UNIVERSITY OF NAIROBI

SCHOOL OF ENGINEERING

DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

GIS APPROACH TO CRIME MAPPING AND SPATIAL ANALYSIS

CASE STUDY: NAIROBI CITY COUNTY

A project report submitted to the Department of Geospatial and Space Technology in partial fulfilment of the requirement for the award of the degree of:

Masters of Science in Geographic Information Systems

BY

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2019

Declaration

I, Joel Karani Gakuru, hereby declare that this project report is my original work. To the best of my knowledge, the work presented here has not been presented elsewhere in any other University.

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Name of supervisor

Date 26-07-2019

Dedication

This project is dedicated to my family and parents for their love and support during the time of this project.

Acknowledgements

First, I thank the Almighty God for His guidance, strength, peace of mind and grace which has made this project a success. I would like to extend my sincere gratitude to my project supervisor, Mr. B. M. Okumu for the encouragement, guidance and assistance that he accorded me from the beginning of the project to its successful completion.

Special thanks goes to my loving Wife, my parents for the support you all accorded me during the period I was undertaking my Degree.

My special thanks to the University of Nairobi, Department of Geospatial and Space Technology staff led by the Chairperson Dr. -Ing. Faith N. Karanja for their endearing support throughout the project.

Abstract

The level of growth of the economy of country largely depends on its state of security. Over the years the rate of crime in Kenya has been on upward trend and criminal activities have been perfected with more sophistication of how they are implemented. Due to poor infrastructures and technologies to curb these security concerns, the efforts have ended futile yet more criminal gangs are being formed every now and then. GIS is a tool that can be employed for effective crime mapping and management. Since every criminal occurrence has a locational aspect, GIS can be a vital tool to display and apply spatial analysis to data, in order to obtain a strong visual appreciation of the patterns of crimes for ease of decision making. This paper attention is on how GIS can be utilized in the mapping and management of crimes in Kenya using Nairobi City County as a case study.

This paper outlines a methodological framework leveraging on GIS analysis to provide insight on the project's intention towards solving crime within the area of study. The main method adopted for this project is a stepwise method of application of GIS in crime mapping and analysis. This technique involved collecting information on crimes and their locations (as well as temporal data), mapping out the administrative boundaries as used by the police and performing various data analysis procedures to extract information from the data. Time which the crime was reported was used to model early warning maps which was significant for forecasting purposes.

From research, various contributory factors of crime in Nairobi have been pointed out some of which are managerial such as incentives and appraisal of the law enforcement officers. Other factors include societal contributory factors like change in crime tactics among perpetrators of crime and an increase in unemployment rate especially among the youth. The development of different crime maps serves as a means of record keeping through which research can be done periodically in order to identify the spatial patterns with regard to any specific crime. This helps the police force in solving crime as it occurs and device new tactics to deal with modern day crimes. Moreover, mapping of crime also creates awareness among the public through various timely decisions from the police force with creating alerts as one example or providing recommendations on where to report in case a crime occurs.

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List of Abbreviations

GIS - Geographic Information Systems

KNBS - Kenya National Bureau of Statistics

GIS - Geographical Information System

ICVS - International Crime Victim Survey

SoK - Survey of Kenya

NPS - National Police Service

USA - United States of America

RCAGIS - Regional Crime Analysis GIS

CHAPTER 1: INTRODUCTION

1.1 Background Information

Nairobi City County, the capital of Kenya, has over 3 million inhabitants and expanding. The crime rates have been on the rise and these are linked to institutional weakness of the society. Increase in crimes rate is directly associated with the social control that operates through formal institutions, police being one of them, and informal organizations is broken or weakened. (Stravou, 2002) With the impact of different crimes highlighted in this project, since early 2000s Nairobi has experienced increased levels of urbanization, with many rural inhabitants migrating and settling within the Capital. Proper urban planning should encompass adequate security mechanism setup, whereby conditions of turbulent transformation in population is not without challenges. (Assiago, 2002)

Accelerated incidents of crime within Nairobi County are caused by low or lack of morals, lack of self-discipline, lack of integrity in leadership, absence of code of ethics especially in the public service stakeholders and police force weakness serving as making crime perpetrators thrive. Poor remuneration and inadequate incentives (which may include technology and infrastructure) in the police service contributes towards increase in rate of crime in Nairobi and other areas. Empowerment of the police force can be a big step towards crime prevention and mitigation. (Pokhariyal & Muthuri, 2014)

Crime mapping involves a number of analyses such as administrative and tactical crime analysis, operational analysis, crime investigative analysis, intelligence analysis and strategic crime analysis. (J. & Martins, 2012) Until the 1970s, modeling of crime and mapping by police, criminal and justice systems were challenged by lack of technology especially in the field of GIS which was not well established until the late 1980s. (Leitner, 2011)

Nairobi City County's population has increased over the years and the negative results such as crime are usually a resultant cause of urbanization. As this is a common feature associated with urbanization, so should community policing and security go with it and this is not usually the case especially in the developing countries where there is no balance between the security personnel and the population expected to be served.

1.2 Problem Statement

The Nairobi City County does not have a location-based (GIS) repository for crime which would facilitate community policing with regard to crime place and time occurrence. The repository could also denote interaction between the police and citizens within the laws provided.

The County also lacks crime prevention strategy that can be drawn from previous crime occurrences within different police jurisdictions and this can be attributed to lack of an elaborate crime data.

Inadequate provisions to the police which include incentives and up-to-date technology to combat crime leaving the law enforcers weak and this accelerates gang networks. CCTV cameras have been installed all over the County, however that has not helped in curbing crime especially robbery involving vehicle use.

Only little research has been done on the history of crime with involved personnel relying on media reports and outdated sources from research-based organizations and NGOs. Having historical crime data mapped provides a good platform for gathering user needs assessment on policing and security issues within the County. Having relevant documentation on crime in Nairobi is important towards managing it and promoting social development especially among citizens who are the major drivers of the economy. There has been an upsurge in criminal activities across Nairobi City County which can be attributed across many factors. Similarly, police have been hampered by lack of GIS tools which can be applied to mitigate crime prevalence in the area of study as well as countrywide.

1.3 Study Objectives

1.3.1 General Objective

The main objective of the study is to map and analyze crime incidences and patterns within the study area with an approach towards developing crime prevention policy and later contributing to the establishment of a crime database at the county level and perform GIS analysis.

1.3.2 Specific Objectives

The specific objectives of the project include:

1. To identify hotspot areas within Nairobi City County,

2. To perform spatial analysis with respect to crime in the area of study,
3. Identify challenges toward crime prevention, crime reporting and suggesting possible approaches towards aiding community policing.

1.4 Justification for the Study

This study has a broad scope both geographically, being carried within the County, and theoretically, by covering a number of issues at once; this maximized the opportunity to highlight the crimes and their areas of occurrence. The core of the project is a mapping exercise, which examines crime in terms of type, volume, place, timing, perpetrators and factors. The project also attempts to complement the findings by establishing the current state of victim support and prevention activities. Crime prevention officers working in a given jurisdiction can leverage on GIS to know where crime is most likely to occur. The officers can similarly predict patterns based on type of crime.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The Nairobi City County has experienced the most infrastructural and technological development as compared to other counties in Kenya. However, there is a negative effect associated with this positive growth which is an increase in the rate of crime based on police reports and other research references.

The rapid increase in suspects characterized with modern offender tactics, and the recurrent utilization of traditional methods by the law enforcement makes crime investigation especially in the current times rather intensive, not ruling out prediction and prevention measures that have become complex and rather resource intensive.

Despite increase in crime reporting in most areas within developing countries, the adoption of digital analysis to solve crime and investigation remains conservative to those dealing with management of crime mostly, the police force. This is to a large extent because crime-related information in many developing countries is not automated, but also because this information has previously remained available to crime mapping researches only. (Mburu, 2013)

2.2 Geographic Information Systems

GIS which can be referred to as a framework for gathering, managing, and analyzing data has its roots from geography as a science. GIS integrates many types of data, analyzes spatial location and organizes layers of information into 2-Dimension and 3-Dimension representation of the world. With this unique capability, GIS reveals deeper insights into data, such as patterns, relationships, and situations—helping users make smarter decisions. GIS is a major innovation for police organizations, enabling crime analysts, intelligence officers, police officers, detectives, and their higher authorities to improve the effectiveness of crime prevention, crime prediction and law enforcement on a day-to-day basis (ESRI, 2019). A participatory GIS system is of essence in crime management work as it connects different players within the domain of crime prevention such as stakeholders, citizens and researchers.

The typical GIS is founded on several basic concepts. First, the real world features on the earth's surface are related to a map grid coordinate systems and recorded in the computer. The computer stores the grid coordinates of these features to show their locations and the attributes of these map features.. Also, GIS can analyze the spatial relationships among map features. (Olba & Al-Ramadan, 2006)

2.3 Crime Mapping

The genesis of computer driven mapping techniques are fundamental to the recent advances in the analytical world especially with regard to crime data associated with time and place of occurrence. Crime mapping can be defined as the process of employing GIS to conduct analysis of crime occurrence and co-related dimensions like place and time. The term crime mapping is used in the world of policing referring to the procedure of conducting spatial analysis within the crime analysis.

2.3.1 Strategic Crime Analysis

This revolves around the domain of long-term applications in analyzing the connection between criminal activities and their indicators which would require policing action to be employed. This type of analysis can be implemented where police force investigates on a given geographical are to place to allocate resources such as police station, barracks or residence which would come in handy placing them in close proximity to social places or public buildings such as schools, hotels and hospitals. This helps greatly in gathering statistical data based on crime occurrence, frequency of occurrence and once this data is integrated with GIS data can be of great use in modelling location-based crime patterns therefore greatly assist in planning.

2.3.2 Administrative Crime Analysis

The concept of information sharing comes in this type of crime mapping analysis where the relevant agency involved in gathering crime data such as researchers is tasked with creating public awareness on crime activities. This can be done through means such as publishing of paper maps on public notice boards or publishing maps in a digital platform such as the web where citizens can access information. This further makes the citizens understand characteristics of crime activities such as areas where crime rate is high, nearest police station to a future crime scene and this is where the concept of location comes into play.

2.3.2 Tactical Crime Analysis

This is crime mapping analysis focusing on mapping out crime patters for decision making. Crime tends to take a specific pattern nowadays with criminals applying modern techniques. GIS can be used to map out spatial patterns and provide more insight through models that can be used to predict crime occurrences based on location and type of business or also with respect to a given time or season. As the word implies, use of tactics to curb crime.

2.4 Types of Crime Maps

Incorporation of GIS into crime analysis results to development of means to visualize crime through various categories of maps depicting spatial characteristics of crime in question. Below are the following GIS applications in crime analysis and mapping:

1. Crime Hotspot maps

2. Pin Maps

3. Early Warning maps

4. Crime Maps for public use

2.4.1 Crime Hotspot maps

These are the kind of maps that employ statistical analysis in order to define locations of high occurrence of given phenomenon, in this case crime as compared to areas of low occurrence. The area designation of it being referred to as a hotspot id defined in terms of statistical confidence. When it comes to crime mapping, analysts use different methods to depict and predict crime hot spots depending on place and degree of occurrence. Deep statistical methods can be applied in areas with less likelihood of occurrence whereas for areas with a high persistence of crime, simple statistical methods are applied. Figure 1 shows crime incidences in San Francisco, USA in 2012 and highlights areas of high and low crimes generated from crime data.

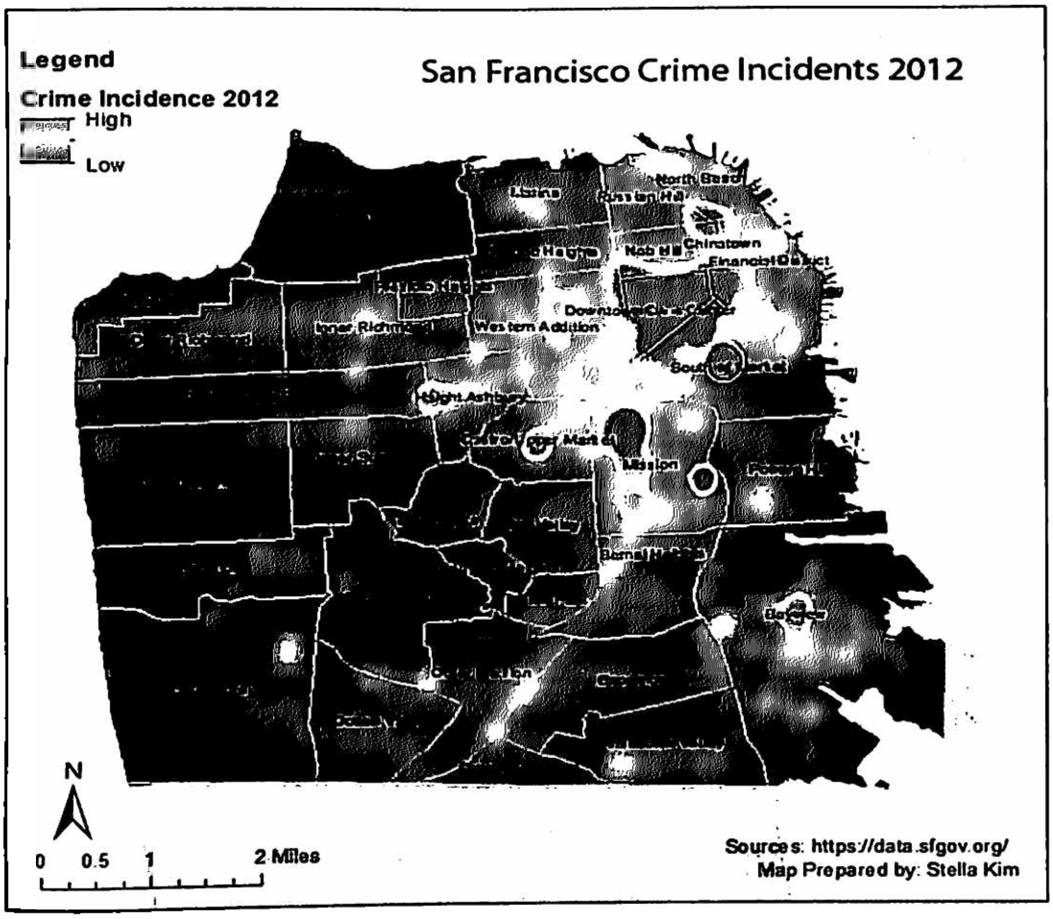


Figure 1: Sample Hotspot Map

2.4.2 Pin maps

In most advanced jurisdictions, police employ a technique of mounting pins onto paper maps as a simple method of marking a place of interest to them. This approach is important for marking and monitoring crime patterns and to some extent differentiating different types of crime. With advancement in technology, digital pin maps are being used in defining a point area of interest with coordinates displayed in the digital map as a pop-up. The advent of modern GIS has enhanced real-time or quasi real-time response to crime incidences with the backing of sophisticated technology like GPS. Figure 2 depicts pin map of Nairobi City County displaying areas that crimes have been reported.

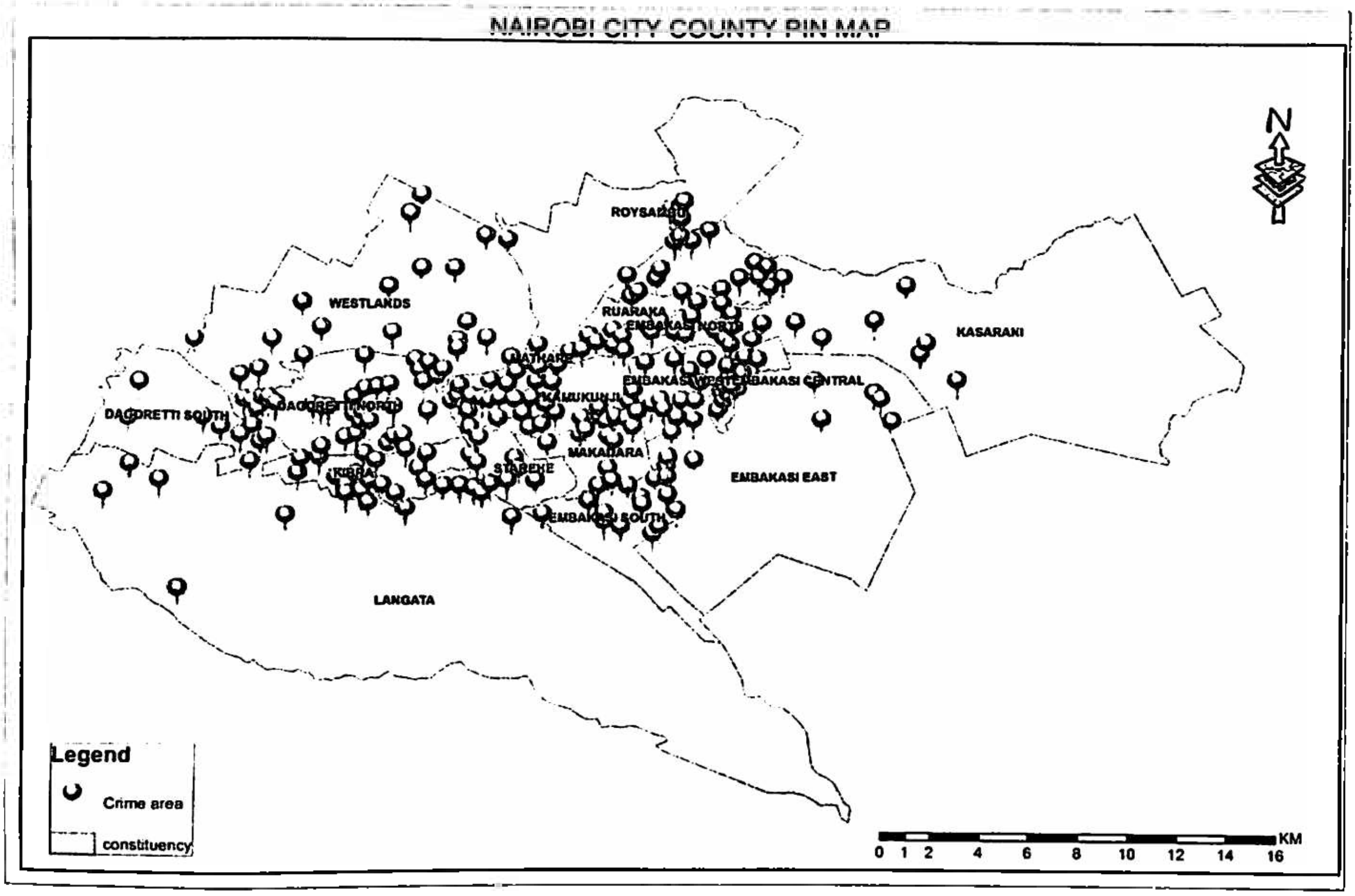


Figure 2: Sample Pin map

2.4.3 Early Warning Maps

This types of maps help police predict crime prevalent areas and detect changes in crime patterns therefore contributing to better planning by the parties involved in solving crime. Making use of geographic information coupled with intelligence based information can help a lot in generation of warning maps or predictive maps providing information of possible crime occurrence. . Figure 3 shows a sample warning map.

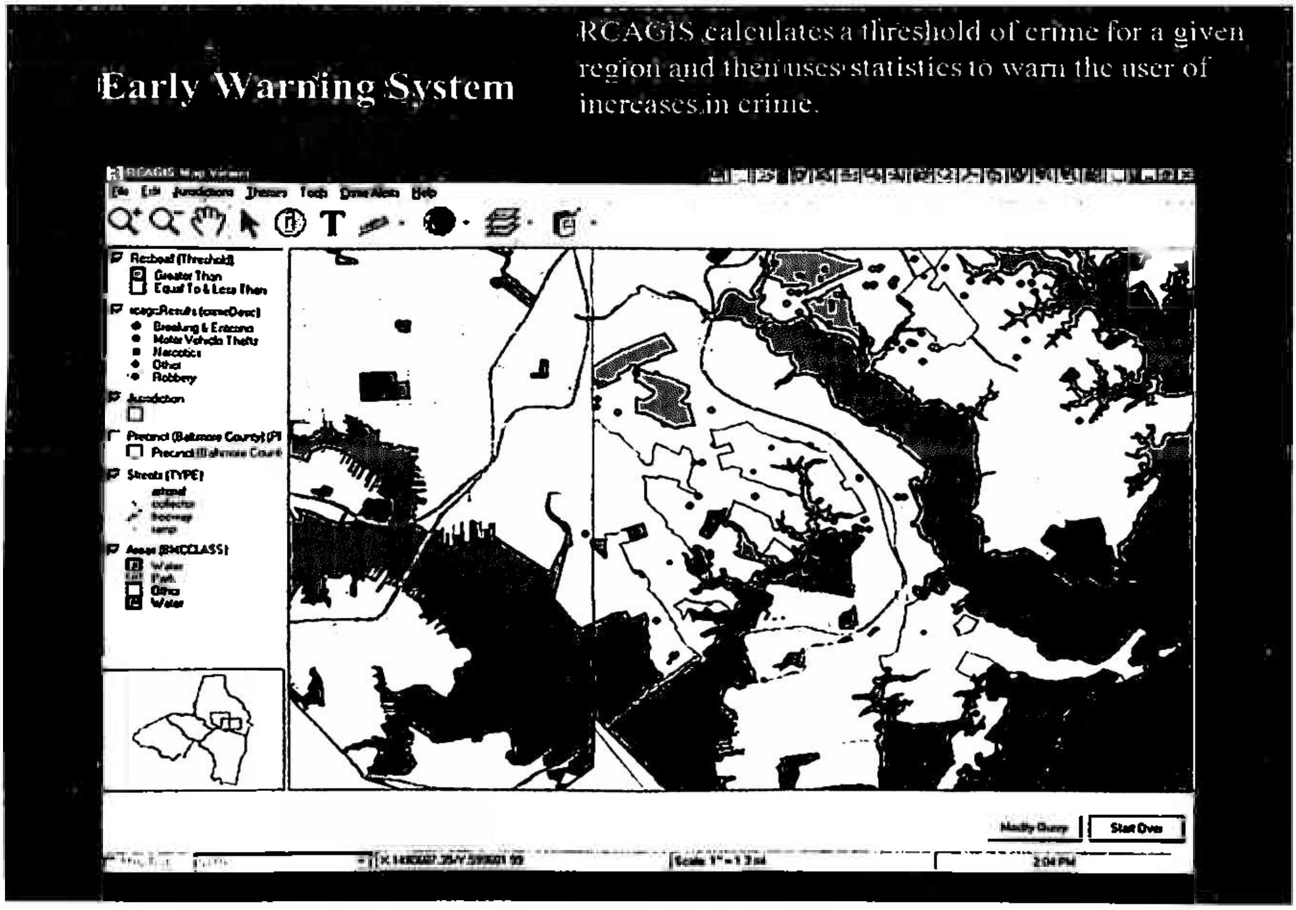


Figure 3: Regional Crime Analysis map (RCAGIS)

2.4.4 Crime maps for public use

These are maps that create awareness to the public and tend to be supported by statistical information on crime occurrences in specific areas rather than in generalized approach. Specific areas such as a given neighborhood or a street can me marked a crime incidence prone area

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter outlines a methodological framework leveraging on GIS analysis to provide insight on the project's intention towards solving crime within the area of study. The main method adopted for this project is stepwise method on the application of GIS in crime mapping and analysis. This technique involved collecting information on crimes and their locations (as well as temporal data), mapping out the administrative boundaries as used by the police and performing various data analysis procedures to extract information from the data. Time which the crime was reported was used to model early warning maps which was significant for forecasting purposes.

3.1.1 Study area

Nairobi City County is one of the 47 counties of Kenya, it is the hosts the capital city of Kenya and is located towards southern end of the Kenya highlands at approximately 1.2 ° south of Equator and 37 ° east of the Greenwich Meridian and is at an approximate altitude of 1676 meters above mean sea level. Nairobi County consist of 9 sub-counties, 17 constituencies and 85 wards. (KNBS, 2015). Figure 4 shows the study area.

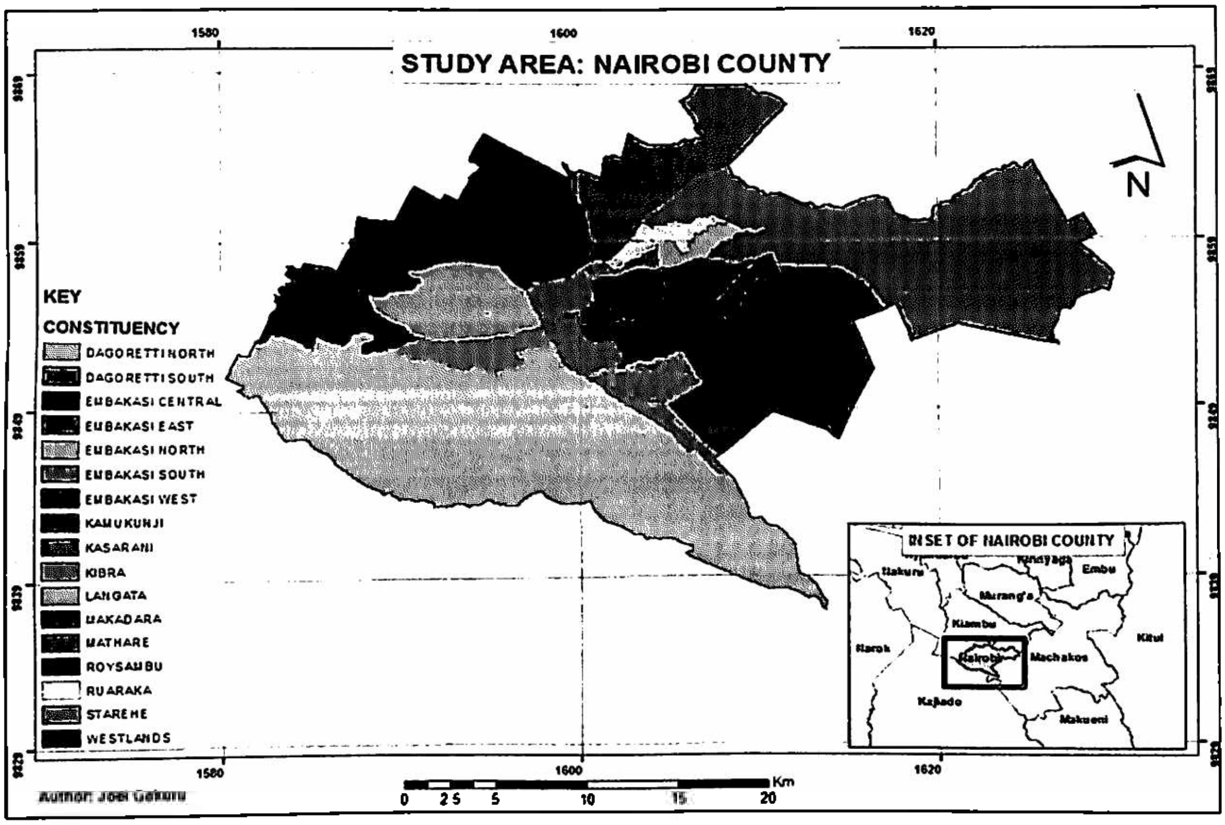


Figure 4: Study Area

3.1.2 Data

Data is defined as information that has been translated into a form that is efficient for movement or processing. (Rouse, 2017)

Data can also be defined as a collection of related facts arranged in a particular format. Often, the basic elements of information that are produced, stored, or processed by a computer. (ESRI, 2018)

The table 1 provides a summary of datasets used and their sources.

[illegible]

Dataset	Features	Source
Crime Data	This data consist of geocoded crime location and type of crimes filtered to robbery, murder and suicide.	NPS
Constituencies	Data comprise of administrative units and their boundaries falling within the county of Nairobi.	SoK
Police Stations	Comprise of police posts located within Nairobi and their divisional units / jurisdiction areas.	NPS
Demographic	Data for Nairobi County population	KNBS

The figure 5 shows the various datasets that are being used to achieve project's objectives

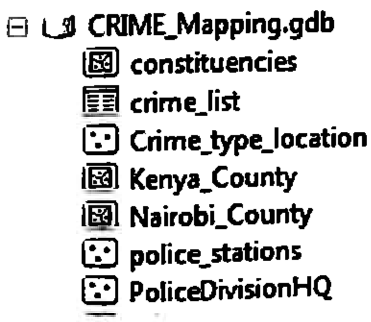


Figure 5: Datasets

3.1.3 Tools

- **Hardware:**
  - Toshiba Laptop
  - 8GB RAM
  - 500GB Hard Drive
  - 2.4GHz Processor
- **Software:**
  - ArcGIS for Desktop 10.4
  - Microsoft Office 2016 Suite

3.1.4 Data Identification and Capture

Data used in this project consist of both spatial and non-spatial attributes which are distinguished by the element of location and metadata. In this case crime types, police jurisdiction and timestamp data falls in the category of the latter and which has been geocoded to give the data geographical coordinates. Spatial element is one among the dimensions of crime, meaning that crime has an inherent geographical quality. (Chainey & Ratcliffe, 2005).

3.2 Crime Data

There is a variety of crime types committed by perpetrators across the County. However, in this project major focus was given to the most common types of crimes namely; murder, robbery and suicide. These crime types have been identified to be the most common types of crime as compared to the myriad of crime types within the area of study. The information extracted after analysis and mapping is very important in illustrating the patterns and trends of various crimes within particular areas. In practice, it is difficulty to analyze data of all crimes since all crimes are not reported due a number of factors such as failed reporting or undetected crimes and fear of victimization by perpetrators. In literature, criminologist refer to all crime that escapes counting as the 'dark figure of crime' (Evans DJ, 1989). Fortunately, the records existing are enough to carry out crime mapping and analysis since they provide a good measure for trends and patterns.

3.2.1 Murder

Under the law of Kenya, anyone who intentionally, with malice aforethought, causes the death of another person is guilty of the crime of murder. (Paul Ilado, 2018). Murder falls in the category of homicide crimes which are a group of crimes considered as the act of one human killing. These crimes includes manslaughter, infanticide, abortion, causing death by dangerous driving as well as murder. However, in this project, the main focus will be on murder which is the most reported form of crime of killing a person by another person.

3.2.2 Suicide

Under Common Law, suicide, or the intentional taking of one's own life, was a felony that was punished by forfeiture of all the goods and chattels of the offender. (Dictionary, n.d.). Preliminary research and observation of the available data for the purpose of this project indicated that Suicide was amongst the most reported case of crimes in Nairobi City County and therefore was considered to be among the data to be used in the analysis of the crimes in the study area.

3.2.3 Robbery

According to the Law of Kenya, any person who steals anything, and, at or immediately before or immediately after the time of stealing it, uses or threatens to use actual violence to any person or property in order to obtain or retain the thing stolen or to prevent or overcome resistance to its being stolen or retained, is guilty of the felony termed robbery. (AG, 2009). Robberies were reported across the study area as one of the three major crimes committed in the study area.

Figure 6 is a map showing the crime types distinguished by color codes and distributed across the study area.

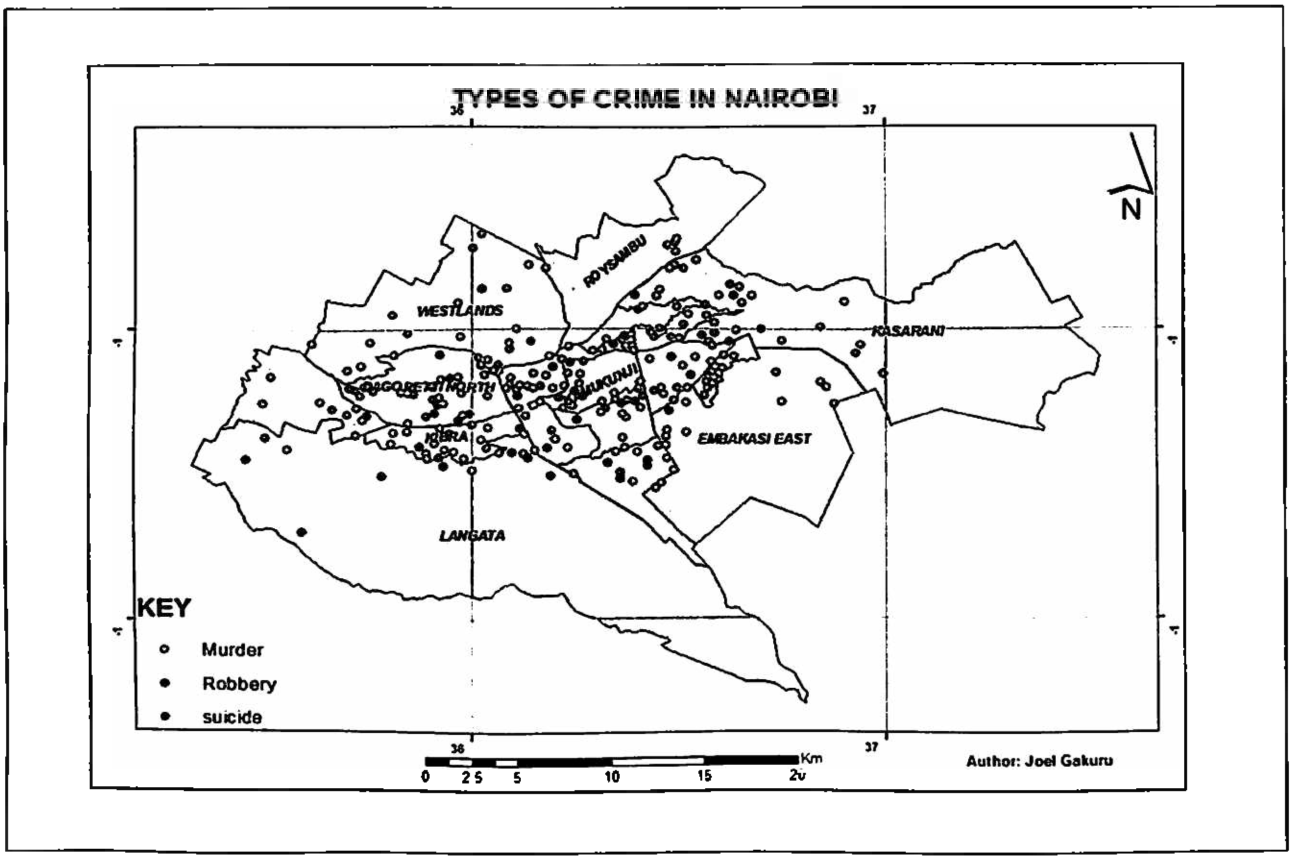


Figure 6: Types of Crimes

3.3 Spatial Analysis & Statistical methods

Using ArcGIS Desktop, statistical information from various attributes of the crime data are generated. For example, prevalence of certain crime could be computed on the fly and results displayed to the user. This is a very important in non-spatial analysis of the data. Nevertheless, the tabular data is linked to spatial data which enhances the spatial querying methods and significantly improves the results.

3.3.1 Attribute Queries

These are queries based on structured formats based on SQL commands. Mathematical logical operations area used to allow fetching of data from the *geodatabase* using attributes. The date attribute was heavily used for querying crime data-based time. Compound criteria comprising of OR and AND connectors were applied to the querying of data in order to achieve multiple filters. The figure 7 demonstrates the spatial queries.

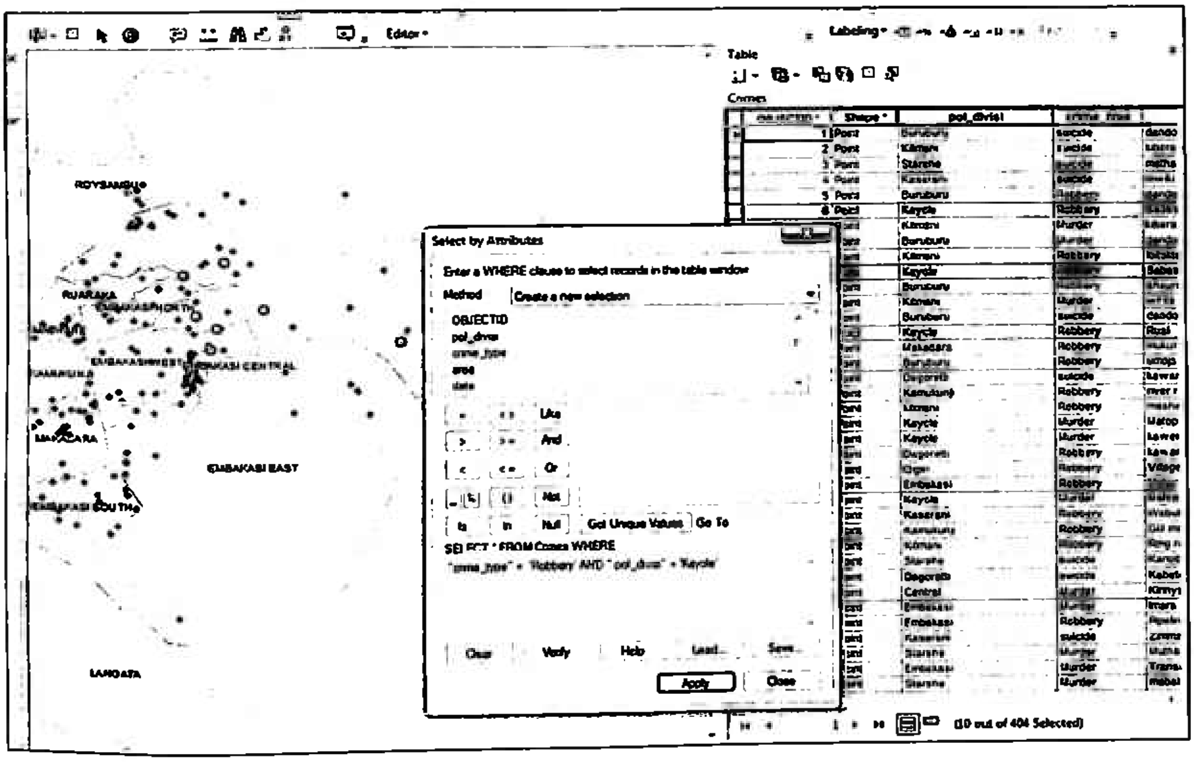


Figure 7: Attribute Query Example

Data can also be filtered by the date attribute as demonstrated in figure 8:

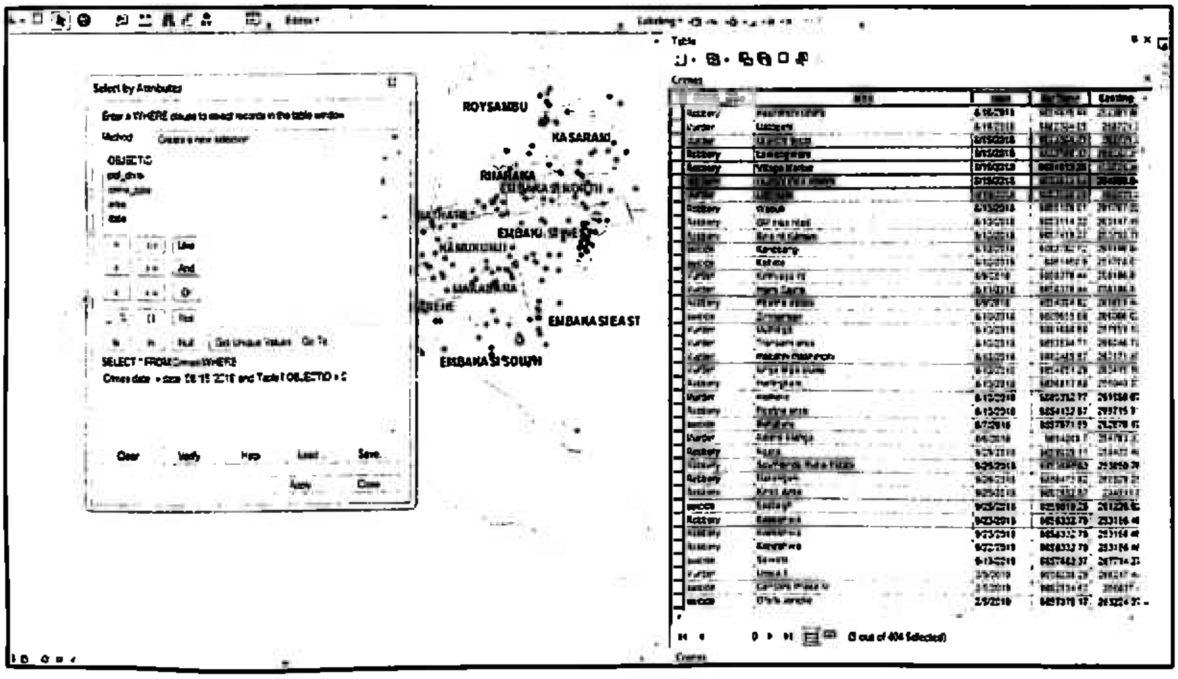


Figure 8: Attribute Query by Date

3.3.2. Spatial Queries

Spatial queries on the other hand are used to select spatial features in relation to other spatial features. A buffer is a specified area engulfing a feature in a map. 500 metres buffers and multi-ring buffers of 500 metres, 700 metres and 1 kilometre distances were created to enhance proximity analysis of crime spots near police stations in Nairobi County.

GIS provides ways of enhancing the conventional pin maps by exposing crime patterns of specific areas. Temporal analysis of crimes reported is very important and is used to expose patterns like emerging and decline crimes in an area and hot spots of crime.

Proximity analysis is one example of spatial query whereby we can highlight how many features fall within a given spatial distance from a certain feature as an example.

Figure9 demonstrates an example of how this was achieved.

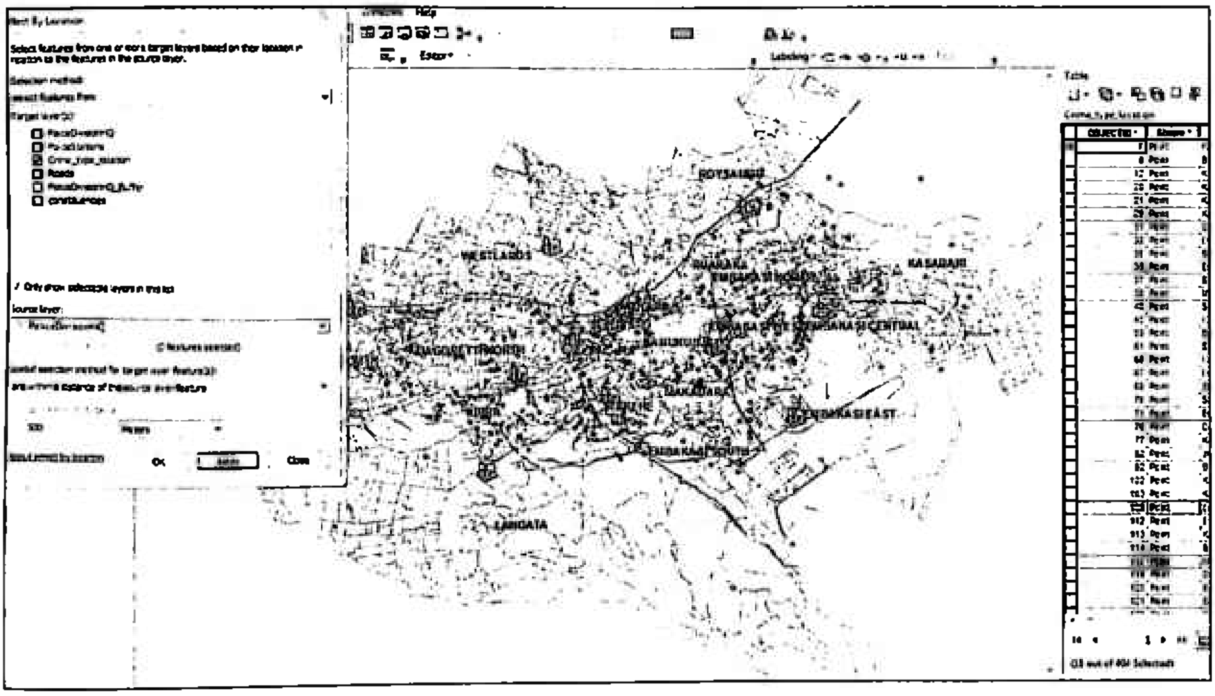


Figure 9: Spatial Query Example

3.4 Automating Crime Mapping

Most of the processes carried out in mapping and analysis of crime are repetitive. This means that the process can be looped by use of ArcGIS Model Builder tool through automation with python scripting language.

3.4.1 Data Preparation

The main base map for this particular project was the County boundary map which was comprised of 17 constituencies. The crime data was in an Excel spreadsheet that was initially used as database. Geocoding of data was simplified by using 2 additional columns for X and Y values for each particular crime reported. The data was converted to a shapefile point layer using ArcMap. On the ArcMap software a new empty layer was created and the Excel document imported and then convert to a shapefile document.

Figures 10 show the data in excel and inside the project *geodatabase* respectively.

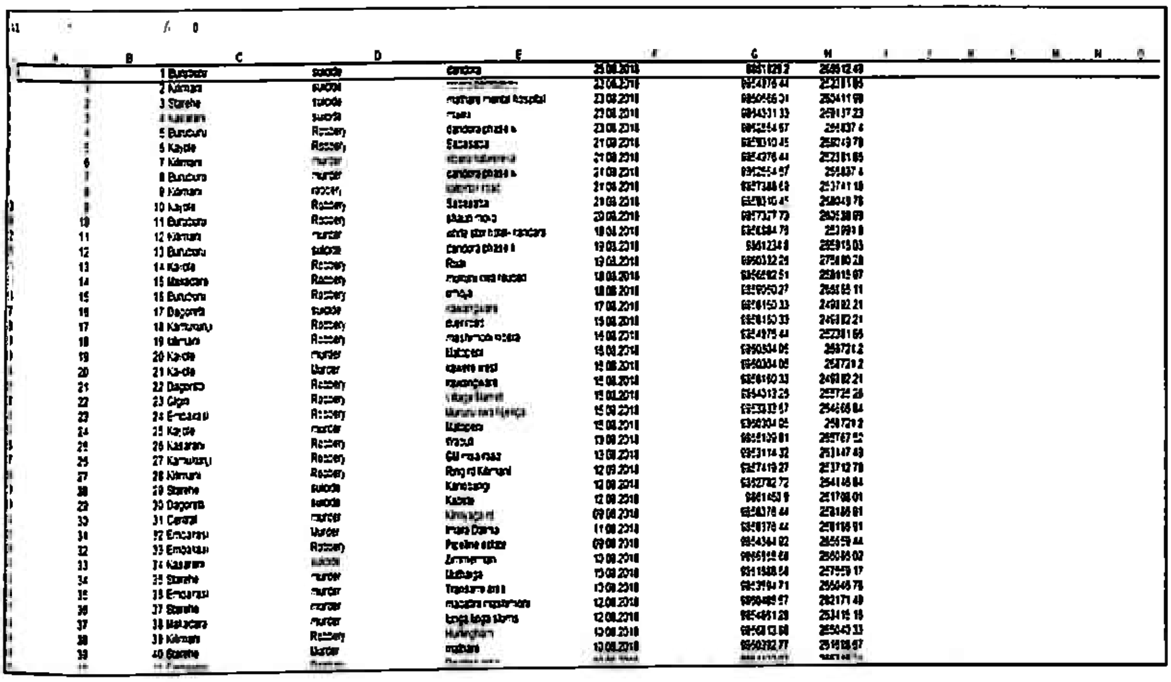
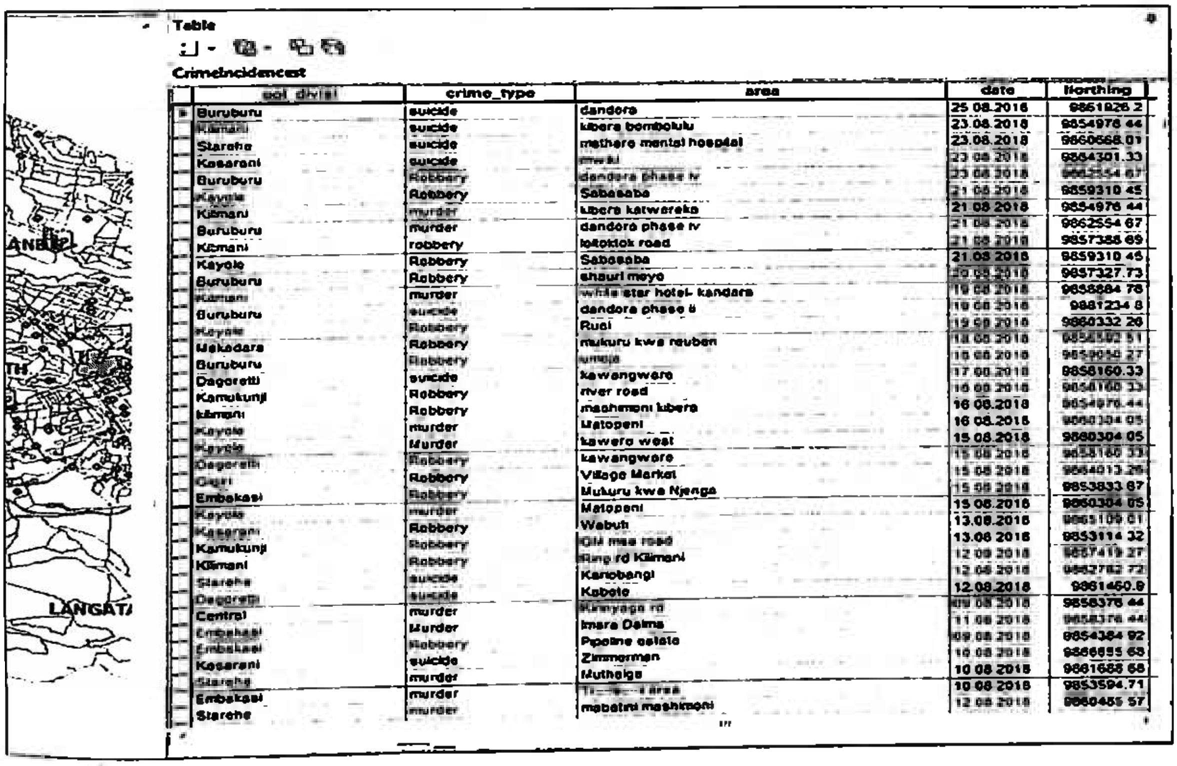


Figure 10: Data prior to geocoding



Table

Crimeincidencest

	sol_divisi	crime_type	area	date	Northing
▸	Buruburu	suicide	dandora	25 08.2018	9861926 2
	Kamani	suicide	kibera bombolulu	23.08.2018	9854978 44
	Starehe	suicide	mathare mental hospital	23.08.2018	9860668.01
	Kasarani	suicide	mwiki	23 08 2018	9864301.33
	Buruburu	Robbery	dandora phase iv	23 08 2018	9862554 67
	Kayole	Robbery	Sabasaba	21 08 2018	9859310 45
	Kilimani	murder	kibera katwekera	21 08 2018	9854976 44
	Buruburu	murder	dandora phase iv	21 08 2018	9862554 67
	Kilimani	robbery	loitoktok road	21 08 2018	9857388 69
	Kayole	Robbery	Sabasaba	21.08 2018	9859310 45
	Buruburu	Robbery	shauri moyo	20 08 2018	9857327.73
	Kamani	murder	white star hotel- kandara	19 08 2018	9858884 78
	Buruburu	suicide	dandora phase ii	19 08 2018	9881234 8
	Kayole	Robbery	Ruai	19 08 2018	9860332 26
	Makadara	Robbery	mukuru kwa reuben	18 08 2018	9856592 51
	Buruburu	Robbery	umoja	18 08 2018	9859050 27
	Dagoretti	suicide	kawangware	17 08 2018	9858160.33
	Kamukunji	Robbery	river road	16 08 2018	9858160 33
	Kilimani	Robbery	mashimoni kibera	16 08.2018	9854976.44
	Kayole	murder	Matopeni	16 08.2018	9860304 05
	Kayole	Murder	kawere west	15 08.2018	9860304 05
	Dagoretti	Robbery	kawangware	15 08 2018	9858160 33
	Gigiri	Robbery	Village Market	15 08 2018	9864013.26
	Embakasi	Robbery	Mukuru kwa Njenga	15 08 2018	9853833 67
	Kayole	murder	Matopeni	15 08.2018	9860304 05
	Kasarani	Robbery	Wabuh	13.08.2018	9865109 01
	Kamukunji	Robbery	Old msa road	13.08 2018	9853114 32
	Kilimani	Robbery	Ring rd Kilimani	12 08 2018	9857419 27
	Starehe	suicide	Korobangi	12 08 2018	9862782 72
	Dagoretti	suicide	Kabete	12.08.2018	9861460.9
	Central	murder	Kirinyaga rd	11 08 2018	9858376 44
	Embakasi	Murder	Imara Daima	11 08 2018	9858376 44
	Embakasi	Robbery	Pipeline estate	09.08.2018	9854384 92
	Kasarani	suicide	Zimmerman	10 08 2018	9866655 68
	Starehe	murder	Muthaiga	10 08 2018	9861668 68
	Embakasi	murder	[illegible] area	10 08 2018	9853594.71
	Starehe	murder	mabatini mashimoni	12 08 2018	9860455 57

Figure 11: Geocoded Data Table

3.5 Mapping Methods

Various mapping techniques were used to generate different kinds of maps. The mapping methods used included:

3.5.1 Hot Spot Mapping

Hot spot maps are generated from analysis based on statistics with the goal of distinguishing between areas of high occurrence versus low occurrence areas. From the output of hot spot analysis, an area can be designated as being a hot spot in reference to a statistical confidence. Another notable thing in the methods is that hot spot analysis uses vector data which is crime locations in this case. These points shall be aggregated to polygons which in this case is the polygons representing constituencies of Nairobi City County.

3.5.1.1 Data Aggregation

Hot spot analysis entails preparing the data by first aggregating it considering the points representing crime occurrence locations are spatially spaced with different distances from each other. In this project, spatial clustering tool was used in order to assess incident intensity by use of integration tool from ArcGIS Toolbox. Figure12 demonstrates the input parameters on the tool's user interface.

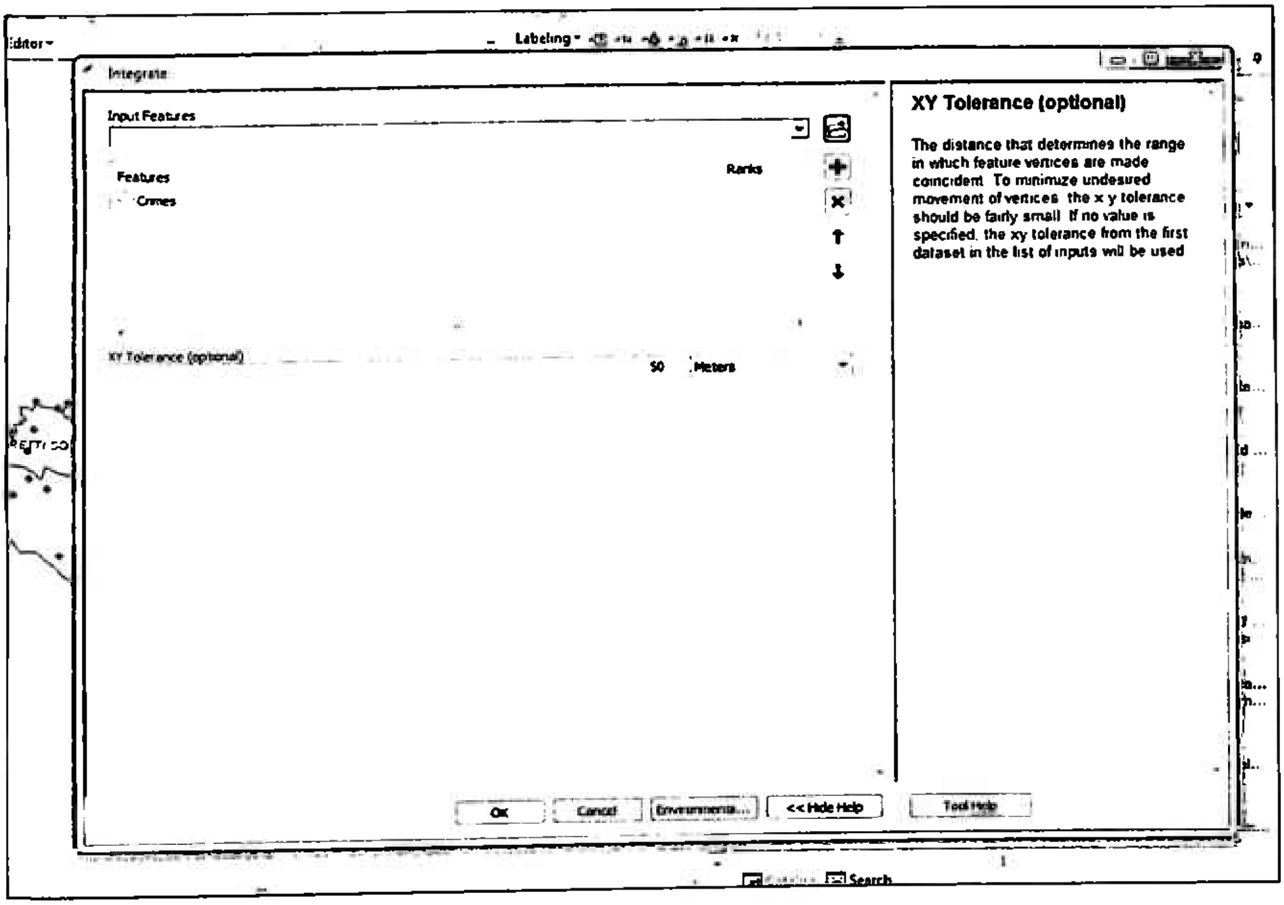


Figure 12: Integrate Tool

After integration, collect events tool is employed in order to snap features within a given distance of each other. The tool also creates a new feature class having a point at each unique location through which a count attribute is generated and indicates number of events. The resultant filed is labelled as ICOUNT and is what we require in the next steps of analysis. Figure 13 demonstrates user inputs in collect event GUI.

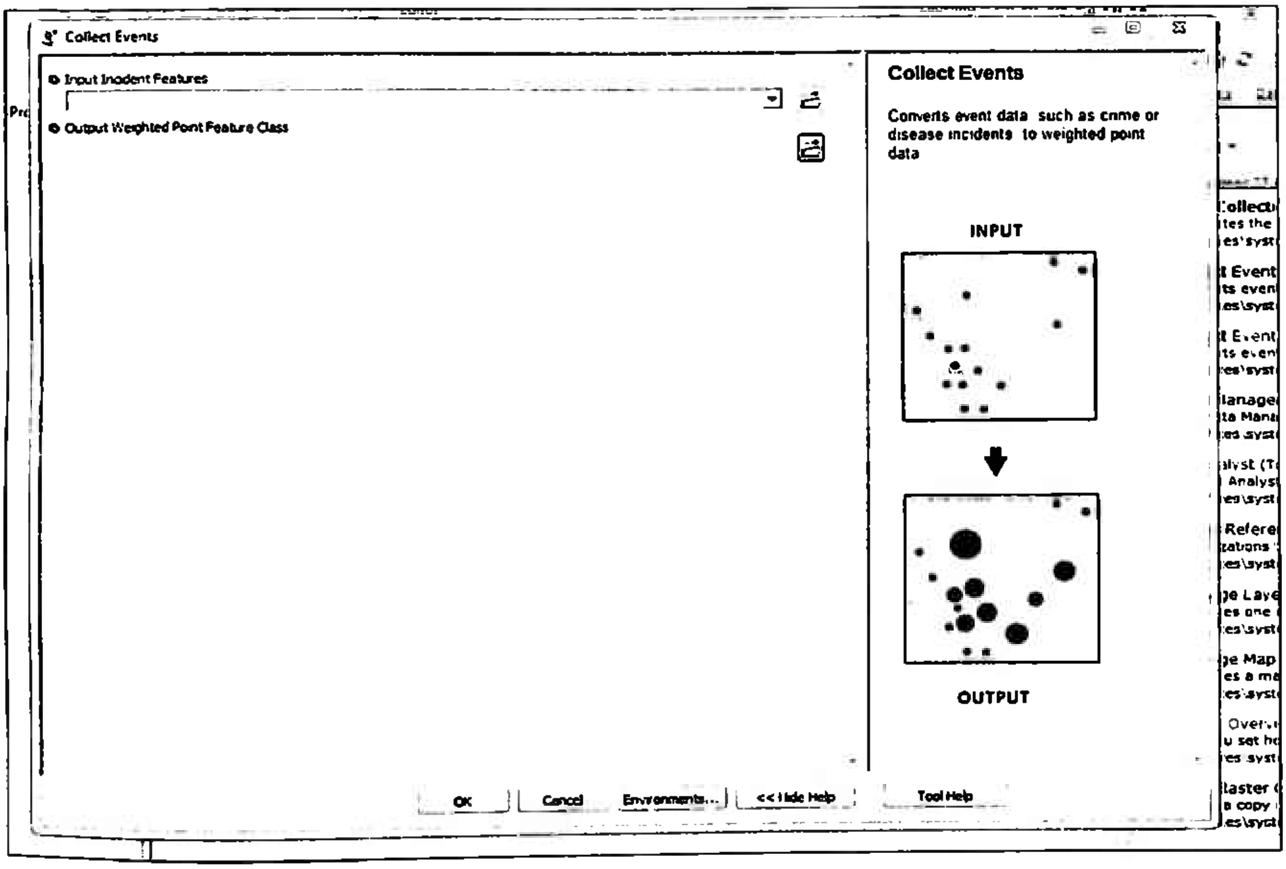


Figure 13: Collect Events Tool

After collecting events the next procedure is performing hot spot analysis which requires input feature, input field (ICOUNT), output feature class and a threshold distance. Threshold distance is obtained by running the Incremental Spatial Autocorrelation Tool whose work is to get the distance that exhibits maximum clustering of points. Spatial autocorrelation increases distances and creates graph of z-score at each distance and from the results we shall use the peak value as the threshold distance during hotspot analysis.

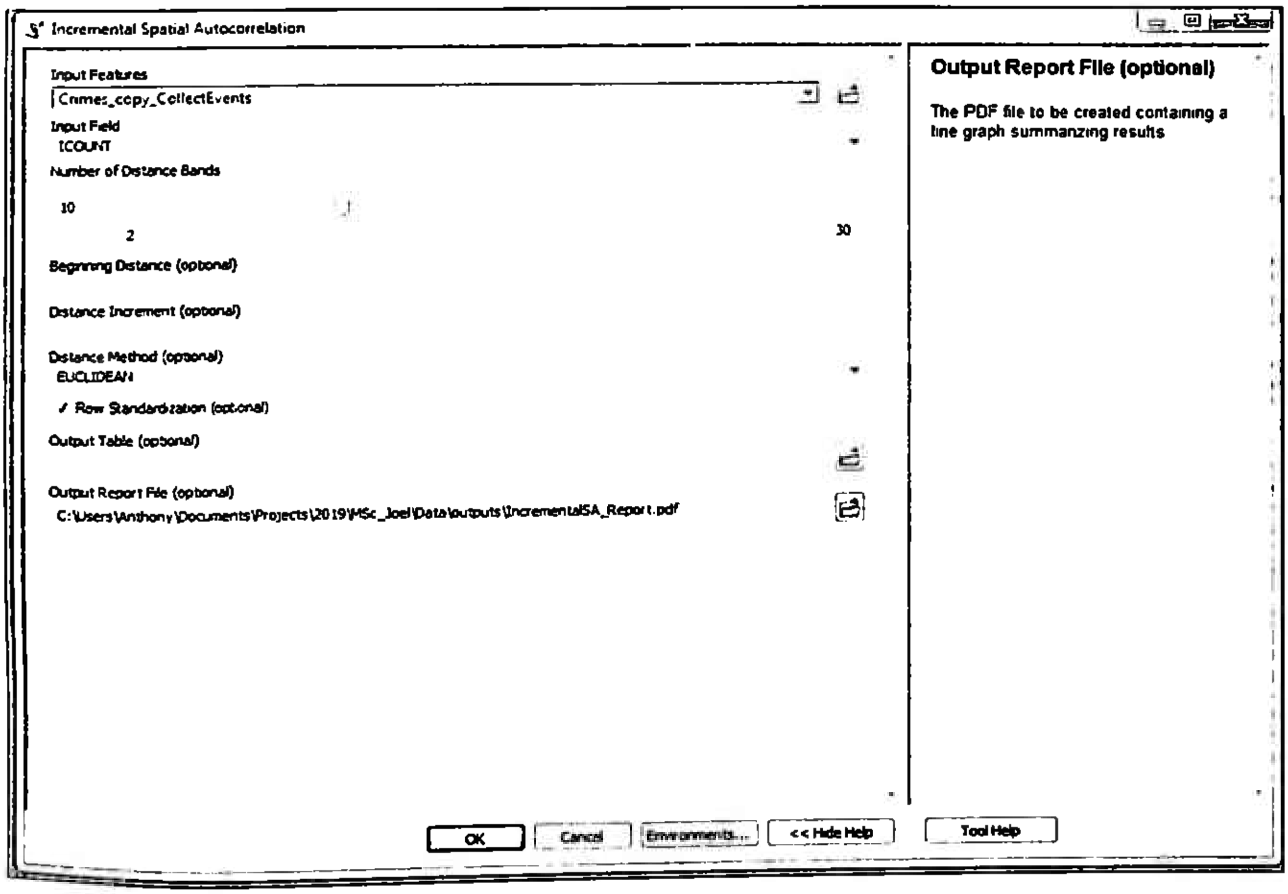


Figure 14: Incremental Spatial Autocorrelation Tool

Proceeding with the hot spot analysis tool, the value obtained from the spatial autocorrelation has been inserted as the final input in the Hot Spot Analysis user interface as shown in figure 15.

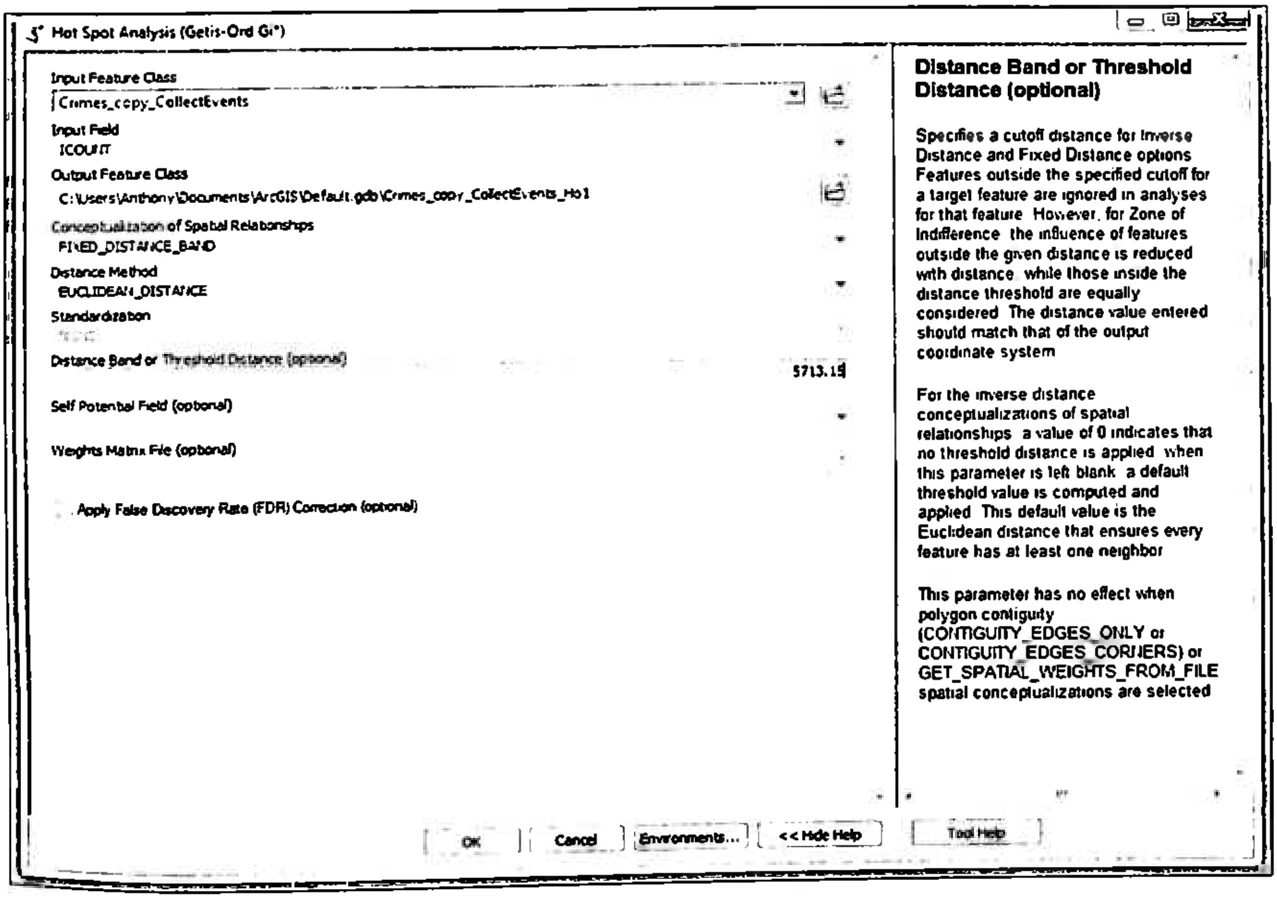


Figure 15: Hot Spot Analysis Inputs

3.5.2. Choropleth Mapping

After crime data is geo-processed, it becomes easier to generate choropleth maps as opposed to having unprocessed data being used directly. The data is joined with administrative boundaries data to enable mapping and identification of crime hotspots. Such map products come in handy in decision making of issues like logistics and staffing i.e. deploying a given number of police staff in a given area for patrol or for a field operation. Examples of choropleth maps include early warning system maps and incidence change maps.

3.5.3 Early Warning Maps

These are maps that make use of color filled polygons to represent quantitative data. Color ramps developed by mapping software are matched to the quantity values of a data such as number of crimes per area. The color ramps vary uniformly based on the variation of the attribute data used.

3.5.3.1 Police Jurisdictions

Due to lack of police jurisdiction zones data, constituencies' data has been used in its place and this data has to be joined with crime data in order to obtain number count of crimes that have occurred within our defined jurisdictions. The output is a map representing distribution of crime in our study area.

3.5.3.2 Spatial Join

To create a count of crime per jurisdiction the spatial join tool from ArcGIS Toolbox is used to merge the attributes of the crime locations which is a point layer with jurisdiction areas which is a polygon layer. Figure 16 shows the spatial join tool interface.

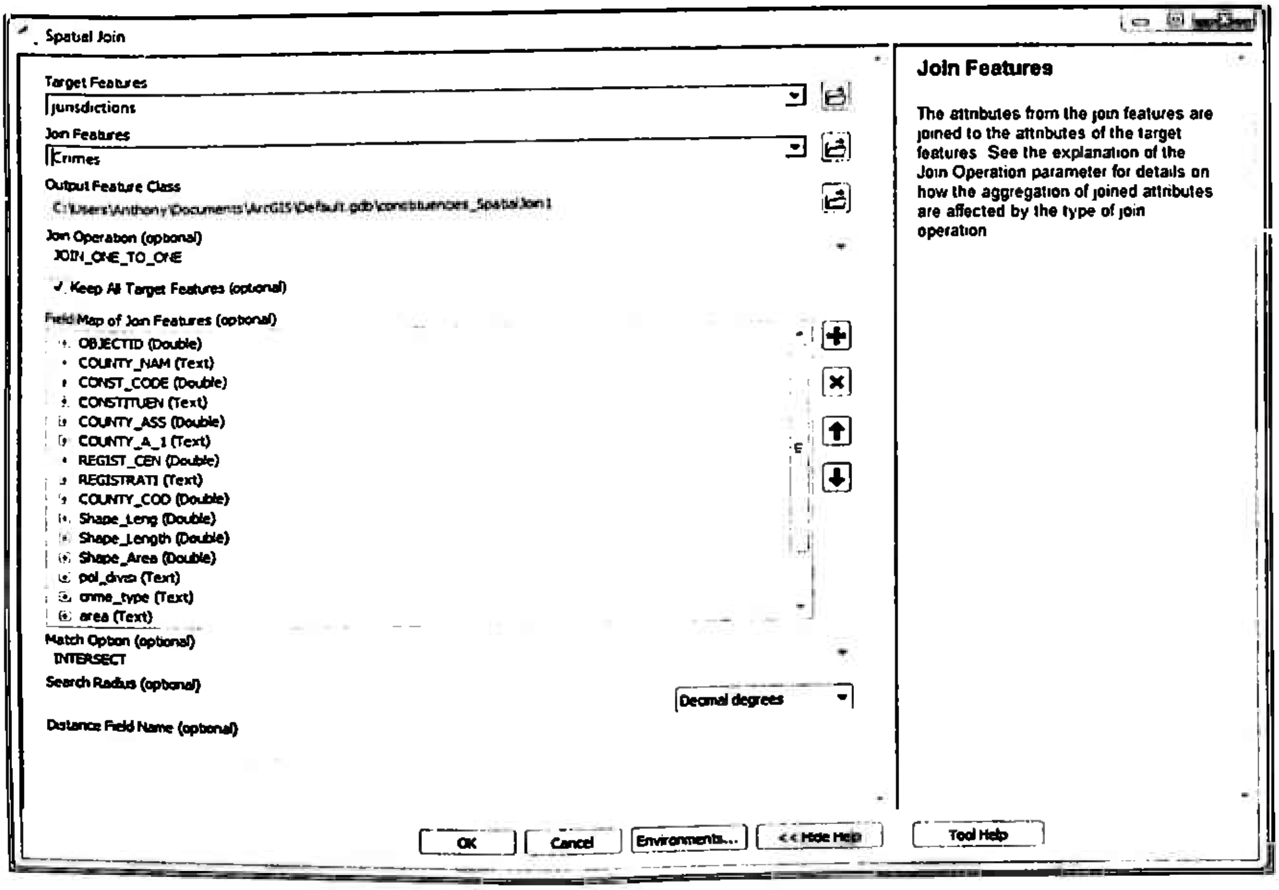


Figure 16: Spatial Join

After performing spatial join it is necessary to sum up the counts of each phenomenon per jurisdiction which is achieved by employing table joins with summation option checked as shown below.

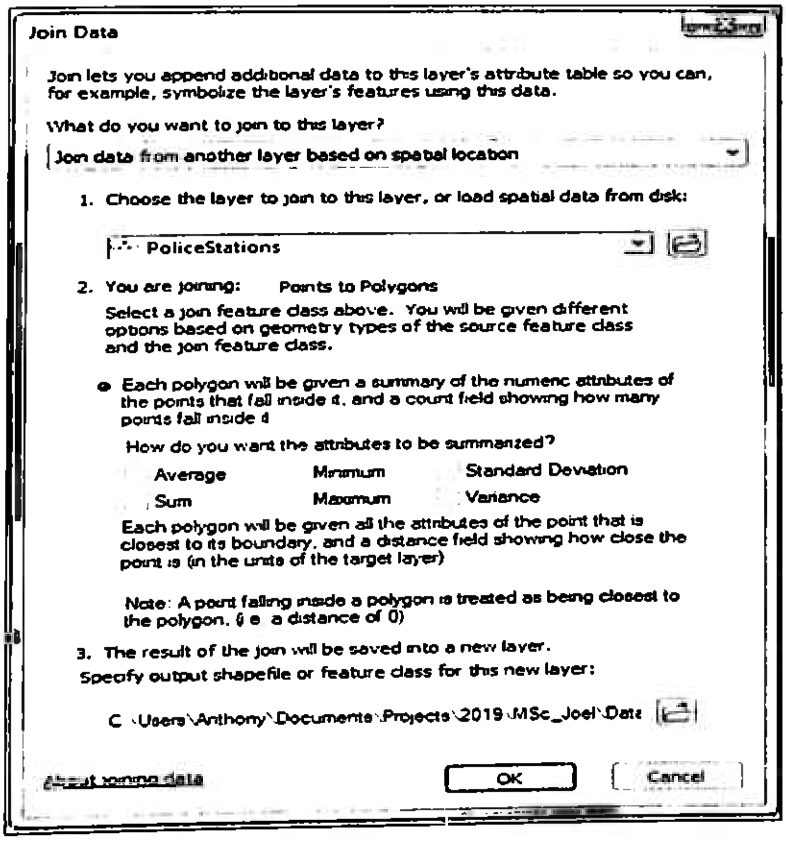


Figure 17: Spatial Join Parameters

3.5.3 Spatial-Temporal Mapping

This comprise of incorporating location-based and time analysis. It answers the questions of 'Where' and 'When' a crime incidence occurred. The period used to generate the spatial temporal map was determined by first identifying distinct periods in crimes reported. Graphs for incidents per month were generated and aided in identifying the spatial-temporal distribution. This period was between August to October in 2018 and November 2018 to January 2019. This type of mapping was facilitated by the time attribute of the crimes reported in the occurrence book. Visualization was achieved by using different colors and sizes of the map elements. The color code is the distinguishing factor of when the crime occurred within the two epochs mentioned.

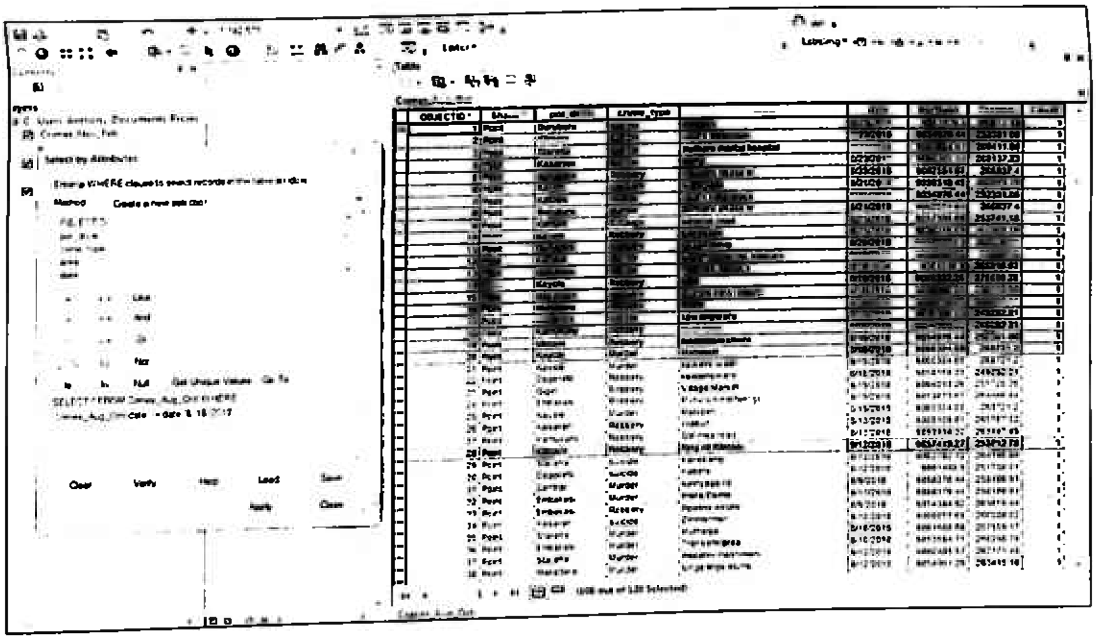


Figure 18: Delineating Data by Date Range

By applying relevant cartography techniques and utilizing the power of GIS software, effective crime maps can be built. Crime maps should be appealing to allow ease of use but, should not lose the focus of conveying information to the interested party. The symbolization methods used apply design principles and are important for policing purposes.

3.5.4 Time Slider

The crime data used has a time attribute. To describe the change in the number of crime spots per unit area, the time attribute must be considered.

Using the Time Slider window in Arc Toolbox, the change in the number of crime spots at unit areas as new crime spots appear was visualized. The time attribute in the crime data was enabled as shown in the figure 19.

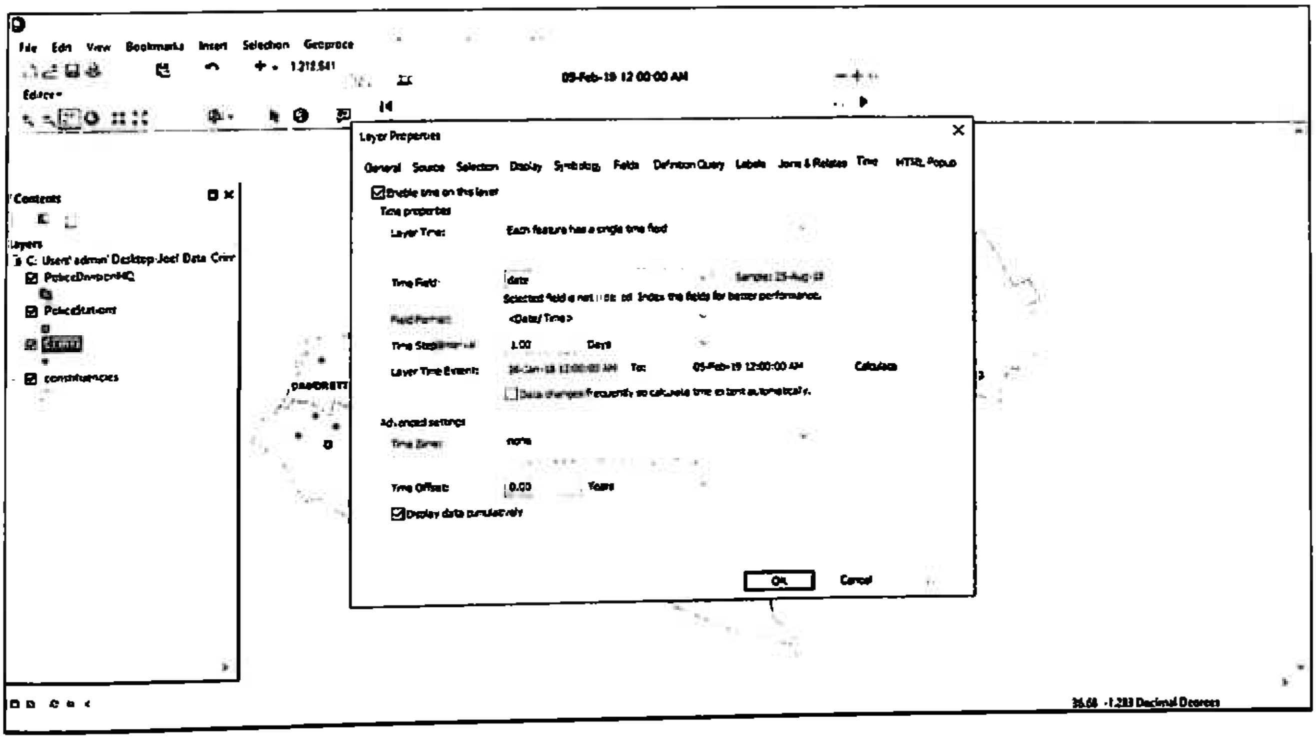


Figure 19: Enabling the time Attribute in Crime Layer

Figure 20 further shows setting up of the first occurrence and the last occurrence that serve as the start and end of crime occurrence corresponding to the crime time attribute data.

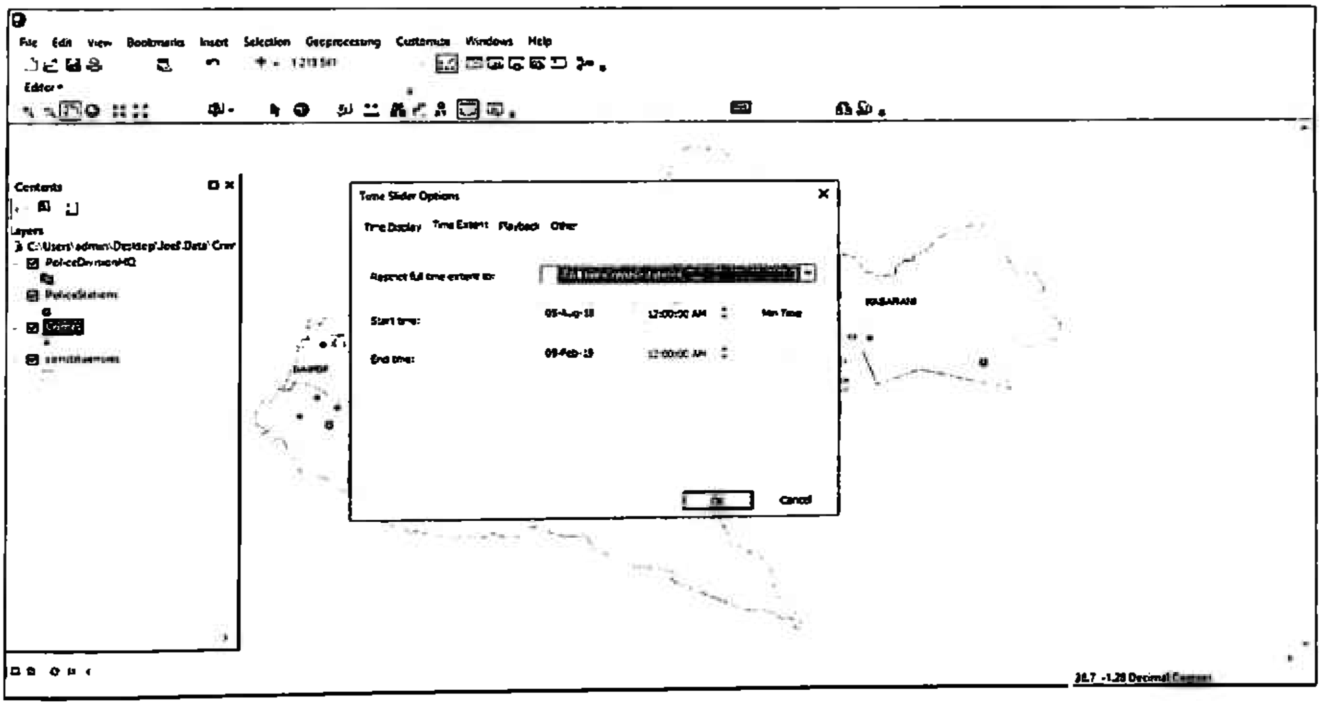


Figure 20: Time slider setting start and end times

3.5.4 Proximity Analysis Mapping

Proximity analysis comprise of the techniques that are used to determine the spatial relationships between a reference point and its neighboring features. In this case, the buffer tool has been employed to delineate buffers of different spatial distances with respect to police stations. Multiple Ring Buffer has been used having different color codes that is used to represent the different zones.

3.6 Summary

The various source and types of data used for crime analysis were discussed in this chapter. The various images used illustrate the crime analysis process and also establishing of the variables used either in mapping or statistics. The objectives mentioned earlier in this document were achieved by borrowing various concepts of mapping techniques. The main reason of selecting choropleth maps was because of the relationship between the police divisions and the reported incidents data. The next chapter discusses the research findings.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Overview

This chapter aims to discuss how the objectives of this project have been accomplished. The discussion is focused on the collection and classification of data and why the various techniques deployed were used in this case.

The main method adopted for this project was a stepwise method of application of GIS in crime mapping and analysis. This technique involved collecting information on crimes and their locations (as well as date data), mapping out the administrative boundaries as used by the police and performing various data analysis procedures to extract information from the data. Time which the crime was reported was used to model early warning maps which was significant for forecasting purposes.

4.2 Hot Spot Map

Crime hot spots represent crime intensity areas. This method of representing crime hot spots was implemented since it is more accurate than the use of distance clustering which groups points together on basis of spatial proximity. However, the approach is rather slow and is effective in large scale maps. The specific areas marked are the exact areas that the crimes happened thus all clusters observed are actually representations and not estimations. This is very important since other mathematical methods depend on the analysts understanding which may be biased or introduce ambiguities unlike in hot spots mapping. Figure below represents crime hot spots in the area of study. The aggregation tool combines points that are near to appear as one bearing multiple attributes of the aggregated points. After aggregation, the collect events tool was used to snap points near each other generating a layer of points within points. A threshold of 100 metres was used meaning that features within the threshold share same address since some of our points especially on the western side of our map are sparsely spaces.

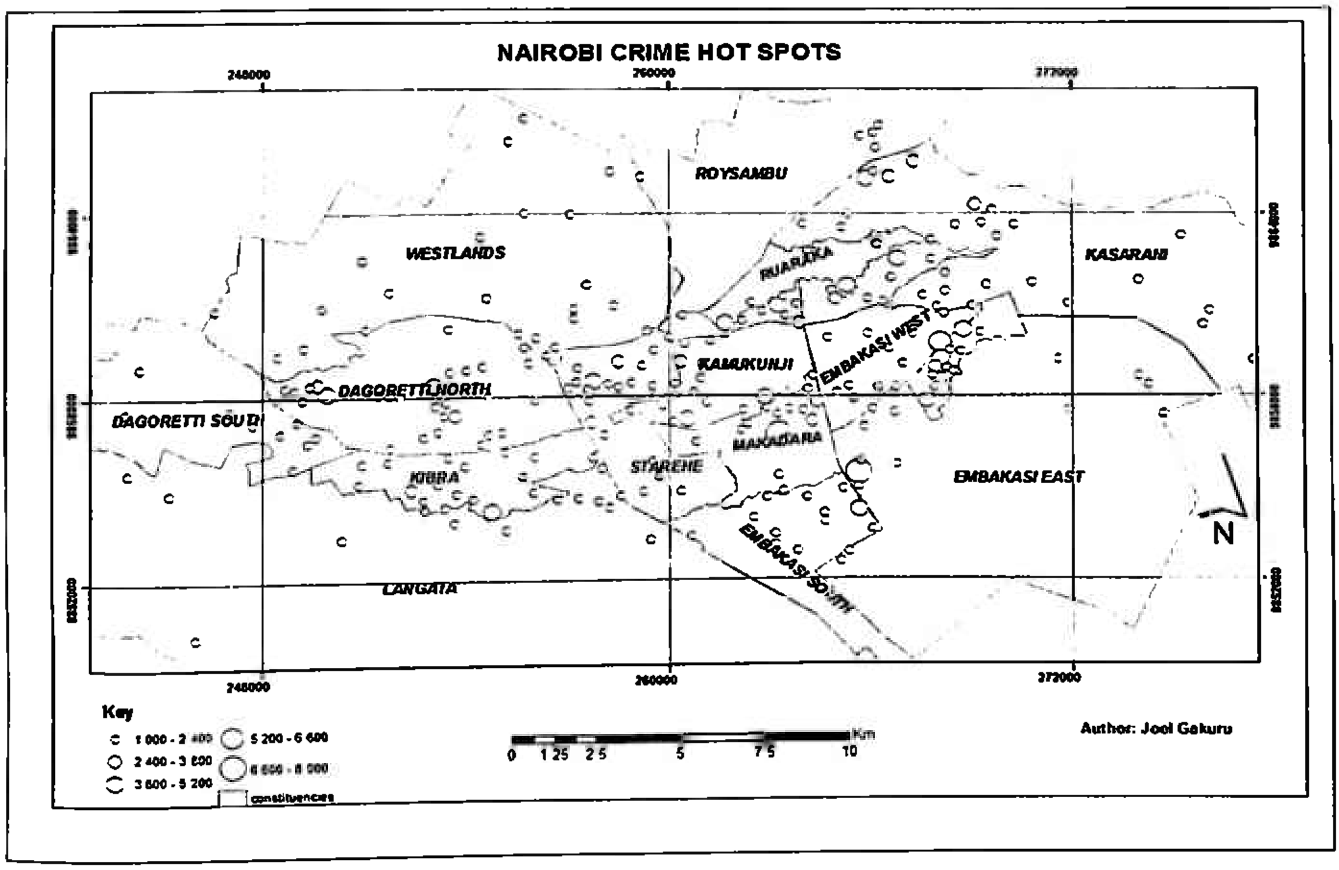


Figure 21: Aggregated Points

Having done the above mentioned steps, the next output is the hot spot map for the study area. The hotspot map output is as shown in figure 22. The point shown contain Z (GiZ) value and P (GiP) value columns where a high Z score and small P score values indicates a significant hot spot and the vice-versa denotes a cold spot. Z score represents spatial clustering whereby a very high or low Z score is directly proportional to an intense spatial clustering.

One of the inputs of Hot Spot Analysis input parameters includes an optional Distance Band (Threshold Distance) which is generated by the Incremental Spatial Autocorrelation Tool. Figures 22 shows the results generated from the Incremental Spatial Autocorrelation.

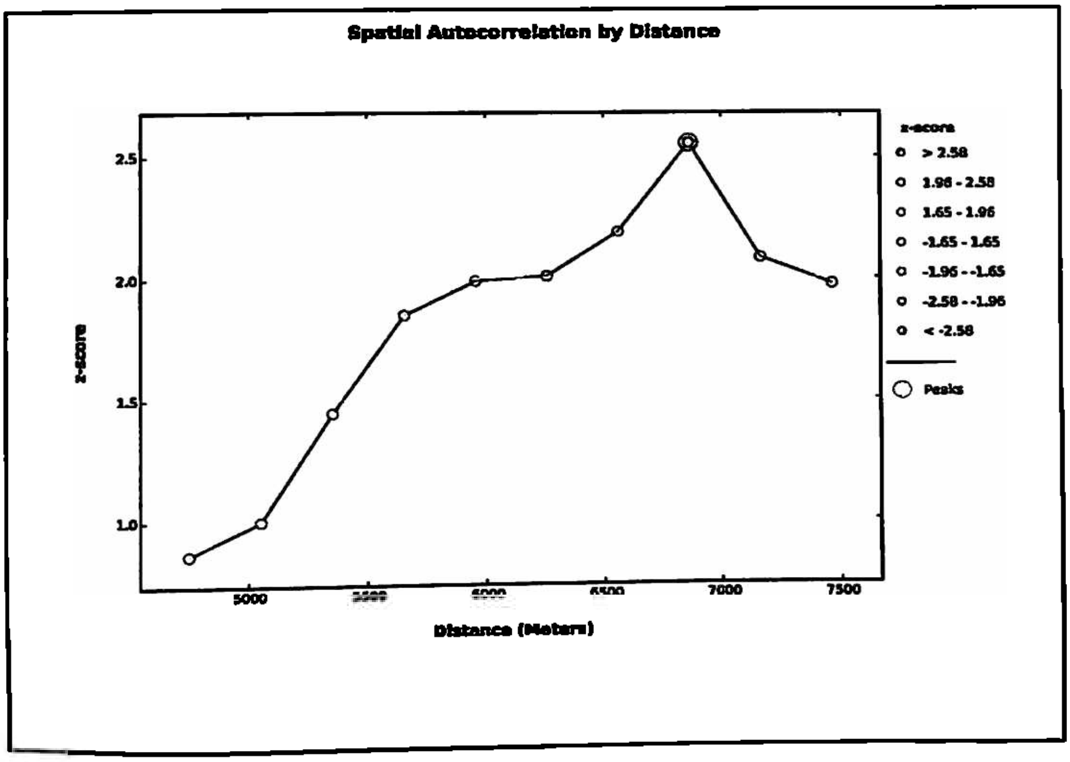


Figure 22: Spatial Autocorrelation Graph

The report consist of three outputs, the first one (in figure 22) being a Spatial Autocorrelation graph denoting the highest possible spatial distance that can be used in hotspot analysis. Note the circled peak point in the graph denoting the recommended (max) threshold distance that we can use in the hot spot analysis to fine tune the output.

Global Moran's I Summary by Distance

Distance	Moran's Index	Expected Index	Variance	z-score	p-value
4749.00	0.007924	-0.004115	0.000195	0.862830	0.388139
5050.65	0.008897	-0.004115	0.000170	0.999411	0.317596
5352.31	0.013134	-0.004115	0.000143	1.442774	0.149084
5653.96	0.016424	-0.004115	0.000124	1.847782	0.064634
5955.62	0.016386	-0.004115	0.000106	1.987731	0.046839
6257.27	0.015258	-0.004115	0.000093	2.006984	0.044751
6558.92	0.015910	-0.004115	0.000084	2.190030	0.028518
6860.58	0.017931	-0.004115	0.000075	2.553866	0.010653
7162.23	0.012721	-0.004115	0.000065	2.083738	0.037184
7463.89	0.011004	-0.004115	0.000059	1.974481	0.048329

First Peak (Distance, Value): 6860.58, 2.553866

Max Peak (Distance, Value): 6860.58, 2.553866

Distance measured in Meters

Figure 23: Global Moran's Index Parameters

The above summary (figure 23) corresponds with the preceding graph, figure 24 and is a list of parameters represented by each point in the graph.

Incremental Autocorrelation Parameters

Parameter Name	Input Value
Input Features	Crimes_copy_CollectEvents
Input Field	ICOUNT
Number of Distance Bands	10
Beginning Distance	4749.000000
Distance Increment	301.653909
Distance Method	EUCLIDEAN
Row Standardization	True
Selection Set	False

Figure 24: Incremental Autocorrelation Parameters

Figure 24 is a list of Spatial Incremental output parameters to be applied in Hot Spot Analysis Tool. There is no right or wrong threshold distance, however it is recommended to run the Incremental Spatial Autocorrelation tool to obtain a fine tuning Threshold Distance.

Figure 25 shows the Hot Spot Tool window.

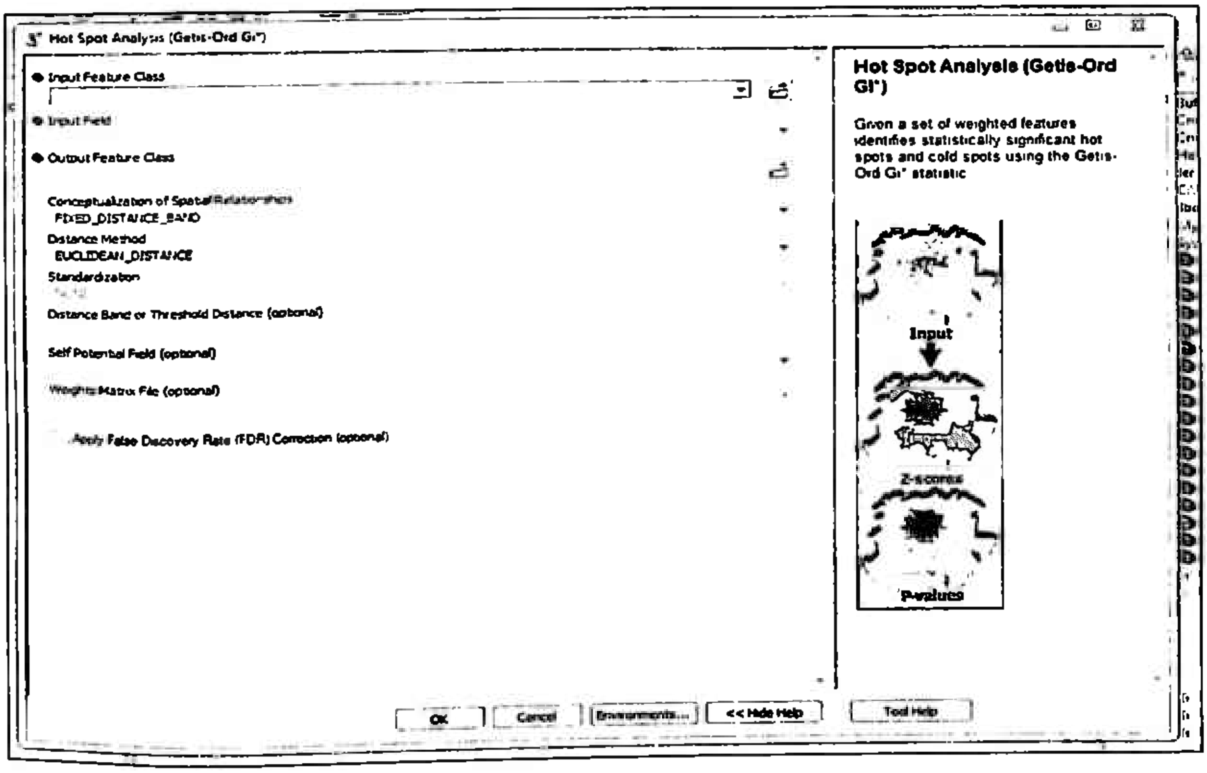


Figure 25: Hot Spot Analysis Tool

To get the Distance Band or Threshold Distance value which is the conceptualization of spatial relationships between the crime point locations, Incremental Spatial Autocorrelation tool under Spatial Statistics toolbox in ArcGIS was used which is discussed in the previous chapter (chapter 3). The succeeding figure 26 shows the Hot Spot tool window with all the inputs and the generated hot spot map.

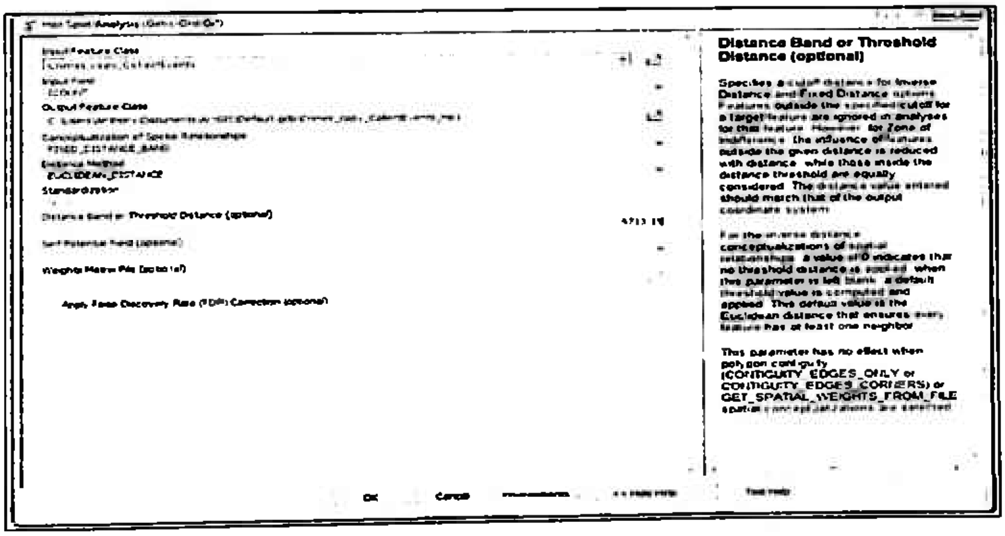


Figure 26: Hotspot Tool with Threshold Distance Input

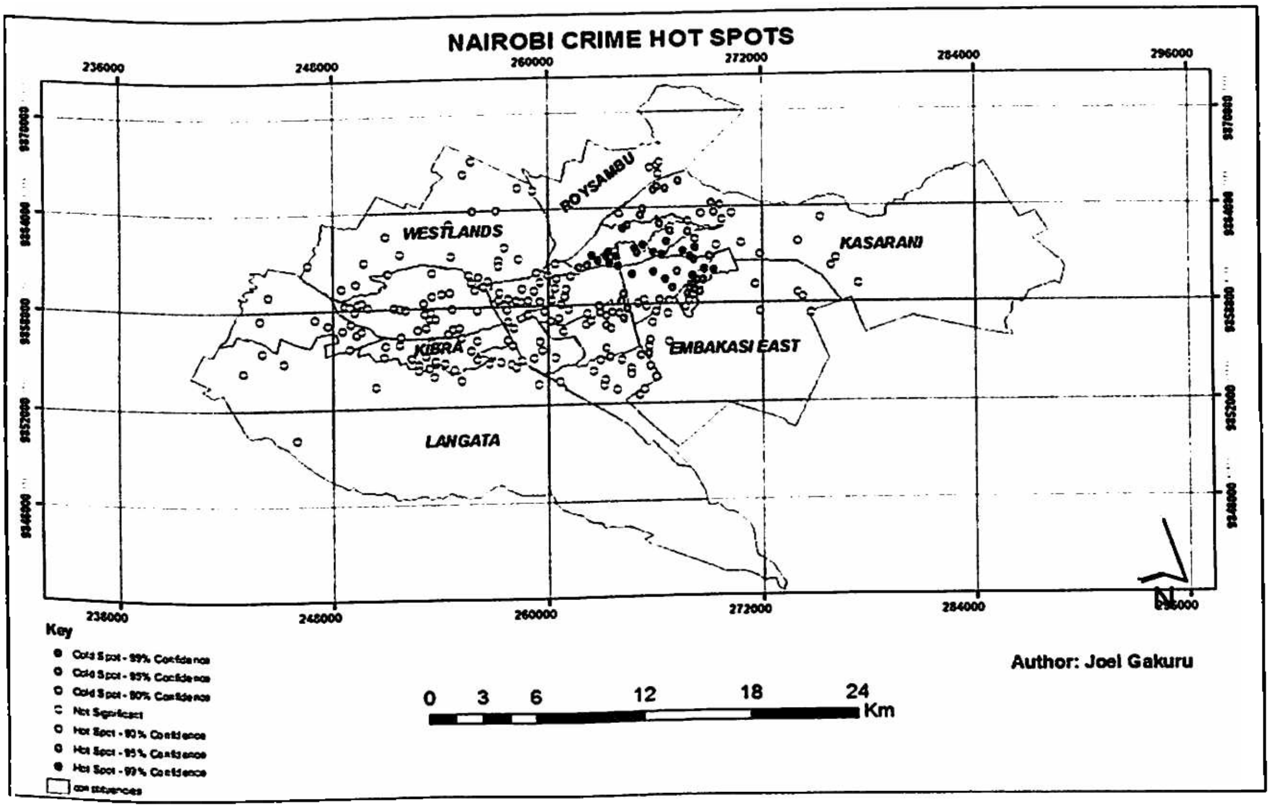


Figure 27: Generated Hot Spots

Note that figure 27 points are not yet interpolated. This leads us to the next output after interpolating with Inverse Distance Weighting (IDW). The essence of IDW tool is interpolated surface generation so as to visualize the intensity of crime with respect to interpolated values on a raster layer.

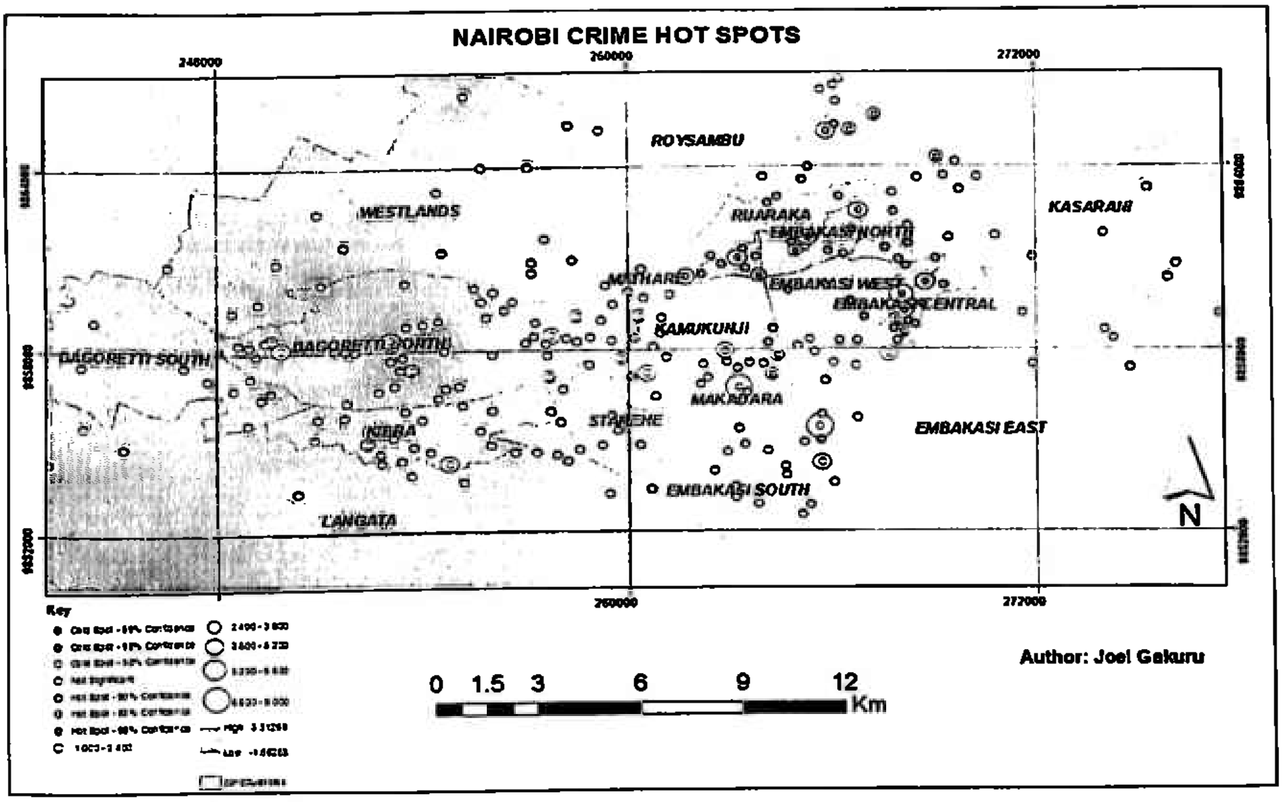


Figure 28: Hot Spot Map with Visualization Surface

It can be noted from the map that areas with a high concentration of crime per location is mostly within Ruaraka and Embakasi Constituencies which bear a high concentration of color code whereas areas towards the West of our study area consists of low crime occurrence as it can be deduced from our results above.

4.3 Choropleth Maps (Early Warning Maps)

Thematic mapping is important when it comes to providing summarized management of information across areas of Interest. This is important especially when there are patterns within the jurisdiction. Early warning strategy is normally incorporated to avoid late change in tactics that may not be effective.

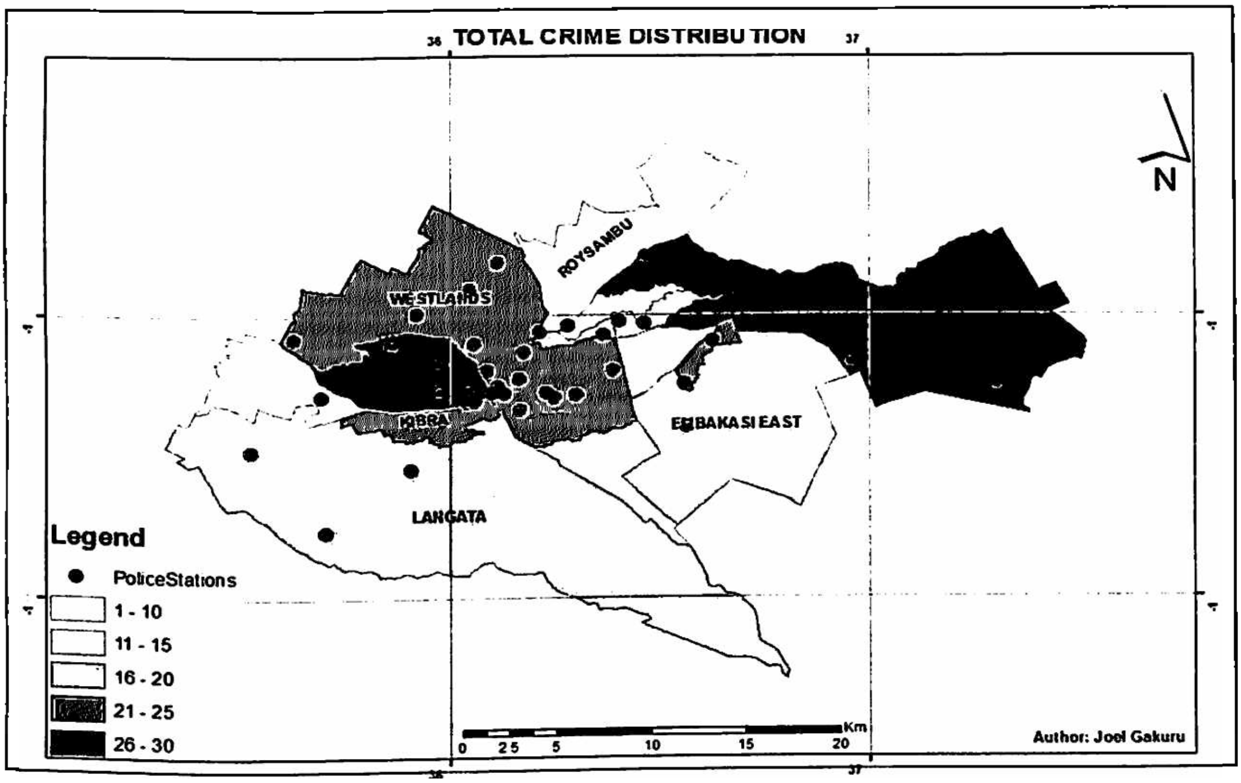


Figure 29: Total Crime Distribution Map

Figure 29 above demonstrates total rate of crime count per constituency having Kasarani and Dagoretti North Constituencies having the highest rate of crime whereas Roysambu and Dagoretti South have least rate of crimes covered under this project. This map can be used to create awareness among the police patrols and other crime force units to be on high alert within these areas over the others.

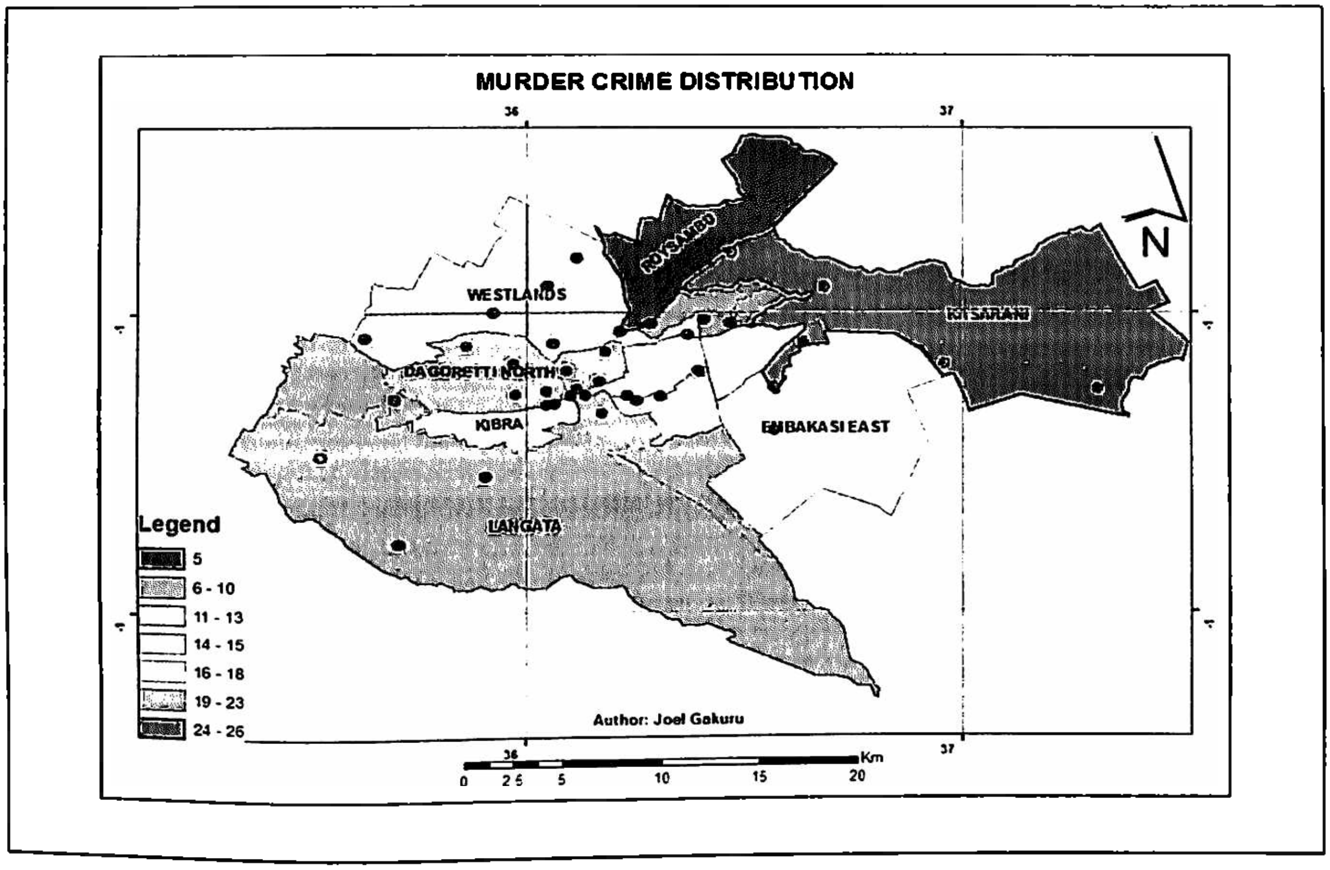


Figure 30: Murder Crime Distribution Map

Figure 30 demonstrates rate of murder count per constituency having Kasarani and Embakasi West Constituencies having the highest rate of crime whereas Roysambu has least rate of murder counts.

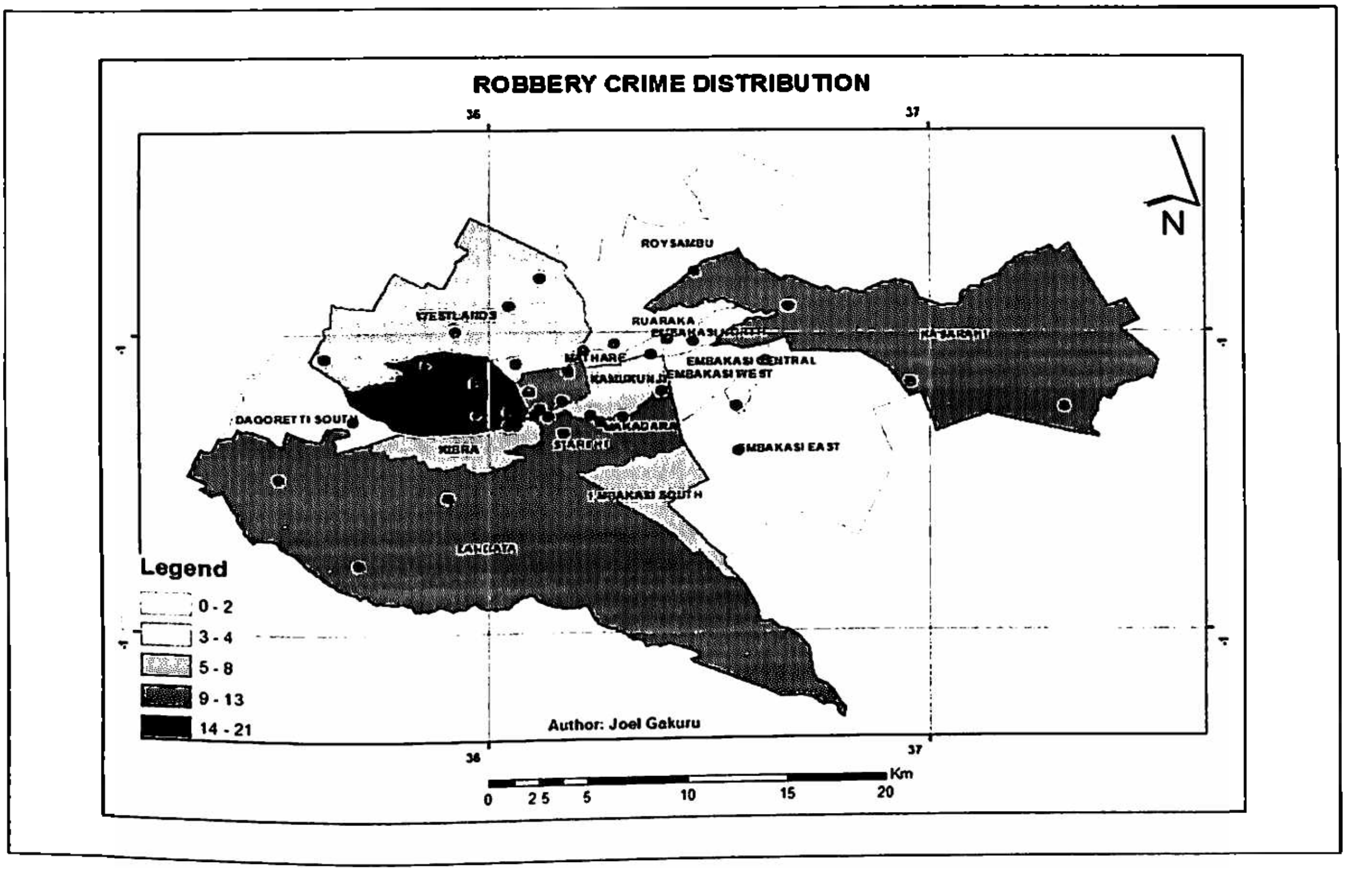


Figure 31: Robbery Crime Distribution Map

Figure 31 above demonstrates rate of robbery count per constituency having Dagoretti North Constituency as the most affected whereas Roysambu, Dagoretti South, Embakasi East, Ruaraka and Embakasi North having least rate of robbery crime. Using different time epochs and analyzing trends can assist crime solutions stakeholders to plan and prepare in advance.

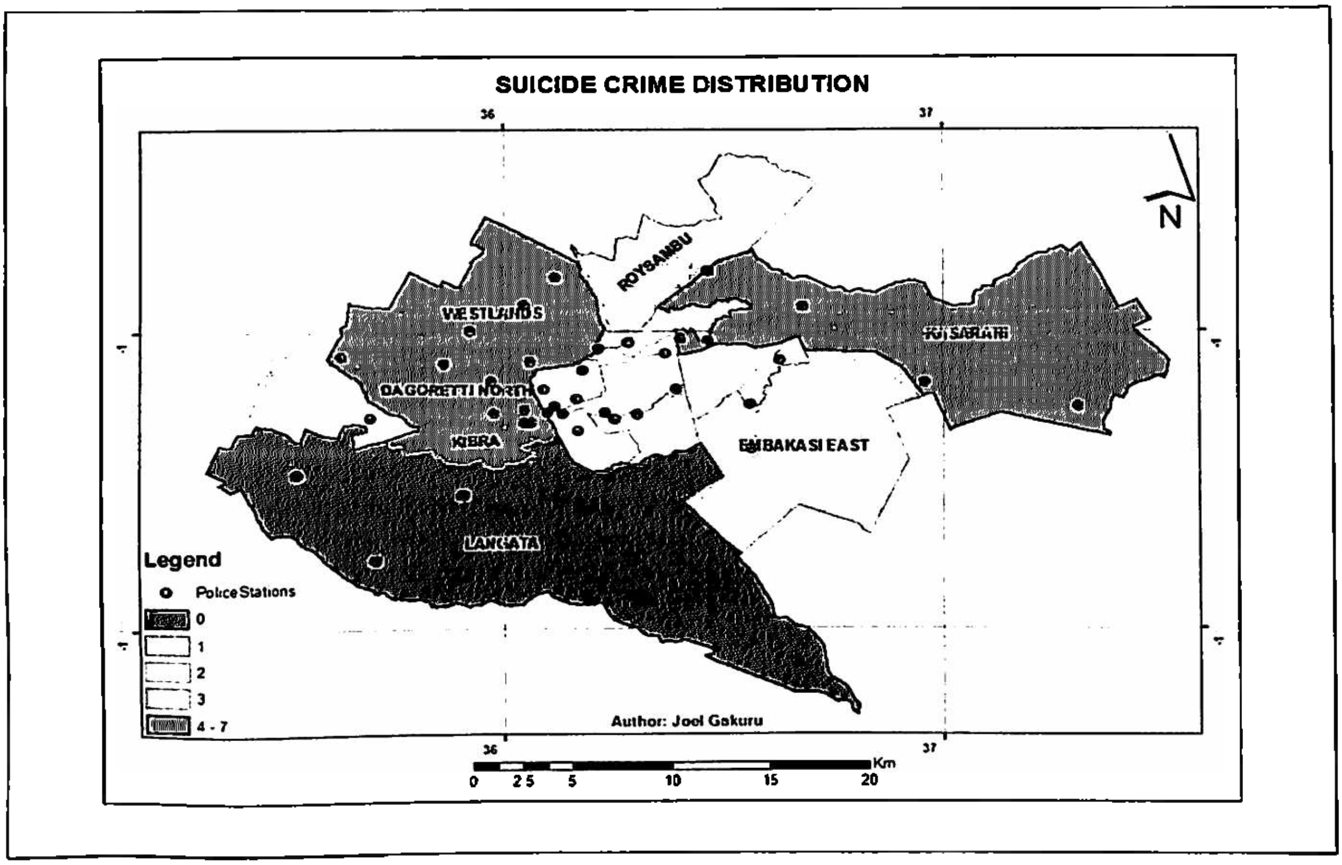


Figure 32: Suicide Crime Distribution Map

Similarly to the previous figures, this map can be used to map out rate of suicide occurrences in Nairobi County.

4.4 Spatial-Temporal Crime Maps

These are maps that showcase spatial phenomenon occurring through a given time frame. In this case, the data has been grouped into two time epochs using the filter SQL in the attribute date column. Purpose of grouping data with respect to a given time frame is to map out crime rate occurrences that can be spread out over years and through these several factors revolving around crime can be extracted; crime spatial patterns, high peak and low peak months or seasons etc.

Figure 33 shows the crimes occurred in the first epoch representing time through August 2018 to October 2018 while figure 34 shows the crimes occurred in the second epoch representing time through November 2018 to January 2019.

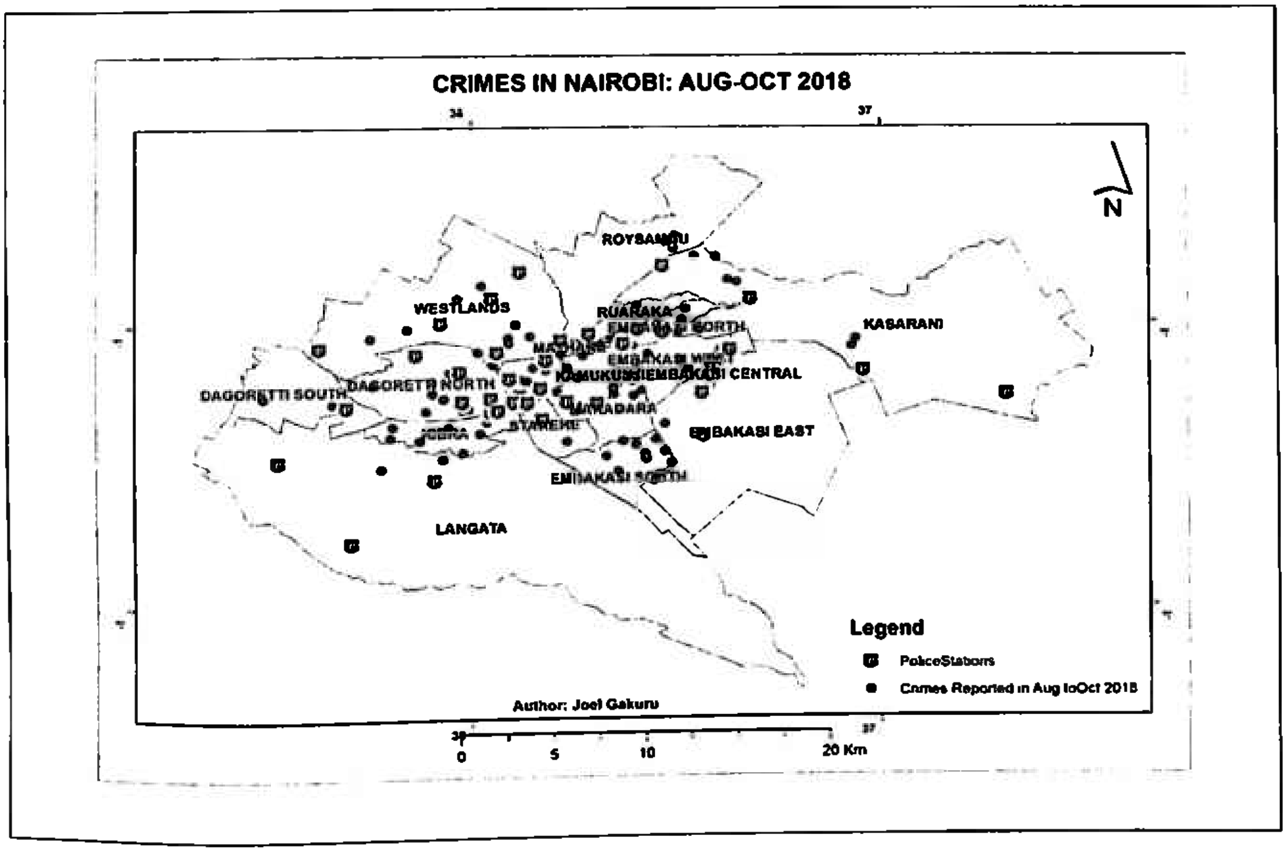


Figure 33: Crimes for August-Oct 2018

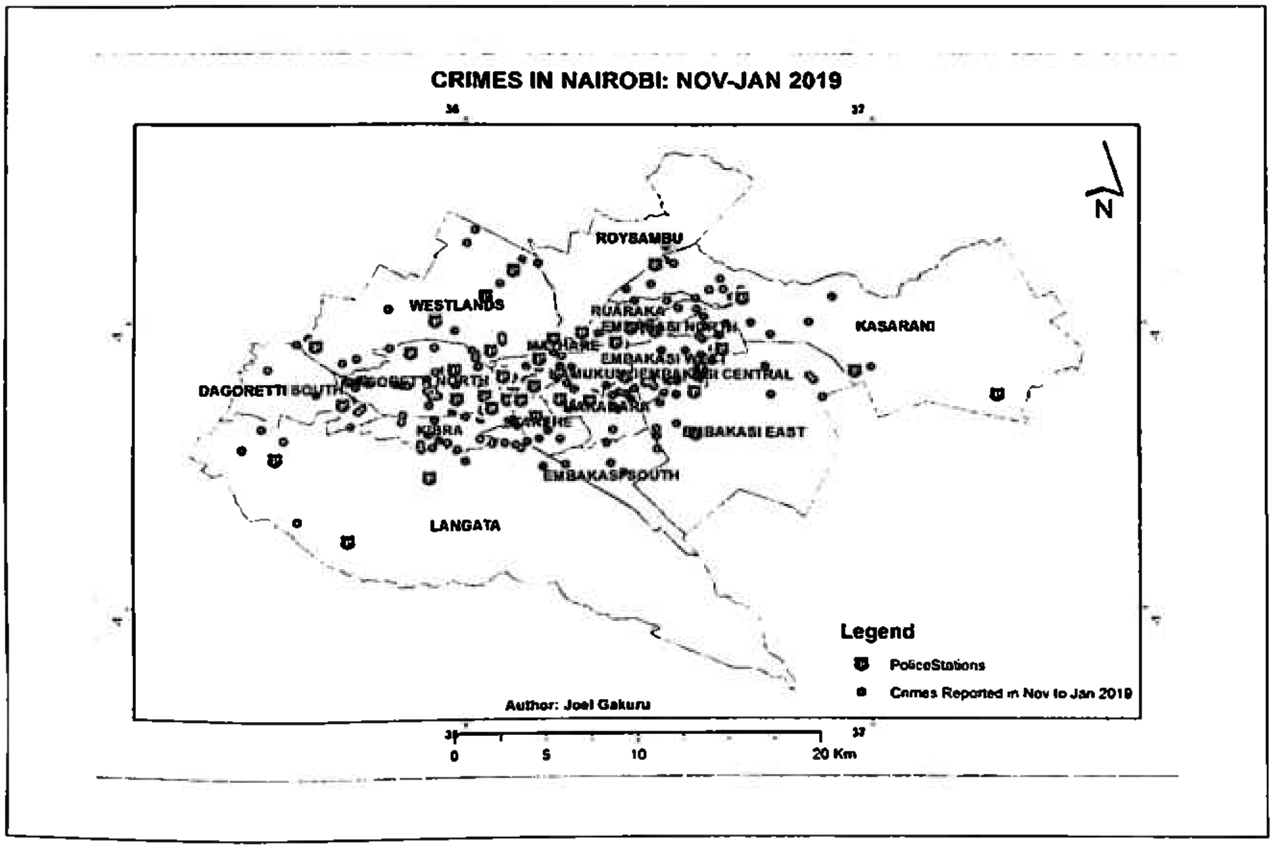


Figure 34: Crimes for Nov '18 - Jan 2019

To add onto the temporal maps, a time video was added to visualize crime occurrence over the period of time corresponding to the time attribute column.

4.4.1 Time Slider Maps

The areas with a higher increase in the number of crime spots were directly observed from the animation created. From the animation, the varying numbers of crime spots were visualized at various times of the crime occurrence as shown in figures 35 and 36.

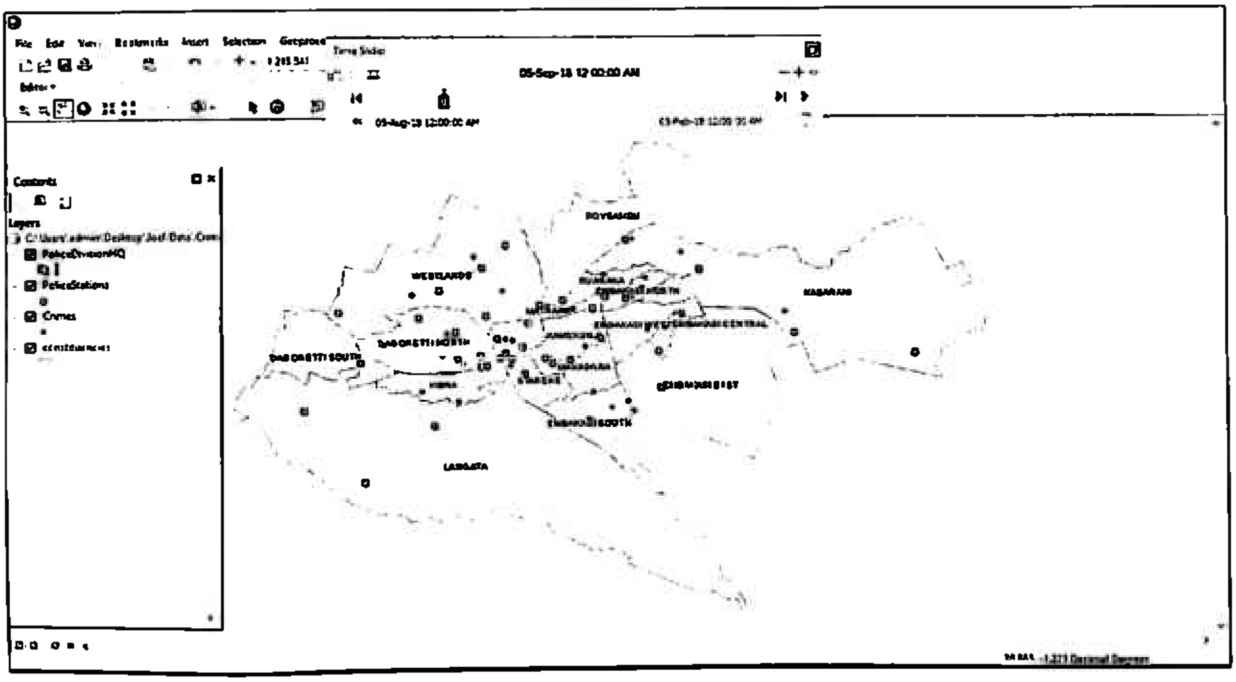


Figure 35: Crimes through Sept 2018

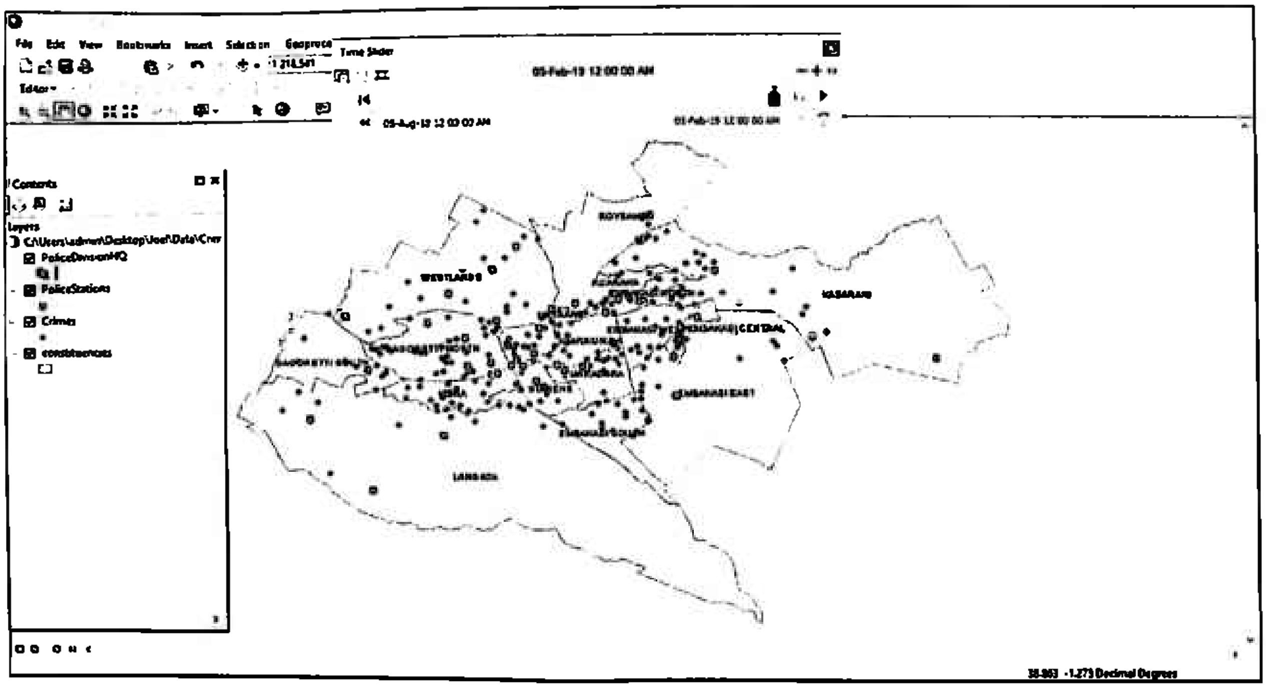


Figure 36: Crimes through Feb 2018

4.5 Proximity Analysis Maps

Proximity analysis are the techniques that are used to determine the spatial relationships between a reference point and its neighboring features. In this case study, the buffer tool has been used to display the crimes within 500 metres, 700 metres and 1 kilometre of police stations. Multiple Ring Buffer were created at the said distances from police stations. Different colors were used to distinguish the different buffer zones.

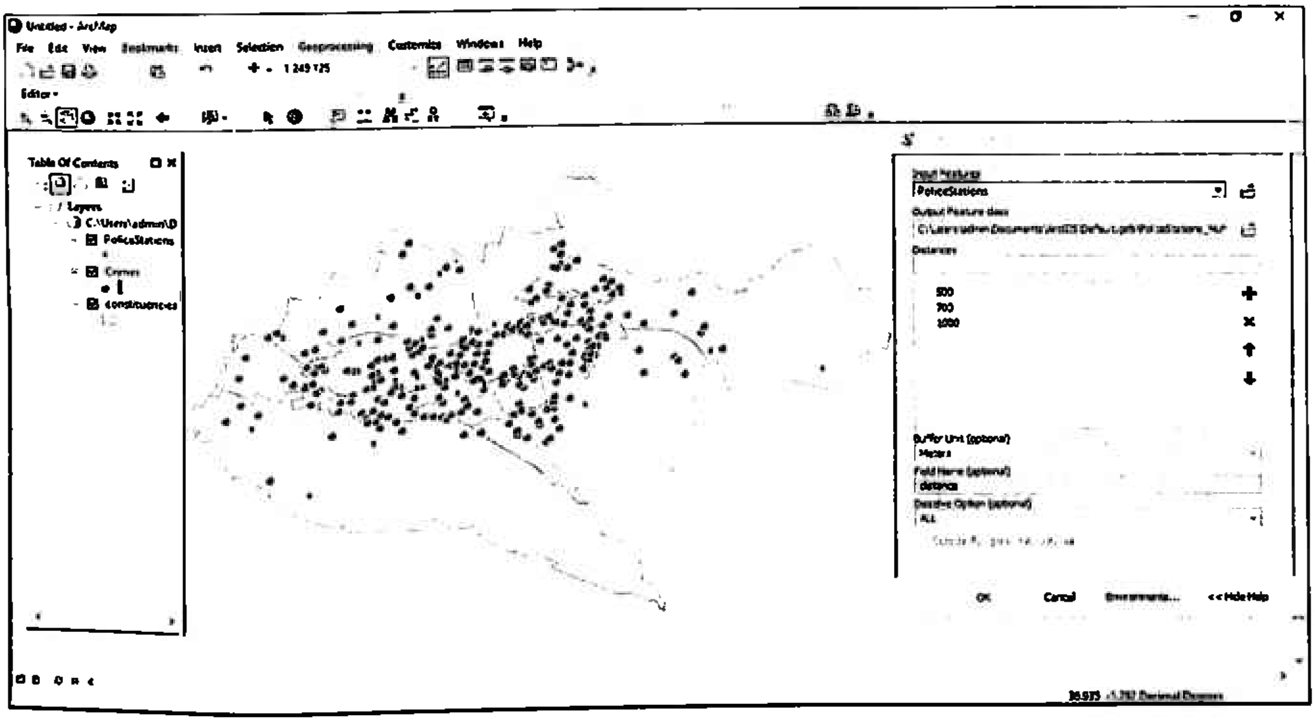


Figure 37: Multiple Ring Buffer

The map figure 38 shows the buffer zones generated around police stations. It can be noted that from the map, limited number of police stations could result in challenges for response time of the police within certain areas especially within Kasarani and Kibra areas where many reported crime locations fall beyond buffer zones.

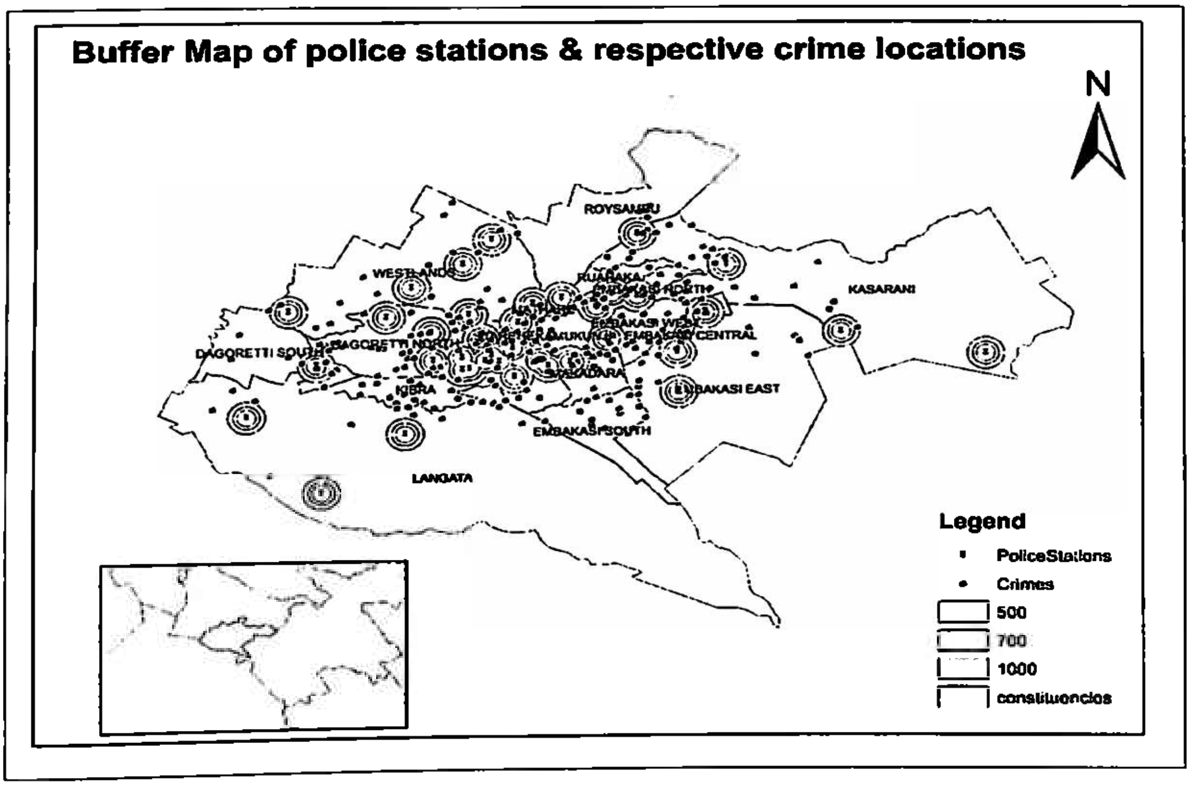


Figure 38: Police Stations vs Crime Locations Map

After generation of the buffer zones, it is necessary to carry out a spatial join of the counts of crime at each of the buffer zone. From the attribute table below, the number of crime scenes at distances of 500 metres, 700 metres and 1kilometre respectively are given.

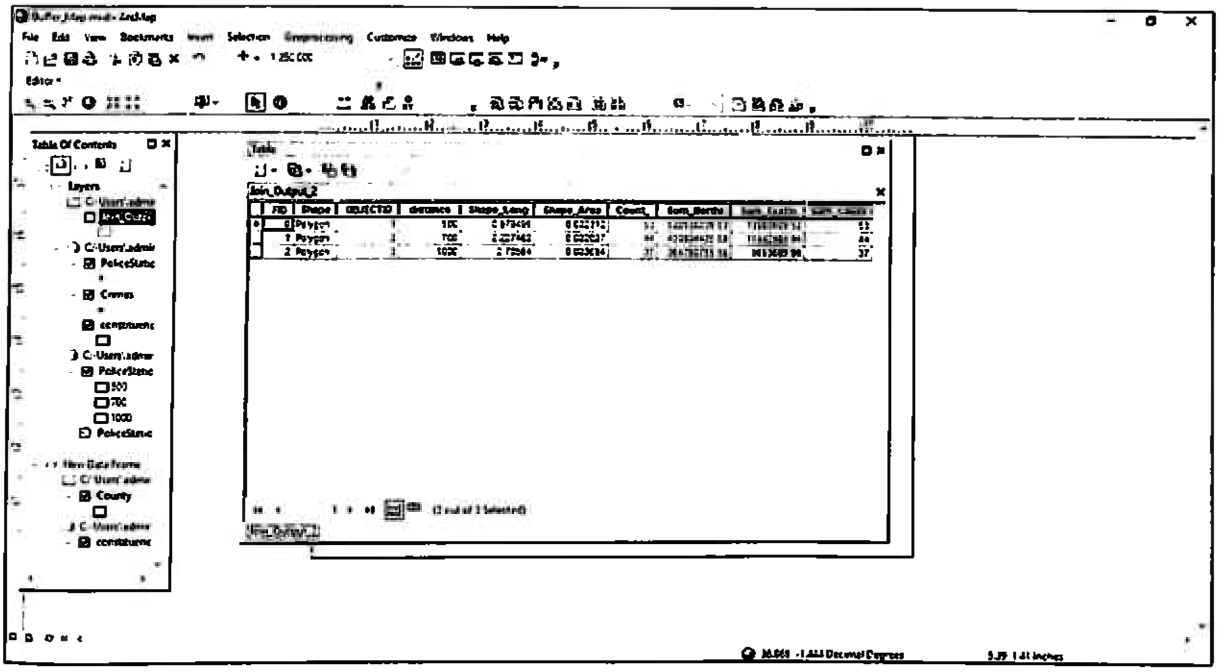


Figure 39: Crime Buffer Distances

From the attribute table in figure 39, it can be noted that at distances of 500 metres from the police stations, 53 crimes were reported as well as 44 and 37 for distances of 700 metres and 1kilometre respectively.

4.6 Police and Population

4.6.1 Police Jurisdictions versus Population

Constituency	No. of police stations (OSM)	No. of police stations (Data)	Population of area (NCC, 2017)
Dagoretti North	5	5	248,841
Dagoretti South	2	2	245,217
Embakasi Central	2	2	252,009
Embakasi East	2	2	222,072
Embakasi North	2	2	245,829
Embakasi South	8	2	272,466

Embakasi West	2	2	244,875
Kamkunji	4	1	287,305
Kasarani	4	4	269,606
Kibera	15	1	241,623
Langata	9	3	245,217
Makadara	2	2	217,431
Mathare	5	2	262,131
Roysambu	3	2	259,791
Ruaraka	5	2	263,084
Starehe	3	5	225,034
Westlands	7	5	239,582

Table 2: Population vs Police Posts

Table 2 above illustrates how the constituencies with highest populations in Nairobi County are underserved. The distribution of police stations has historic inclination to the former Provinces, districts and divisions.

4.6.2 Police Stations to Population Ratio

Table 3 below shows the number of number of people from the demographic data served by a police station. This ratio has been obtained to demonstrate the limited police force within Nairobi County.

Constituency	Ratio
Dagoretti North	1/49,768.2
Dagoretti South	1/122,608.5
Embakasi Central	1/126,004.5
Embakasi East	1/111,036.0
Embakasi North	1/122,914.5
Embakasi South	1/34,058.3

Embakasi West	1/122,437.5
Kamkunji	1/71,826.3
Kasarani	1/67,401.5
Kibera	1/16,108.2
Langata	1/27,246.3
Makadara	1/108,715.5
Mathare	1/52,426.2
Roysambu	1/86,597.0
Ruaraka	1/52,616.8
Starehe	1/75,011.3
Westlands	1/34,226.0

Table 3: Police Posts to Population Ratio

The ratio above demonstrates the workload on the police force in mitigating crime occurrence in Nairobi County with inclusion of other factors like infrastructure, incentives etc. The number of people being served by police stations in Makadara, Embakasi North, East, Central and Dagoretti South exceeds hundred thousand count.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The goal of this project was to demonstrate specific types of crimes in the area of study; Nairobi City County. These crimes include robbery, murder and suicide. These crimes have been mapped based on location of reporting within the area of study and various geographic based and non-geographic based phenomenon have been incorporated in the maps. Distribution of these crimes has been well demonstrated using hot spot maps, choropleth maps and spatial-temporal mode of analysis.

From research, various contributory factors of crime in Nairobi have been pointed out some reflecting managerial based contributory factors like incentives and appraisal within stakeholders dealing with management of crime. Other factors include societal contributory factors like change in crime tactics among perpetrators of crime and an increase in unemployment rate especially among the youth.

Compilation of various crime statistics incorporating demographic data adds more value to the objectives of the project on demonstrating perceived risk factors which can be addressed from the jurisdiction level up to the county-specific level, ground up approach toward reducing the rate of crimes.

Development of different crime maps serves as a means of record keeping through which research can be done periodically in order to identify the spatial patterns with regard to any specific crime. This helps the police force in solving crime as it occurs and device new tactics to deal with modern day crimes. Moreover, mapping of crime also creates awareness among the public through various timely decisions from the police force with creating alerts as one example or providing recommendations on where to report in case a crime occurs.

Maps developed within this project demonstrate challenge in terms of noting police jurisdiction extents as there is no data on polygons representing jurisdictional extents. The importance of having this is to notify the public about where to report to in the event of a crime occurrence whereby an individual can report a crime to the nearest police stations and also a means through which a dispatch can be made within a good time in response to crime.

5.2 Recommendations

The key players in the mitigation of crime in Nairobi can appreciate the use of various GIS analyses outputs which show the true picture of what is reflected on the ground. One of the recommendations include setting up of a crime repository within the police departments through which temporal and spatial data can be stored for use in the future or whenever needed. A repository could be useful in providing more information about the various aspects discussed in this project, one of them being mapping crime patterns

Provision of either a centralized GIS laboratory for the police through which crime occurrences once reported can be booked with respect to a given location, say the police station at which the crime was reported and booked in the occurrences book. This facilitates a process of dispatch, crime analysis based on a given police area of jurisdiction and also serves as an additional tool to the crime repository though which various police posts can share data based on crime occurrence and location.

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