



ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

**SCHOOL OF CIVIL AND ARCHITECTURE ENGINEERING
DEPARTMENT OF GEOMATICS ENGINEERING**

SPATIAL DISTRIBUTION ANALYSIS OF CRIME AGAINST PROPERTY AND CRIME AGAINST PERSON USING GIS: A CASE OF ADAMA CITY, ETHIOPIA

**A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF
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DECLARATION

I hereby declare that the study entitled “Spatial Distribution Analysis of Crimes against Property and Crime against Person Using GIS: A Case of Adama City, Ethiopia” has been carried out by me under the supervision of Dr. Tilahun Erduno and A.S.Mohammed Abdul Athick M.Sc,M.Tech, Department of Geomatics Engineering, Adama Science and Technology University during the year 2015-2016 as a part of Master of Science program in Geodesy and Geomatics Engineering. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

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Date: July, 2016

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CERTIFICATE

This is to certify that the study entitled “Spatial Distribution Analysis of Crime against Property and Crime against Person: A Case of Adama City, Ethiopia” is carried out by Aman Hussen under our guidance and supervision. This is the actual work done by Aman Hussen for the partial fulfillment of the award of the Degree of Master of Science in Geodesy and Geomatics Engineering from Adama Science and Technology University, Adama, Ethiopia.

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LIST OF ACRNOMYS

GIS	Geographic Information System
KDE	Kernel Density Estimation
CSA	Central Statistical Agency
M-A	Melka Adama
B-SH	Boku Shenen
D-S	Dabe Soloqe
D-A	Deka Addi
FDRE	Federal Democratic Republic of Ethiopia
GPS	Global Positioning System
ESRI	Environmental Systems Research Institute
RAM	Radom Access Memory
UTM	Universal Transverse Mercator

ABSTRACT

Spatial distribution of crimes against property and crimes against person were analyzed using GIS in Adama city, in Ethiopia, for the period of 2013 and 2014. In the study, both statistical and spatial analyses were performed. Accordingly, the rate of crime per 1000 persons, point density estimation, area density estimation, kernel density estimation, proximity and both overlay & crime rate per square kilometers analyses were carried out to reveal the spatial distribution of crime in Adama city.

The finding suggests that the rate of crime incident is increasing by 11.2 % compared to the 2013 and the 2014 number of crimes in Adama city. The reason is; because of unplanned urban expansion, rapid population increment particularly due to migrations and the police manual crime analyzing scheme in the city. Crime against property is the highest from the two categories which account 62.14 % from the total. The rate of crime against property per 1000 persons is highest in kebele 08 which is 12.7 crimes while; crime against person is highest in kebele 06 which account 9.9 crimes per 1000 persons. Using the three GIS crime hotspot identification techniques which are point density estimation, area density estimation and kernel density estimation reveals that, the center of Adama city is identified as crime hotspot area. The proximity analysis revealed that both crimes against property and crimes against person are highest in the distance between 250m and 500m from the police station which they account 37.87 % from the total crimes. The results of the spatial relationship of crime incidents with land use and population density revealed that, most of the crimes were committed on commercial and very high populated areas which they account 434.26 and 430 crimes per square kilometers respectively. Therefore, there were strong relationships between the rate of crime incidents with land use and population density.

Key Words: GIS, Hotspot, Crime Rate, Proximity.

INTRODUCTION

1.1Background

Various studies conclude that crime has no single definition but can be defined in legal and non-legal sense concepts. From a legal point of view, it refers to breaches of the criminal laws that govern particular geographic zones (jurisdictions) and are aimed at protecting the lives, property and rights of citizens within those jurisdictions and in non-legal point of view would define crime as acts that violate socially accepted rules of human ethical or moral behavior [1]. According to 2005 (Art. 23 (1)), Criminal Code of Federal Democratic Republic of Ethiopia (FDRE), “A crime is an act which is prohibited and made punishable by law”. In this Code, an act consists of the commission of what is prohibited or omission of what is prescribed by law [2].

According to Dambazau (1997) [3], crimes are categorized into four main categories: Crime against person, Crime against property, Crime against lawful authority and Crime against local act. But, the purpose of this thesis only crime against person and crime against property were discussed. The term “crime against person” refers to a category of crime which usually involves bodily harm, the threat of bodily harm or other actions committed against the will of an individual. These include murder, attempted murder, attempted suicide, wounding, stabbing with knife, rape, kidnapping, etc. Crime against property refers to a category of crime which either takes or destroys the property of someone else or attempt. These include: snatching, pick pocketing, theft from shop, burglary, burning crops or attempt, fraud/cheating, purchasing stolen property, etc.

There are three theories that suggest the importance of places for understanding crime: routine activity theory [4], crime pattern theory [5], and rational choice theory [6]. Routine activities theory suggests that when motivated offenders and suitable targets meet in the absence of capable guardians, crime is likely to happen. Crime pattern theory is a way of explaining why crimes are committed in certain areas. Rational choice perspective in that it focuses on the characteristics of crime rather than on the characteristics of the offender. Crime is a global problem even though the rate of occurrence differs from country to country. Particularly, the rate of crime incidence is increasing in developing countries due to unplanned urban expansion and

the rapid urban population growth of the cities resulting from industrialization and technological advancement [7]. And also due to poor socio, political and environmental conditions and their classical crime recording and analyzing systems [8].

As the Ethiopian Federal Police Commission statistics reports from 1996 to 2002 showed, the rate of crime incident is increasing in Ethiopia. In Oromia Police Commission, there are no modern tools and techniques that can support in managing crime records properly and efficiently [9]. As a result almost all the decision-making processes of the commission are not supported by tools and techniques that could extract patterns from previous crime records [9]. In the same manner, the rate of crime incident is increasing in Adama city and the city police station used manual crime recording and analyzing techniques. The rate is increased by 11.2 % from 2013 to 2014 recorded crimes against property and crimes against person together. Hence, the study examined the spatial distribution of crimes supported by GIS technology for crime incident recording and analyzing techniques. Using these techniques, crime hotspot areas were identified and the spatial relationship of crime incidents with police station, land use and population density were examined.

1.2 Statement of the Problem

In Adama city, the crime incidents are showing an increasing rate. For instance, the total number of crimes committed on 2013 both crime against property and crime against person was 956 but on 2014, it was 1199 number of crimes. This might be because of unplanned urban expansion and rapid population increment particularly due to migrations. However, the city police station uses manual crime recording and analyzing techniques. Hence, law enforcement organizations like that of police stations are facing difficulties with the tasks of: easily examining the spatial distribution of crimes, identifying hot spot crime incident areas and their spatial relationship with other factors, allocating resources based on the degree (the frequency) of crime occurrence, active decision making and taking proactive respond to the crime situations before they become problematic, easy crime data sharing among concerned bodies, demonstrating the crime situations statistically and visually to the community in order to have their active participation for minimizing the crime incidences.

However, GIS technology integrated with statistical analysis techniques can be important to minimize the existing problems. GIS technology is used for capturing data from disparate sources and compiling them in one place to facilitate visual and statistical analysis. Using the functionality of GIS technology; law enforcement agencies can easily enter, map and analyze crime incident data together with other variables such as census demographics, land use etc. Hence, it is possible to minimize the occurrence of crimes in addition to the availability of laws, rules, policy and regulations for maintaining the security of the societies. Therefore, the study was employed to assess the spatial distributions of crimes in Adama city both statistically and spatially related with other spatial pattern constraints. For this, GIS technology and statistical analyzing techniques were employed.

1.3 Objectives

The **general objective** of this study is to show the spatial distributions of crimes against property and crimes against person in Adama city using GIS.

The **specific objectives** in connection with the above general objective are to:

- identify hotspot crime incident areas using the different hotspot identification techniques and compare one another
- examine the proximity of crime incidences with police stations
- Illustrate the spatial relationship of crime incidents with land use and population density of Adama city.

1.4 Research Questions

- How hotspot crime incident area is identified using different crime hotspot identification techniques?
- At what distance the crime incidences are concentrated from the police stations?
- Are there any spatial relationship among crime incidents, population density and land use of Adama city?

1.5 Significance of the Study

The study attempted to examine the spatial distribution of crimes against property and crimes against person using statistical and GIS techniques. Hence, the city police station is the foremost beneficiary from the outcome of this study. Therefore, knowing the spatial distribution of crimes enable police officials where and why crime occurs. Having this knowledge, law enforcement agency or police station can take a proactive response to the crime situations before they become problematic. They can also use it for allocating resources and educating the public with visual information to clarify crime concerns and enlist community action. For media organizations, it can be used as a valuable tool to convey criminal activity information to the public.

1.6 Scope of the Study

The study was conducted on Adama city to visualize the spatial distribution of crimes against property and crimes against person which were recorded on the year 2013 and 2014 using GIS. The primary concern of this research is to introduce some techniques of GIS for analyzing crime spatial distribution to Adama city police station who are mostly unfamiliar with GIS. The study specifically gives an overview of how GIS can be used as a tool to identify hotspot crime incident areas and the spatial relationship of crime incidents with population density, land use and police stations. Furthermore, the rate of crimes for each Adama city kebele was computed and compared one another. Therefore; crime data, population data, Adama city kebele boundary map and land use map were used in the study.

1.7 Limitation of the Study

While conducting this research, it had the following constraints:-

- Data constraint
- Time constraint
- Financial constraint

As a result, this study has been confined on the data which are recorded and readily available in Adama city.

1.8 Structure of the thesis

The thesis report comprised five major chapters. Chapter One outlines the background of the thesis, highlighting the research problem, objective, questions, significance, scope and limitation of the study. Chapter Two focused on related literature, publications, research, booklets and crime spatial distribution assessment related notes which is relevant to the thesis. Chapter Three describes the study area location, data collection, methods of data analysis with technological scheme thesis work, geo coded crime data analysis using different analyzing techniques and analysis of the spatial relationship of crime incidents with other parameters. Chapter four describes the results and discussions of the analyzed data. Chapter five provides a brief summary of the thesis and recommendations of necessary activities that strengthen the findings of the thesis.

2. LITERATURE REVIEWS

2.1 Crime Definition

Literally, the word “Crime” was originally taken from a Latin term “Crimen” which means “to charge”. The Greek expression “Krimos” is synonymous to a Sanskrit word ‘Krama’ which means “Social order”. Therefore, in common parlance the word crime is applied to those acts that go against social order and are worthy of serious condemnation [10]. The Oxford English Dictionary defines crime as “an act punishable by law as forbidden by statute or injurious to public welfare” or “an action or omission which constitutes an offence and is punishable by law” According to Macmillan dictionary crime is “an illegal activity or action commit a crime”

Different scholars’ defined crime as follows, Odgers W.B (1911) [11], has defined crime as “an act committed or omitted in violation of a public law either forbidding or commanding it”. According to Stephen (1873) [12], crime is “an act forbidden by law and which is at the same time revolting to the moral sentiments of the society”. Austin (1832) [13], defined crime while making a distinction between civil and criminal wrongs. He observed, “A wrong which is pursued by the sovereign or his subordinates is a crime. A wrong which is pursued at the discretion of the injured party and his representatives is a civil injury”. Thakur (2003) [14] has defined crime as an act or omission of an act, which is punishable by law. However, an act that is considered as a crime in one place and time may not be true in another place or time.

Again, crime can be defined in legal and non-legal sense. From a legal point of view, it refers to breaches of the criminal laws that govern particular geographic zones and are aimed at protecting the lives, property and rights of citizens within those jurisdictions. Non-legal point of view would define crime as acts that violate socially accepted rules of human ethical or moral behavior. As the moral principles that underpin the notion of crime are subject to gradual change over time, the types of behavior defined by the legal system as criminal may also change. Examples of behaviors that have been de-criminalized in some jurisdictions include prostitution, abortion, attempted suicide and homosexual intercourse. Other behaviors, such as tax evasion or credit card fraud, have been criminalized over time [1]. Therefore, it is conclude that there is no a single definition of crime since no satisfactory definition of crime acceptable and applicable to

all situations could be derived, penal statutes define, specifically, different criminal behaviors, which they purport to check. Even the Criminal Code of Federal Democratic Republic of Ethiopia (FDRE), which has codified the great bulk of the criminal law of the country, does not give any standard definition of crime. Art. 23(1) simply states that, “A crime is an act which is prohibited and made punishable by law. In this Code, ‘an act consists of the commission of what is prohibited or omission of what is prescribed by law’” [2]

2.2 Crime Categories

There are different types of crimes depending on the level and kind of crimes committed against the victims. But, it can be divided into four major categories according to Dambazau (1997) [3]. These are: crime against person; these are crimes that result in physical or mental harm to another person. These include Murder, Attempted murder, Manslaughter, attempted Suicide, Wounding, assault, stabbing with knife, Child stealing, rape, kidnapping, battery etc. Crimes against property; these are crimes that do not necessarily involve harm to another person. Instead, they involve an interference with another person’s right to use or enjoy their property. These include robbery, burglary, house breaking, store breaking, cheating, receiving stolen property, unlawful possession (drugs/guns), arson, and other offences. Crimes against lawful authority: forgery of currency notes, coining offences, gambling, breach of peace, perjury, bribery and corruption, escape from custody, etc. Crimes against local act: traffic offences, township offences, liquor offences, dog act, Narcotics, Other crimes. But, the purpose of this thesis paper only crime against person and property were discussed [3].

2.3 Theories of Crime and Place

There are three theoretical viewpoints to understand the (the relationship of crime and place) importance of place in crime prevention efforts. These are: routine activity theory [4], rational choice theory [5] and crime pattern theory [6]. Routine activity theory: it was developed by Cohen and Felson (1998) [4]; the primary principle is that the offender and victim must intersect in time and space for a crime to occur. This theory provides a frame work within which to prevent crime through alerting at least one of these elements (the offender, the target or the presence of capable guardians). An activity may consist of the regular areas an offender travels

such as work, school, home or recreational areas. ChingEng Leong (2014) [15] explained in the same manner as follows: For a crime to occur, first there must be a motivated offender. Second, there must be a desirable target. Third, the target and the offender must be at the same place at the same time. Finally, three other types of controllers: 1) intimate handlers, 2) guardians and; 3) place managers; must be absent or ineffective.

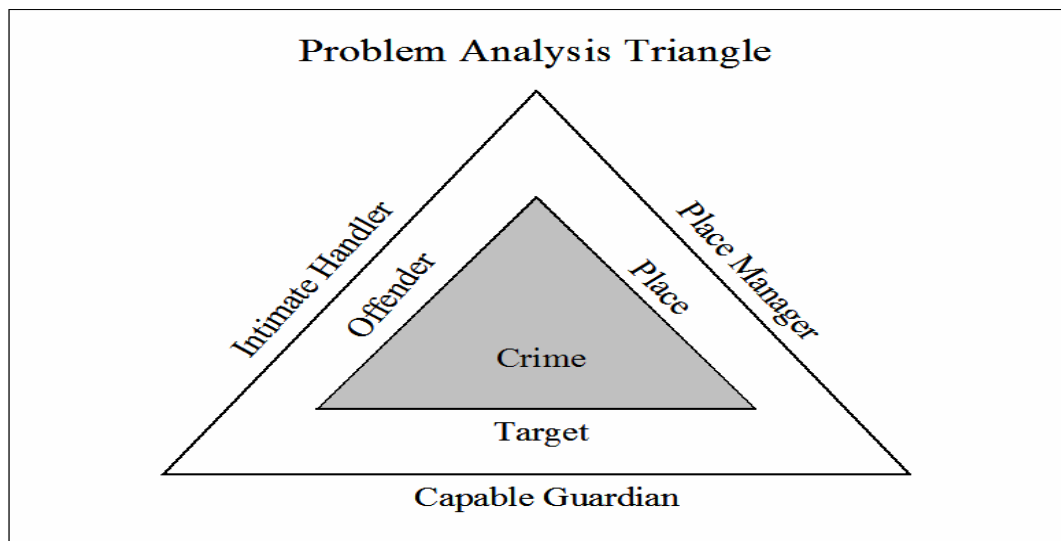


Fig 2.1. Problem analysis triangle

Source: The Problem Analysis Triangle (Goldstein, H, 2001) [15]

Rational choice theory: it was constructed by Cornish and Clarke (1986) [5], they suggest that offenders will weigh the risk involved in committing a criminal act before selecting target and the basic rationale for selecting a place is important to achieve their goals. Crime pattern theory: It was developed by Brantingham P.L. and Brantingham P.J (1984) [6], they suggest that why crimes are committed in certain areas. According the theory, crime happens when the activity space of a victim or target intersects with the activity space of an offender. As Ching Eng Leong (2014) [16] written, it is particularly important in developing an understanding of crime and place because it combines rational choice and routine activity theory in aid of explaining the distribution of crime across places. The distribution of offenders, targets, handlers, guardians, and managers over time and place will describe crime patterns. In short, it is the interaction of between the offender's mental maps of spatial surroundings and the allotment of victims.

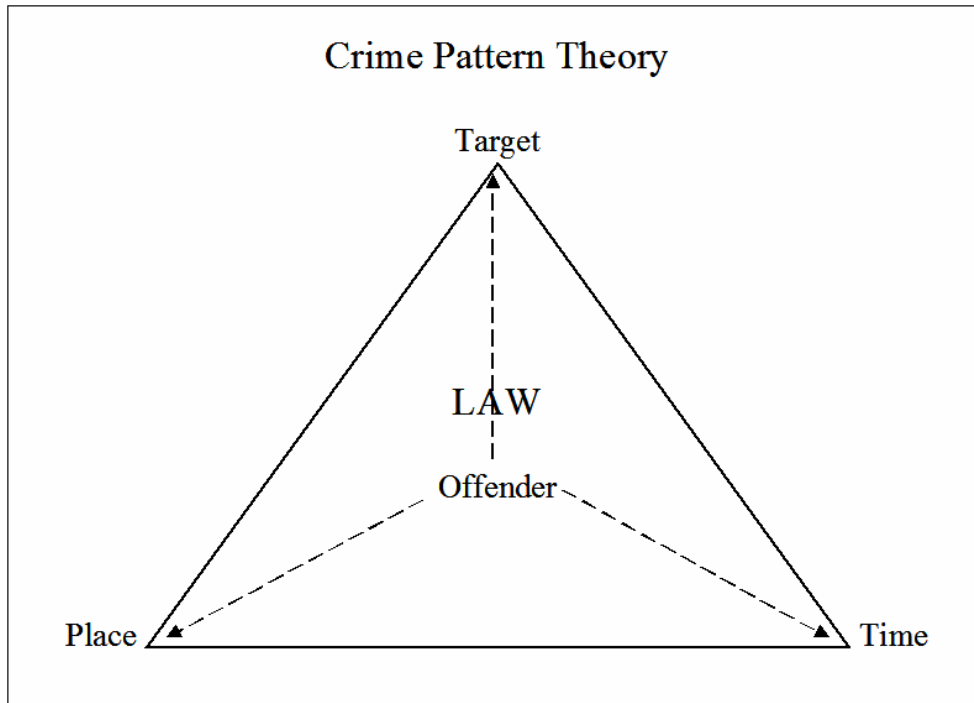


Fig 2.2. Interaction of Crime Pattern Theory

Source: Compiled by author based on Crime Pattern Theory, Brantingham and Brantingham, 1995 [17]

2.4 Trend of Crime in Ethiopia

According to Leul Woldu (2003) [9], in Ethiopia the crime statistics of the Federal Police Commission has shown that the rate of crime is increasing. A sample survey conducted in the year 1996 by a research team of the Federal Police has shown that in 1986 about 51,869 crimes were reported to the police [9]. Taking the total population of the country during this period, this figure indicated that one crime was committed among 800 people during this year. Whereas the research report has shown that in the year 1994 about 96,995 different crimes were reported. This reveals that during this period one crime is committed among 568 people. As compared to the year 1986 the total number of crimes committed in the 1994 have shown a significant increment. The national crime statistics report compiled by the Federal Police Commission in 2003 for the year 2002 has shown that about 219,539 crimes were reported to police throughout the country and out of this 51 percent were committed in urban area while the remaining 49 percent were occurred in rural areas [9].

According to the Overseas Security Advisor Council (OSA) criminals are active throughout Ethiopia. For example, the most common crimes that are committed in Addis Ababa are: pick pocketing, beating, stabbing, harassment, snatch and run including occupied vehicles. Beginning in 2011, purse snatching and harassment by gangs of youths in Bole area of Addis Ababa have increased. These incidents have occupied both the day time and night [18].

2.5 Concept of Crime Mapping

A map is the fundamental tool that can illustrate the spatial distribution of any kind of phenomena. In map quantitative and qualitative data can be depicted. Quantitative maps portray numerical information, such as number of population, numbers of crimes in an area or crime rates etc. Qualitative maps show none numerical data like land use types or crime incident location etc. According to Keith Harries (1999) [19], crime analysts use both quantitative and qualitative maps. Crime mapping offers a powerful way for police and the public to define the patterns of crime that the police must address and track how police actions affect crime. Mapping plays a very significant role in crime location, detection, control and monitoring, prediction [19].

For decades, police agencies have relied on pin maps to detect patterns in the locations of certain crimes. Pin mapping is placing pins on a map to visualize the locations of crime. Conversely, the recent use of computers to map crime has greatly increased the value of mapping. Computer crime mapping allows for identification of hot spots, crime trend, pattern and comparing crime patterns in the same place at different times and overlaying a wide variety of non-criminal data and geographic conditions to understand crime patterns. Computer crime mapping is a procedure for using GIS to conduct spatial analysis of crime problems and police-related issues and is a sub discipline of crime analysis which has three functions. The first one is to facilitate visual and statistical analysis to unravel the spatial nature of crime. The second one is to provide a link to unlink data sources on geographic variables. And the last one is to produce maps that help to communicate for analysis results [20]. Using Geographic Information System (GIS); crime analysts can overlay different datasets to identify crime hot spots, along with other trends and patterns such as locations of crimes, census demographics, land use types etc. Therefore, law enforcement agencies can use crime maps to understand the cause of crime, to formulate strategies to deal with the problems, to allocate resource and to make better decision, to measure

their own performance and hold themselves accountable and to disseminate information about crime to the public [21].

2.6 Crime Hotspot Identification Techniques

The term hot spot has become an integral part of the study called crime analysis and is popular with most of the analyst. A hotspot as the name suggests, it is a state of indicating the concentration of crime incidents in identifiable places or the occurrence of high numbers of crime incidents in relatively small areas in the spatial distribution of crimes [19]. In short, it is the cluster of geographical areas consisting of high number of crime events are known as Hotspots [22].

Crime hotspot can be identified through statistical and spatial analysis techniques. Statistical analysis is an interpretation of numerical data in terms of samples and populations whereas, spatial Analysis is the process of checking the spatial distribution of features and connection of features within one another as well the attributes of those features using different GIS analytical techniques; which is used for acquiring knowledge that can be used in different aspect[23].As a result, crime rate computation and GIS techniques were reviewed for identifying hot spot crime incident areas. And also, the techniques for showing the spatial relationship of factors which offer opportunity for the occurrence of crime incidents were reviewed. Crime studies that examine the spatial distribution of crime clearly demonstrate that land uses and population characteristics are associated with crime hotspots [24].

2.6.1 Computation of Crime Rate for Crime Hotspot Area Identification

This technique is used to examine how the numbers of crime incidence differs from one area to another. Crime rate counts the number of crimes per distributed populations of an area or district. Crime counts do not take into consideration variations in distribution of people within a city, making comparisons between dissemination areas difficult. Crime rates are the number of crimes per 1,000 or 100,000 populations in a dissemination area. Crime rates are used to normalize the variables and display the number of crime divided by a common denominator [25]. The formula for computing the rate can be written as follows: $Crime\ rate = C/P \times 1000$. where C = crime count, P = population. Crime rates are calculated for each dissemination area by calculating a new field

from the crime count field and the population field using the above equation. For crime rates, there is often debate about the best type of denominator used to reflect crime in an area.

2.6.2 GIS Techniques for Crime Hotspot Area Identification

Geo Spatial technology approach such as GIS has the digital capabilities for creating a single meaningful visual output by combining or overlaying multiple data layers. A Geographic Information System (GIS) is a set of computer-based tools that allow a person to modify, visualize, query, and analyze geographic and tabular data. GIS has the capability to integrate and analyze crime data in relation to other factors for identifying hot spot crime incident areas. It also has proactive behavior through effective allocation of resources and better policy setting [26]. Mapping and identifying crime hotspot using the technique GIS, can impressively communicate crime patterns and crime prevention policies to decision makers and the public [27].

In general, applications of GIS in crime analysis (generally just called “crime mapping”) are numerous: 1) identify crime patterns and hot spots, 2) provide a visual aid to the analysis of patterns and hot spots, 3) show the relationship between crime and other spatial factors, 4)to look at direction of movement in crime patterns, 5)to query data by location (e.g., buffers), 6) to create and modify patrol districts, 7)to track changes in crime and 8)to make maps for police deployment and general police information [28].

In GIS; there are different mapping techniques that are used for identifying hotspots of crime – a graduated point mapping (point density), choropleth mapping (thematic mapping of geographic areas) and kernel density estimation (KDE). Several research studies have discussed the use of these methods for identifying hotspots of crime, usually based on their ease of use and ability to spatially interpret the location, size, shape and orientation of clusters of crime incidents or the scale of the map, and the amount of data mapped. Any of crime hot spot mapping techniques can most effectively guide police action when production of the maps is guided by crime theories (routine, rational and pattern theories), [29] [30].

2.6.2.1 Graduated Point symbols Hotspot Identification (Point Density) Technique

In a graduated point symbol mapping technique, the size of the symbols are used to reflect the numbers of crimes at the location (the size of the dot is proportional to the numbers of crimes occurring a place). The goal is to identify isolated high-crime locations. The technique allows the depiction of repeat and non-repeat places on the same map and permits comparison among repeat places about the number of crimes. A graduated point symbol mapping is not appropriate if too many data are analyzed at once. Because, graduated dots can obscure nearby features (e.g. a large dot may overlap nearby smaller dots), the technique is best if it is used on large-scale maps [29].

2.6.2.2 Choropleth Hotspot Identification (Area Density) Technique

Choropleth maps are sometimes called “area symbol maps or statistical surface maps” [31]. Choropleth map analysis is used for representing the spatial distributions of features in a boundary. For instance, the spatial distributions of crime events in the administrative or political boundary. Crimes as points on a map can be aggregated to these geographic unit areas that can then be shaded in accordance with the number of crimes that fall within them. Ratecliffe, J.H (2002) [32] assert that maps created in this way are quick to produce and require little technical expertise to interpret. Furthermore, this technique enables the user to quickly determine which areas have a high incidence of crime. In addition, census areas can easily be linked with other data sources, such as population, to calculate a crime rate – increasing their versatility for analysis.

Owing to the varying size and shape of most geographical boundaries, thematic shading can beguile the map reader in identifying the existence of the highest crime concentrations [33]. Hence this technique can fail to reveal patterns across and within the geographical division of boundary areas [34].

2.6.2.3 Kernel Density Estimation Technique

Kernel density estimation (KDE) is regarded as the most suitable spatial analysis technique for visualizing crime data [34, 30, 33]. Kernel Density calculates the density of features in a neighborhood around those features. The kernel density function is implemented in the spatial

analysis tool of Arc GIS. It can be calculated for both point and line features. Possible uses include finding density of houses, crime reports or density of roads or utility lines influencing a town or wildlife habitat. The population field could be used to weigh some features more heavily than others, depending on their meaning, or to allow one point to represent several observations. It is dependent on grid cell size and bandwidth (search radius); however, despite many useful recommendations there is no universal doctrine on how to set these and in what circumstances [34, 30, 33]. However; the size of the band width can be determined by taking the square root of the X or Y variance of the extent of the study area (which is smaller) and divided by 5 or 10. For instance, with search radius and output cell size set to 2000 meter and 200 meter respectively [35].

2.6.3 Overlay and Buffer

The spatial relationship of crime incident with other factors can be assessed using the technique overlay and buffering in the GIS environment. The integration of information from various sources through overlay is one of the most important functions of a GIS. Overlay refers to the digital integration of location and attributes information of several spatial layers. A GIS allows layers of information such as crime location, roads and land use are to be stacked as layers on top of each other and displayed in GIS. Probably, it is said to be overlay analysis. [36]. According to Santos R. B. (2012) [37]. The rate of the crime incidents stacked on either land use or population density layer or any other layers can be computed by number of crime per square kilometers. Hence, the spatial relationship of crime incidents with these layers can be examined using the rate.

A buffer is a specified area around a feature on a map. Buffers can be set at small distances, such as 50 meters, or larger distances depending on the purpose and scale of the map. Buffers help in crime analysis by illustrating the relative distances between features on a map [39].

2.7 Crime Analysis Process

Crime analysis studies daily reports of serious crimes in order to determine the location, time, spatial characteristics, similarities to other criminal attacks, and various significant facts that might help to identify either a criminal or the existence of a pattern of criminal activity. Such information is helpful in planning the operations of a division or district [39]. Crime analysis is

an important process to law enforcement in understanding the occurrence of a crime. It involves the collection and analysis of data relating to a criminal incident, offender and victim, and develops information of use for crime prevention and detection activities [40].

There are five major types of crime analysis conducted on a regular basis by law enforcement agencies: tactical crime analysis, strategic crime analysis, administrative crime analysis, criminal investigative analysis, and police operations analysis [41].

2.7.1 Tactical Crime Analysis

It describes the daily identification and analysis of emerging or existing crime patterns, including series and hot spots. Analysis of a crime pattern typically focuses on who, what, when, where, or how factors that are common across a significant number of incidents [42]. Tactical crime analysis can also be explained as the study of recent criminal incidents and potential criminal activity by examining characteristics such as how, when, and where the activity has occurred to assist in problem solving by developing patterns and trends, identifying investigative leads/suspects, and clearing cases. It also focuses on specific information about each crime such as method of entry, point of entry, type of victim, type of weapon used, as well as the date, time, location, and type of location. Field information such as suspicious activity calls for service, criminal trespass warnings, and persons with scars, marks, or tattoos collected by officers is also considered in the analysis [43].

2.7.2 Strategic Crime Analysis

The study of crime and law enforcement information integrated with socio-demographic and spatial factors to determine long term “patterns” of activity, to assist in problem solving, as well as to research and evaluate responses and procedures [43].

The two primary purposes of strategic crime analysis are

- 1) To assist in the identification and analysis of long-term problems such as drug activity or auto theft
- 2) To conduct studies to investigate or evaluate relevant responses and procedures.

These types of studies include evaluation of crime prevention programs, in depth examination of a particular crime problem, and implementation of a survey of citizens' perceptions of crime and the police. In sum, strategic crime analysis uses statistical techniques and research methods to investigate long-term problems and evaluate organizational procedures [43].

2.7.3 Administrative Crime Analysis

The presentation of interesting findings of crime research and analysis based on legal, political, and practical concerns to inform audiences within law enforcement administration, city government/council, and citizens [43]. In administrative crime analysis, crime mapping is a valuable tool used by police, researchers, and media organizations to convey criminal activity information to the public [38]. Web sites operated by police departments and news organization routinely post maps that depict areas of crime, along with corresponding tables and definitions. For example, a police agency can reduce citizen requests for neighborhood crime information by placing monthly or weekly crime maps on a Web site that members of the public can access using computers in their homes or at the local library [38]

2.7.4 Criminal Investigative Analysis

Criminal investigative analysis is the study of criminal personality behavior, especially in violent crimes. It involves profiling of offenders, victims and geographical features with a view to linking and solving current serial criminal activity. This is a very specific type of crime analysis that is primarily carried out by law enforcement agencies as it requires professional skills and a high degree of expertise [43].

2.7.5 Operations Analysis

Analysis to support the optimal allocation of personnel and resources by time, geography, and department function [28]

2.8 Summary

Over the past few decades, the development of crime analysis has been developing due to the following contributing factors: (1) the conceptual transformation of crime prevention from criminal behavior based to crime and place theory assists law enforcement in formulating

effective strategies focusing more on the geographical effects; (2) the technological evolution from manual mapping to automated GIS mapping has improved the mapping process greatly in quality and in quantity and (3) the expansion of scope of crime analysis from investigative-centered to a multifaceted dimension allows the management a better understanding of the impact of crime to resources allocation and may even strengthen public confidence in fighting crimes.

In the absence of any useful literature on the subject of crime spatial distribution analysis, this research will evaluate the spatial distribution of crime from the available data. This research has utilized crime mapping techniques to identify crime hotspots and their spatial correlations with other factors.

3. MATERIALS AND METHODS

3.1 Study Area Description

Adama is a city in central Ethiopia and the previous capital of the Oromia regional state. In fact Adama still houses the Oromia state parliament although the capital city of Oromia is now Addis Ababa. It was established in 1915 following the construction of the Ethio-Djibouti railway. Based on the projected figures from central statistical agency in 2015, the city has an estimated total population of 324000 and this makes the second largest city of the country. Adama city is one of the most known tourism destinations in the Country. According to ministry of urban development and construction office (2011), Adama city has economic linkage with several regions and towns. The city is destination for agricultural inputs and manufacturing and commercial products from Djibouti port. The economic activity rate for both sexes is 58.2%, 66.8% for males and 49.8% for females, while unemployed rate is 21.4% for both sexes 16% for males and 28.8 % for females.

The city is accessible with asphalt, all weather gravel, cobble stone and dry weather roads. The city is a busy transportation center, being a large numbers of trucks and public buses that travel from Djibouti and Dire Dawa to Addis use the same route including in and out from the city. But, it is constructing a new ten (10) kilo meter asphalt ring road that goes around the city. The ring road will enable trucks coming from Djibouti to avoid the trouble of going through the city.

3.1.1 Geographical Description

Adama city is located in East showa zone of Oromia region which is situated in central rift valley of Ethiopia about 100km Southeast of Addis Ababa (but, it is far from 78.46km on the new express way). Taking UTM coordinate system as a reference, the location of the city is nearly between 524000m – 536000m in the West- East direction and 932000m – 956000m in the South-North direction as shown in Fig 3.1. Its elevation is 1712m above mean sea level. The city administration consisted of 18 kebeles but previously it was 20 kebeles. Melka –Adama, Dabe – Soloque, Boku-Shenan and Deka-Adi are the newly emerged kebeles among the eighteenth kebeles. Each kebele has their police station. These police stations again categorized by four woreda police stations.

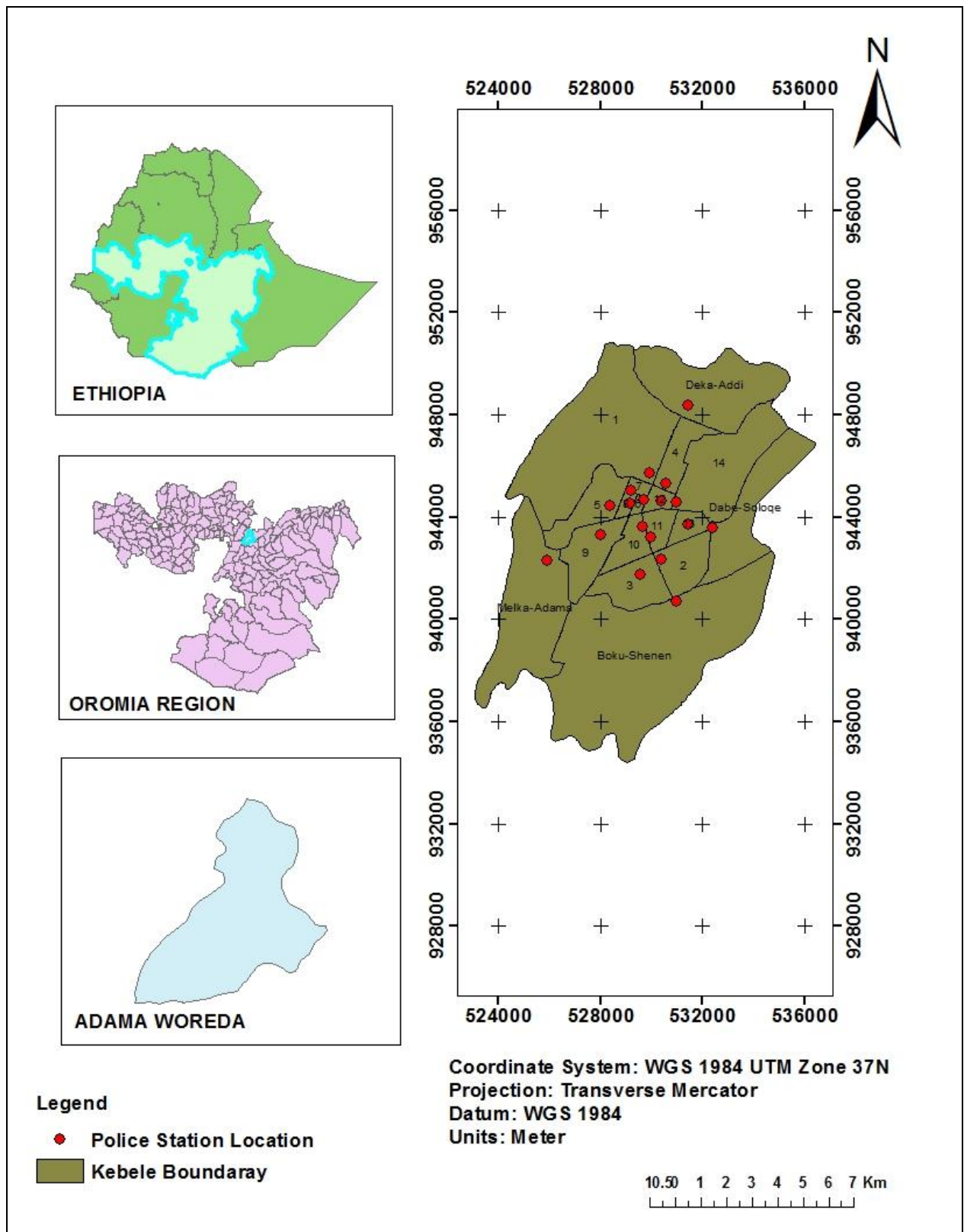


Fig 3.1. Location Map of the study area

3.1.2 Population

According to the last three consecutive censuses conducted in Adama city by central statistical agency of Ethiopia (CSA), the city is showing in the rapid increment of population. The 1984 census showed that the city had a total population of 77,237. The second census which was held on 1994 showed that the city had a total population of 127,842 of which 61,965 were males and 65,877 were females. According to the 2007 census, the city had a total population of 222,035 of which 109,659 were males and 112,376 females.

According to the survey taken from all Adama city kebeles by finance and economic development office on 2014, the total population of the city was 303,500 of which 148,974 were males and 154,526 were females. Currently, the total population of the city is estimated to be 324,000 based on the projected figure from central statistical agency in 2015. Demographically, Adama is the most rapidly growing city both in terms of population and in terms of physical areas in Oromia Regional State starting from the outset of its establishment due to ongoing urban sprawl, natural growth of population and high level of rural urban migrations.

Table 3.1 Population distribution of Adama city by kebeles, 2014

Kebele Name	Male	Female	Total Population	Total Population in percent (%)
01	10970	12340	23310	7.77
02	8471	8638.5	17109	5.64
03	12186	12070	24256	7.99
04	11178	13527	24705	8.14
05	12538	10876	23413	7.71
06	4523	5115	9638	3.17
07	7789	7070.5	14859	4.89
08	7360	6760	14119	4.65
09	12948	13783	26731	8.90
10	10178	11766	21944	7.23
11	11002	11974	22976	7.66
12	6131	7692	13824	4.55
13	7060	6959	14020	4.61
14	13043	12501	25545	8.50

MelkaAdama	3149	3051	6200	2.04
BokuShenen	3840	3666	7506	2.47
DabeSoloqe	3558	3742	7300	2.41
DekaAddi	3050	2995	6045	1.99
Total	148974	154526	303500	100

Source: Finance and economic development office of Adama city administration, 2015

3.1.2.1 Migration

Migration is the act or the process of moving persons from one place or region or country to another and has a direct effect on the geographic distribution of a population. Moreover, it has an interaction with other demographic forces as well as other aspects of socio-economic change (CSA, 1996), this migration is not only the poorest people as a usual, the rich or person with better economic standards also migrate from countryside or from other towns to more better cities which can cause the changes to infrastructures, utilities, better houses, hospitals, educational institute & etc. to fulfill the human needs.

According to the 1994 census the total migrant population to Adama City was 67,632 while non-migrant was 60,210. This means that migrant population constituted about 53 percent of the total population of Adama. This implies that migration contributed large to the population growth of the City in the period stated. The level of internal migration by sex showed that 46 percent of the males and females were non migrants, while the remaining 53 percent were migrants. (CSA, 1996) which has direct effect to urban geospatial change.

3.1.3 Crime Distributions of Adama City by Kebele Police Stations, 2013/2014

A total of 2155 crimes were reported to the police stations which were committed on Adama city between the year 2013 and 2014 and 2363 criminals were participated. On 2013, the numbers of criminals were 1097. From this, 1001 were males and 96 were females. On 2014, 1266 criminals were participated. Among this, 1187 were males and 79 were females. The total numbers of reported crimes and their distribution of crimes by year, types and kebeles have been showed at Table 3.2.

Table 3.2: Summary of Reported Crime Cases of Crime in Adama City, 2013/2014

Kebele Name	Numbers of crime in the year,2013			Numbers of crime in the year,2014			Total numbers of crime b/n 2013 & 2014	Percentages of crime
	Crime against property	Crime against person	Total	Crime against property	Crime against person	Total		
01	33	14	47	43	18	61	108	5.01
02	17	8	25	33	15	48	73	3.39
03	13	11	24	18	19	37	61	2.83
04	23	18	41	39	21	60	101	4.69
05	26	11	37	13	16	29	66	3.06
06	35	42	77	44	53	97	174	8.07
07	54	25	79	42	30	72	151	7.01
08	76	21	97	103	34	137	234	10.86
09	27	32	61	52	36	86	147	6.82
10	42	28	72	47	35	80	152	7.05
11	42	15	57	19	22	41	98	4.55
12	60	37	97	91	38	129	226	10.44
13	38	23	61	34	19	53	114	5.29
14	36	17	53	56	23	79	132	6.13
MelkaAdama	12	11	23	11	33	44	67	3.12
BokuShenen	26	14	40	34	15	49	89	4.13
DabeSoloqe	19	15	34	33	15	48	82	3.81
DekaAddi	19	12	31	29	20	49	80	3.71
Total	608	348	956	755	444	1199	2155	100
In percent from total	28.20	16.2	44.4	35	20.60	55.6	100	

Source: Adama police station, 2015

3.2 Data, Software and Materials

3.2.1 Data Used

Table 3.3: Data Used in the Study

No.	Data	Source
1	Administrative Boundaries	Adama City Municipality
2	Kebele Boundaries	Adama City Municipality
3	Crime Data (2013 - 2014)	Adama City Police Stations
4	Master Plan (2004)	Adama City Municipality
5	Kebele Population Data (2014)	Finance and Economic Development of Adama City administration
6	Census (2007)	Central Statistical Agency

3.2.2 Materials and Software Used

Table 3.4: Materials and Software Used in the Study

No.	Material Name or Software	Source	Purpose
1	Hand Held GPS	Dire Dawa University	For collecting the location of crime incidents and police station spatial data
2	Computer RAM, 4GB		For processing the input data, typing the report, etc.
3	DNR Garmin		For downloading crime and police station spatial data
4	Arc GIS 10	ESRI	For data processing, main analysis, mapping etc.
5	Microsoft Excel 2013	Microsoft Corporation	To integrate the spatial location of crime and police station with other attribute data
6	Microsoft Word 2013	Microsoft Corporation	For composing the report

3.3 Data Collection

Primary and Secondary data collection was undertaken to achieve the objective of this thesis. The primary data were collected through direct field observation and surveying. Like the spatial location of crime incidents and police stations. The secondary data was obtained from relevant text books, journals, past thesis, internet materials, governmental institutions and other documents.

In the year between 2013 and 2014, 2155 cases of crimes against property and crime against person were recorded from eighteen Adama police stations. Based on the reported crime location descriptions, the spatial locations of each crime were collected using hand held GPS and other prominent features like police stations. However, for some places approximate location was made being the exact locations of the crimes were not written. Then, the collected crime incidents and police stations spatial data were downloaded using DNR Garmin downloading software into CSV file format to match with other attributes data.

Finally, the geo coded (Geo coding or address matching is the process of transforming tabular and geographic data, some non-spatial attributes or addresses in this study) crime data together with other attributes data brought into Arc GIS software for analysis. Census data collected from Central Statistical Agency of Adama branch and Finance and economic development office of Adama city administration which Contains information on population and other demographic variables. Adama city structural plan, city boundary and kebele boundary also used which was collected from city administration.

3.4 Methods

GIS based spatial distribution of crime analysis was applied to achieve the overall objectives of this study. Spatial analysis is now recognized as a tool for the study and control of crime [44]. In order to examine the spatial distributions of crime incidences in the study area, both spatial and attributes data was collected. The collected data was analyzed statistically and spatially to examine the spatial distributions of crime incidences and for the identification of crime hotspot areas. Furthermore, the spatial relationships of crime incidents with land use and population

density were examined in the study. Statistically, the crime rates per 1000 persons of both property and person crime of each kebele was calculated.

In the spatial analysis framework, first the geocoded crime incident data was analyzed using the most common crime hotspot identification techniques in the GIS environment. These techniques were point density estimation, area density estimation and kernel density estimation. Each of these techniques also requires certain parameters to be set for them to operate or for them to generate a visual map output. All the techniques are discussed one by one below. The spatial relationship of crime incident activities with police station was examined by using proximity analysis with a minimum buffer distance of 50m and a maximum distance of 6000m from the police station. Multiple ring buffering technique was employed for illustrating the relationship.

The location where crime events occur is an important factor in the analysis of crime. It is not only important where a crime take place but also the characteristics of those places and the environment in which incident occur [45]. Thus, examinations of spatial relationships of crime incidents with land use and population density were examined in the study. Statistical method was employed to study the relationship between crime concentration with land use and population density, which is number of crimes per area square kilometers. The crime rate counts the number of crimes per dissemination area.

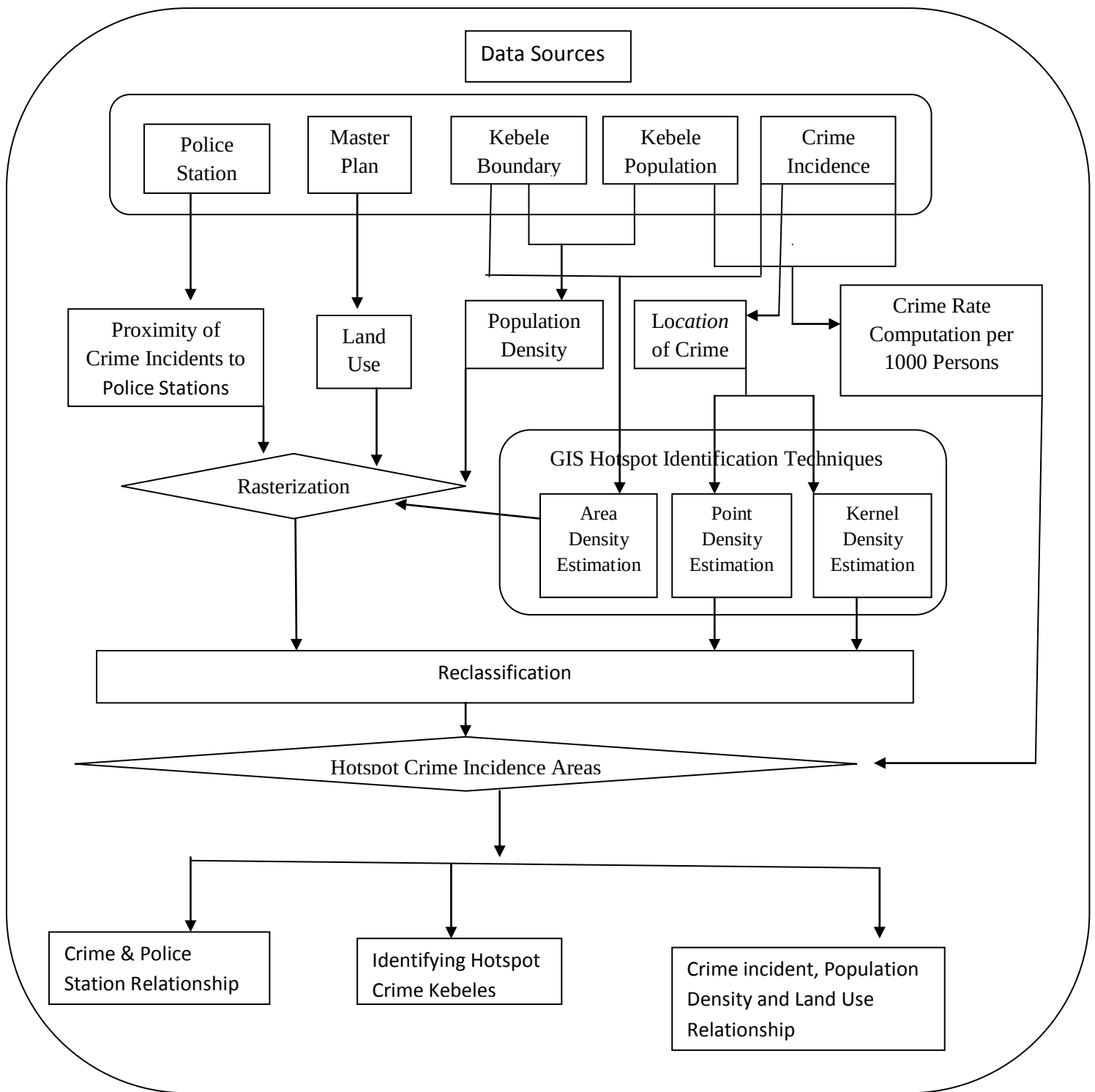


Fig 3.2. Technological Scheme of the thesis work

3.5 Data Analysis

3.5.1 Crime Rate Computation

The term rate mathematically defined as: “it is the ratio between two measurements with different units”. According to Bruce (2007) [25], crime rate can be expressed as the number of crimes per 1000 persons or number of crimes per area square kilometers. Primarily, crime rate is designed to estimate the number and the type of crime not reported to the police and to permit comparisons over time and types of areas. Accordingly, the crime rate per 1000 persons was used in this study in order to compare the rate of crime against property and person for each Adama city kebele. Therefore, the formula for calculating the rate would look like this: $(\text{Number of Crimes} / \text{Population}) \times 1000$. Computing the crime rate by number of crimes per areas of square kilometers is used to examine the spatial relationship of crime pattern with other related factors [25].

Table 3.5: Crime Rate Distribution in Adama city, 2013/2014

Kebele name	Kebele population	No of Property Crime	Property Crime rate	No of Person Crime	Person Crime Rate	Total Crime Rate	Total Crime Rate in percent
1	23310	76	3.3	32	1.4	4.7	3
2	17109	50	2.9	23	1.3	4.3	2.8
3	24256	31	1.3	30	1.2	2.5	1.6
4	24705	62	2.5	39	1.6	4.1	0.9
5	23413	39	1.6	27	1.2	2.8	1.8
6	9638	79	8.2	95	9.9	18.1	11.6
7	14859	96	6.5	55	3.7	10.2	6.6
8	14119	179	12.7	55	3.9	16.7	10.7
9	26731	79	3	68	2.5	5.5	3.5
10	21944	89	4.1	63	2.9	6.9	4.4
11	22976	61	2.7	37	1.6	4.3	2.8
12	13824	151	10.9	75	5.4	16.3	10.5
13	14020	72	5.1	42	3	8.1	5.2

14	25545	92	3.6	40	1.6	5.2	3.3
Melka-adama	6200	23	3.7	44	7.1	10.8	6.9
Boku-Shenen	7506	60	7.9	29	3.9	11.2	7.2
Dabe-Soloqe	7300	48	6.5	32	4.4	11.8	7.6
Deka-Addi	6045	52	8.6	30	4.9	12.1	7.9

Source: Adama Police Station and Finance and economic development office of Adama city Administration

3.5.2 GIS Techniques for Crime Hotspot Identification

The concern of this section was to visualize the spatial distribution of crime and identifying crime hotspot areas using GIS techniques. The most common GIS techniques for visualizing the spatial distribution of crime and identifying crime hotspot are: point density (point mapping), area density (choropleth mapping) and kernel density estimation (KDE) [30, 34, 37]. Therefore, using the three different techniques the spatial distribution of crime incidents as well as crime hotspot areas were examined below.

3.5.2.1 Graduated Size Point Mapping

In graduated size point mapping, the spatial distribution of crime incidents are shown by assigning graduated size point symbols going from lowest to highest. The size of each symbol is proportional to the numbers of crime committed at the location. Accordingly, graduated size point thematic map was prepared for indicating the spatial distribution of crime for the year 2013/2014 of Adama city as presented in the Fig 3.3 using natural break classification technique. Resulted from the natural break classification technique, the graduated point symbols was classified into very low, low, moderate, high and very high crime incidence areas depending on the frequency of crimes at the location and represented by the colours: peony pink, ultra blue, solar yellow, fire red and mars red respectively as shown in the table below.

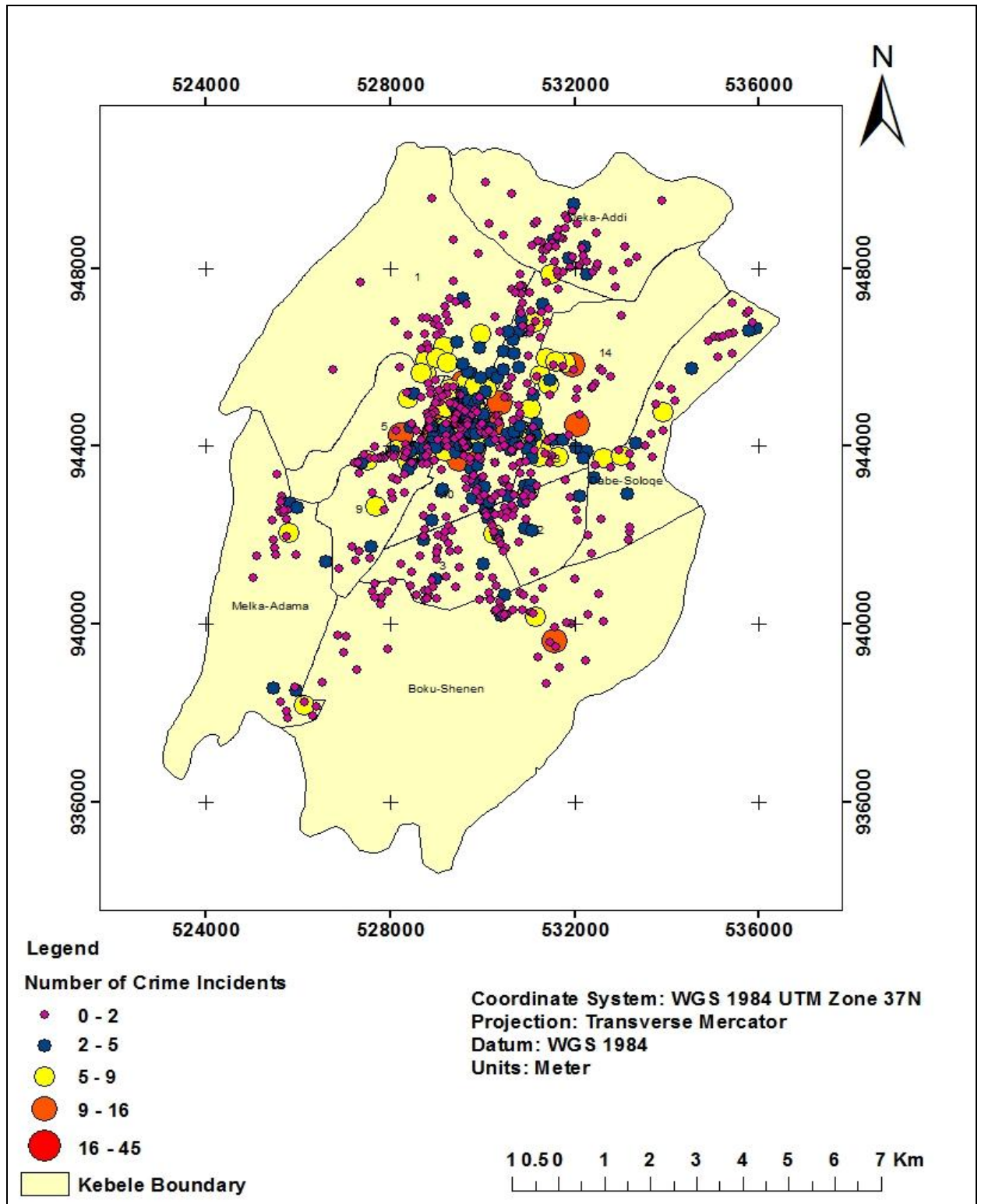


Fig 3.3. Graduated Size Point Map Depicting Numbers of Crimes at a Location in Adama city,
2013/2014

Table 3.6 Crime Range Distributions Using Graduated Point Symbols

Numbers of Crime Incidents	Ranking	Level of Crime Intensity	Colour Representation
0 - 2	1	Very low	Peony Pink
2 - 5	2	low	Ultra Blue
5 - 9	3	moderate	Solar Yellow
9 - 16	4	high	Fire Red
16 - 45	5	Very high	Mars Red

3.5.2.2 Choropleth Hotspot Identification Technique

In choropleth crime hotspot identification technique, the total number of crimes committed in each kebele police station was filled in the attribute table of each police station boundary. Then, using the Conversion Tools/ Feature to Raster, the city kebele police station boundary shape file was converted to raster layer by its number of crimes and reclassified using natural break classification technique. Finally, the spatial distribution of crime incidents in the administrative boundaries are shown by assigning graduating colours across the range of value categories which are going from lowest to highest as shown in the Fig 3.4.

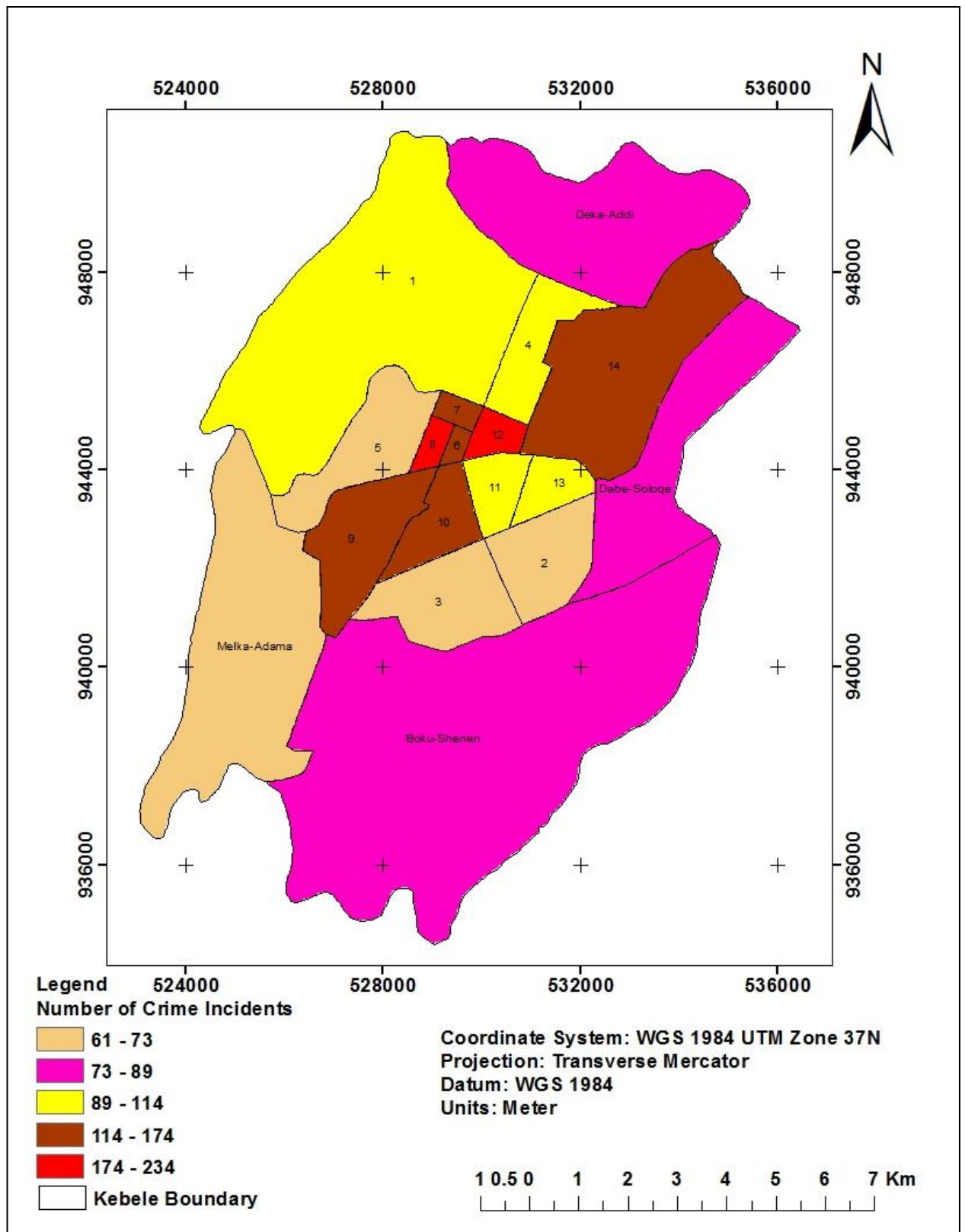


Fig 3.4. Choropleth Map Depicting Number of Crimes in Adama City, 2013/2014

Table 3.7: Crime Rage Distributions of Adama City Using Choropleth Mapping

Numbers of Crime Distribution	Ranking	Area in Sq. Km.	% of Area	Level of Crime Intensity	Colour Representation
61 - 73	1	27.59	20.64	Very low	Medium Sand
73 - 89	2	57.91	43.33	low	Ginger Pink
89 - 114	3	28.85	21.59	moderate	Solar Yellow
114 - 174	4	17.90	13.39	high	Cherry Cola
174 - 234	5	1.41	1.05	Very high	Mars Red
Total		133.66	100		

3.5.2.3 Kernel Density Estimation Technique

The Kernel Density Estimation technique is implemented in the spatial analysis tool of Arc GIS. Therefore, density mapping techniques using kernel density estimations (KDE) can be applied to identify and map crime hotspots. The kernel estimation method requires two parameters to be set prior to running. These are the grid cell size and bandwidth (search radius). In the KDE-algorithms, the study area first overlaid with a grid of user definable cell size. In a Second step, density values for each cell are calculated depending on the implemented bandwidth (search radius) in the study area. The size of the search radius will determine how generalized the density patterns will appear. The smaller the cell size, the smoother the density surface will be. However, very small cells also require considerably more processing time and computer storage space [33]. In general, the band width and cell size selected depending on the extent of the study area. Which means, taking the square root of the X or Y variance of the extent of the study area (which is smaller) and divided by 5 or 10 [35]. For the case of this study, a bandwidth parameter (search radius) of 1200 meters and a cell size of 30 meters was used. The 1200 meter bandwidth value produces the most reasonable output as hotspots are visualized as well as the overall distribution of crime scenes.

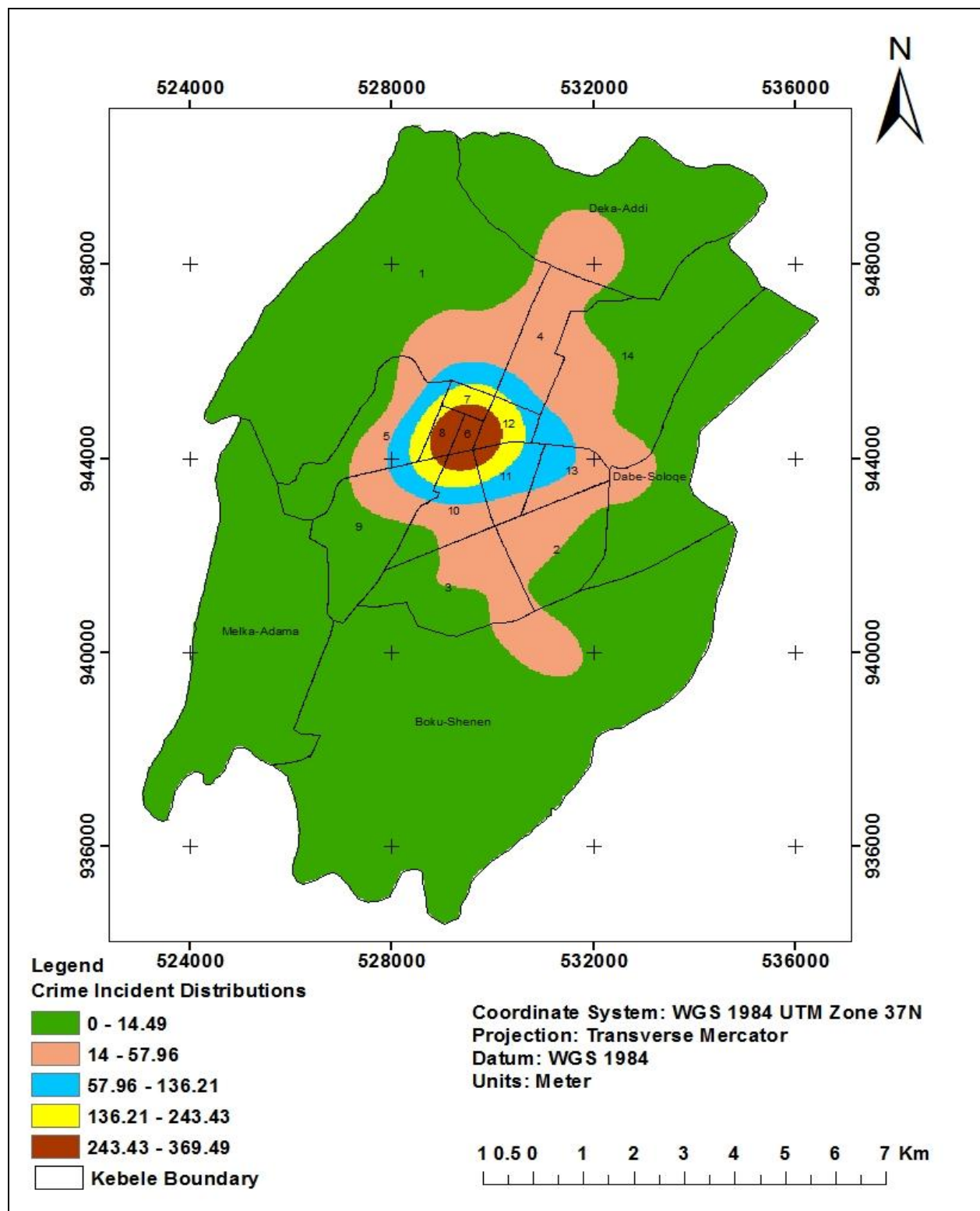


Fig 3.5. Kernel Density Map Depicting Crime Distributions in Adama City, 2013/2014

Table 3.8 Crime Range Distributions of Adama City Adama Using Kernel Density Estimation

Numbers of Crime Distribution	Area in Sq. Km.	% of Area	Ranking	Level of Crime Intensity	Colour Representation
0 – 13.41	104.44	78.14	1	Very low	Leaf Green
13.41 – 49.99	21.21	15.87	2	low	Orange Dust
49.99 – 115.83	4.29	3.21	3	moderate	Big Sky Blue
115.83 – 206.07	2.19	1.64	4	high	Solar Yellow
206.07 – 310.93	1.52	1.14	5	Very high	Cherry Cola
Total	133.65	100			

3.5.3 Crime Incident Proximity

The concern of this study was to make proximity analysis of incidents of crime from police stations. Thus, eighteen police station locations were collected in the study area to analyze the proximity of crime against person and crime against property. Multiple Ring Buffer tool in Arc GIS has been used to make proximity analysis. Multiple ring buffering creates a new feature class of buffer features by using a set of buffer distances. The buffer distance was selected depending on researcher decision. According to SahrTengbeh (2006) [36], the proximity of crimes from the police station was examined from a distance of 50m, 100m, 150m, 200m, 250m, 500m, 1000m, 2000m and 4000m from minimum to maximum respectively. In the same manner, the buffer distance 50m, 100m, 150m, 200m, 250m, 500m, 1000m, 2000m, 4000m and 6000m was used for the case of this study. After generating buffer distance, the crime incidents were overlaid on each buffer distance. Then, Crime against person and property was examined by manual visual interpreting as depicted in the Fig A1 in the appendix separately. Accordingly, a table was generated which illustrates the spatial relationship of crime incidents with police stations as indicated in Table 3.9 below.

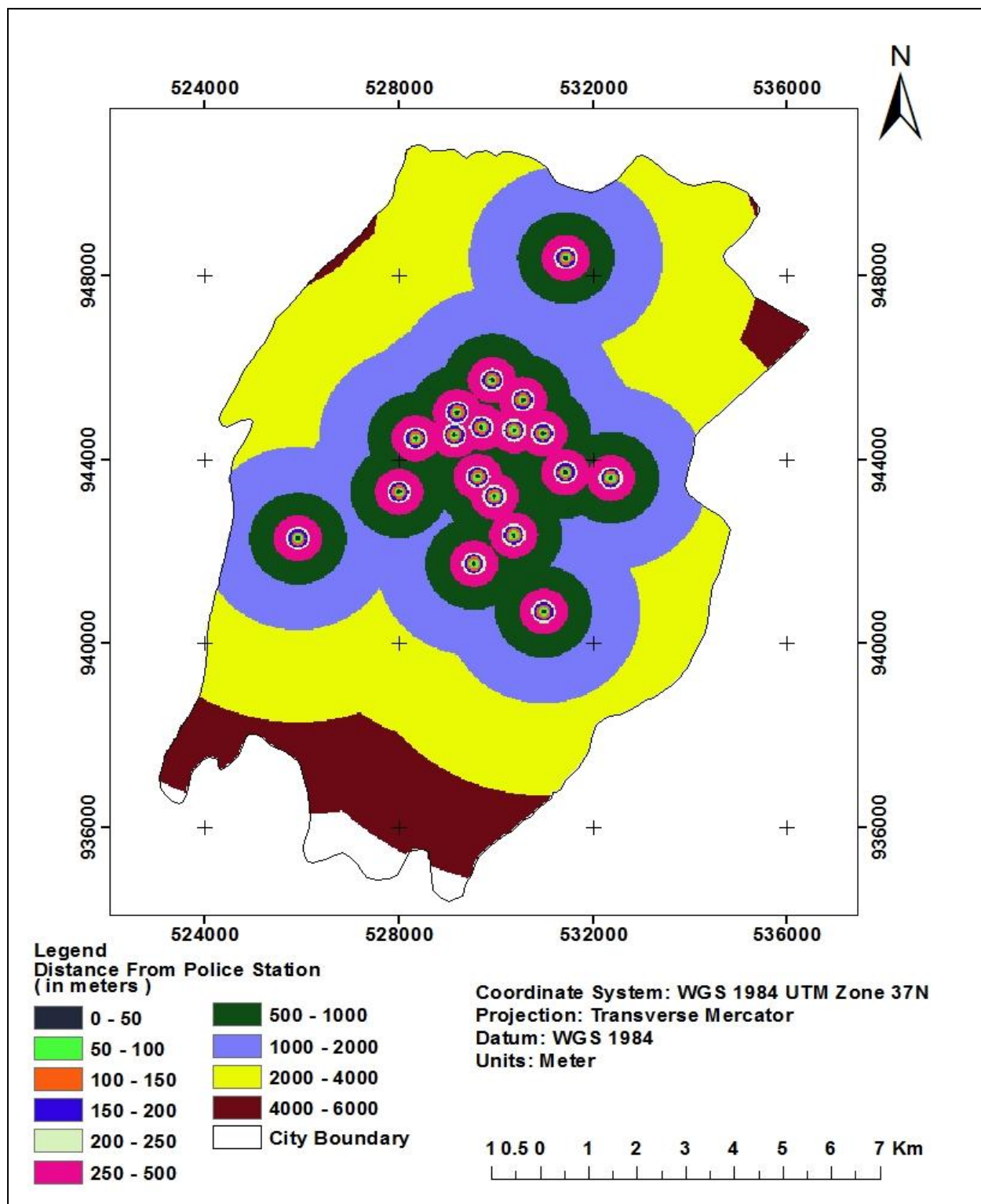


Fig 3.6.Proximityof Crime against Property and Person from Police Stations, 2013/2014

Table 3.9. Number of Crimes Distance from Police Stations in Adama City, 2013/2014

Proximity to Police Stations (in meters)	Numbers of Crime against Property	Crime against Property in Percent (%)	Numbers of Crime against Person	Crime Against Person in Percent (%)	Total number of crimes in the range	In percent
0 – 50	3	0.22	6	0.74 %	9	0.42
50 – 100	31	2.31	19	2.33	50	2.32
100 – 150	91	6.79	41	5.03	132	6.13
150 – 200	65	4.85	43	5.27	108	5.01
200 – 250	99	7.39	80	9.80	179	8.02
250 – 500	512	38.24	304	35.26	816	37.87
500 – 1000	350	26.14	199	24.39	549	25.48
1000 – 2000	156	11.65	79	9.68	235	10.91
2000 – 4000	25	1.87	18	2.21	43	1.99
4000 - 6000	7	0.54	17	2.08	24	1.11
Total	1339	100	816	100	2155	

3.5.4 Crime Pattern and Related Factors

In this section, the spatial relationship distribution of crime incidents with population density and land use were analyzed. According to (Roncek and Maier, 1999) [24], the spatial distributions of crime clearly demonstrate that land uses and population characteristics are associated with crime hot spots. From the viewpoint of environmental criminologists, crime is closely related to the society, economy, population, land use and so on [44]. Therefore; using the crimes against property and person which were recorded in 2013 and 2014 and including the information where crime incidents occurred, the study attempted to analyze the relationship of crime incidents with population density and land use of Adama city under this section.

3.5.4.1 Relationship between Adama City Crime and Land Use Types

The land use types were obtained by digitizing Adama city structural plan which was prepared in 2004. From the beginning the land use types of the study area were eighteen (18), while examining the intensity of crimes which occurred on each land use types again reclassified into five as shown in the Fig A2 in the appendix. As a result, the land use was reclassified as commercial, mixed (both commercial & residential), residential, services and others. After selecting land use parameters, the relationship between these land use and the crime incidents were studied by manual visual interpreting as shown the Fig A2 in the appendix. Finally, the crime density was computed for each land use which is numbers of crime per area square kilometers as shown in the Table3.10 below for both types of crimes [25].

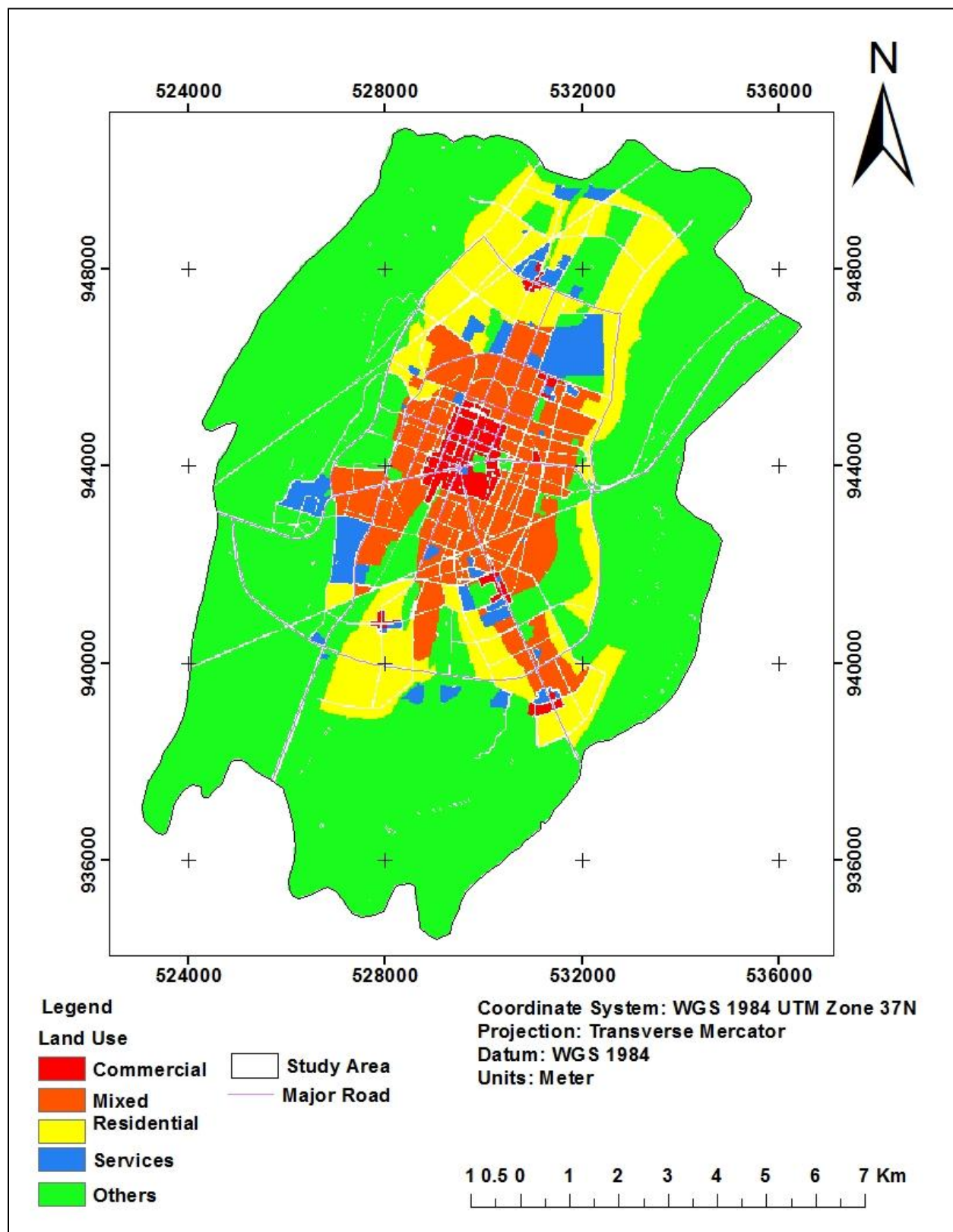


Fig 3.7 Land Use Map of Adama City

Table 3.10 Crime incidents and land use relationship in Adama city

Land use	property	person	Area in sq.km	Area in Percent	Crime Density (crime numbers per sq.km	
					Property	Person
commercial	562	351	2.1024	1.64	267.31	166.95
mixed	432	201	14.1057	11.002587	30.6259	14.249558
residential	139	98	17.5501	13.689254	7.92	5.5840
services	83	45	4.6611	3.635706	17.8069554	9.654373
others	123	116	89.78418	70.032561	1.36995	1.291987
Total	1339	816	128.20348	100		

3.5.4.2 Relationship between Adama city crime and population Density

In order to investigate the relationship between the crime activities and population density of Adama city, first projected kebele population data was collected from finance and economic development of Adama city administration. Then, the gross population data was filled the attribute table of each kebele boundary using GIS. Following this, population density was calculated by the number of person per square kilometer of each Adama city kebele. Using the Conversion Tools/ Feature to Raster, the city kebele boundary shape file was converted to raster layer by its population density. Furthermore, the data layer was reclassified in five sub-groups using the standard classification scheme. After the population density has been reclassified, the relationship of crime activities and population density was examined by manual visual interpreting as depicted in the Fig A3 in the appendix. As a result, areas categorized from very low to very high in ascending order based on the result obtained from the crime rate density which is number of crimes per area square kilometers as revealed in Table 3.11 (Steve Gibbons, 2003).

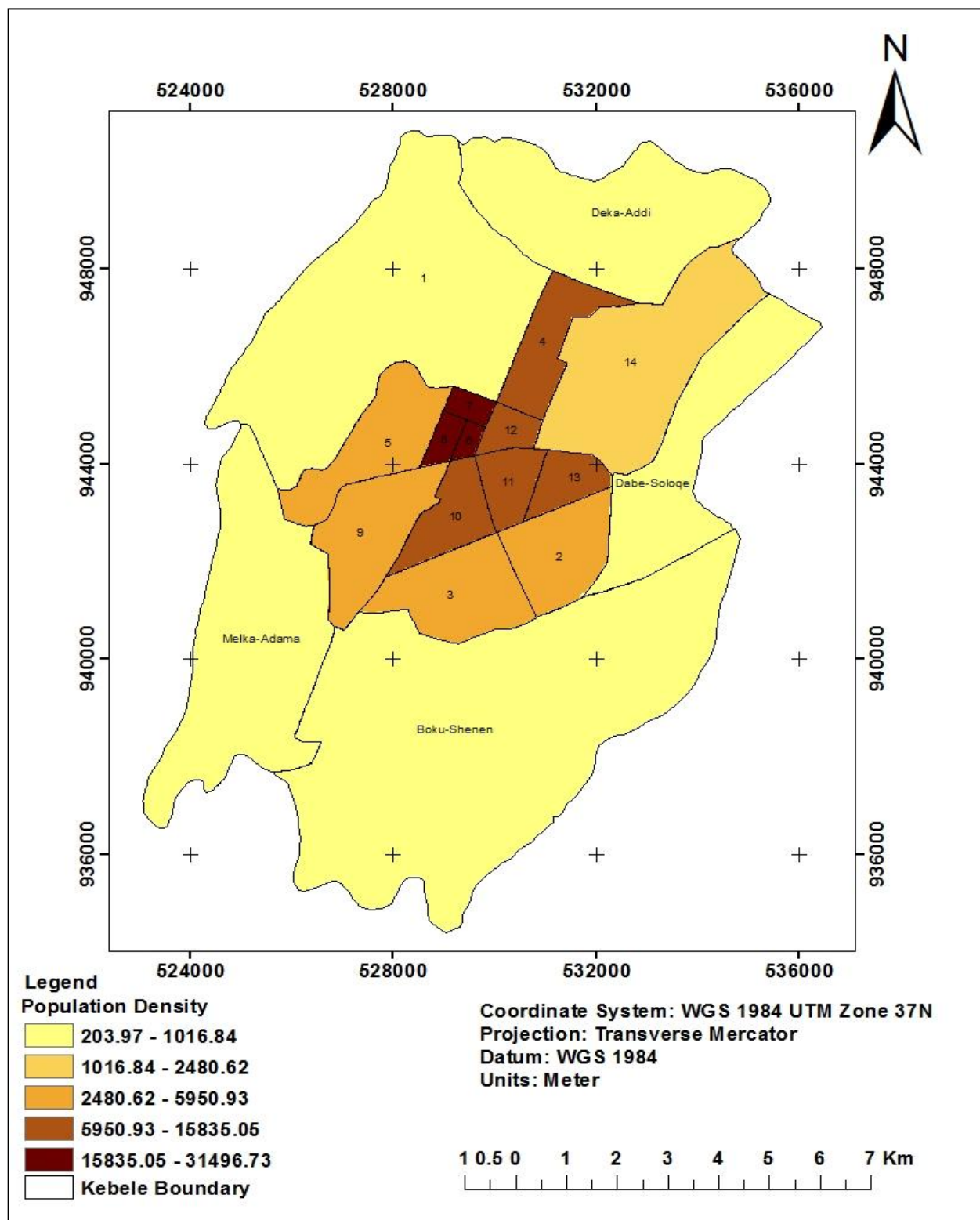


Fig 3.8 Population density of Adama city

Table 3.11 Crime incidents and population density relationship in Adama city

Population density (No/ Sq.Km)	property	person	Area in sq.km	Area in Percent	Crime Density (no. of crimes per sq.km		Level of Crime Intensity
					Property	Person	
203.97 - 1016.84	259	167	95.9409	71.79	2.699	1.74	Low
1016.84 - 2480.62	92	40	10.2978	7.71	8.93	3.88	Very low
2480.62 - 5950.93	199	148	16.9479	12.68	11.74	8.73	moderate
5950.93 - 15835.05	435	256	9.099	6.81	47.807	28.13	high
15835.05 - 31496.7	354	205	1.3464	1.01	262.92	152.26	Very high
Total	1339	816	133.63				

4. RESULTS AND DISCUSSION

4.1 Crime Rate per 1000 Persons Computation Result

The rate of crimes against person and property of Adama city kebeles were computed per 1000 residents and presented in the Fig 4.1 below. Hence, the rate of crimes against person and property easily compared among kebeles and identified which kebeles are highest for crimes against property and crimes against person. As a result, crimes against property are highest in kebele 08 and kebele 12 respectively. In kebele 08, there are 12.7 crimes against property per 1000 persons. In kebele 12, there are 10.9 crimes against property per 1000 persons. Whereas, the rate of crimes against person are 3.9 and 5.4 per 1000 persons in those kebeles respectively. In those kebeles, both categories account 21.35% from the total crimes occurred in the study area. Crime against person is highest in kebele 06 which has 9.9 crimes per 1000 persons. Crimes against person are lower in kebele 03, kebele 05, kebele 02, kebele 01, kebele 04 and kebele 14 respectively. As shown in the graph below, they have less than two (2) per 1000 persons. Whereas, the rate of crimes against property are lower in kebele 03 and kebele 05 respectively. In general, the rate of crime against property was highest in Adama city in the year between 2013 and 2014.

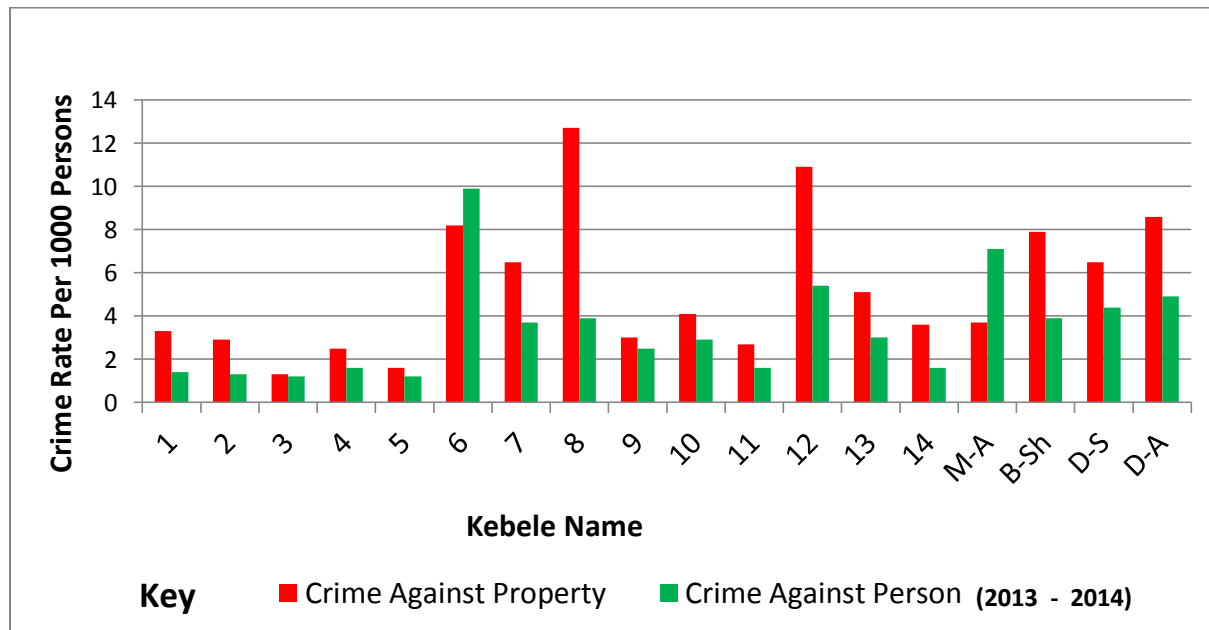


Fig 4.1 Crime rate of Adama city per 1000 persons, 2013/2014

4.2 GIS Techniques for Crime Hotspot Identification Result

4.2.1 Graduated Size Point (Point Density) Hotspot identification Result

While manual visual interpreting technique was applied on a graduated point symbol crime hotspot identification technique which is indicated in the Fig 3.3, all types of graduated point symbols, which they refer the numbers of crime occurring at a location, concentrated at the downtown of the city. Specifically, major parts of kebele 06, kebele 07, kebele 08 and kebele 12. In general, away from the city center, the crime incident is sparsely distributed as suggested by the Fig 3.3.

4.2.2 Choropleth Hotspot Identification Technique (Area Density) Result

As can be shown in the Fig 3.4, Adama city kebeles are classified into very low, low, moderate, high and very high based on the number of crimes that they have. It was observed that out of the eighteen kebeles in Adama city, kebele 08 and kebele 12 were classified as very high crime incident kebeles. Whereas, kebele Melka-Adama, kebele 02, kebele 03 and 05 kebele classified as very low crime incident kebeles. The low incidences were observed in Boku-Shenen, Dabe-Soloque and Deka-addi. The moderate incidence was observed in 01 kebele, 04 kebele, 11 kebele and 13 kebele. The remaining high incidences were observed in 06 kebele, 07, kebeles, 09 kebele, 10 kebele and 14 kebele. The technique enables the user to quickly demine which areas have a high incidence of crime.

4.2.3 Kernel Density Hotspot Identification Result

The Kernel density analysis in Fig 3.5 demonstrates that from 2013 to 2014 reported crimes against property and crimes against person, an area of 1.52 square kilometers coverage from the study area identified as crimes hotspot area. The area is designated by cherry cola colour in the Fig 3.5 which indicates in the downtown of Adama city. More specifically, whole and parts of kebele 06, kebele 08, kebele 12, kebele 07, kebele 10, kebele 09 and kebele 11. These kebeles are sequenced based on the intensity of crime incident occurrence as examined visually. Going from the city center, the crime incidents are distributed sparsely.

4.2.4 Comparison of Crime Hotspot Identification Techniques

In a graduated point map, some points overlapped one another. Therefore, the technique is better if it is used on a large scale map. Choropleth map can be interpreted as crimes were uniformly distributed within the kebeles. This can be far from the truth. However, the failures that have been seen on graduated point map and choropleth map not appeared on kernel density estimation map. Therefore, the best result was obtained from kernel density map. It works by first overlaying an area of interest with a fine rectangular grid. It then calculates an estimate of the density of crime incidents in each grid cell which is based on kernel density function.

4.3 Proximity to police station result

The results of proximity of crimes against property and crimes against person to police stations which are shown in the Fig 3.6 and in the Table 3.9, illustrate that most crimes occurred between 250 and 500 meters from the police stations. Within this distance, 37.87 % (816 incidents) of the total crime was recorded between the year 2013 and 2014. When compared to proximity of crimes against property and crimes against person from the police stations, there were more property crimes in the distance between 250 and 500 meters which accounts 38.24 % (512) from the total property crimes. Majority of them are from the downtown police station as shown in the Figure A1 in the appendix. As clearly shown in the proximity graph in Fig 4.2, less number of crimes against property together crimes against person reported nearby 100 meters from the police station and far from 4000 meters from the police station up to the extent of the study area which, they account 2.74 % (59) and 3.1 % (67) from the total reported crimes respectively.

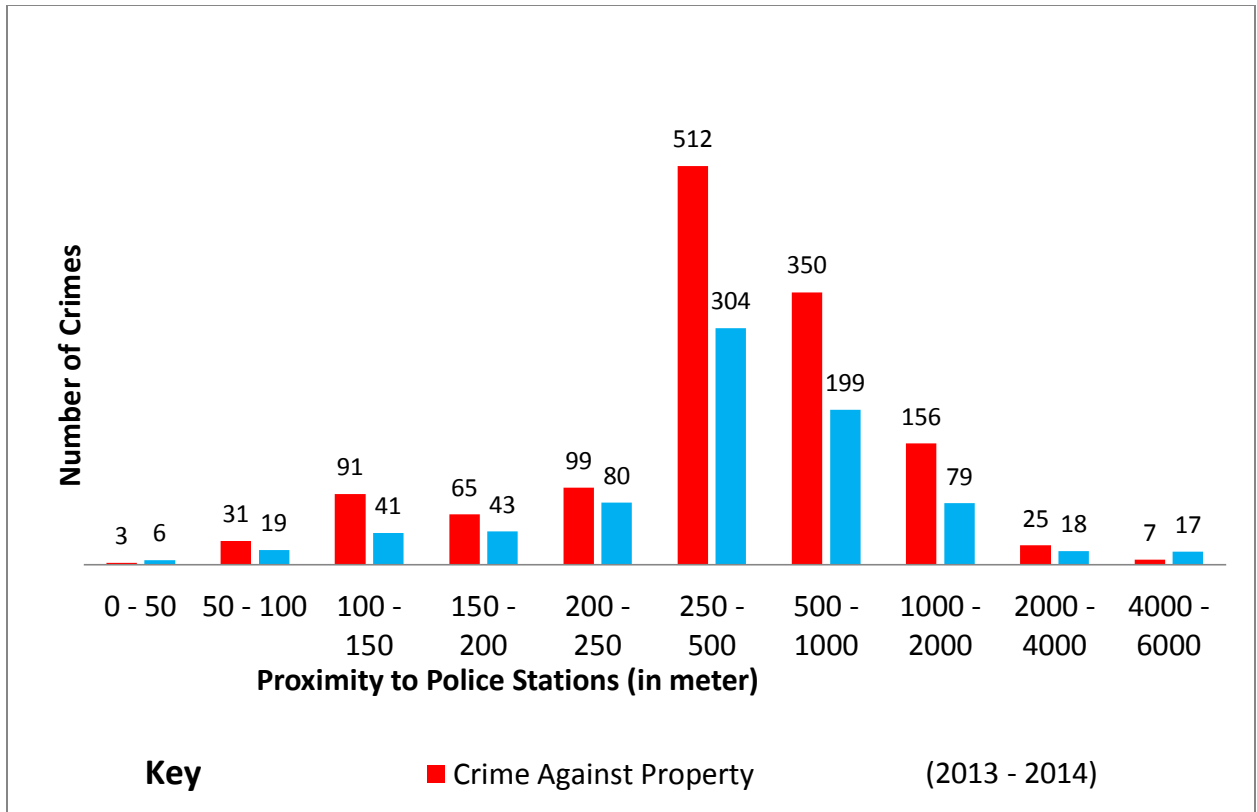


Fig 4.2 Categories of crimes proximity to police stations

4.4 Relationship between Crime Incidents and Land Use Result

The results of land use and crime incident distribution which are shown in the Fig 4.3 and in the table reveal that, the rate of crime against property and crime against person on commercial areas are 267.31 and 166.31 per square kilometers respectively. Hence, the rate of crime against property and crime against person are highest in commercial areas which account 1.67 % of the study area. When the two crime categories compared, crime against property is highest in the area. Mixed, Residential, Services and Other land use types mentioned in the appendix have the rate of crime against property 30.62, 7.92, 17.80, 1.36 and the rate of crime against person 14.24, 5.58, 9.65, 1.29 per square kilometers respectively. A graph is used below to quickly understand their distributions.

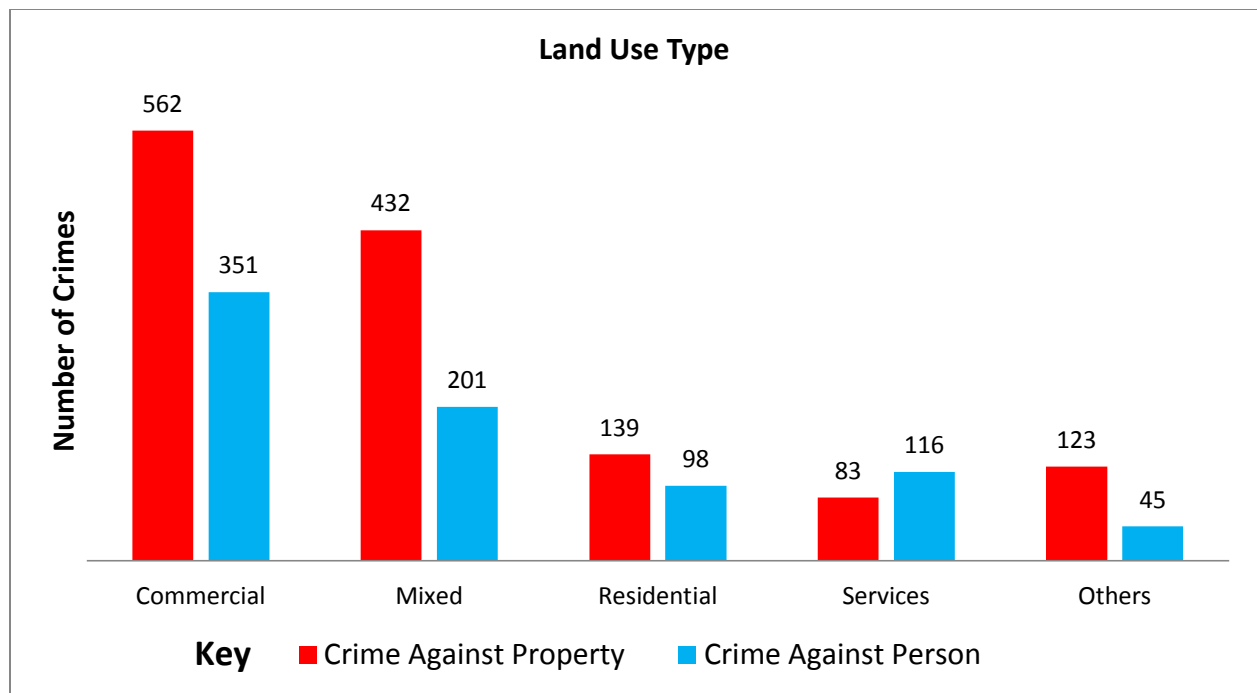


Fig 4.3 Crime incidents and land use relationship result

4.4.1 Relationship of Land use and Crime Hotspot Areas Identified by KDE Result

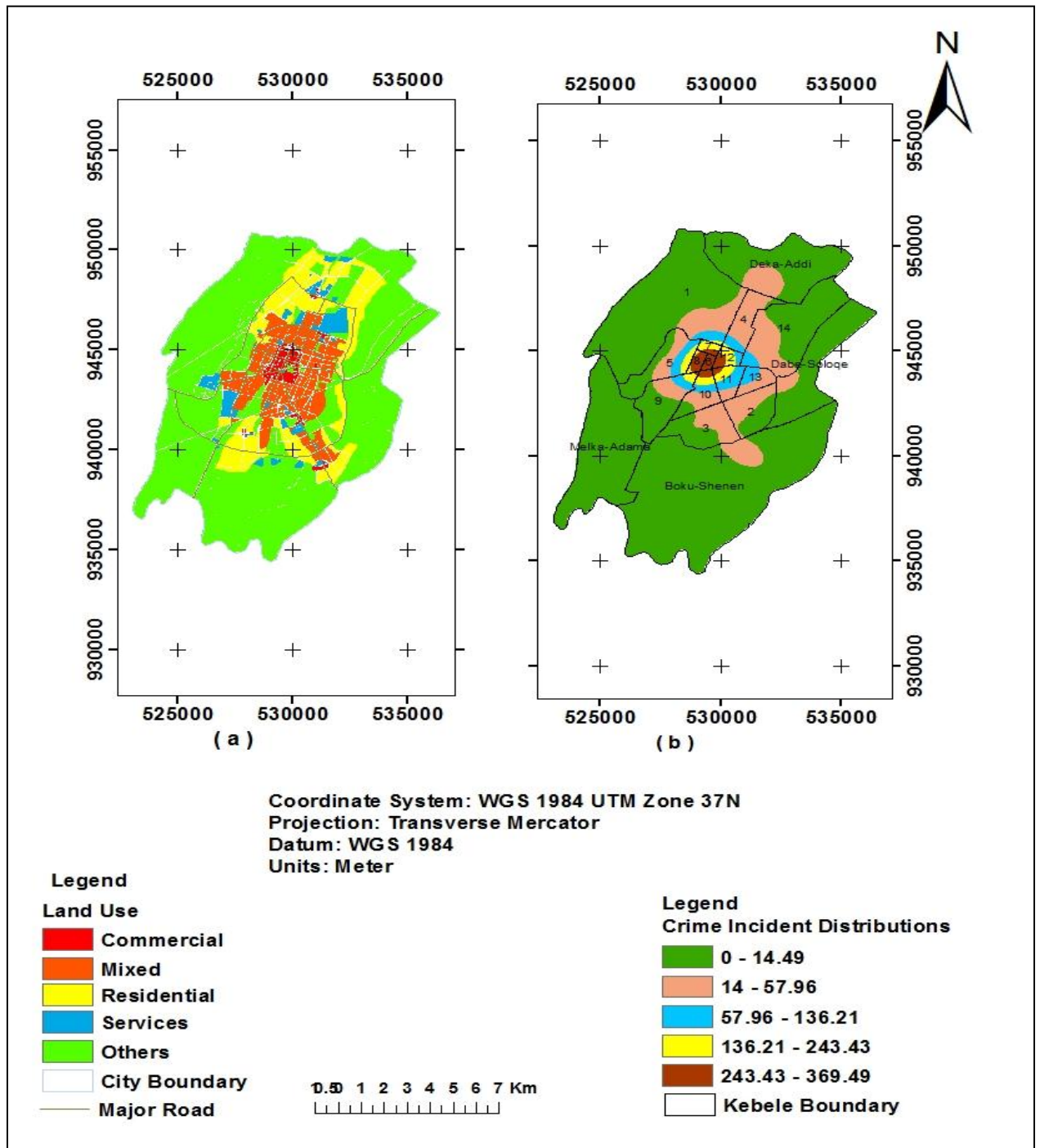


Fig 4.4 Relationship of Adama city, (a) land use and (b) crime hotspot areas

Left column of the Fig 4.4 at (a) shows the land use type which was classified based on the intensity of crimes occurred on each land use type. In the result of crime incidents and land use relationship which has been discussed under the topic 4.3, the rate of crime is highest in commercial area which is indicated by mars red colour in the Fig 4.4 (a). The area is center of the city and account 1.67 % of the study area. On the other hand right column the Fig 4.4 at (b) indicates crime incidents distribution resulted from using kernel density estimation. As illustrated in Fig 4.4 at (b), the intensity of crime is highest in the area which is denoted by cherry cola colour. The area is center of the city and account 1.52 square kilometers from the total study area. In (a) and (b), the center of the city was identified as the crime hotspot area. Whereby, high economic and transportation activities are taking place. As a result, the chances of visiting by so many persons are very high which is convenient for criminals. In the case of comparing these two columns, somehow similar crime hotspot area results can be detected at (a) and (b).

4.5 Relationship between Adama city crime and population Density Result

As indicated in the table, the population density value that lied between 194.76 to 484.76 covers large portion of the study area which is 71.79 % but has very low level of crime rate per square kilometers. Thus, the rate of crime against property and crime against person are 2.699 and 1.74 in the area respectively. As illustrated in the Fig, the area consisted of Melka-Adama, Boku-Shenen, Deka-Addi and 01 kebeles. Whereas, the rate of crime against property together with crime against person is very high in the population density range that lied between 15835.05 and 31496.7 which covers 1.01 % of the study area. Thus, the rate of crime against property and crime against person are 262.92 and 152.26 in the area respectively. Specifically, the area consisted of kebele 06, kebele 07 and kebele 08 which are in the downtown of the city. The rest of the study area was identified as high, moderate and low level of crime intensity and cover areas of 9.099 km^2 (6.81%), 16.9479 km^2 (12.68%) and 10.2978 km^2 (7.71%) with crime intensity scales of 4, 3 and 2 respectively.

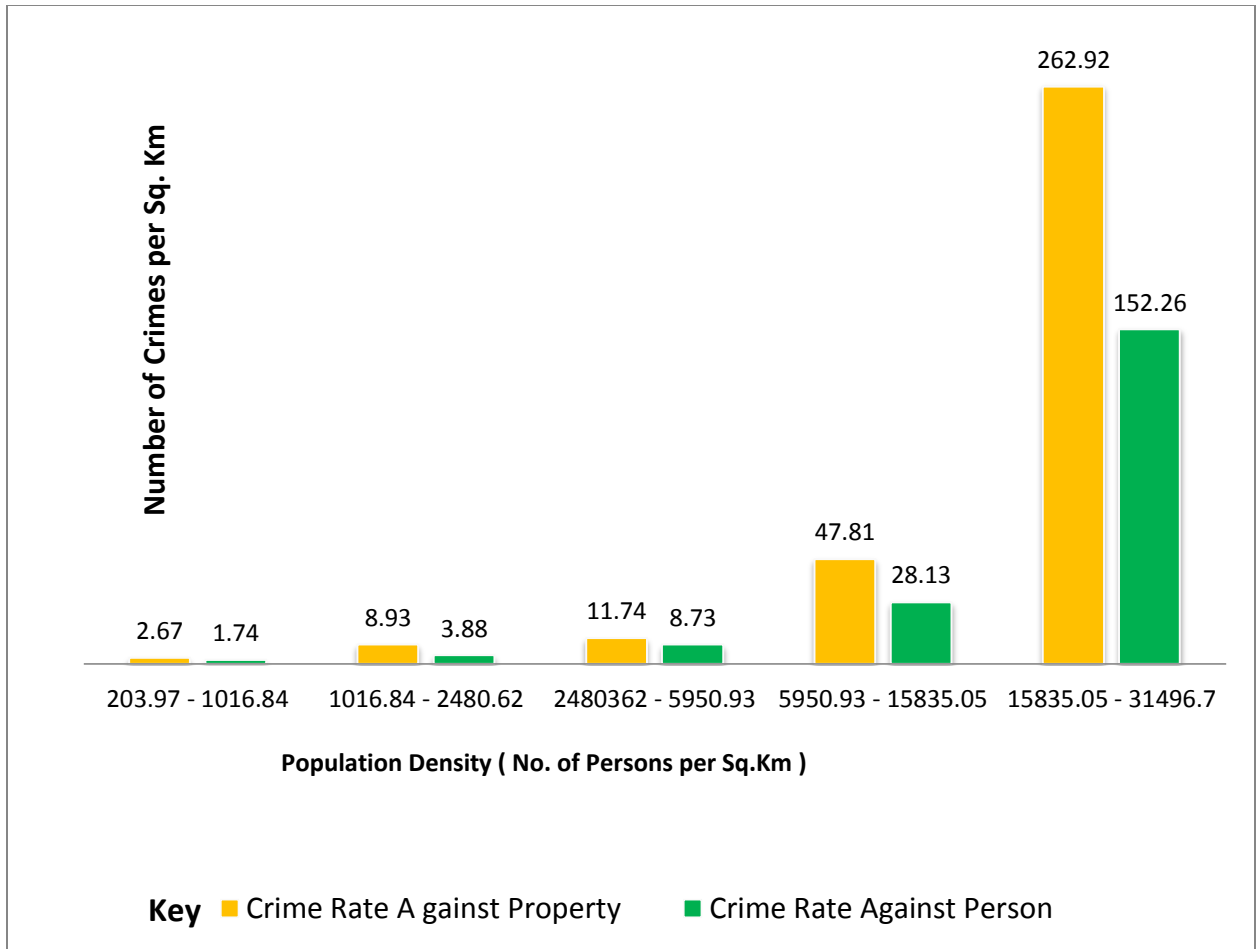


Fig 4.5 The rate of crime over population density per square kilometers

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study employed Geographic Information System (GIS) to assess the spatial distribution of crimes against property and crimes against person which was recorded in the year 2013 and 2014 in Adama city. In the study, a total of 2155 crimes were recorded in Adama city in 2013/2014. The number of crimes recorded in 2014, increased by 11.2 % compared to the 2013 recorded crimes. Generally, the study can be classified into two. The first one is identifying crime hotspot areas using statistical and spatial analysis. In the statistical analysis, crime rate computation was made which is, by number of crimes per 1000 persons. In the spatial analysis, point density, area density and kernel density estimation GIS techniques were used to identify and visualize crime hotspot area. The second one is the spatial relationship of crime incidents with police station, land use and population density were illustrated. Accordingly; based on the data obtained and the analysis made, the following conclusions are drawn.

1. The center of Adama city is identified as the main crime hotspot area; while going from the city center to the periphery, the intensity of crimes are distributed sparsely.
2. Highest number of crime against property and crime against person are occurred in the distance between 250m and 500m from the police stations.
3. The rate of crime is found to be highest at the commercial area of the city, which is the center of the city. Commercial area of the city comprised the following kebeles:- 06, 07, 08, 09, 10, 11 and 12 fully or partially. Particularly, the area where their part is nearer to the center of the city.
4. Mixed (both commercial and residential) areas are identified as the second highest crime hotspot area in the land use classification.
5. In the crime incidents – population density relationship result: - it is found that the rate of crimes against property and crimes against persons are highest in the population density classification range of 15835.05 and 31496.73. In the range, it is revealed that 262.92 and 152.26 numbers of crimes against property and crimes against person per square kilometers respectively. Kebele 06, kebele 07 and kebele 08 are comprised in the range.

5.2 Recommendation

Based on the results of the study conducted, the following recommendations are forwarded to alleviate the problem.

1. When crimes are occurred their spatial locations should be collected using GPS to present a more precise indication of where crimes are occurring.
2. The police station locations should be based on the spatial distributions of crimes, the land use types and the population density.
3. Law enforcement agency should allocate additional resources and forces to commercial and populated areas of the city. In fact, not only this area but also at home or residential area.
4. The study revealed that combating crime in Adama city will require corporation of law enforcement agency, city administrative, central and statistical agency and the community too.
5. Urban planners or city administrative, should consider the spatial distributions of crime for the future planning and design of Adama city.
6. Finally, there is a need for future research which should consider the category of crimes against lawful authority such as corruption, escape from custody etc. and the category of crime against local act such as traffic offences, narcotic offences etc. The future research should also include service location information that will be available in a website such as police station location to report the crime situations where the internet service is available. In addition to this; if the road service locations are known and the police patrol units are equipped with GPS, the police force can quickly reach the place where the crime incidents are reported.

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APPENDIX

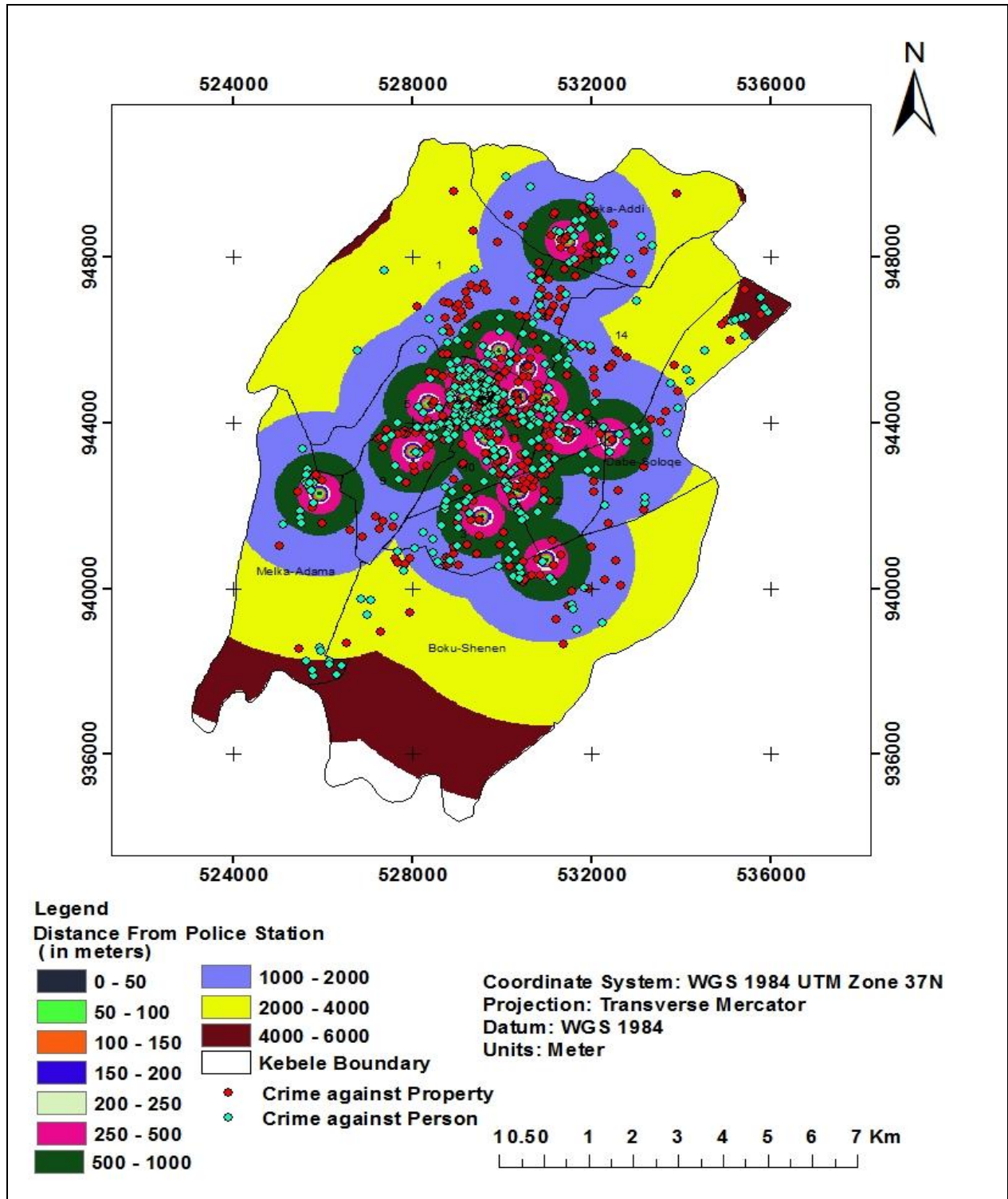
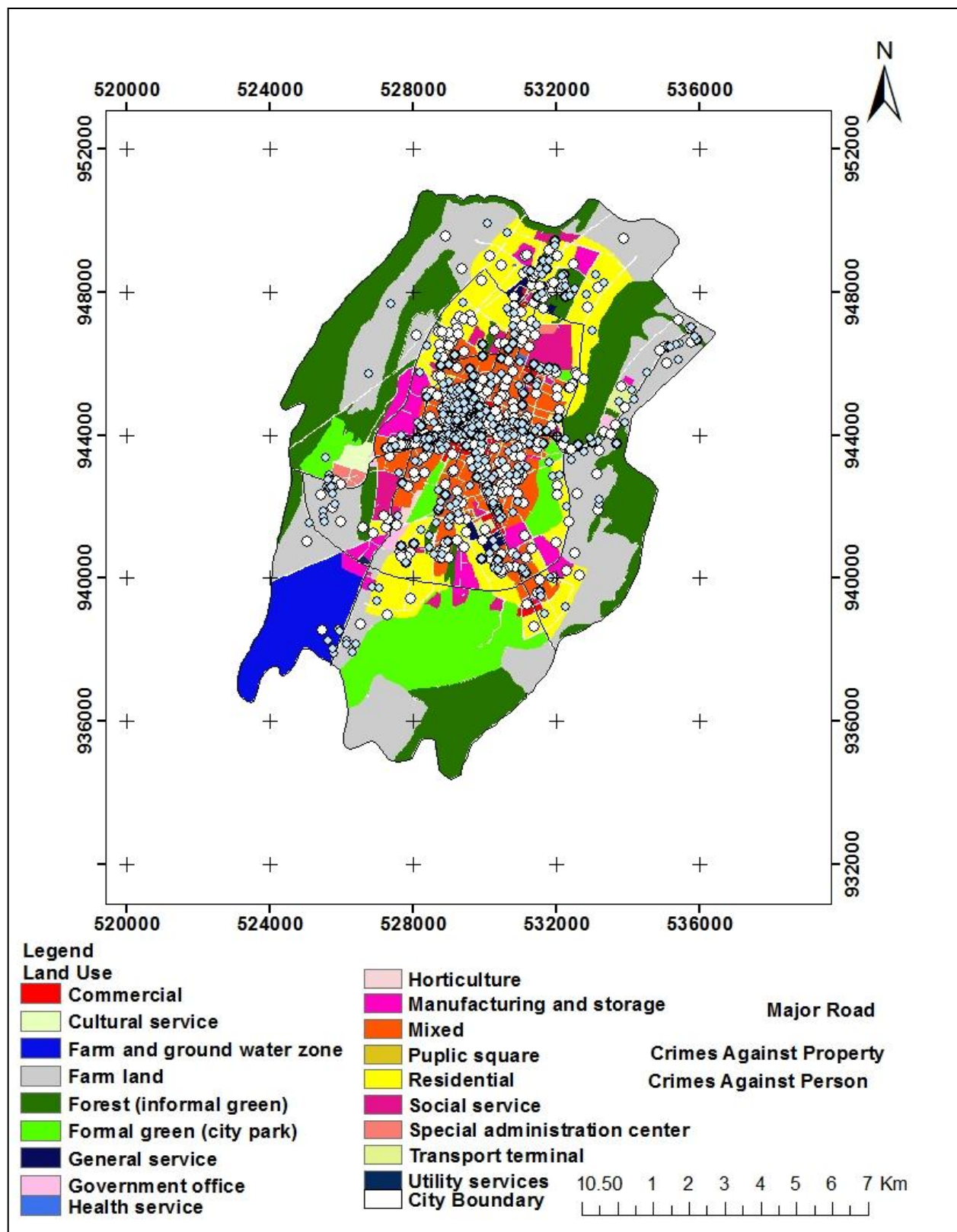


Figure A1, Proximity of Crimes against Property and Crimes against Person to Police Stations



FigA2. Crimes against Property and Crimes against Person over Adama City Land Use

Table A1, Adama city land use type and categories

Number	Land Use Type	No. of Crimes	Category
1	Commercial	562	Commercial
2	Mixed	432	Commercial & Residential
3	Residential	139	Residential
4	Health Service	28	Services (83)
5	Social Service	34	
6	Cultural Service	12	
7	Utility Service	6	
8	General Service	3	
9	Farm Land	43	Others (123)
10	Forest / informal green/	18	
11	Manufacturing & Storage	12	
12	Horticulture	8	
13	Government Office	4	
14	Public Square	7	
15	Special Administration Center	0	
16	Informal Green / city park/	20	
17	Terminal	12	
18	Farm Ground Water Protection Zone	0	

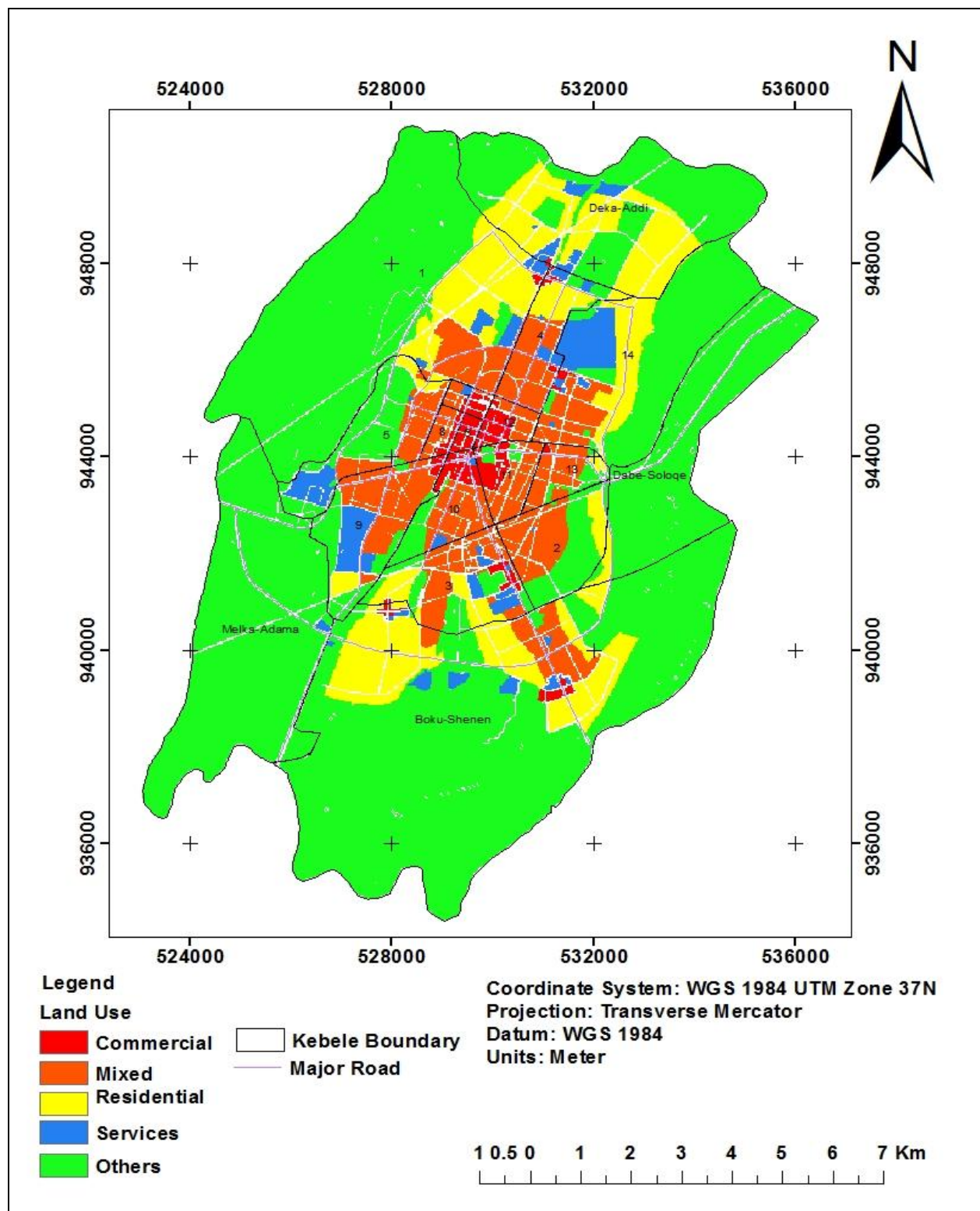


Fig A3. Reclassified Land Use of Adama City

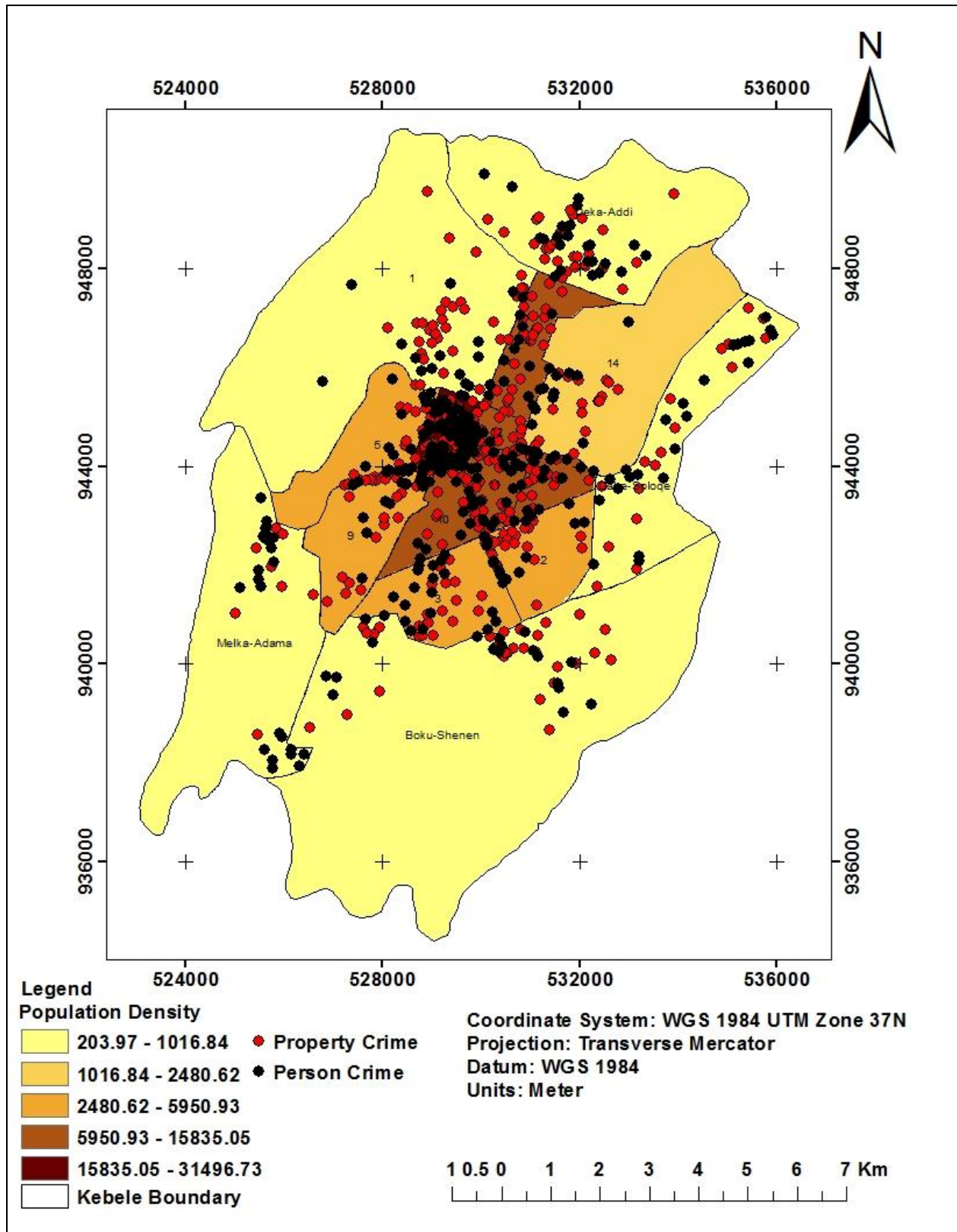


Fig A4, Crimes Against Property and Crimes Against Person over Population Density