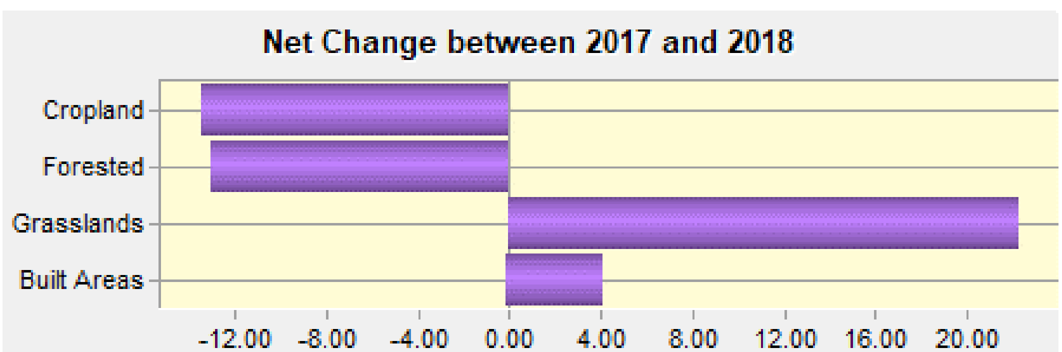


Figure 4. 6: Net land cover changes between 2017 and 2018 (in sq. km)

An analysis of the net changes shows grasslands gained as much as 22 sq. km (Figure 4.6). Built areas experienced only a marginal net gain of around 4 sq. km.

4.1.2.3 Land Cover Change 2018–2019 Epoch

Figure 4.7 shows how the different classes changed during this period. Grasslands increased by close to 28 sq. km while decreasing by as much as 40 sq. km. Croplands on the other hand increased by 29 sq. km while decreasing by 28 sq. km. Built areas increased by 22 sq. km while decreasing by 14 sq. km. Forested areas show an increase of 13 sq. km and a decrease of 8 sq. km.

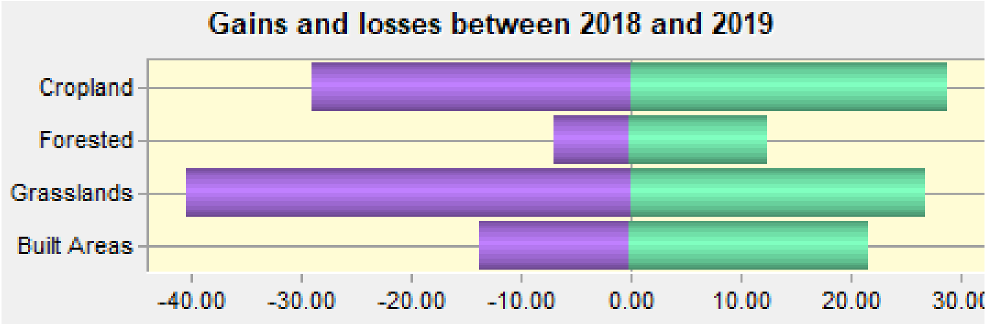


Figure 4. 7: Land cover classes gains and losses between 2018 and 2019

Overall it can be seen that the grassland class experienced the highest changes, consistent with the previous epochs examined.

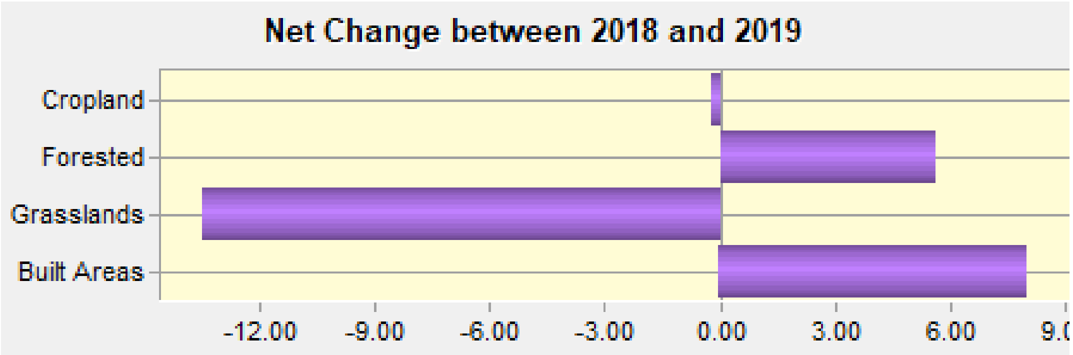


Figure 4. 8: Net land cover changes between 2018 and 2019

Analysis of the net changes shows that grasslands lost around 14 sq. km in total while built areas experienced a net gain of 8 sq. km (Figure 4.8). On the other hand, forested areas experienced net gains of around 5 sq. km during the period with croplands having insignificant changes.

4.1.2.4 Overall Changes between 2016 and 2019

This analysis looked at the changes that occurred between the years 2016 and 2019 to get an overall picture of how things had changed across the four years. Figure 4.9 to figure 4.13 show findings from the overall change analysis across the four-year period.

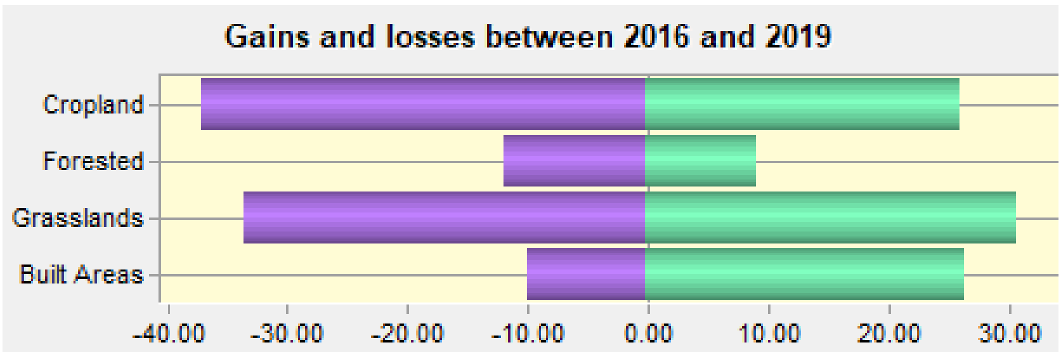


Figure 4. 9: Land cover classes gains and losses between 2016 and 2019

Over the four-year period, results show that croplands and built areas increased by 26 sq. km (Figure 4.9). However, croplands decreased by 38 sq. km while urban areas reduced by only 10 sq. km. Grasslands on the other hand increased by 30 sq. km while reducing by 34 sq. km. Finally, forested areas had the least changes increasing by 9 sq. km while reducing by 12 sq. km.

Mapping out the exchanges between classes over the period shows changes were distributed across the thesis area (Figure 4.10). The eastern part of the thesis area where the national park lies had the least changes compared to the rest of the area. Aside from mapping out the changes, it was also important to map out class persistence across the four-year period. This was to indicate areas that had the highest stability during the period as they did not change much through those four years.

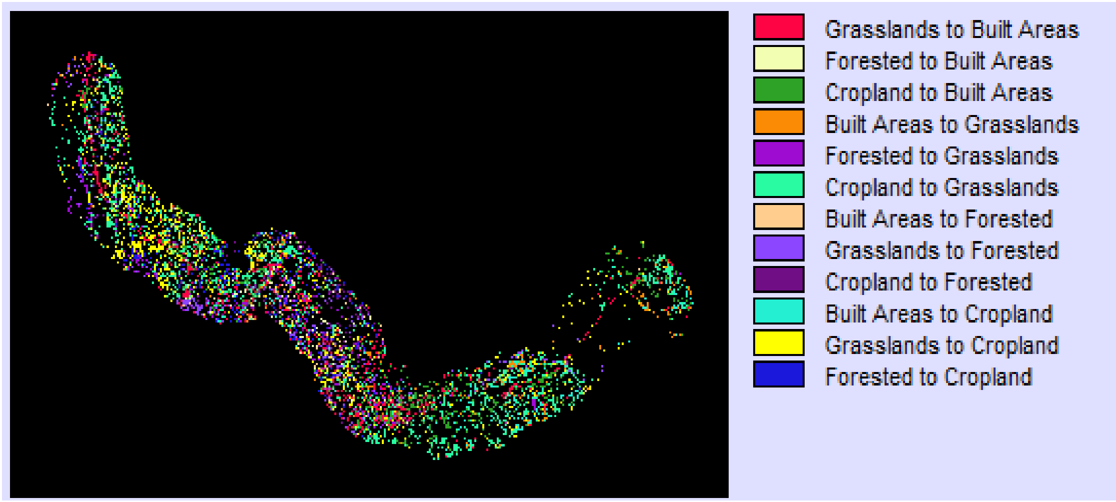


Figure 4. 10: Map of changes in land cover classes between 2016 and 2019

Figure 4. 11: Map of persistence in land cover classes between 2016 and 2019

The persistence map (Figure 4.11) shows that the extremities of the thesis area were the most stable. The eastern part especially shows high stability as the size of both the national park and the residential area next to it remained quite stable across the four (4) years.

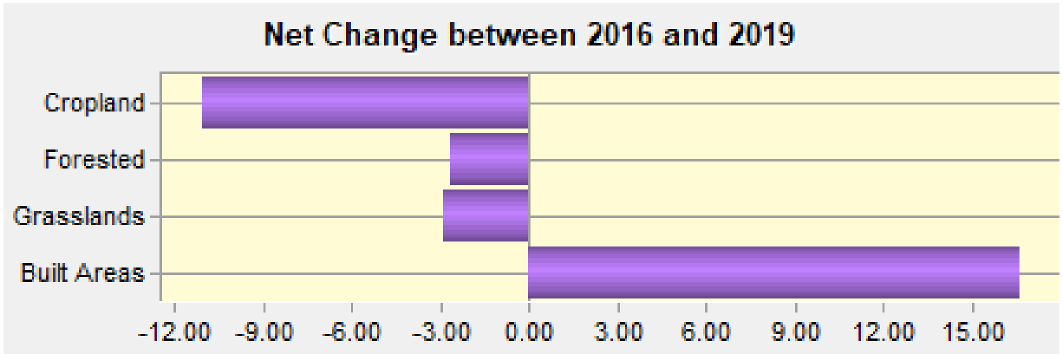
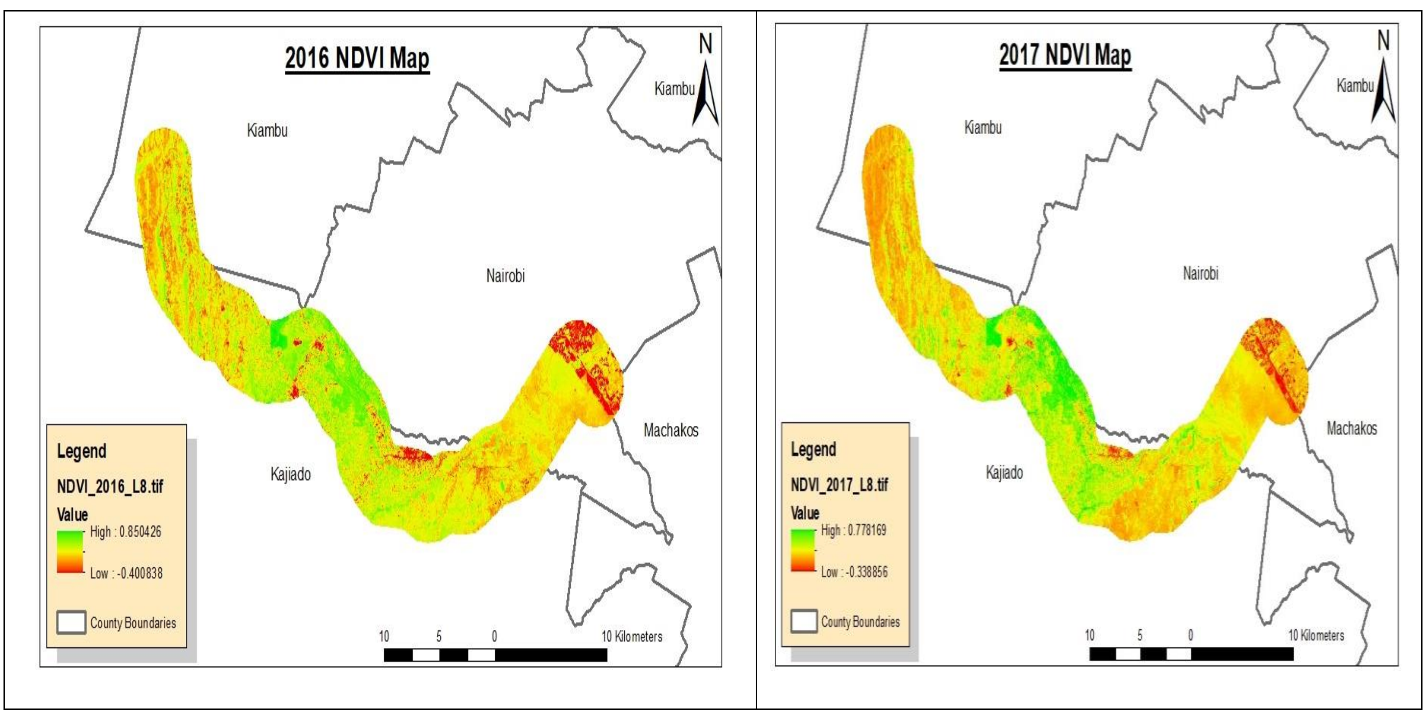


Figure 4. 12: Net land cover changes between 2016 and 2019 (in sq. km)

Analysis of the net changes for each class shows that built areas were the only class that gained acreage with a net increase of 17 sq. km (Figure 4.12). Cropland lost the most with an 11 sq. km reduction while grasslands and forested areas had almost similar reductions of about 3 sq. km each.

4.1.3 Mapping NDVI

Figure 4.13 shows maps of NDVI index values for each of the four years.



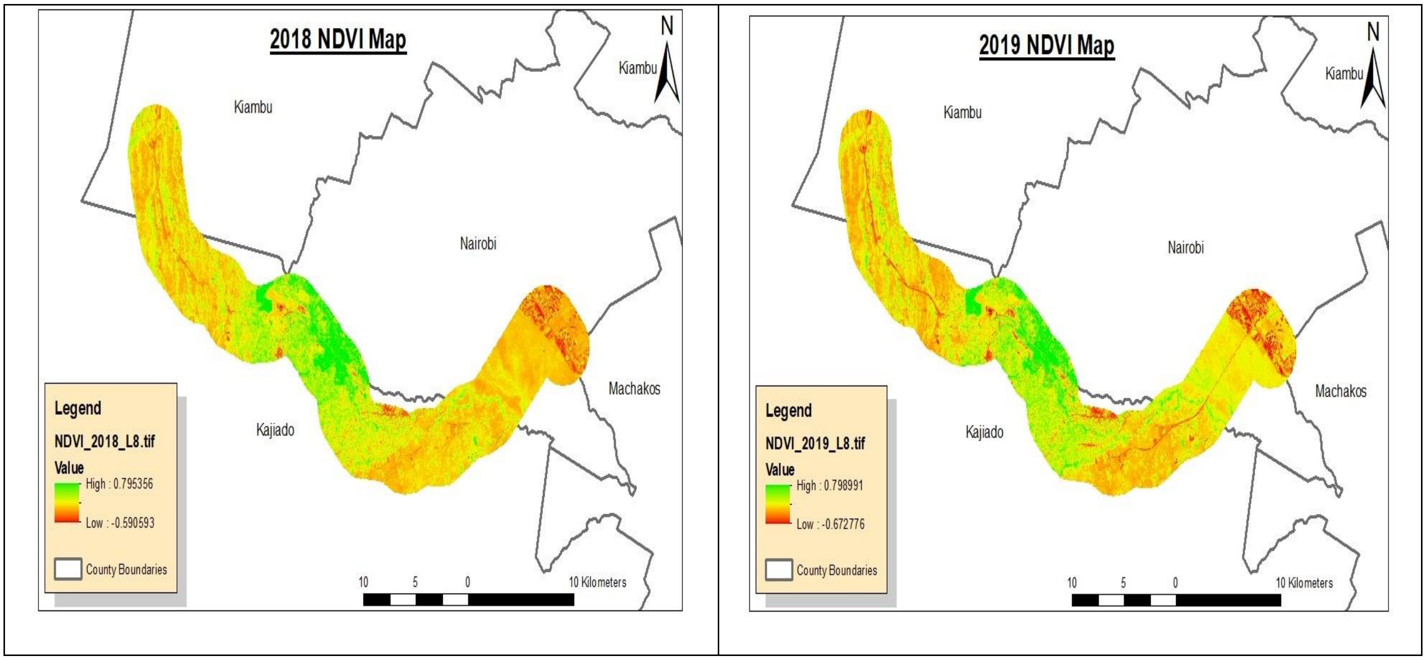


Figure 4. 13: Map of Normalized Difference Vegetation Index (NDVI) for 2016, 2017, 2018 and 2019

In this year 2016, the railway track of the SGR project is not yet visible on the NDVI map (Figure 4.13). This could be because the image was captured during a season when the vegetation was still heavy and thus obscured the tracks. The effect of the same enhanced vegetation density is seen on the right side of the map where built areas seem to have more vegetation during this year compared to the others. These could be manifestations of phenological changes in vegetation sensitive to the rainy season. In 2018 the SGR line becomes visible in the western part of the thesis area (Figure 4.13). The railway track can be seen running from the top left of the map to its central region.

In the 2019 map, the SGR railway track becomes visible across the extent of the thesis area. The central region of the thesis area has the highest NDVI values because that is where the forested and croplands classes intermix. These are the two classes with the densest vegetation compared to the grasslands class and built areas. The SGR line is not very visible in the central region with forested and dense vegetation although slivers of it can still be spotted. However, it is quite visible in the rest of the thesis area, particularly across the grasslands and cropland classes.

4.1.4 NDVI Difference Maps

The difference between NDVI across the years was also looked at to examine where the NDVI index has changed most across the years. Maps of the NDVI differences between the years as well as across the whole period were created. Figure 4.14 show where the change in vegetation density was most pronounced.

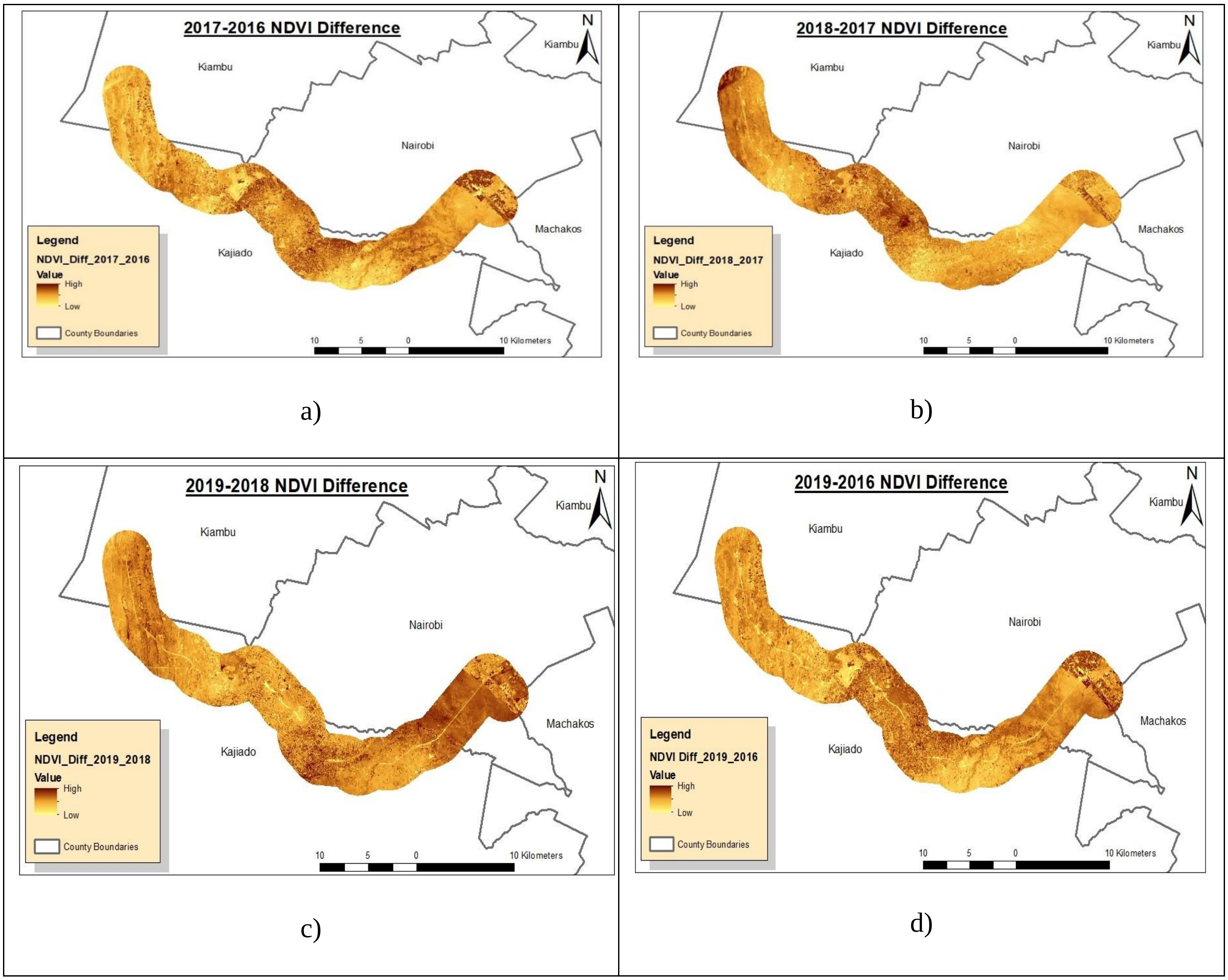


Figure 4. 14: NDVI difference map for the thesis area

In this 2016/2017 epoch, NDVI changes were seen to concentrate in the right part of the thesis area and the central region (Figure 4.14a). In the 2017/2018 epoch, the highest changes can be seen to have occurred in the western part of the thesis area and in the central region (Figure 4.14b). In the 2018/2019 epoch, the highest change in vegetation density seems to have occurred in the grasslands class as well as the croplands class, mostly in the east and central regions of the thesis area (Figure 4.14c).

A final analysis across the entire 2016 to 2019 period shows that the built areas class, grasslands, and croplands classes experienced the most significant changes in the NDVI values during this time (Figure 4.14d). This dovetails quite well with previous findings.

4.1.5 Change Vector Analysis

A change vector analysis was carried out to map out the angle and magnitude of the change vectors across the thesis area. Figures 4.15, 4.16 and 4.17 show the maps produced from this change vector analysis for several epochs.

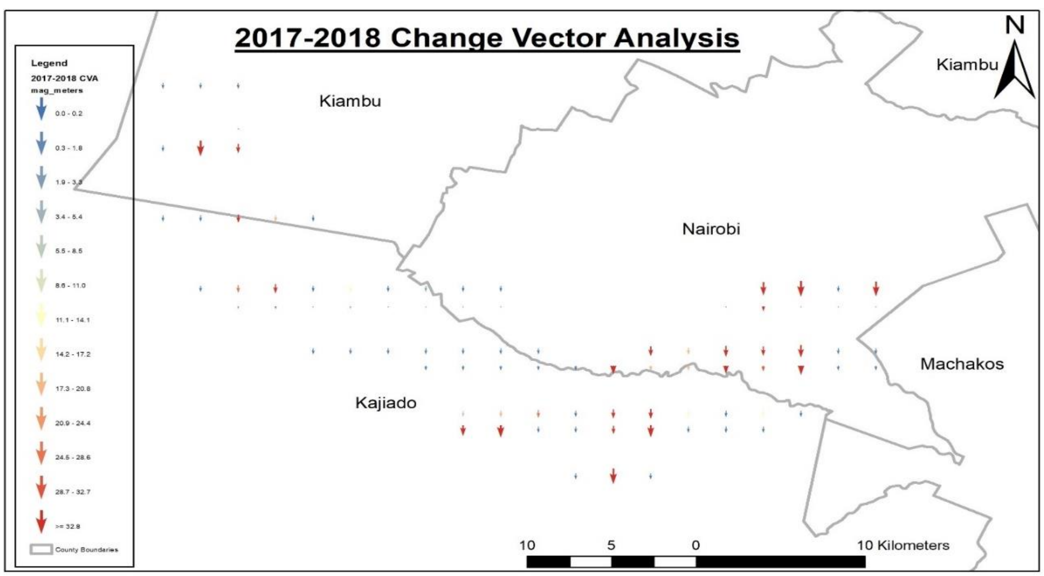


Figure 4. 15: Change vector analysis map for 2017–2018 period

In the 2017–2018 epoch the CVA shows the highest magnitude of change was experienced in the eastern and central regions of the thesis area, with only a little in the west (Figure 4.15). In the 2018-2019 epoch the CVA reveals that the highest magnitude of change occurred in the central region of the thesis area and a bit to the east as well (Figure 4.16).

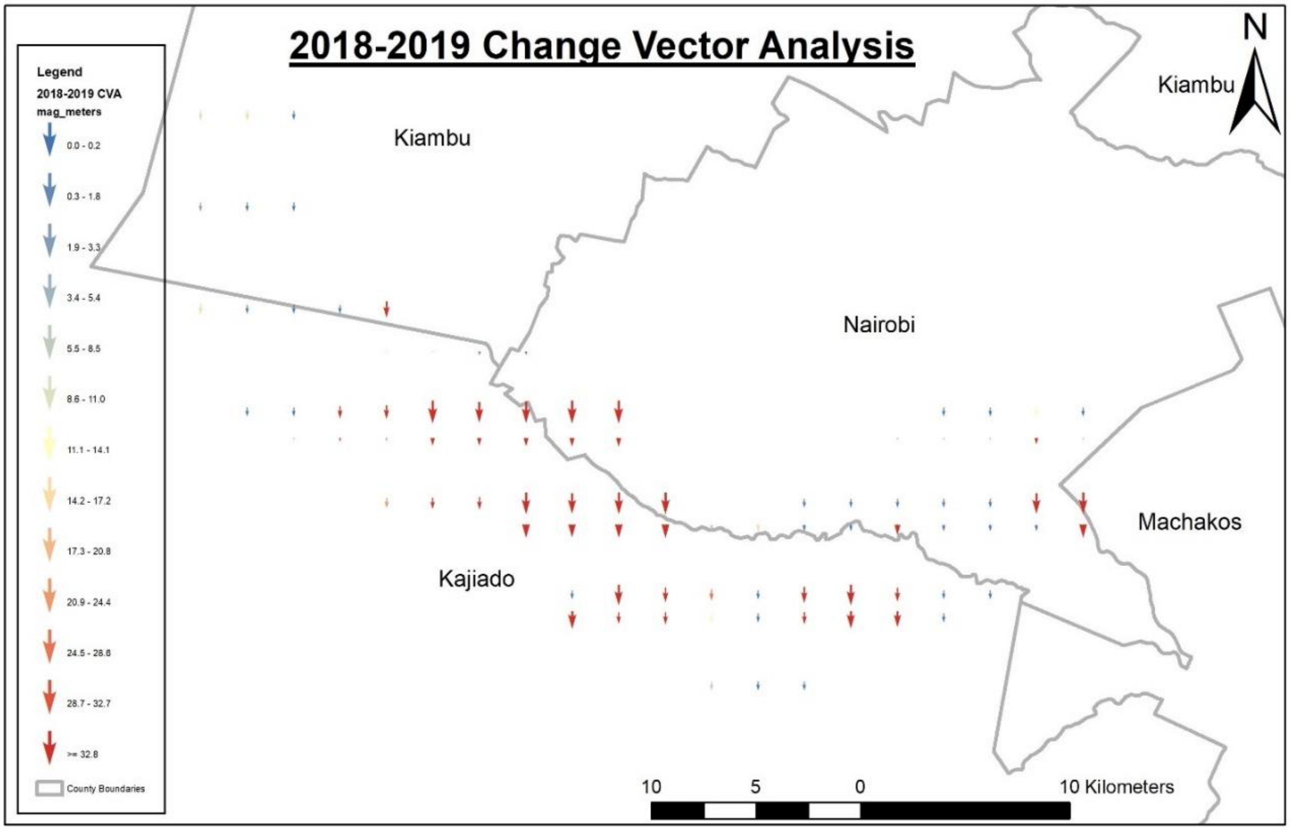


Figure 4. 16: Change vector analysis map for 2018–2019 period

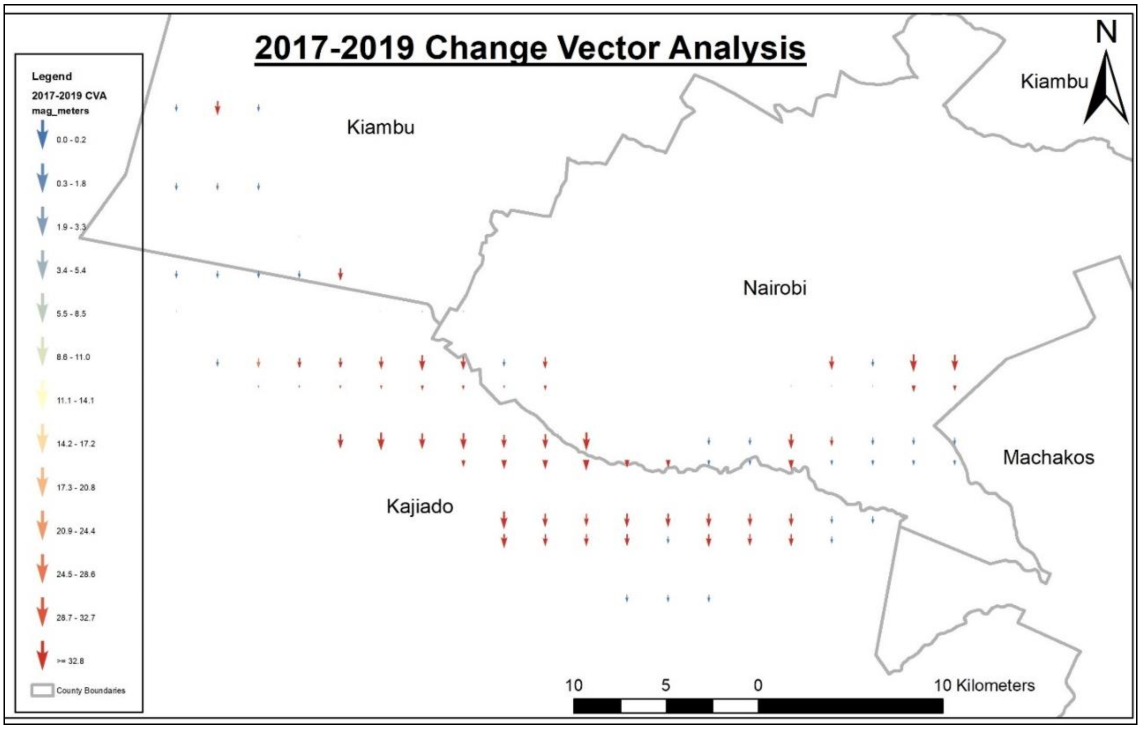


Figure 4. 17: Change vector analysis map for 2017–2019 period

A CVA analysis between 2017 and 2019 shows the magnitude of change is once again highest in the central region and tending towards the eastern part of the thesis area (Figure 4.17).

4.1.6 Mapping Forests Clearance

Figure 4.18 is a map showing where this clearance happened in the central region of the thesis area. An analysis of high-resolution imagery for forests cleared revealed that 0.173 sq. km of forests had been cleared along the railway track. The previous size of that forested area was 6.76 sq. km which got cut down to 6.58sq. km. This translates to 2.56% of that forest area cleared.

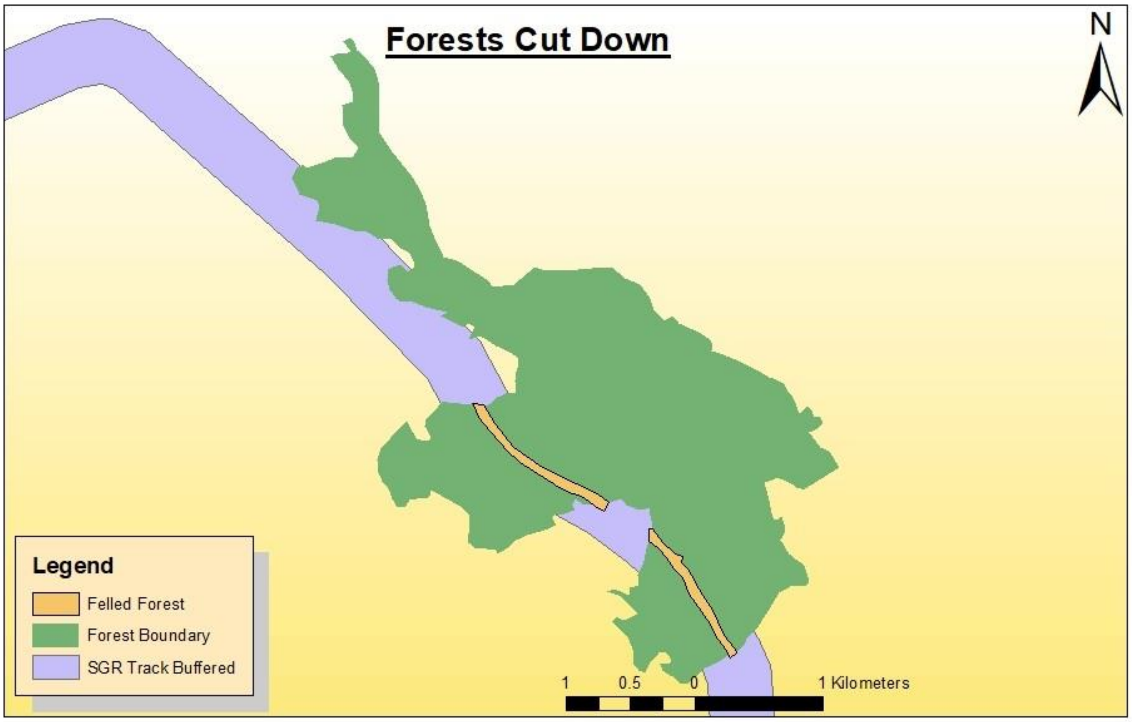


Figure 4. 18: Map of forests cut down to clear a path for the SGR track

4.1.7 Mapping Dug Out areas

An analysis of the dug areas revealed 15 sites that had been excavated. These locations were mapped, and summary statistics of their areas were generated as shown in table 4.2.

Table 4. 2: Values for the descriptive statistics of the dugout areas

Statistic	**Value (in sq. km)**
Count	15
Minimum	0.036556
Maximum	0.86938
Sum	1.786332
Mean	0.119089
Standard Deviation	0.202502

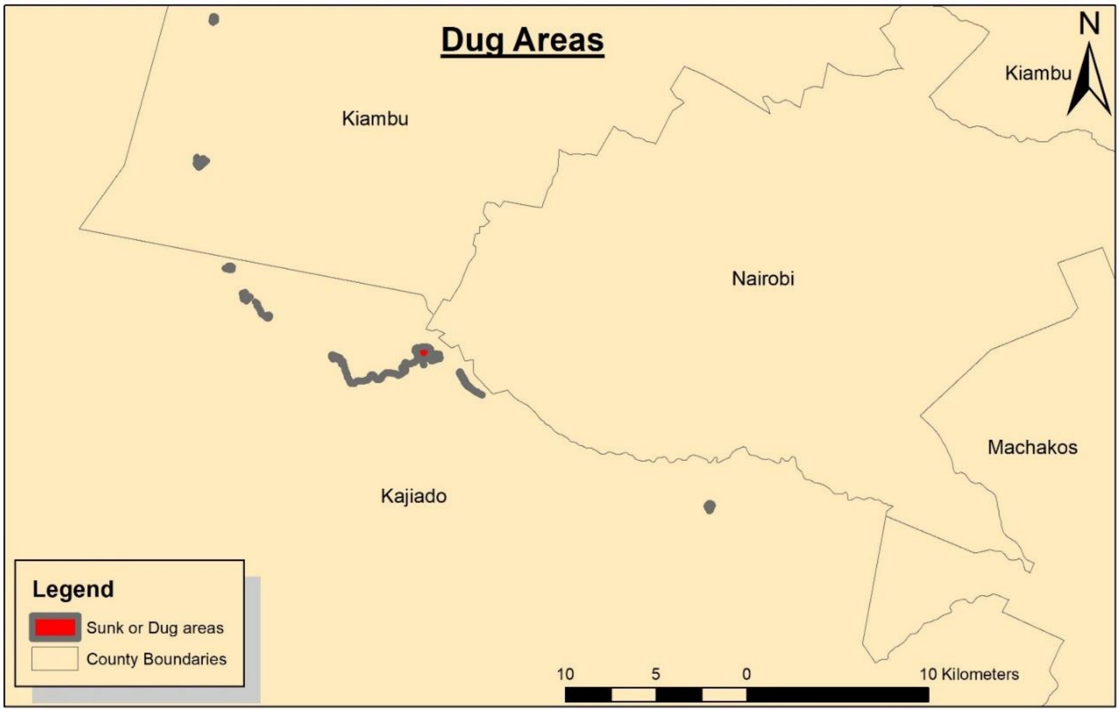


Figure 4. 19: Map of sunk or dug areas along the SGR transect.

The analysis shows a total of 1.786 sq. km were dug up and the mapping shows that most of this was concentrated around the central region of the thesis area (Figure 4.19).

4.1.8 Mapping Demolished Houses

An analysis of demolished houses using high resolution imagery enabled the mapping out of residences that were directly cleared for the SGR development. These have been shown in figure 4.20 and disaggregated by size and number of occupants into two categories.

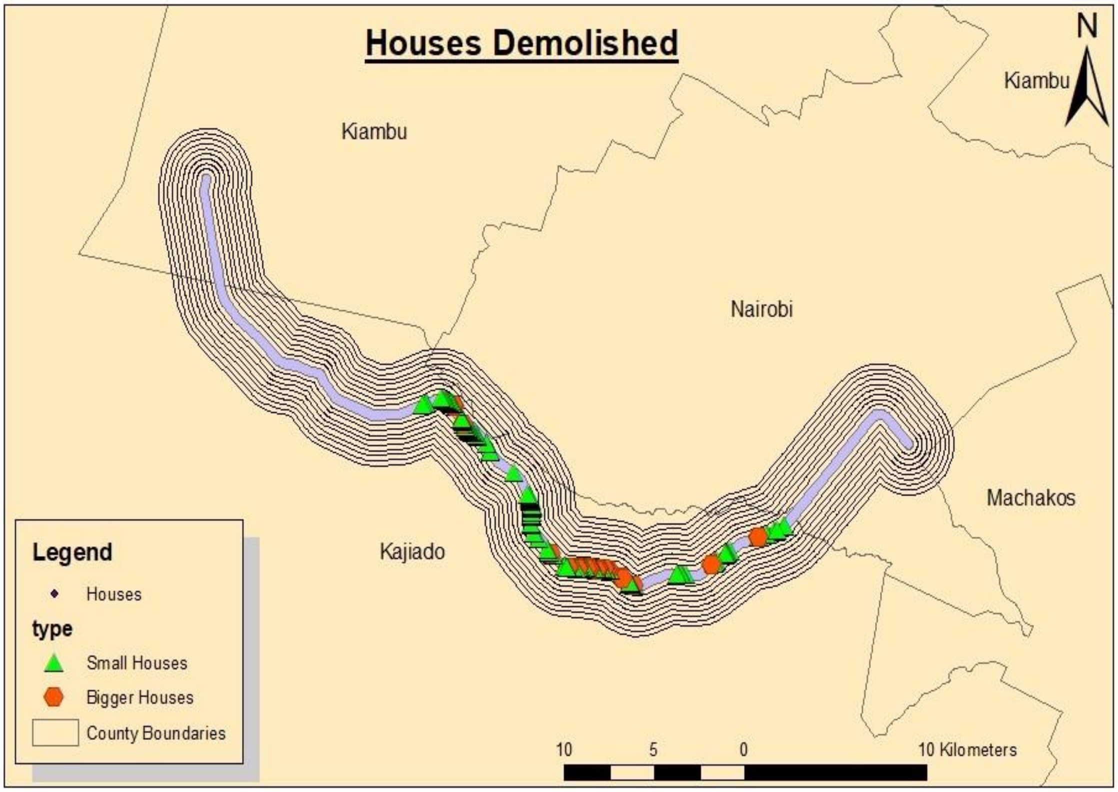


Figure 4. 20: Map of demolished houses along the SGR track

It can be seen that most of the activity occurred in the central region of the thesis area (Figure 4.20). This might be because this is the area through which the railway track passed and had the highest population density and residential houses. It appears that smaller houses along the track were demolished compared to bigger houses although they seem to be mixed in.

4.2 Social Impact Analysis Results

This section entails the socio-economic analysis findings as stated in the research methodology chapter.

4.2.1 Current Status after Displacement by SGR?

Table 4.3 shows the current status after displacement by SGR. The respondents were asked whether their current residence area was a result of displacement to pave way for the construction of SGR. Only 34% of the respondents had been displaced by the SGR project whereas 66% had not been displaced by SGR. Table 4.6 provide these details.

Table 4. 3: Current status after displacement by SGR

Displaced by SGR?		Frequency	Percent	Valid Percent	Cumulative Percent
	Yes	34	34.0	34.0	34.0
Valid	No	66	66.0	66.0	100.0
	Total	**100**	**100.0**	**100.0**	

4.2.2 Residents' Concerns about SGR Traversing their Residential Area

The researcher inquired from respondents about their feeling about the SGR traversing through their areas of residence. The respondents who were somewhat concerned totaled 35%, 33% were not concerned, 16% were extremely concerned whereas the remaining 16% were very concerned about SGR traversing their areas of residence, as shown in table 4.4

Table 4. 4: Residents concern on SGR traversing in area of residence

Concerned about SGR traversing your residential area?		Frequency	Percent	Valid Percent	Cumulative Percent
	Extremely concerned	16	16.0	16.0	16.0
	Very concerned	16	16.0	16.0	32.0
Valid	Somewhat concerned	35	35.0	35.0	67.0
	Not concerned	33	33.0	33.0	100.0
	Total	**100**	**100.0**	**100.0**	

4.2.3 Safety Levels Due to SGR Presence

On safety levels, 28% of respondents felt very safe, another 28% felt slightly safe, 23% felt extremely safe whereas only 21% felt not safe at all. In general, 79% of the respondents felt safe with the presence of SGR as shown in table 4.5. Those who felt unsafe stated possibility of accidents involving wild animals from the park and trucks, risks of diseases due to dust and flooding, and also environmental pollution both noise and air pollution from the sounds of engines and emissions from the engines respectively.

Table 4. 5: Safety levels due to SGR presence

Safety levels due to SGR presence		**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	Extremely Safe	23	23.0	23.0	23.0
	Very Safe	28	28.0	28.0	51.0
	Slightly Safe	28	28.0	28.0	79.0
	Not safe at all	21	21.0	21.0	100.0
	Total	**100**	**100.0**	**100.0**	

4.2.4 Dust Pollution as a result of the SGR

Respondents were also asked about their views about dust pollution brought about by the SGR in their environment. Most respondents agreed that the SGR had brought about dust pollution, 14% of the respondents viewed the converse while 10% were not sure, as shown in table 4.6.

Table 4. 6: Dust pollution as a result of the SGR

Any dust pollution as a result of the SGR		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	76	76.0	76.0	76.0
	No	14	14.0	14.0	90.0
	Not sure	10	10.0	10.0	100.0
	Total	**100**	**100.0**	**100.0**	

4.2.5 Effect of SGR construction through Nairobi National Park

The researcher inquired from respondents on their feeling on whether the construction of SGR through Nairobi National park had affected them in any way. Forty percent of the respondents indicated that they had been affected by the SGR construction, 45% of the respondents indicated that they had not been affected while 15% were not sure. Table 4.7 provides the details.

Table 4. 7: Effect of SGR construction through Nairobi National Park

Has SGR construction through Nairobi National Park affected you?		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	40	40.0	40.0	40.0
	No	45	45.0	45.0	85.0
	Not sure	15	15.0	15.0	100.0
	Total	**100**	**100.0**	**100.0**	

4.2.6 Flooding cases during rainy seasons

The researcher asked the respondents on whether they had experienced unusual flooding during the rainy seasons. 60% of the respondents answered to the affirmative, 37% of the respondents indicated that they had not experienced any flooding, whereas 3% were not sure, as shown in table 4.11.

Table 4. 8: Flooding cases during rainy seasons

Has any unusual flooding been noticed during rainy seasons?		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	60	60.0	60.0	60.0
	No	37	37.0	37.0	97.0
	Not sure	3	3.0	3.0	100.0
	Total	**100**	**100.0**	**100.0**	

4.2.7 Incidences of Water Borne Diseases

On whether there were incidences of waterborne diseases experienced by the community living in the neighborhoods of the SGR, 27% of respondents indicated that there were cases of diseases reported, 44% said that there were no incidences of waterborne diseases whereas 29% of the respondents were not sure, as shown in table 4.9. Those of the view that there were incidences of waterborne diseases mentioned of diarrhea, vomiting and malaria cases.

Table 4. 9: Incidences of water-borne diseases

Has there been incidences of water-borne diseases		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	27	27.0	27.0	27.0
	No	44	44.0	44.0	71.0
	Not sure	29	29.0	29.0	100.0
	Total	**100**	**100.0**	**100.0**	

4.2.8 Difficulties in Accessing Grazing Land

The researcher sought to establish whether there were any difficulties experienced in assessing grazing land as a result of the construction of the SGR. Of the total respondents, 35% answered to the affirmative, 46% of the respondents answered to the contrary whereas 19% were not sure whether there were any difficulties in assessing grazing land (Table 4.10).

Table 4. 10: Difficulties in accessing grazing land

Any difficulties in assessing grazing land?		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	35	35.0	35.0	35.0
	No	46	46.0	46.0	81.0
	Not sure	19	19.0	19.0	100.0
	Total	**100**	**100.0**	**100.0**	

4.2.9 Human–Wildlife Conflict

The researcher sought to find out whether the community living in the neighborhood of the SGR had witnessed any cases of human–wildlife conflict in the recent past. 80% of the respondents indicated that they had witnessed incidences of human–wildlife conflict, 18% indicated that they had not witnessed any human–wildlife conflict, whereas 2% of the respondents were not sure, as shown in table 4.11.

Table 4. 11: Human–wildlife conflict

Any cases of human–wildlife conflict		**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	Yes	80	80.0	80.0	80.0
	No	18	18.0	18.0	98.0
	Not sure	2	2.0	2.0	100.0
	Total	**100**	**100.0**	**100.0**	

4.2.10 Levels of noise pollution with the advent of SGR

About the levels of noise pollution with the advent of the SGR, 61% point out that there were high levels of noise pollution, 5% said that there were moderate levels of noise pollution, while 34% of the respondents indicated that there were low levels of noise pollution since the construction of SGR, as shown in table 4.12.

Table 4. 12: Levels of noise pollution

Your opinion on levels of noise pollution		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	34	34.0	34.0	34.0
	Moderate	5	5.0	5.0	39.0
	High	61	61.0	61.0	100.0
	Total	**100**	**100.0**	**100.0**	

4.2.11 Possible Positive Impact of SGR on the Surrounding Community

The researcher sought to establish what the respondents thought on the possibility of any positive impact of the SGR on the surrounding. 57% of the respondents said that they foresaw a positive impact, 28% thought that there was no positive impact while 15% were not sure about any possibility of positive impact, as shown in table 4.13. The positive impact entailed the creation of jobs, the connection of towns, economic growth, increased population along the SGR corridor as well as increased business opportunities.

Table 4. 13: Possible positive impact of SGR on the surrounding community

Will SGR have any positive impact on the surrounding community?		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	57	57.0	57.0	57.0
	No	28	28.0	28.0	85.0
	Not sure	15	15.0	15.0	100.0
	Total	**100**	**100.0**	**100.0**	

4.3 Measures to Mitigate Environmental Challenges As a Result of SGR

The researcher sought to establish the measures that should be implemented to correct the challenges brought about by the advent of SGR. The majority of respondents recommended the planting of more trees, putting in place measures to control dust and noise pollution, securing the park, rehabilitating the park, relocating the stone crushing sites, and creating more water drainage channels.

CHAPTER FIVE

DISCUSSION

5.1 Changes in land cover classes

The results from the land cover change analysis shows a clear increase in area under the built areas class starting at 46 sq. km and ending up at 63 sq. km. All the other three classes seem to have some amount of fluctuation where they go up and down at different times.

5.1.1 Built areas

The built areas class initially took up only 16% of the thesis area but over the four years had grown to cover close to 22% of the area. That's a change of 6% over four years or 1.5% per year. Similar findings were reported by Fitawok et al. (2020) who reported the conversion of other land classes to built areas as a result of the increased expansion of urban areas. In addition to the construction of the SGR line, another possible reason for the increase in could be due to the increase in urban population as a result of rapid urbanization in Kenya (Güneralp et al., 2017). This has led to increased pressure on agricultural lands, shrub land, grassland and other resources which are already limited. There are several reasons for the increase in urbanization, however, non has had such an impact by the devolution of resources over the past 20 years, initially initiated by the Constituency Development Fund in 2003 (Auya and Oino, 2013), and later the implantation of the devolved system of governance in 2013 (Njunguna, 2016). The ripple effects of this have been the increase in the construction of buildings, roads, and railways; leading to the creation of more employment opportunities (Ntara, 2013). The resulting impact has been a rapid increase in the urban population, for example, the urban population in Kenya in 2009 was 12.84 million (ROK, 2013), this has risen, and by 2019 the population was 14.83 million KNBS, 2019). Other causes of the increase in urbanization are infrastructure development (Nyumba et al., 2021) subdivision of agricultural lands (Ntara, 2013), and inefficient land use policies (Gichenhe and Godinho, 2019). The above findings call for efforts to sustainably manage the transitions to built areas, especially considering its negative impact on water resource quantity and quality (Nyumba et al., 2021).

5.1.2 Forest

The map shown in figure 4.19 demonstrates the portioning effect that the SGR track has had on the forest. The map shows that a once contiguous forest has been broken down into 3 smaller parts, making it vulnerable to transitioning. The impact of the development on the forest comes not only from the 2.56% of the forest destroyed to pave way for the track but also from the interruption of the ecosystem by the manmade feature. Deforestation can be attributed to a lack of public awareness of the role of forests in both environmental conservation and the economy (ROK, 2018). Additionally, there is a lack of adequate policy implementation on the conservation and protection of forests (Juma, 2012). The need to expand agricultural activities has further increased pressure on this forest with the growing demand for food as a result of an increase in the human population (Albertazzi et al., 2021). Changes in forest cover could potentially close off parts of the range enjoyed by wildlife living in that forest. The clearance also has implications for ecosystem services provision and mitigation against climate change as they influence the amount of carbon dioxide in the air (Longobardi et al., 2019). Other impacts of deforestation include degradation of water towers impacting water availability, and loss of biodiversity and habitat (Sang et al., 2022).

5.1.3 Cropland

The findings show that across the entire period cropland class declined by close to 13%, a situation that could have serious impacts on food security if not sustainably managed. Given the reduction that has happened in the size of the croplands class across the period, future productivity and the food security of the area might be impacted. The decrease in cropland can be attributed to the conversion of agricultural land to settlements i.e. increase in built area cover (Musa, 2015; Wandaka and Francis, 2019).

Since impacts on a forest affect the precipitation received in an area, a correlation of change in rainfall patterns with change in forested areas might reveal interesting information with implications for rain-fed agriculture. Having been partitioned into discontiguous pieces which enhances the risk of transitioning, the forested class requires close monitoring to manage future changes.

5.1.4 NDVI

The most significant NDVI changes were experienced in the 2018–2019 epoch compared to the 2016-2018 epoch. This dovetails well with the CVA analysis which highlights the 2018–2019 epoch as having experienced a higher magnitude of change. Changes in NDVI values indicates reduction in vegetation density which might have implications on soil erosion and flooding since ground cover modulates the action of surface runoff. Its loss should therefore be a concern and mitigating actions might be required.

Despite these changes, the findings of the thesis also show us that there is high persistence in the land cover classes across the period. This has implications since it shows the segmentation of the land cover into smaller patches might be preceding the transitions in land cover. This might indicate the importance of prioritizing areas with discontiguous land cover when targeting interventions to manage transitions sustainably.

5.2 Environmental and Social Impacts of the SGR Development

Along the SGR corridor, it is evident that all the natural systems are already affected by biological disturbance, pollution, and exploitation from the SGR development making them more vulnerable to impacts of climate change, which could lead to multiple ecosystem stressors (Staudt et al., 2013; Grimm et al., 2013).

The findings from the thesis show that natural land cover classes are transitioning into anthropogenic classes. Grasslands and forests are giving up land to built areas. The same can be seen happening in croplands.

5.2.1 Environmental impacts

Habitat fragmentation

The most obvious impact of the SGR has been habitat fragmentation, habitat alteration, and barrier effects. The SGR made way across key ecosystems such as parks, forests, and grasslands limiting the movement of both animals and reduction in available resources. The park's partitioning of both the rangelands in the Nairobi national park as well as the major forest has an impact on the habitat of wild areas. The research made a similar observation when they looked at the impact of road and rail infrastructure on wildlife. Wildlife residing close to infrastructure is mainly affected by vibration, noise, chemical pollution, and human presence (Dorsey et al., 2015). Planned mitigation measures of having underpasses and bridges to allow free movement of animals have been compromised by people settling around them. This was emphasized by most respondents with one of them saying “The underpasses have done nothing to aid the movement of animals; in fact, they created favorable areas for illegal settlement with the animals avoiding the areas entirely".

The destruction of a swathe of the forest as well as its partitioning might have an impact on the services it provides. In particular, there may be impacts on carbon sequestration, groundwater recharge, and the aesthetic appeal of the forest.

Ecosystem degradation

From an ecosystem services point of view, the reduction of vegetation might increase the risk of land degradation. Processes such as soil erosion, as well as unchecked surface runoff leading to floods, become more likely with a reduction in ground cover. This would impact the value of ecosystem services the soils of that area can provide. From the aforementioned illustrations, the change can be seen to be concentrated in the central portion of the thesis area. This is the same region where the core of the croplands class is located. The impact of reduced vegetation density which is shown by relatively high NDVI value changes in the cropland areas, should therefore be investigated further and its drivers identified.

Ecosystem destruction

One finding is that most of the forest clearance is in the central region of the thesis area. This might indicate a greater proportion of people in the thesis area live in this region. It also highlights where socioeconomic interventions to counter any negative effects of the SGR development can be targeted.

The analysis mapped out areas where pits were dug to get soil during the construction of the railway track. These excavated areas represent both a risk to people as well as the environment. During the rainy season, such open pits can hold water and become a drowning risk for children and livestock. In addition, they act as source points for sediments and might encourage soil erosion from the landscape.

Pollution

With regards to pollution, a majority of the respondents reported being impacted by the dust from the SGR project either during its development or afterward. Similar sentiments are expressed with regard to noise pollution where 61% of the respondents reported the impact of the SGR on their health. The respondents stated that noise pollution is mainly experienced when the trains are passing, and due to blasting during the construction stage. Dust pollution also came up as a challenge and there was increased evidence of pulmonary diseases i.e. coughs and chest pains. It can therefore be seen that the SGR has had a tangible impact on the population with regard to pollution. This is something that needs mitigating to prevent future deterioration of the health of residents in the area.

Flooding

Regarding water, 60% of the respondents reported having experienced flooding which they believe to be tied to the SGR development. The flooding may be indicative of the loss in vegetation cover. This will be exacerbated by the expected increase in precipitation extremes due to landscape stressors on natural vegetation leading to negative feedback as reported by McMahon et al, (2010). Similar reports of flooding along the SGR have been recorded. For example, Sang et al. (2022) reported flooding along underpasses when it rained while some rivers had been blocked due to the construction

5.2.2 Social Impacts

Pasture availability

The change of grasslands to built areas has implications for the future availability of fodder for livestock and wildlife. About a third of respondents also reported having difficulties accessing grazing lands due to the SGR development. This has impacts on the livestock in the area and might similarly be impacting the wildlife. The same issue of denied access to feeding grounds might be affecting wildlife causing them to venture into different areas already settled by people. Overall there seems to be some impact of the SGR on both domestic and wild animals, a factor that requires deeper investigation.

Human–wildlife conflict

A majority of the respondents reported having experienced human–wildlife conflict. This might be an indicator of human encroachment into wildlife habitats as natural classes transition to anthropogenic classes. The results show that human and wildlife ranges frequently overlap over the thesis area and increased cases of conflict are likely to arise in the future as more land transitions. This was emphasized by the respondents who observed that "previously there was minimal interaction between humans and wild animals, but since the construction of SGR there has been mushrooming of settlements on the buffer areas which has led to more close contact with wild animals".

Human displacement

On displacement due to the SGR development, a third of the respondents reported having felt this impact. This represents a significant, though non-majority, a portion of the population. About half of demolished houses were multi-resident dwellings housing several individuals. This illustrates the SGR development had housing impacts on some of the residents living in the area.

However, this is modulated by the information from table 4.13 which shows the majority of residents are not concerned about the SGR traversing through their area. The majority of the respondents also reported feeling safe about the SGR presence.

Despite the aforementioned challenges, over half the respondents (57%) reported net positive impacts of the SGR development. They cited the creation of jobs, economic growth, and increased business opportunities among the positive impacts the development had brought.

Mitigation Measures

The results of the thesis indicate that there has been significant land cover change along the SGR due to numerous factors. The changes have not only led to socio-economic impacts but also social-ecological impacts such as loss of biodiversity and habitat, water pollution, reduced river flows and groundwater recharge, and land degradation.

Various measures need to be taken to mitigate the negative impacts of the SGR.

Enforcement of a robust monitoring and evaluation program

With regards to land degradation, robust monitoring and evaluation program needs to be implemented to continuously watch over the landscape. Changes such as the decline in vegetation density ought to be regularly assessed. Further, interventions such as initiating soil protection measures should be targeted based on the findings of studies such as this one.

Incorporation of migratory routes for pastoralists

Impacts on domestic and wild animals due to part of their ranges being cut off also need to be mitigated. Underpasses for animal traffic were implemented at several points along the SGR track during its construction. More needs to be done to cater to the complaints of herders not being able to access certain fields. Mitigation of this impact might help reduce future instances of human–wildlife conflict.

Sustainable land management

Impacts on forested areas can be mitigated by ensuring sustainable land management within these areas (Branca et al., 2013). Techniques such as fencing could be taken into consideration but with allowances made for animal migration. Non-contiguous forested areas should be prioritized in implementing interventions to conserve the forests.

Enforcement of robust land management policies

Impacts on cropland and food security can be mitigated by controlling the rate of transitions from cropland to built areas. Implementation of zoning regulations where agricultural land is maintained free of housing might provide one way to do this. In addition, improved agricultural practices and intensified production can also be used to mitigate future food security concerns. In the future, policymakers should come up with robust policies considering that land management policies influence land cover change (Qian et al., 2015).

Incorporation of environment and socioeconomic development in land use planning

Impacts on displacement can be mitigated by resettling residents whose houses were demolished. For future infrastructure projects, participatory planning should be considered as it has been shown to enhance inclusivity which enhances sustainability. Other aspects of human impact such as pollution are more complex. Whereas dust pollution during development was mitigated by trucks with water sprinklers to keep the dust down, the same cannot be used during the operation of the SGR track. Other technologies might have to be employed in areas where residents are seriously impacted by dust. Noise pollution on the other hand is even harder to mitigate. The only possible option would be for the worst affected residents to be resettled further from the SGR track.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

This thesis has adeptly demonstrated the invaluable utility of Geographic Information Systems (GIS) and remote sensing (RS) techniques in assessing environmental impact. Integrating these technologies with socioeconomic analysis, the research has provided a robust foundation for characterizing the thesis area, comprehending the dynamic changes occurring within it, and drawing connections between these transformations and their ramifications on both the ecosystem and the local populace.

The thesis zone is presently undergoing a profound state of transition, as evidenced by the escalating dominance of the built area class at the expense of grasslands, croplands, and forestlands. This shift signifies a significant alteration in the landscape, precipitating a series of impacts, both direct and indirect, on the environment and the people inhabiting this region.

Building upon this, it is evident that the alterations observed in land cover over the years, as unveiled by the thesis's GIS and RS analysis, have multifaceted implications. The increased prominence of built areas, particularly in proximity to the SGR track, underscores the extensive transformations linked to the project's construction. The reduction of grasslands and croplands and the encroachment into forested areas depict a landscape in flux, which raises concerns about potential ecological disruptions.

Additionally, the socioeconomic analysis undertaken in this thesis has uncovered the human dimension of these environmental shifts. The experiences of individuals who have been displaced, concerns expressed by local residents, and reports of dust pollution, flooding during rainy seasons, and waterborne diseases all underscore the real-world consequences of these environmental changes.

To address the multifaceted challenges arising from this transitional phase, mitigation measures are essential. It is crucial to formulate and implement policies and strategies that strike a balance between infrastructure development and environmental conservation. Informed decision-making and proactive interventions are necessary to ensure the sustainable coexistence of the SGR project and the well-being of both the ecosystem and the community. The comprehensive insights obtained through this thesis underscore the need for further research and monitoring in the region, as the landscape continues to evolve.

6.1.1 Recommendations

Despite the fact that this thesis was able to successfully investigate the changes in land cover and environmental impacts of SGR using GIS, remote sensing, and household surveys. It is recommended that more detailed studies be carried out to better understand the more hidden processes behind the change. For instance, detailed hydrologic modeling is needed to understand how the above-ground changes in the forested class affect below-ground resources such as groundwater and aquifers. Similarly, modeling of species distribution and habitats is needed to better understand the impact of these changes on the wildlife. A thesis on pollution in the area and how to address is also recommended given the sentiments expressed by residents on the ground. Finally, it is recommended that further studies be done on those areas shown to be at risk of land degradation. The thesis should extend to finding ways to improve agricultural practices in the area to both prevent land degradation and also promote its productivity.

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APPENDICES

Appendix I: GIS Remote Sensing Tools – Scripts

```
#####################################################################
# R script to pre-process Landsat images using RStoolbox
# and raster packages and to crop images to study area extent.
# Radiometric Calibration and Correction,
# Before running this code unzip Landsat tif images (zipped gz.tar)
# to a folder that will be then defined by setwd() function
# copyright @ Mika Siljander August 2019
#####################################################################

rm(list = ls())
dev.off()

.libPaths("C:\\rlibs\\3.6.0")
.libPaths()
setwd("C:\\Users\\Public\\Lape")
getwd()
library(raster)
library(RStoolbox)

LC08_2016 <- stack("LC08_20160225.tif")
LC08_2017 <- stack("LC08_20170110.tif")
LC08_2018 <- stack("LC08_20180129.tif")
LC08_2019 <- stack("LC08_20190201.tif")
#2,3,4,5,6,7
## Run tasseled cap (exclude thermal band 6)

LC08_2017_tc <- tasseledCap(LC08_2017[[c(2:7)]], sat = "Landsat8OLI")
LC08_2017

LC08_2018_tc <- tasseledCap(LC08_2018[[c(2:7)]], sat = "Landsat8OLI")
LC08_2018

## Run tasseled cap (exclude thermal band 6)
LC08_2018_tc <- tasseledCap(LC08_2018[[c(2:7)]], sat = "Landsat8OLI")
LC08_2018

## Run tasseled cap (exclude thermal band 6)
LC08_2019_tc <- tasseledCap(LC08_2019[[c(2:7)]], sat = "Landsat8OLI")
LC08_2019

LC08_2016_tc <- tasseledCap(LC08_2016[[c(2:7)]], sat = "Landsat8OLI")
```

```
LC08_2016_tc

writeRaster(LC08_2016_tc, filename="all_LC08_2016_tc.tif", bylayer=FALSE,
format="GTiff")
writeRaster(LC08_2017_tc, filename="all_LC08_2017_tc.tif", bylayer=FALSE,
format="GTiff")
writeRaster(LC08_2018_tc, filename="all_LC08_2018_tc.tif", bylayer=FALSE,
format="GTiff")
writeRaster(LC08_2019_tc, filename="all_LC08_2019_tc.tif", bylayer=FALSE,
format="GTiff")

rm(list=ls())
#.libPaths("C:\\rlibs\\3.6.0")
library(raster)
library(RStoolbox)

#C:\\Users\\Lape
path <- setwd("C:\\Users\\Public\\Lape")
dir()

setwd("C:\\Users\\Public\\Lape")
LC08_2016 <- raster("LC08_20160225.tif")
LC08_2017 <- raster("LC08_20170110.tif")
LC08_2018 <- raster("LC08_20180129.tif")
LC08_2019 <- raster("LC08_20190201.tif")

LC08_2016 <- stack("LC08_20160225.tif")
LC08_2017 <- stack("LC08_20170110.tif")
LC08_2018 <- stack("LC08_20180129.tif")
LC08_2019 <- stack("LC08_20190201.tif")

plot(LC08_2016[[1]])
plot(LC08_2017[[1]])
plot(LC08_2018[[1]])
plot(LC08_2019[[1]])

#2,3,4,5,6,7
## Run tasseled cap (exclude thermal band 6)
LC08_2017_tc <- tasseledCap(LC08_2017[[c(2:7)]], sat = "Landsat8OLI")
LC08_2017

## Run tasseled cap (exclude thermal band 6)
LC08_2018_tc <- tasseledCap(LC08_2018[[c(2:7)]], sat = "Landsat8OLI")
LC08_2018

## Run tasseled cap (exclude thermal band 6)
```

```
LC08_2019_tc <- tasseledCap(LC08_2019[[c(2:7)]], sat = "Landsat8OLI")
LC08_2016

#2,3,4,5,6,7
## Run tasseled cap (exclude thermal band 6)
lsat_tc <- tasseledCap(lsat[[c(2:7)]], sat = "Landsat5TM")
lsat_tc

#################################################
# Bands
# sentinel - ndvi = (B08 - B04) / (B08 + B04);
# landsat 8 - 5 and 4
#################################################

ndvi16 <- (LC08_2016[[5]] - LC08_2016[[4]]) / (LC08_2016[[5]] + LC08_2016[[4]])
ndvi17 <- (LC08_2017[[5]] - LC08_2017[[4]]) / (LC08_2017[[5]] + LC08_2017[[4]])
ndvi18 <- (LC08_2018[[5]] - LC08_2018[[4]]) / (LC08_2018[[5]] + LC08_2018[[4]])
ndvi19 <- (LC08_2019[[5]] - LC08_2019[[4]]) / (LC08_2019[[5]] + LC08_2019[[4]])

plot(ndvi16)
plot(ndvi17)
plot(ndvi18)
plot(ndvi19)

########################
#Sentinel_2A_2016
#Sentinel_2A_2019

## Create PCA
#pca2016 <- rasterPCA(LC08_2016)$map
pca2017 <- rasterPCA(LC08_2017)$map
pca2018 <- rasterPCA(LC08_2018)$map
pca2019 <- rasterPCA(LC08_2019)$map

################################
## TO do change vector analysis
################################

cva_17_18 <- rasterCVA(pca2017[[1:2]], pca2018[[1:2]])
cva_18_19 <- rasterCVA(pca2018[[1:2]], pca2019[[1:2]])
cva_17_19 <- rasterCVA(pca2017[[1:2]], pca2019[[1:2]])

cva_17_18
plot(cva_17_18)

cva_18_19
```

```
plot(cva_18_19)

cva_17_19
plot(cva_17_19)

writeRaster(ndvi16,"NDVI_2016_L8.tif", "GTiff", overwrite=TRUE)
writeRaster(ndvi17,"NDVI_2017_L8.tif", "GTiff", overwrite=TRUE)
writeRaster(ndvi18,"NDVI_2018_L8.tif", "GTiff", overwrite=TRUE)
writeRaster(ndvi19,"NDVI_2019_L8.tif", "GTiff", overwrite=TRUE)

writeRaster(cva_17_18,"L8_2017_2018_Change Vector Analysis_PCA.tif", "GTiff",
overwrite=TRUE)
writeRaster(cva_18_19,"L8_2018_2019_Change Vector Analysis_PCA.tif", "GTiff",
overwrite=TRUE)
writeRaster(cva_17_19,"L8_2017_2019_Change Vector Analysis_PCA.tif", "GTiff",
overwrite=TRUE)

writeRaster(pca2017,"pca2017_L8.tif", "GTiff", overwrite=TRUE)
writeRaster(pca2018,"pca2018_L8.tif", "GTiff", overwrite=TRUE)
writeRaster(pca2019,"pca2019_L8.tif", "GTiff", overwrite=TRUE)

### End of the script
```

Appendix II: Research Questionnaire

A Questionnaire Submitted To Residents Living Along The SGR Line From The Nairobi Terminus To The Kimuka Aquifer

Request To Participate In Research

Dear interviewee, I am **OKOTH AUGUSTINE LAPE (FR)** a Geographic Information Systems MSc student from Taita Taveta University. I solicit your time in order to respond to questions that will assist me to document the **ENVIRONMENTAL IMPACT OF THE SGR FROM NAIROBI TERMINUS TO KIMUKA ACQUIFER**. This survey is being independently conducted for partial fulfillment of a degree in Geographic Information Systems. Taking part in this survey contributes to the quality of the environment around the SGR path. Answering the questions below will take between 20 and 40 minutes and it can be answered in English/Kiswahili or with an interpreter in your language. The information you volunteer will be treated and safeguarded with utmost confidentiality. By selecting the "I agree" button below you agree to participate in this thesis and have read and understood the information presented. Your decision to participate or not is completely voluntary.

I agree ☐ I disagree ☐

1. **Coordinates of the house:**

Latitude:______________________________ Longitude:____________________________

2. **Area of residence**

Syokimau/Around SGR Nairobi Terminus ☐ Mombasa Road ☐

Ongata Rongai ☐ Ngong ☐

Kimuka ☐

3. **ID#:** ☐☐☐

4. **Date of the interview (DD/MM): ☐/☐/2019**

5. **Language preferred for interview:**

English ☐ Kiswahili ☐ Maasai ☐ Kamba ☐ Other ☐ ____________________

6. **Details of Respondent:**

Name of Respondent:____

Age bracket of Respondent:

18-23☐ 24-29☐ 30-35☐ 36-40☐ More than 40☐

Employment Status

Civil Servant ☐ Self-employment ☐ Unemployed ☐

Other ☐Kindly specify:______________________________________

7. **Is your current area of residence as a result of displacement to pave way for the construction of the SGR**

Yes ☐ No ☐

8. **How concerned are you about the SGR traversing through your residence and other surroundings?**

Extremely concerned☐ Very concerned ☐Somewhat concerned ☐Not concerned

9. **How safe do you think your area of residence and any other area is with the construction of SGR close to it?**

Extremely safe ☐ Very safe ☐ Slightly safe ☐ Not safe at all ☐

10. **What danger do you think that the SGR poses to your residential area or place of work:____**

____

____

11. **Do you think construction of SGR has brought dust pollution?**

Yes ☐ No ☐ Not sure ☐

12. **Has the construction of the SGR through the Nairobi National Park affected you?**

Yes ☐ No ☐ Not sure ☐

If yes explain how: ____

____

____

13. **How do you think the SGR has affected terrestrial animals in the Nairobi National Park?**

____

____

____

14. **What environmental issues do you think were not properly addressed before and after the SGR construction?**

.____

____

____

15. **Have you noticed any decline or increase in availability of portable water and water for farming and grazing?**

____

____

16. **Has any unusual flooding been noticed during the rainy seasons?**

Yes ☐ No ☐ Not sure ☐

17. **Are there incidences of water borne diseases recorded as a result of any flooding?**

Yes ☐ No ☐ Not sure ☐

Mention the particular disease(s):____

18. **Have you heard of Kimuka acquifer?**

Yes ☐ No ☐ Not sure ☐

19. **Has this aquifer affected you**

Positively? Yes ☐ No ☐ Not sure ☐

Negatively? Yes ☐ No ☐ Not sure ☐

20. Explain in a few words how has this aquifer affected you?

.____

____

21. Is there any difficulty in accessing grazing lands of late?

Yes ☐ No ☐ Not sure ☐

22. Have you witnessed or heard of any human-wildlife conflict recently?

Yes ☐ No ☐ Not sure ☐

23. What do you think of the noise pollution in with the advent of the SGR?

.____

____

____

24. What solution do you have in mind that can be put in place to mitigate environmental challenges as a result of SGR?

.____

____

____

25. Do you think the SGR will have any positive impact on the surrounding community?

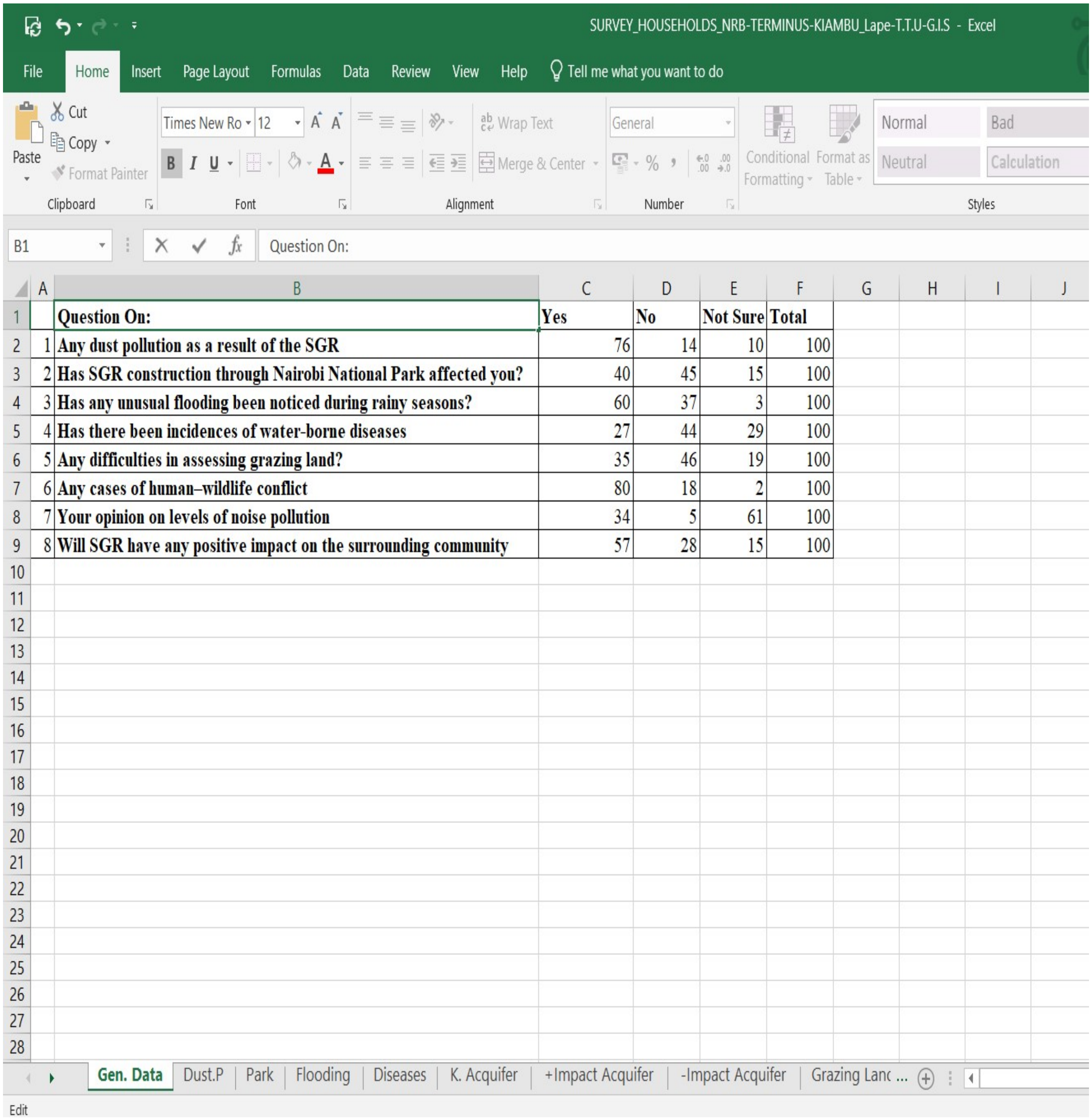
Yes ☐ No ☐ Not sure ☐

Explain:____

____

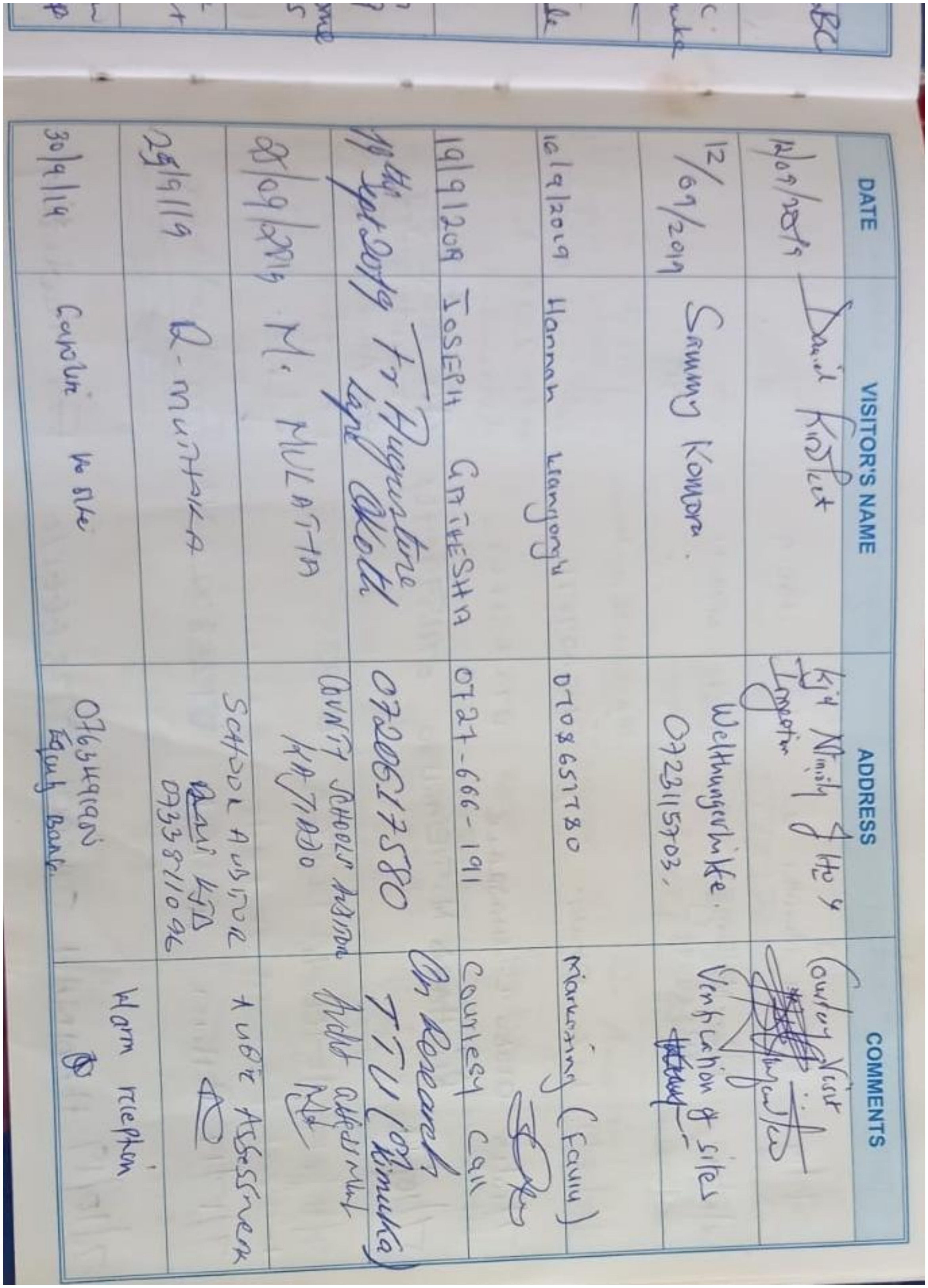
____

Appendix III: Spreadsheet Analysis Of Survey Data:



	Question On:	Yes	No	Not Sure	Total
1	Any dust pollution as a result of the SGR	76	14	10	100
2	Has SGR construction through Nairobi National Park affected you?	40	45	15	100
3	Has any unusual flooding been noticed during rainy seasons?	60	37	3	100
4	Has there been incidences of water-borne diseases	27	44	29	100
5	Any difficulties in assessing grazing land?	35	46	19	100
6	Any cases of human–wildlife conflict	80	18	2	100
7	Your opinion on levels of noise pollution	34	5	61	100
8	Will SGR have any positive impact on the surrounding community	57	28	15	100

Appendix IV: Visit To Kimuka Primary School



DATE	VISITOR'S NAME	ADDRESS	COMMENTS
11/09/2019	David Kinstert	KJA Ministry of the Inspection	Courtesy visit
12/09/2019	Sammy Komora.	Welthungerhilfe. 0723115703.	Verification of sites
16/9/2019	Hannah Wanjongu	0708657780	Marketing (Family)
19/9/2019	JOSEPH GATHESHA	0727-666-191	Courtesy Call
19th Sept 2019	Fr Augustine Lyai Okoth	0720617580	On Research TTU (on Kimuka)
20/09/2019	M. MULATTA	COUNTY SCHOOLS AUDIT KAJIADO	Audit affirmation
28/9/19	Q. MUTHAKA	SCHOOL AUDITOR Ruai 0733811096	Audit Assessment
30/9/19	Caroline Wambe	0763449091 Equity Bank	Warm reception

Appendix V: Published article and anti-plagiarism-report

1. Published Article (Attached)

Lape, O. A., Mwagha, S. M., & Siljander, M. (2023). Quantifying the Environmental Impact of Standard Gauge Railway (SGR) on Land Cover Changes along the Nairobi-Kiambu Corridor from 2016 to 2019. Journal of Geography, Environment and Earth Science International, 27(4), 21–37. https://doi.org/10.9734/jgeesi/2023/v27i4677

2. Anti-plagiarism Report (Attached)

Published Article

Journal of Geography, Environment and Earth Science International

Volume 27, Issue 4, Page 21-37, 2023; Article no.JGEESI.98476
ISSN: 2454-7352

Quantifying the Environmental Impact of Standard Gauge Railway (SGR) on Land Cover Changes along the Nairobi-Kiambu Corridor from 2016 to 2019

Okoth Augustine Lape [a*], Solomon Mwanjele Mwagha [a] and Mika Siljander [b]

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

Received: 11/02/2023
Accepted: 15/04/2023
Published: 21/04/2023

Anti-plagiarism Report

ASSESSMENT OF CHANGES IN LAND COVER AND ENVIRONMENTAL IMPACT OF THE STANDARD GAUGE RAILWAY FROM NAIROBI TERMINUS TO KIAMBU COUNTY IN KENYA

ORIGINALITY REPORT

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