(RESEARCH ARTICLE)

Crime mapping and hot spot analysis using geospatial data in Jalingo metropolis of Taraba State, Nigeria

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Abstract

Crime mapping and hot spot analysis are topical and significant research across the fields of criminology, data digging, city planning and law enforcement for crime control. This study seeks to identify high crime areas which require an officer presence and predicting the possible response demand to increase the efficiency of response officer patrols. Crime type and patterns exist on a spatial level; these patterns and type can be grouped geographically by physical location, and analyzed contextually based on the region in which crime occurs. The study aimed at analyzing crime hotspots using geospatial data in Jalingo metropolis by identifying the different kinds of crime in the study area, determine the spatio-temporal variation of crime occurrences in the study area and determine the high crime density area (hotspot).This study proposed a method to identifying level crime, localize crime hotspots, identify relationship between spatiotemporal crime patterns and social trends, and analyze the resulting data for the purposes of knowledge discovery and anomaly detection. Several types of crime were analyzed in this dataset, including burglary, bribery, forgery ,murder ,rape ,theft drug abuse, assault, and robbery analysis, several interesting findings were drawn about crime in Jalingo metropolis, including: Crime mapping and hotspots with steadily increasing crime levels, hotspots with unstable crime levels, synchronous changes in crime trends throughout Jalingo metropolis as a whole, individual months in which certain hotspots behaved anomalously, and a strong relationship between crime hotspot locations. This type of statistical and correlative analysis of crime patterns will help law enforcement agencies predict criminal activity, allocate resources, and promote community awareness to reduce overall crime rates in Jalingo metropolis. Policing approaches like patrolling and response to crime incidents can be more effective if proper crime mapping and crime hot spot analysis data are available for policing is used to make decisions on crime control in the study area. Predictive policing in crime management use information such as historical crime data to predict crime patterns and response demand. Historical crime data is used to identify high crime areas through kernel density estimation. It is also used to anticipate the levels of response demand. Both of these factors are used to determine how to direct police patrols. This study revealed how kernel density estimation is used for crime mapping and hot spot.

Keyword: Crime mapping; Crime hot spot; Kernel density estimation; Geospatial

1. Introduction

Over the last few years, a new worldwide socio-economical order led to an increasing number on crime rates and raised the need to find new ways to handle information about criminality [7]. Crime is defined as an antisocial act that violates

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a law and for which punishment can be imposed [4]. The security of lives and properties in human settlements is of great importance to the socio-economic, health and the general wellbeing of people in any society [18].

There is no doubt that insecurity in towns and cities is a major challenge to the Nigerian authority and its security operatives [13]. The scenario of crime in Nigeria disregards class distinction in the society, as both high and low experienced similar and equal visitation of the hoodlums from time to time. The resultant tragedy, suffering, colossal loss and distress, occasioned by those inimical visits, have been pervasive and had left an indelible mark on our national psyche and societal tranquility [22]. As an entity, crime has spatial attributes, location, time and process. The spatial attributes of this phenomena imply quantitative and qualitative variables and to understand its magnitude, it is necessary to capture, analyze and correlate them [12]. In essence, availability and quick access to timely and up -to - date spatial information about crime-prone areas, to the law enforcement agencies, will in no small way contribute to effective policing of the entire state [14].

To better understand its causes, local, regional and national security authorities turned to new decision support tools such as Geographic Information Systems (GIS) and other information technologies to help them in finding better solutions. Policing methods in Nigeria are still manual and un-automated [10]. The old filing system of record-keeping is still in use. This limits the force from having the technological edge over the ever-increasing technology sophistication of the criminals [22];[15]. Crime mapping has long been an integral part of the process known today as crime analysis. According to [6], the use of maps in crime study has been traced back to at least the year 1900. Most developed nations have migrated from the "pin on maps" to the use of computer GIS[9]. Unfortunately, most of the developing nations, including Nigeria, still utilize analog and outdated file systems. In most cases, police operations are carried out based on intuition, tip-off information and the simple "trial-and-error" method [16].

Furthermore, the old pin maps were useful for showing where crimes occurred, but they had serious limitations because as they were updated, the prior crime patterns were lost [3]. The maps being analogs are usually not easy to manipulate.

In addition, pin-maps could be quite difficult to read when several types of crimes, usually represented by pins of different colours, are mixed together [1]. Pin maps occupied a lot of space, wasted a lot of time, and were incapable of developing a logical, national data base. Based on these disadvantages, the need to carry out research on a better way to map crime and manage it becomes paramount [17].

1.1. Statement of the problem

The problem of crime in Jalingo local government area is an issue; Jalingo been the state capital of Taraba state is largely a settlers' area inhabited by people from other parts of the state and Nigeria. Based on the city historical, political, administrative and nodal attributes, Jalingo has witnessed an arithmetic progression in commercial growth, size, population and civilization [2]. Simultaneously it has also witnessed a corresponding and progressive crime growth. In Jalingo metropolis, crime is on increase, occurring in different forms, thus stimulating the need to tackle it before it expands beyond control. It is no longer a hidden fact that the city is a conducive setting for criminal activities, since it provides the anonymity required for individual crime, and the space for a specialized and organized underworld. According to [23] the increasing social sophistication and modernization of the country, the growing inequality, and the continuous rise in unemployment (especially among young school leavers and university graduates) have greatly accentuated urban crimes in recent times. Burglary, for instance, is on the increase in Jalingo metropolis. Despite trying their best, the law enforcement agencies are becoming frustratingly helpless as the criminals become more sophisticated on a daily basis [24]. As a result, the citizens daily grapple with the fear of the unknown and insecurity of lives and property with little or no hope of remedy [5]. Unfortunately, at present, there is little or no application of even the inadequate pin-on-maps in some stations in Jalingo, let alone the use of GIS. Worse still is the fact that the law enforcement agencies are yet to be computerized for effective record keeping, analysis of cases, easy reference cum retrieval and storage of information to help strategize and adequately plan the combating and eradication of crimes in general [19].

The non-application of GIS and geo-database in the fight against crime in this technological age is coastland counter-productive [11]. The emerging dimensions and complexities of crime in Jalingo require serious and proactive programs of crime management and control looking at the population density of the area. Such management measures will require adequate information and knowledge on the spatial patterns of crime incidence and hotspots in all settlements to ensure effective monitoring and control. This is therefore the gap which this research work intends to fill.

1.2. Significance of the study

Considering increasing rise of crime in Jalingo and Taraba state at large, there was an urgent need to conduct statistical research that if completed would guide security agencies in drawing effective strategies in deployment of personnel; and in promoting rational decisions by the policy makers[6]. This study has achieved a better understanding of the dynamics of crime and criminal activities that have bedeviled the state. This research has also provided relevant information that would serve as a guide to those who may wish to conduct further research relating to crime, crime hotspots and related issues.

1.3. Scope and limitations of the study

The purpose of this study is to analyze the hotspots of crime in Jalingo metropolis of Taraba state. The content scope consists of crimes that have taken place in the study area. Spatial scope of the study is limited to Jalingo Local government area which comprises of ten political and administrative wards. The temporal scope of the study is 12 months (one year; 2017, based on the availability of reliable data from the Nigerian Police Force (NPF), the state security service (SSS) and the National Drug Law Enforcement Agency (NDLEA) in the study area.
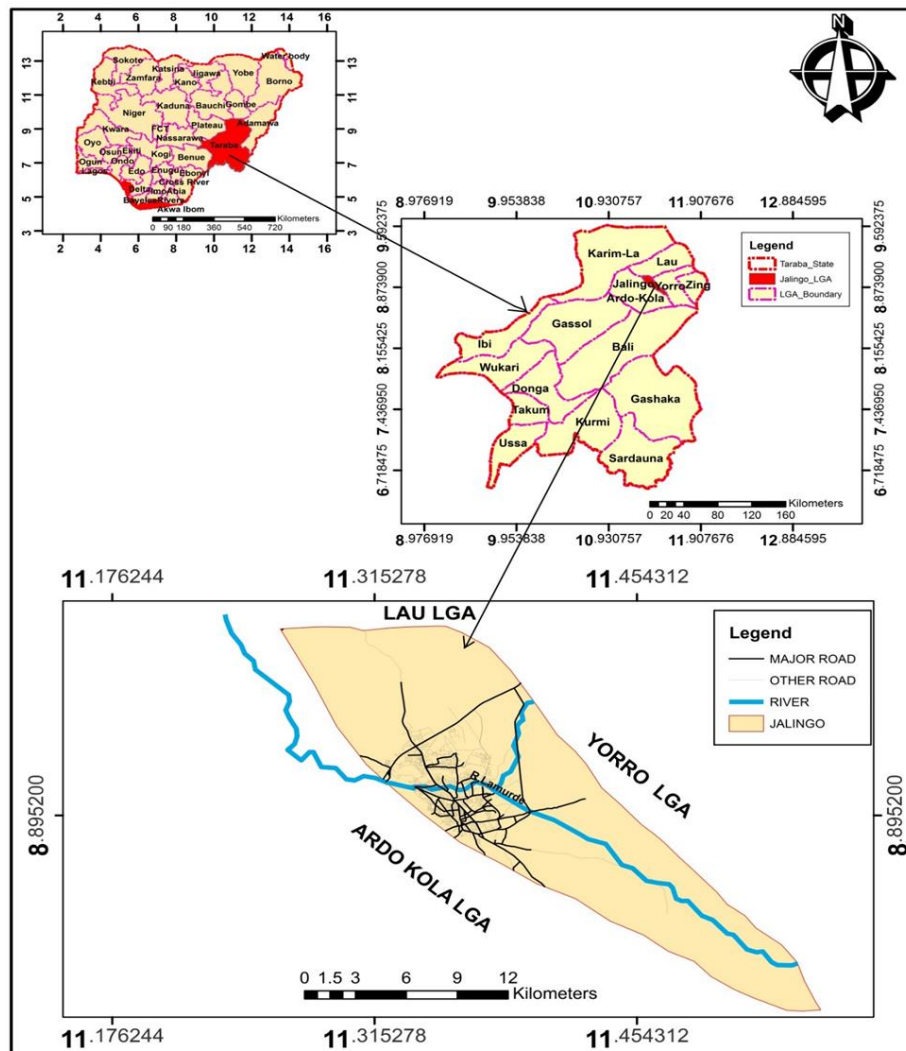
Figure 1 The study area

The study was conducted in Jalingo local government area of Taraba state. Jalingo LGA is roughly located between latitudes 8°47" to 9°01"N and longitudes 11°09" to 11°30"E. It is bounded to the North by Lau Local Government Area, to the East by Yorro Local Government Area, to the South and West by Ardo Kola Local Government Area. It has a total land area of about 195km². Jalingo is the capital city of the Northeastern Nigerian state of Taraba, and has ten wards for political and administrative convenience.

Aims and Objective of the Study

The aim and objectives of the study was to analyze crime hotspots using geospatial data in Jalingo metropolis. The specific objectives of this study are to:

- Identify the different kinds of crime in the study area
- Determine the spatio-temporal variation of crime occurrences of the study area.
- Determine the high crime density area (hotspot).

2. Materials and methods

2.1. Reconnaissance Survey

Reconnaissance survey was carried out in order to have a general knowledge of the study area, the three police stations, National Drug Law Enforcement Agency and Department secret service in the area were visited and reports concerning crimes committed for one year was obtained for the study purpose. The survey also enabled the researcher to know the major types of crime committed in the study area because of the report gotten from the police stations NDLEA and DSS. With the crime report gotten from the police stations which contains the types of crimes committed and the various locations of the crimes it was possible to collect the coordinates of the crime locations.

2.2. Data and source

Table 1 Type and source of data

S/no	types of data	source	purpose
1	Geographic coordinates of crime location	Global positioning system (GPS) Garmin CX76 2015	Coordinates of the crime scenes and police station locations
2	Crime records of the study area from June 2017 to May 2018	Police stations and NDLEA from Jalingo local government area	Crime analysis
3	Satellite	Google earth image	Digitizing (Road Network Extraction)

2.3. Methodology for Data Processing and Analysis

2.3.1. Types of Crimes Committed in the Study Area

The different types of crime were identified from the various crimes in the study area as seen in the crime records obtained from NDLEA, DSS and the police stations [8].

2.3.2. Crime Hotspots in the study area

The Kernel Density Estimation in ArcGIS (10.3) was utilized in mapping out the crime hotspots in Jalingo LGA. This provides an estimate of the proportion of total crime that can be expected to occur in any given map location[20]. It works by first overlaying an area of interest with a defined rectangular grid. It then calculates an estimate of the density of crime in each grid cell which is based on a weight function-ths Kernel. The kernel is a deeption of specified shape and bandwidth (search radius). The Kernel Density Estimation is given by the equation 1 (Deepthi and Ganeshkumar, 2010):

$$f(x,y) = \frac{1}{nh^2} \sum_{i=1} K\binom{di}{h} \text{---------------------} 1$$

Where f(x, y) is the density estimate at location (x, y), h is the search radius (bandwidth or kernel size), n is numbers of observations (total number of crimes), K is a kernel function and d, i is the distance between the location (x, y) and location of the ith observation.

The mean and standard deviation of the kernel Density Estimation was used to determine the hotspot and also a raster map was generated, where the intensity of crime is presented by continuous surface.

Mapping the spatial pattern of the crime scene was achieved using coordinates of various crime location obtained using a handheld GPS receiver. The coordinates were imported into the ArcGIS 10.8 environment, where point overlay analysis (mapping) was carried out.

3. Results

3.1. Types of Crime Committed in the Study Area

In an attempt to identify the types of crime committed in the study area, police and NDLEA records for twelve (12) months from June 2021 to May 2022 were analyzed and the result is presented in Table 2 below.

Table 2 Types of Crime Committed in study area

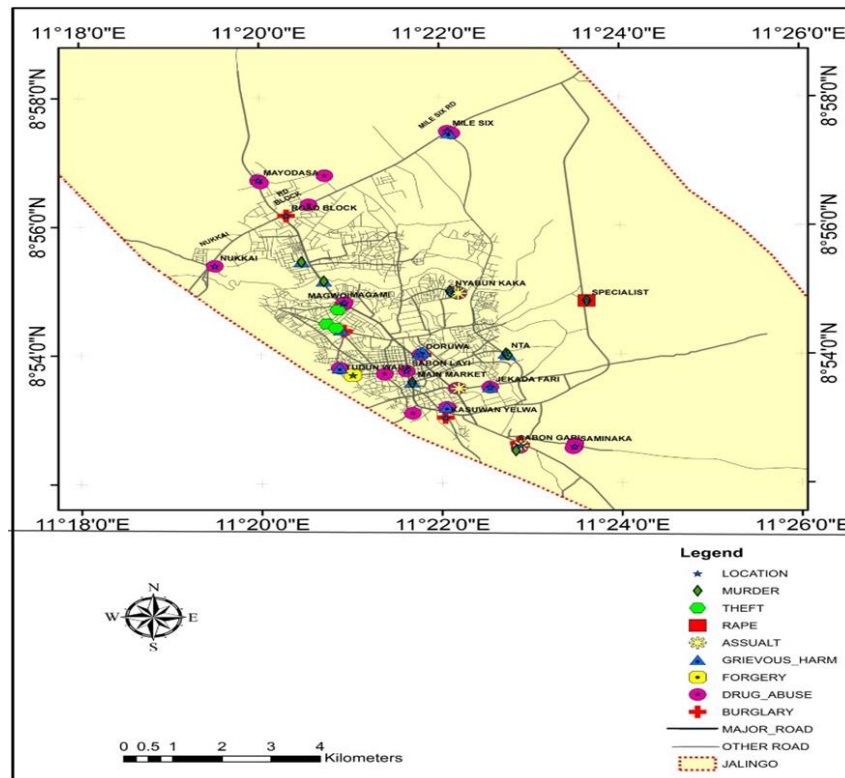| Types of Crime	No. of Crime	Percentage (%)
Bribery	1	0.6
Forgery	2	1.2
Murder	4	2.4
Rape	5	2.9
Theft	34	20.1
Grievous Harm	25	14.8
Drug Abuse	49	29.0
Burglary	21	12.4
Assault	17	10.1
Robbery	11	6.5
Total	169	100

Source: Police stations and NDLEA,2018)

From the analysis of the data collected from the police and NDLEA, ten (10) crimes were identified in the study area. These crimes include bribery, forgery, murder, rape, theft, grievous harm, drug abuse, assault and robbery. The result in Table 2 shows that of the 169 crimes recorded, drug abuse is the most committed crime in the area which amount to 29.0% of the total crime. This is followed by theft with 20.1%. Grievous harm constitutes about 14.8% while murder, forgery and bribery were found to be the least crimes committed with 2.4%, 1.2% and 0.6% respectively.

3.2. Spatio-temporal Variation of Crime Occurrence in Jalingo

The spatial distribution of the various types of crime is further presented in figure 2 below. The findings agreed with that of [Table 2] that also identifies drug abuse to be the highest crime in Jalingo metropolis accounting for 84.89% of the total crimes committed.

The temporal variation of the distribution of crime locations was determined for 2021 (June, July, August, September, October, November, December) and 2022 (January, February, March, April, May) based on the data obtained from police stations in Jalingo and NDLEA Taraba state command. Table 3 below shows the monthly variation of the distribution of crime in the study areas

Figure 2 Spatial distribution and types of Crime in Jalingo Metropolis (Source: Field Survey,2022)

Table 3 Temporal Variation of Crime in Jalingo LGA

Month	No. of Crime	Percentage (%)
June	7	4.1
July	9	5.3
August	11	6.5
September	12	7.1
October	14	8.3
November	13	7.7
December	14	8.3
January	16	9.5
February	17	10.1
March	19	11.2
April	17	10.1
May	20	11.8
Total	169	100

Source:(Field survey, 2018)

The result shows that the highest number of crimes was recorded in the month of May 2018 with 11.8% of the total number of crimes committed at different locations within the study period. The least number of crimes was also recorded in the month of June 2017 with 4.1% of the total crimes committed in the study area within this period. The rise and increase of crime in Jalingo metropolis from June 2017 to May 2018 could be attributed to the influx of people

from other   parts of the country especially Borno and Adamawa as a result of the Boko Haram insurgency. This could also be attributed to increase in poverty and youth unemployment rate in the country at large.

3.3. Crime Densities and Hotspots in Jalingo

The result in Table 4 based on wards revealed that Barade ward has the highest crime record with 15.4% of the total crime committed during the study period. This is followed by Mayo-Gwoi and Kona wards with 13.6% and 11.2% of the total crime committed respectively. Sintali and Abbare Yelwa recorded the least number of crimes committed with 6.6% and 4.7% of all the crime committed respectively. Similar study by [3] revealed the existence of fourteen (14) crime types from the police crime records. The result reveals that Burglary had the highest incidence rate of 24.72%, while Treason and Rioting were the least with 0.57% and 0.36% respectively. The Krigging spatial pattern result revealed the intensity of crime is on the increase along the major transport route moving towards the city centre in some specific areas such as Kona, Barade, Road block, Mile 6, Sembe and Wuro Sembe .
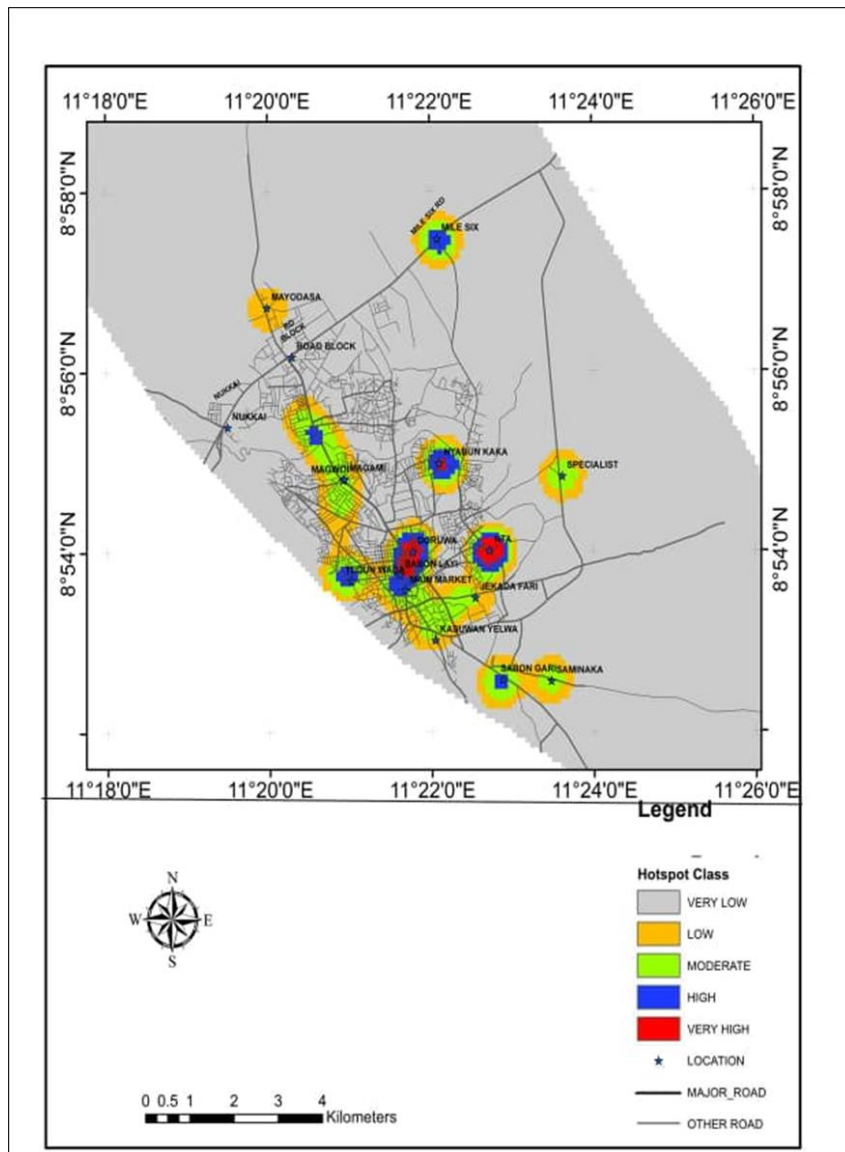

Figure 3 Crime Hotspots in Jalingo LGA (Source: Field Survey, 2018)

Table 4 Crime Densities Based on wards in the study area

Type of Crime												
Ward	**Assault**	**Bribery**	**Burglary**	**Drugs**	**Forgery**	**Grievous Harm**	**Murder**	**Rape**	**Robbery**	**Theft**	**Total**	**%**
Abbare Yelwa	0	0	0	2	0	0	0	0	2	4	8	4.7
Barade	4	0	2	4	0	4	2	1	4	5	26	15.4
Majidadi	1	0	1	3	0	3	0	0	0	4	12	7.1
Mayo Goi	1	1	5	4	1	2	0	1	0	8	23	13.6
Kachalla Sembe	1	0	3	5	0	2	0	1	0	5	17	10.1
Kona	2	0	4	2	0	3	0	0	1	7	19	11.2
Sarkin Dawaki	3	0	1	4	0	4	1	0	0	4	17	10.1
Sintali	1	0	1	4	1	0	0	0	1	3	11	6.5
TurakiA	2	0	2	3	0	4	0	0	2	5	18	10.7
Turaki B	2	0	2	3	0	3	1	2	1	4	18	10.7
Total	17	1	21	34	2	25	4	5	11	49	169	100
%	10.1	0.6	12.4	20.1	1.2	14.8	2.4	2.9	6.5	29.0	100	

Source:(Field Survey, 2018)

From the result in figure 3, the areas with red spot have the highest crime rate which is in Barade, Mayo-Gwoi and Turaki wards. This is associated with nature of the area as low-income earners; ground for sale of drugs, ground for burglary and theft which are common crimes in the study area. The grey spots show the areas with very low crime rate.
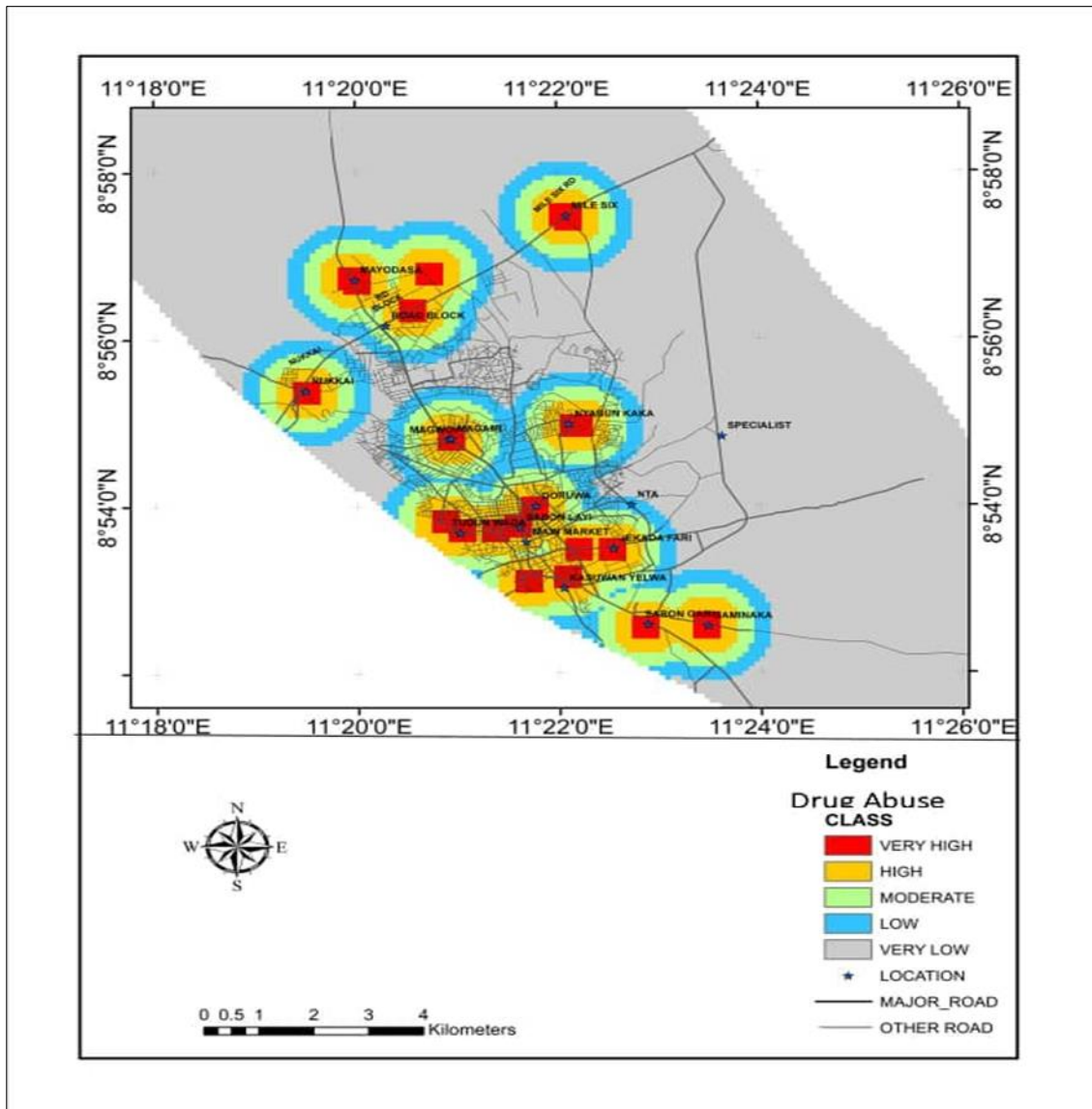
Figure 4 Hotspot of Drug Abuse (Source: Field Survey, 2018)

From the result in Figure 4 above, it shows that the areas with red spot have very high rate of drug abuse which is very common in most of the areas as it is not clumped or concentrated to a particular area. This could be the reason for the high rate of drug abuse and theft in the study area as is associated with various forms of crime.

study provides an overview of spatial analysis of crime report datasets. It presents examples of spatial crime patterns and describes the features of current analytical tools that are available for use by the law enforcement community. We illustrate the utility of these spatial crime patterns and analytical tools using in the study area. Due to the analysis carried above it shows that the crime level occurs as a result of laxity of various police outpost.

4. Discussion

The Kernel Density Estimation method was used in mapping the crime hotspots, and the affected areas around the major hotspots. The study identified 10 crimes ranging from; assault, bribery, burglary, drugs, forgery, grievous harm, murder, rape, robbery and theft. The finding of this study shows that of the total frequency 169 crimes recorded, drug abuse was the highest crime committed within Jalingo with 29.0% of the total crime recorded.

The study also revealed that the highest number of crimes committed during the study period was in the month of May, 2018 with 11.8% of all the crimes recorded. There also seems to be an increase in the number of crimes from June, 2017 to May, 2018.

Similar study conducted in Taraba by [21]. also revealed that Sabon-Layi and Market area in Barade ward are the major crime hotspots in Jalingo metropolis as Barade ward recorded 15.4% of all the crimes committed during the study period. These are youth concentrated areas with social centres such as the local film viewing centre in Sabon-Layi and market area. These areas recorded the highest number of drug abuse.

5. Conclusion

The study revealed that GIS is a much more compatible means of crime analysis because of its geographic referencing capabilities. The three basic categories of GIS functions (database management, spatial analysis and visualization) in a single computer base-based system created an environment that is better than the present method of analysis used by the law enforcement agencies. Not only can GIS application help the law enforcement agencies in their effort to combat crime, but it is also potentially beneficial to the public to be aware of crime prone areas so as to be careful of such areas. Through GIS, communities can be provided with better information on criminal activities in their areas, and work with law enforcement agencies to determine the best measures to combat the crime rate in their neighborhoods. Other public and private organizations could benefit from GIS in determining the allocation of resources and initiating new programs.

Recommendations

From the study, the following were recommended as measures to reduce the rate of crime in Jalingo metropolis:

- There is the need for Nigerian Police Force and other relevant law enforcement agencies to focus and devote more policing activities to combat crimes such as theft, drugs and burglary which are the most dominant in Jalingo metropolis.
- The crime hotspots areas require close monitoring and evaluation. Security agencies should devote more time and personnel to the crime hotspot areas towards reducing criminal activities in Jalingo.
- The association of high crime rate with low environmental quality is an indication for serious need for slum neighborhoods improvement. Government should pursue an aggressive programmed of urban development and renewal in areas with high crime density as well as low-income earners to reduce the level of deprivation and social delinquency that promote criminal activities in the area.
- Poverty and lack of means of economic livelihoods are key elements of the high density and low-income neighborhoods that promote criminal activities among the young adults. The economic livelihood and poverty reduction programmed of the state government should give priority to crime hotspot neighborhoods so as to engage the young adults in productive activities.

Compliance with ethical standards

This research would not have been possible without the collective efforts and support of these individuals and institutions. We are grateful for their contributions to the advancement of knowledge in the field of crime mapping and management.

Disclosure of conflict of interest

The authors of the paper " Crime mapping and hot spot analysis using geospatial data in Jalingo metropolis of Taraba State, Nigeria" declare that they have no financial or non-financial conflicts of interest that could have influenced the research, analysis, or interpretation of the findings presented in this paper.

Author Contributions

- Boyi Mairiga contributed to the conceptualization of the study, data collection, methodology of interpretation of results and manuscript writing.
- Murna Joy Dawarga contributed to data analysis.
- Taimanda Keren Ezekiel provided expertise in geospatial analysis and contributed to the interpretation of geospatial data on crime mapping.
- Kebati Danjuma Madaki contributed to the analysis of crime data and laboratory work.
- Frichi Bilham assisted in the fieldwork and data collection.
- Mustapher Yusuf contributed to the spatial analysis and mapping of crime hot spot.

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Ethical Considerations

The research adhered to ethical guidelines and regulations relevant to scientific research, including obtaining necessary permissions from security agency for the crime mapping, hot spot analysis and crime management.

Contact Information

For any inquiries related to this paper or the research presented herein, please contact the corresponding author Mr. Boyi Mairiga, at Musamairigachess@gmail.com.

This disclosure of conflict-of-interest statement is provided to ensure transparency and integrity of the research presented in the paper. The authors affirm that there are no undisclosed conflicts of interest that could potentially affect the objectivity or credibility of the study's findings.

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