



AN INTELLIGENT CRIME MANAGEMENT SYSTEM FOR LAFIA METROPOLIS

*¹Jeffrey O. Agushaka, ²Chijioke E. Chinwokwu, ³Daniel I. Yakmut

¹Department of Computer Science, Federal University of Lafia-950101, Nigeria

²Department of Sociology, Federal University of Lafia-950101, Nigeria.

³ICT Directorate, Federal University of Lafia-950101, Nigeria

*Corresponding authors' email: jo.agushaka@science.fulafia.edu.ng

ABSTRACT

Security is one of the major concerns in our societies today, and the issues related to it are steadily increasing in both intensity and complication. Predicting crimes could help, but that is a huge challenge as it requires a study of the behavioral pattern or trend of criminal activities. This research aims to develop an Intelligent Crime Management System for the Nigeria Police Force using a case study of Lafia metropolis in Nasarawa State. The java development kit (JDK), android software development kit (SDK), sinch sdk for app-to-app call, android studio, firebase and a virtual emulator, were used to accomplish the research objectives. This system is comprised of an android based mobile application for crime reporting and awareness, a geospatial database that houses both legacy and new crime data, and a web-based intelligent application. The system can utilize the crime data stored in the database to identify hotspots and clusters in the Lafia metropolis. It can also predict the crime likely to occur at a location and analyze risk assessment and situation assessment of crime in Lafia metropolis.

Keywords: Intelligent Crime Management System, web-based, Lafia metropolis

INTRODUCTION

Lafia metropolis, as shown in Figure 1, is the capital and central administrative city of Lafia Local Government Area, which is the capital of Nasarawa State. Its geolocation is 8,50766° N, 8,52044° E. Lafia has witnessed tremendous growth in size, population, and civilization since its status changed to the State's administrative capital. No population census has been conducted in Nigeria since 2006, and the population of the city as of 2006 was 330,712 (NPC, 2006).

However, with an estimated annual growth of 2%, the population can be estimated to be 445,697 by the end of 2019 (NPC, 2006). As the State's commercial center and the fastest-growing metropolis, it hosts three major tertiary institutions: Federal University of Lafia, Nasarawa State Polytechnic, and Nasarawa College of Agriculture. All government departments and agencies are also located in the metropolis, not to mention the expansion in commercial activities.

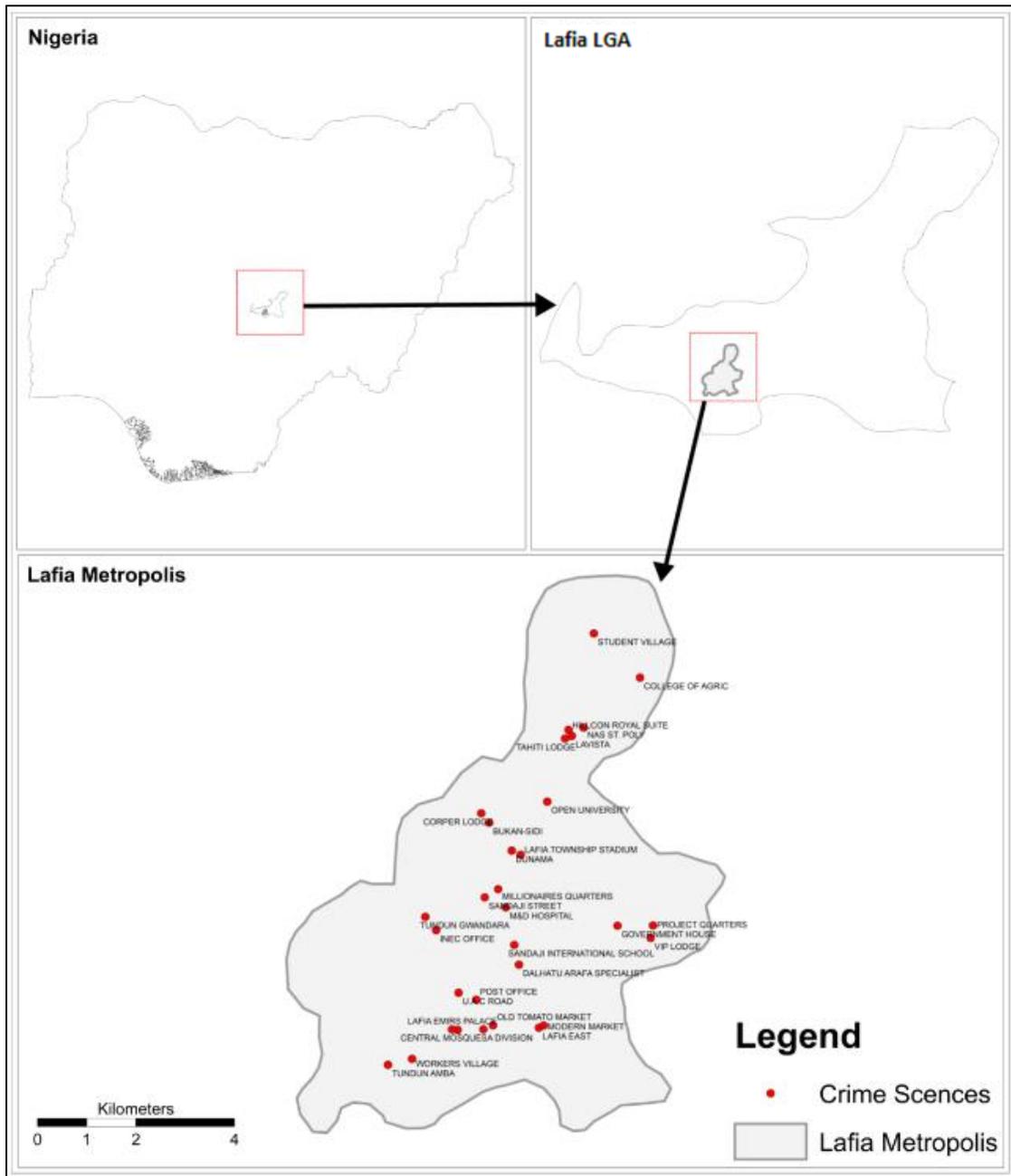


Figure 1. Location Map of Lafia Metropolis

These physical expansions and commercial growth usually attract a diverse population, putting a great security burden on Nigerian Police. Population growth comes with a corresponding rise in the crime rate, as a larger population can provide an atmosphere for crime to thrive. The increasing social sophistication, modernization, growing inequality, and the continuous rise in youth unemployment have greatly heightened urban crimes in recent times (Chinwokwu, 2017). In particular, youth restiveness, ethnic conflicts, and kidnapping are on the rise in Lafia. Combating these malaises requires deploying new methods and tools that will aid Police in Lafia. The map in Figure 1 shows the location of the study area and the general distribution of the reported crime incidents in Lafia Metropolis. The locations of crime incidents are shown in red dots on the map.

Many challenges are facing policing in general; these challenges can be in the method used in detecting and

preventing crime, the sociological structure of the society, other economic and political factors. Therefore, effective application of technology for crime prevention, crime detection, crime analysis, crime mapping, trend analysis, and policing management is critical to police operations, especially in preventive and pro-active policing strategies (Chinwokwu, 2017).

Crime-fighting and crime prevention go beyond police personnel's physical presence to include modern technological innovations and strategies that the Nigerian Police generally lack or do not utilize (Chinwokwu, 2017). The use of Geospatial technologies, particularly GIS, has greatly influenced the way crimes are mapped and analyzed globally. Some of these technological innovations and strategies for crime prevention and control rely on data availability about crimes. Currently, the Nigerian Police in Lafia metropolis still rely on traditional policing methods

where crime data are collected using little or no technology. The crime incidents are manually recorded on paper or crime logbooks; this data collection method makes it difficult to use the latest advances in Geo-spatial technologies and data mining tools. Also, informed decisions that could help direct crime prevention resources and rapid response are not easily made. Thus, this study is imperative and acts as a boost in crime-fighting through technological innovation and applications in the Lafia metropolis.

The major contributions of this research can be outlined as follows:

- A crime reporting app that can be used by the populace to report crime incidents was developed. This app captures the location of the crime incident and other details which are stored in a Geospatial crime database for the Lafia metropolis.
- The study also developed a Geospatial crime database for Lafia metropolis which is used to create the crime maps.
- Finally, an intelligent crime management system that analyses the trends of crime in the database and, based on these trends, predicts future crime occurrences in a specific location was developed. This can help the police plan preventive and other proactive schemes.

The rest of the paper is structured as follows: Section 2 presents the study literature review, the materials and methods are described in Section 3, while Section 4 presents the results and discussion, and finally, Section 5 presents concluding remarks and recommendations for future work.

Related Literature

Technological advances have made available resources like GIS, Remote Sensing (RS), satellite communication (Satcom), and Global Positioning System (GPS), which have changed the landscape of crime mapping, analysis, and monitoring into the 21st century. They have also influenced operational and tactical components of strategic policing planning, which have effectively led to apprehension and accurately track criminals and identify their modus operandi. Combating crime using these methodologies has recorded enormous successes, as shown in Shillingford and Groussman (2010), Gorr and Kurland (2012) and Markovic and Stone (2002).

Early attempts at using computerized crime maps for crime analysis can be found in the works of Pauly, et al. (1967) and Carnaghi and McEwen (1970). Their success set the path for automated visual representations of crime and traffic accidents. Since then, many researchers have contributed to the growth of this research area (Maltz et al., 1990; Block, 1993; McEwen and Taxman, 1994; Simpson and Hipp, 2019). The use of GIS for crime mapping and analysis comes with challenges, especially for developing countries like Nigeria. Ibrahim and Kuta (2015) highlighted that these challenges include inaccurate or corrupt data, non-availability of computers, limited knowledge of GIS, unavailability of power, and internet access. However, they posited that these challenges are surmountable if the Government's commitment to fund the police force is carried out.

Though GIS greatly helps crime management, Rilwani and Eguabor (2000) reported that the Nigerian Police are handicapped in modern automated information systems. This fundamentally adds to the problems thus militating against the effective prevention, detection, and control of crime in Nigeria. They used GIS for crime prevention, detection, and control using Edo State Police Command in Nigeria as the study area.

The spatiotemporal distributions of the crimes from the three years in Dala Local Government Area of Kano State, Nigeria, were explored using Geographic Information Systems (GIS) and the spatial database of crime to identify patterns that helped in the determination of hotspots in the study area. Their findings showed that crime hotspots occurred outside the city wall, far from the location of police stations, and recommended the creation of police buffer zones every 2 kms (Ahmed and Salihu, 2013).

Balogun, et al. (2014) did a study that operationalized the application and utilization of geographical information systems in crime management and security situation analysis in Benin-Nigeria. They concluded that effective crime control and management in Nigeria could be achieved provided the security operatives use modern policing standards by adopting and integrating GIS methodology. A similar study using Abuja-Nigeria as a case study was carried out by Adepoju, et al. (2014).

An online reporting system dedicated to crime reporting can really enhance public/police collaboration in crime-fighting. Mwangala, et al. (2015) developed Tip Soft, a tip submission mobile software that allows citizens in Zambia to anonymously submit crime tips to law enforcement. This has improved the rate of crime reporting by its populace using cell phones incredibly. In this era of Big Data, Intelligent Crime Systems are vital because they help decision-makers make data-driven decisions under time burden (Ranjan, 2009). Sergio (2015) posited that big data analytics could support law enforcement agencies, especially Police, to protect their communities by proactively fighting the crimes before they happen. The data from police reports and other sources can be studied, and results from the study can help the Police forestall, forecast, and prevent crimes. Crime is predictable (statistically) because criminals tend to operate repeatedly in their comfort zone (Walter, et al., 2013).

Many authors have established a clear link between modernization and increasing levels of criminality (Adisa, 1994). This is worst in developing countries where unplanned cities spring up rapidly, with poor living conditions of the majority of the population, undermining social relations and increasing tendency for conflict, violence, and crime. Some causes of crimes are identified in the work of Andrea (1997); poverty, and not race, is identified as the leading cause of spatial crime clusters. The Problem-Oriented Policing theory (POP) propounded by Goldstein (1979) and Routine Activity Theory developed by Weisburd (2010) was utilized to direct this study. The problem-oriented policing theory is based on the need for police officers to be more "proactive in identifying underlying problems that could be targeted to alleviate crime and disorder at their root."

On the other hand, the routine activity theory states that for crime to occur, three elements must be present: an available target, a motivated offender, and a lack of capable guardians. It must be stated that for crime to be committed, the target and offender must be at the same place, at the same time, and the three elements must converge in unity. The people who can protect targets are law enforcement officers. The law enforcement officer's target and main objective is to ensure adequate protection of their allocated and assigned areas of responsibility. This they do by frustrating every effort of potential criminals through due diligence, which is exhibited in their alertness at their static duty post and surveillance, monitoring through close circuit television, patrol, supervision of guards, and hardening of targets (Bottoms and Wiles, 1997).

Hotspots policing requires that security officers focus their attention on specific geographical locations to prevent and

incapacitate disorderly and illegal activities of criminals (Weisburd and Eck, 2004). While Braga, et al. (2014) agreed that hotspot policing helps reduce crimes, they posited that the extent is minimal but noteworthy. They found that while policing the hotspot, criminal activities tend to spiral to nearby areas. The relationship between police response and crime incidents was explored by Simpson and Hipp (2019). They found a complex relationship exists between crime calls and police response and posited that police action must be evaluated within the context of the place for which it is applied if a long-term deterrent is desired. Their study discovered which policing strategy between shorter but more

frequent patrols or less frequent but more extended patrols of hotspots led to crime reduction; Williams and Coupe (2017) posited that a less frequent but more prolonged patrol was more effective in reducing the crime rate. Similarly, Hutt, et al. (2018) posited that a police patrol of a hotspot that is less than 10 minutes or more than 20 minutes in a shift is less effective in crime reduction; however, a 10-20 minute police patrol in a shift impacted significantly in crime reduction.

MATERIALS & METHODS

The visual representation of the methodology used for this study is shown in Figure 2.

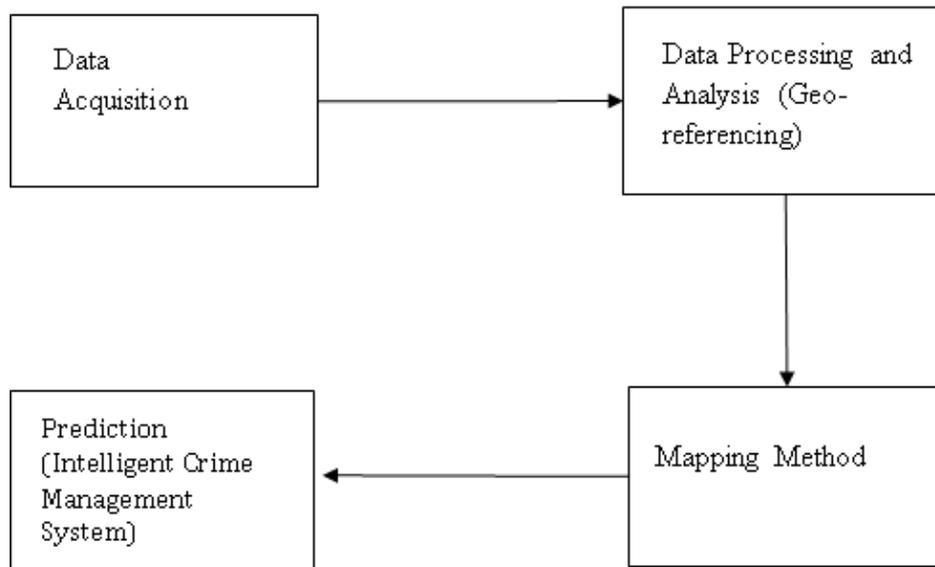


Figure 2. Process Methodology

Data Acquisition

The crime incidence data for the last 10 years at various police stations within the metropolis were collected. Because many crimes occur and are unreported, a total of 300 questionnaires were administered based on random sampling to gather information about prevalent crimes from the public within the metropolis. The number of questionnaires returned was 267; after that, GPS was used to establish each crime's geographical location that was reported on the questionnaires. Shapefiles for the study area are not available, and the government officials said they are working on that. Also, 100 questionnaires were administered to the Police Public Relation Officers (PPRO) for distribution to police officers in charge of different police stations to gather information about responses to crime such as patrolling and other policing strategies. The map of Lafia Metropolis was produced from information supplied by officials of Nasarawa Geographical Information System (NAGIS, 2019).

Data Processing and Analysis (Geo-referencing)

Data acquired was checked for inconsistencies, measurement errors, and outliers following methods described in Puustinen, et al. (2007). Also, the responses from the questionnaire were categorized into two groups: victims of crimes (crimes that respondents say are reported to the Police were cross-checked with data from Police to avoid duplications), and those who have never experienced any kind of crime. These data were then cleaned in Excel before they were transformed into a shapefile using ArcGIS software. Abnormalities such as projection and symbolization errors

were rectified during geo-referencing. Some statistical analyses were carried out in the Microsoft Excel environment.

Mapping Method

The Kernel Density estimation method was used to generate the crime hotspot and cold hotspot maps using ArcGIS 10.0 software package. A bandwidth of 0.10km based on the study area's extent was the set criteria for generating the maps. From the results obtained, an overlay analysis was carried out to establish the relationship between the crime hotspot areas and parks and gardens as well as the Police Divisional Stations in the various districts.

Intelligent Crime Management System

Predictive Crime analysis was implemented using Random Forest (RF). The crime patterns were analyzed using parameters such as crime types, location, time of crime occurrence, and police station, which were used to form clusters. Then the system predicted/found the probability of crime occurrence based on these parameters. This algorithm was implemented in Python using the standard RF library. To avoid overfitting and accomplish a more accurate result, the dataset was divided into two parts: training dataset and testing dataset. The training dataset contains all features along with the corresponding target feature. The testing dataset only contains the features from which a RF machine learning model predicts the target value. Twenty-five percent (25%) of the original dataset was used as a test dataset size.

Crime Reporting

The crime incidents in Lafia metropolis are manually recorded on paper or crime logbooks; this data collection method makes it difficult to use the latest advances in geospatial technologies and data mining tools. The mobile crime reporting and monitoring application were developed for the general public to report crimes and allow the Police to monitor these crimes in real-time. The tools used for this development are; i. Java Development Kit (JDK); ii. Android Software Development Kit (SDK); iii. Sinch SDK for App-to-App call; iv. Development environment: Android studio; v. Database: Firebase; and vi. Device: Virtual emulator.

System Architecture

The Intelligent Crime management system architecture is shown in Figure 3. The general populace interacts with the system via the mobile app; they report crime incidents (text, audio, video, or a combination). These data are then stored in the Geospatial database (Firebase), which can be exported to the ArcGIS. The ArcGIS uses a copy of these data to generate crime maps and hotspots. The populace can then request crime maps, hotspots, updates, and advice. Law enforcement officers or the Police can view reported crime and crime statistics through the mobile app. They can also interact with the crime system directly via the web app, which enables them to do crime analysis and predictions.

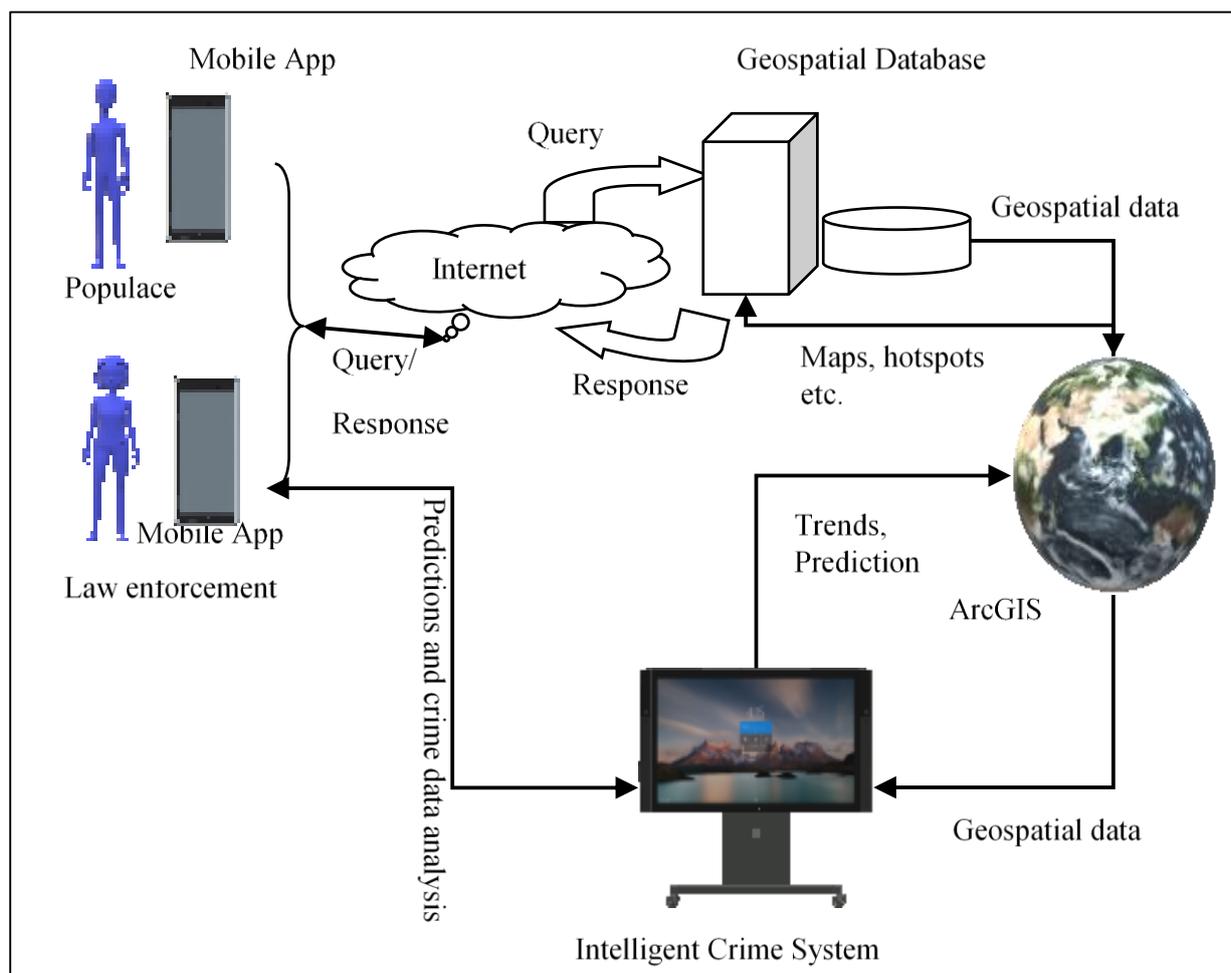


Figure 3. Crime Management System Architecture

RESULTS AND DISCUSSION

Analysis of the administered questionnaires showed that all the respondents are above the 18-25 age range. Maritally, 29% were married, 60% were single, and 11% others (separated/widow-widower). All the respondents have lived within the area for more than one year, which implies they knew their area relatively well.

The crime rate around student populated areas was high. This could be attributed to the fact that, unlike in most tertiary institutions worldwide where students are accommodated in the hostels, Nigeria's case is different particularly in Lafia metropolis. Most of the hostel facilities built in the 1970s when the student population was manageable are still available for the present students despite the upsurge in population and school enrolment. Most of the students cannot

be accommodated in the hostels, and as such are left to seek alternative housing in the city or built up student villages, thus mixing up with the locals. These students live in accommodation outside of school regulations and thus are beehives of cultism and other gang-related crimes (Adepoju, et al., 2014). It is worth mentioning that many of the population declined to take part in the study for fear of being victimized by the Government or being sold out to criminals. The crime dataset for Lafia metropolis was analyzed to show the various types of criminal activities within the metropolis and show the areas where most crimes are committed and where crimes are least committed (hotspots and coldspots). The study also analyzed the relationship between criminal activities and factors such as proximity to recreational areas (bars, parks, gardens, stadiums) and the nearest divisional

police stations. DeMotto & Davies (2006) posited that poor neighborhoods are hideouts for criminals and criminal activities are high around recreational areas (parks and gardens). Also, there is a growing public opinion that crime rates are high around recreational areas as adjacent residential and commercial dwellings may constantly fall victim to such crimes.

Based on data collected, Figure 4 shows the different types of crimes committed in the Lafia metropolis. This shows that there is a high incidence of stealing, followed by

housebreaking. Kidnapping is the least (though kidnapping for ransom is on the rise, the lack of faith in the Police has resulted in less reporting because most of the families deal directly with the kidnapers to secure the release of their loved ones), followed by rape and sexual assault. Figure 5 shows the location within Lafia metropolis where these crimes occur. Areas around Lavista, NasPoly, Modern market, and post office, have high crime rates. These are areas with high nightlife, student population, and trade and commerce.

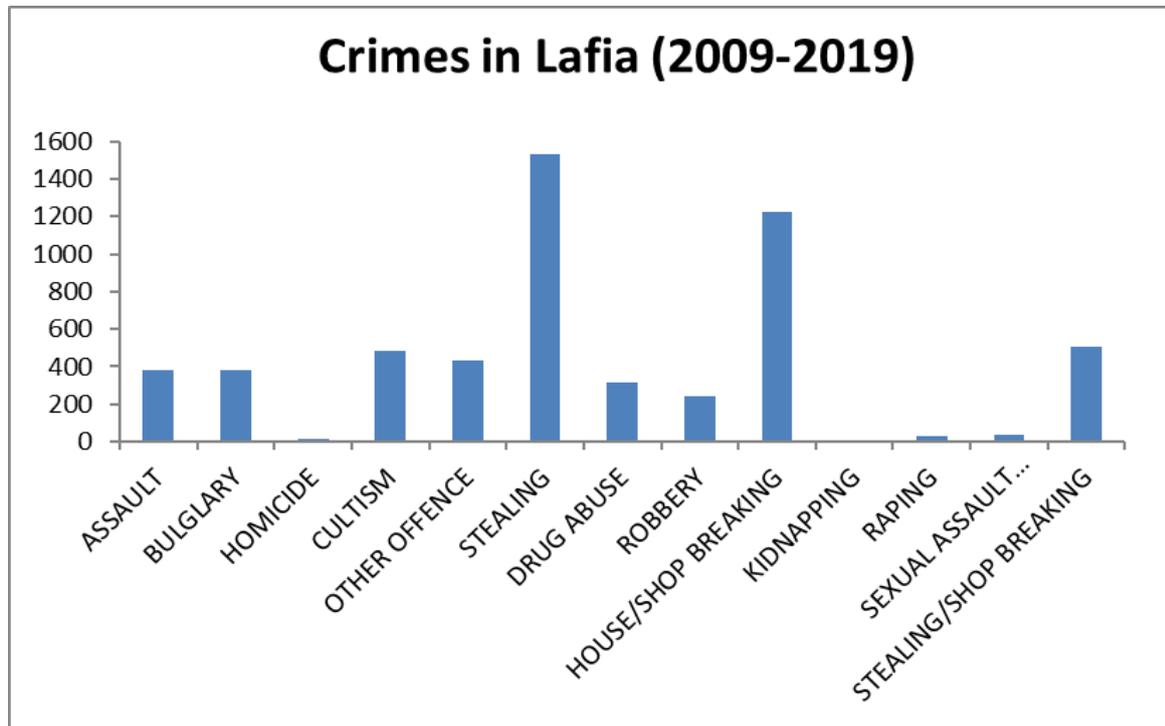


Figure 4. Types of Crimes

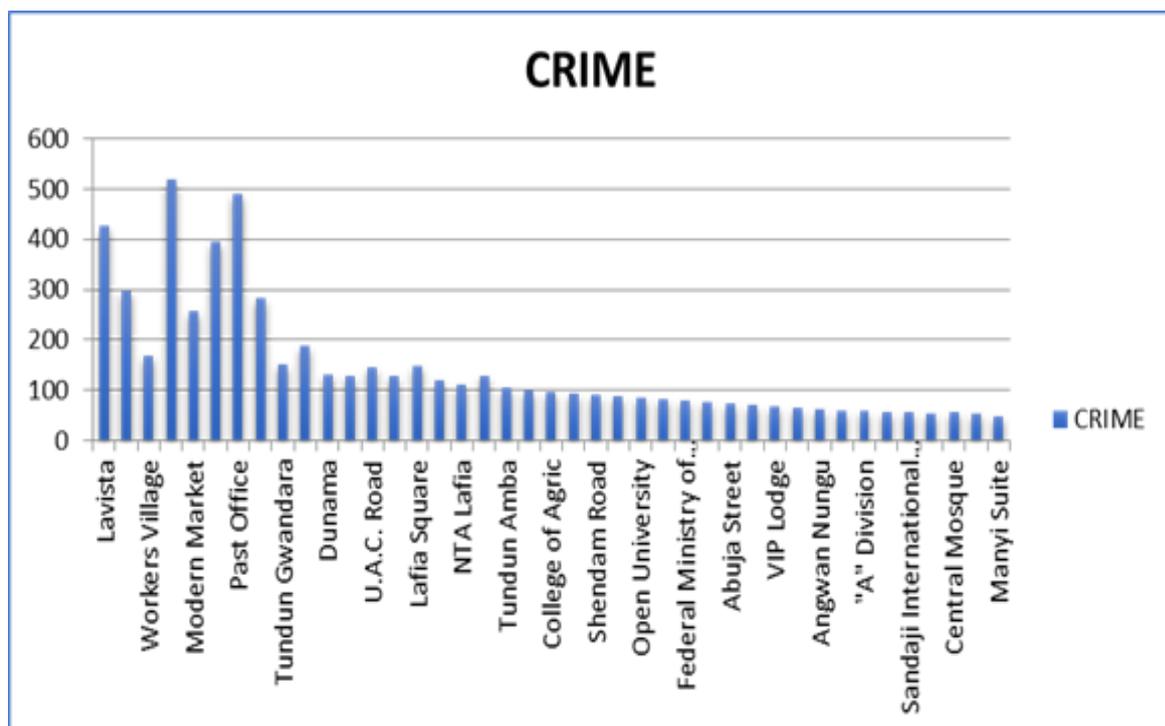


Figure 5. Crime Location

Crime Map

The crime map shows the point location where various types of crimes were committed across Lafia metropolis. Symbologies was used to annotate and represent the diverse crime activity in the study area, and this was generated from the crime data. There are situations where more than one type of crime were committed; for example, a person or household can be robbed, assaulted, and even raped. These are all accounted for in the maps. In Figure 6, the map on the left shows the reported/actual number of crime scenes per location in Lafia, while the one on the right shows the probability of crime occurrence. Dark blue areas indicated hotspot areas, whereas the lighter blue areas show cold spots.

The probability map was established using the Density function found in ArcMap. This helps law enforcement agencies see on the map the concentration of crimes in different locations and helps decide where policing resources can be concentrated. For instance, it makes it easier for the Police to respond promptly to calls and be well prepared knowing the common and frequently committed crime in the location. Data collection from crime scenes and sharing information with their partners, and reassuring the public are greatly enhanced. Analysis and generation of intelligence as well as the deployment of patrols and target responses can be made according to findings in Weisburd and Eck (2004), Braga, et al. (2014), Simpson and Hipp (2019), Williams and Coupe (2017), and Hutt et al. (2018)

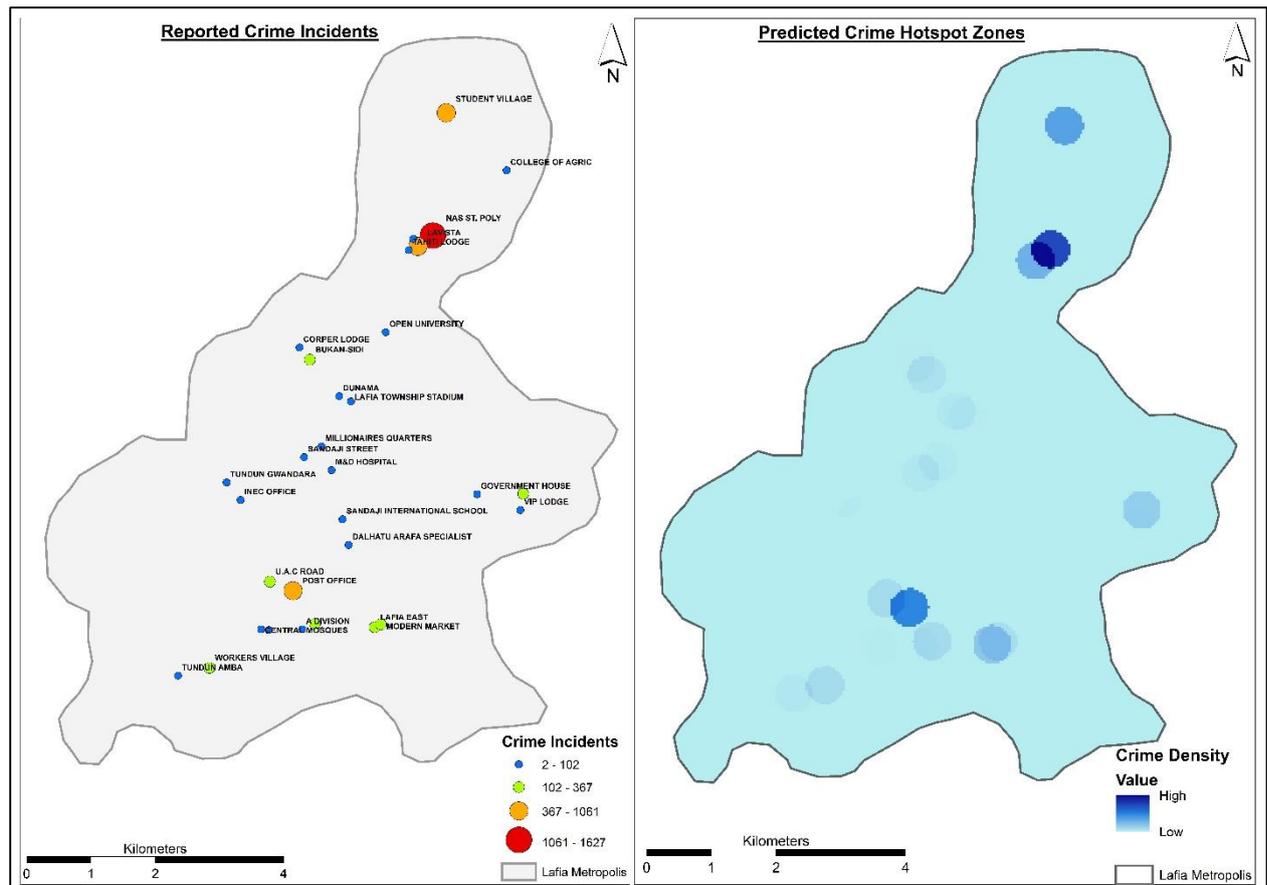


Figure 6. Crime Incidents and Density Map

From the data gathered from the Police, the arrest status map was plotted, as shown in Figure 7. This map shows the status of arrest per area of the crime scene. The green colour indicates the number of arrests that have occurred, while red highlights the non-arrests. This can help the authorities understand the dynamics of crimes in relation to the law enforcement measures put in place to combat crime. For instance, in areas where there are many rapes and murder crime-related incidents, one would expect to see more arrests, but if this could be reversed, that would call for much closer attention.

A minimum of three (3) clusters can be seen from Figure 7. The workers' village cluster is where the state housing estate is situated. The area is in the outskirts of Lafia town, and the nearest police unit (D division) is far away, which makes for slow response time to crime calls. The second cluster is the new market area; the commercial activities around the area make it a beehive for criminal delinquents. The last cluster is the NasPoly cluster, and this area is predominantly a student dominated area. With no hostel accommodation for students, they find accommodation in this area.

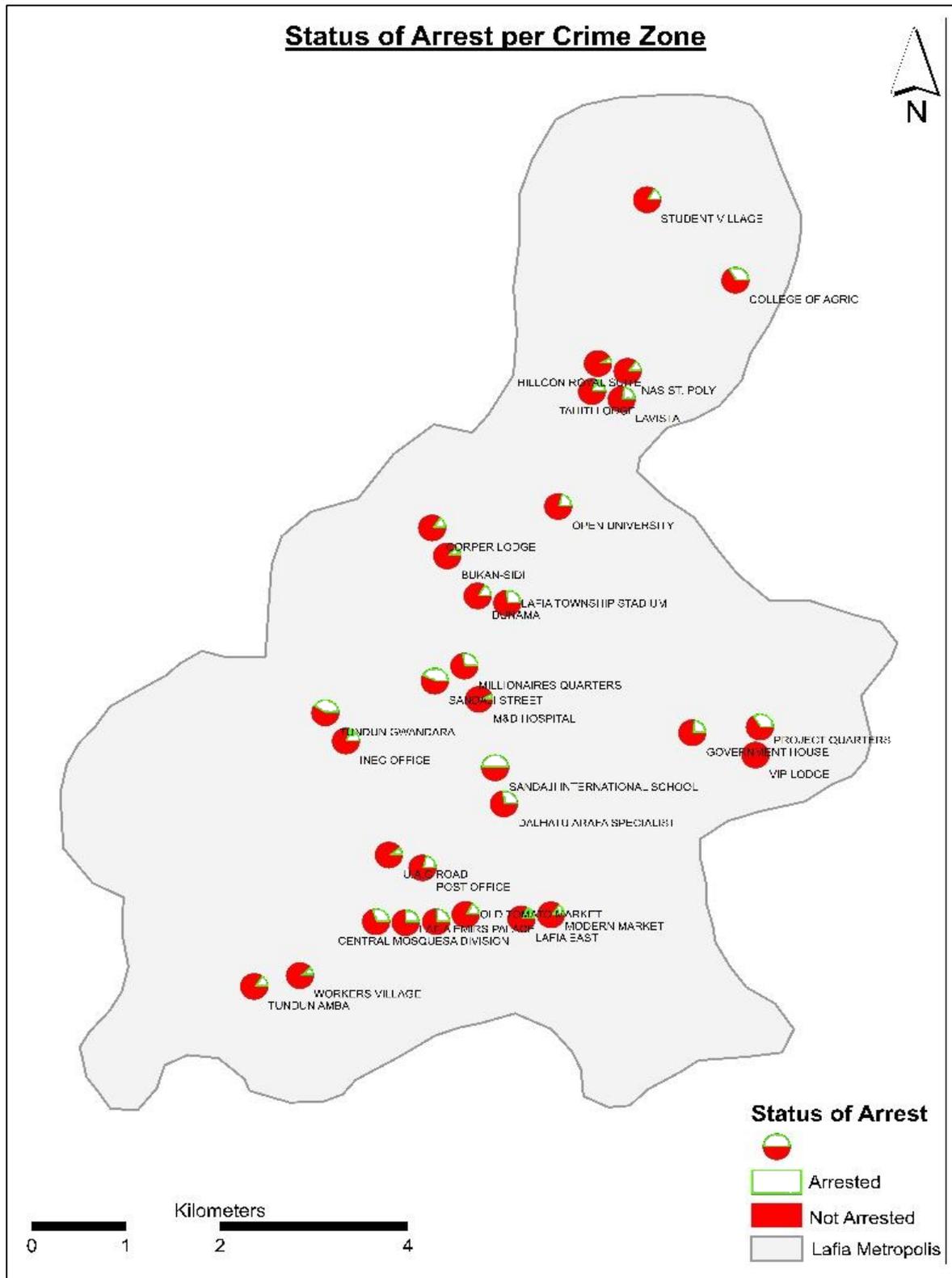


Figure 7. Arrest Status Map

Mobile Crime Reporting App

The login page and home page of the crime reporting app provide the user with the choice of performing several activities. These activities include logging in (Figure 8a), then performing activities such as managing account, reporting crime, making SOS calls, and reporting an emergency crime

in panic mode, as shown in Figure 8b. The user can navigate through the app from this page and manage his/her account more efficiently. In order to enable vetting or checking the validity or genuineness of the crime reporter, the App allows for signing in using already existing emails only, and this can be used to prosecute fake reports of crimes.

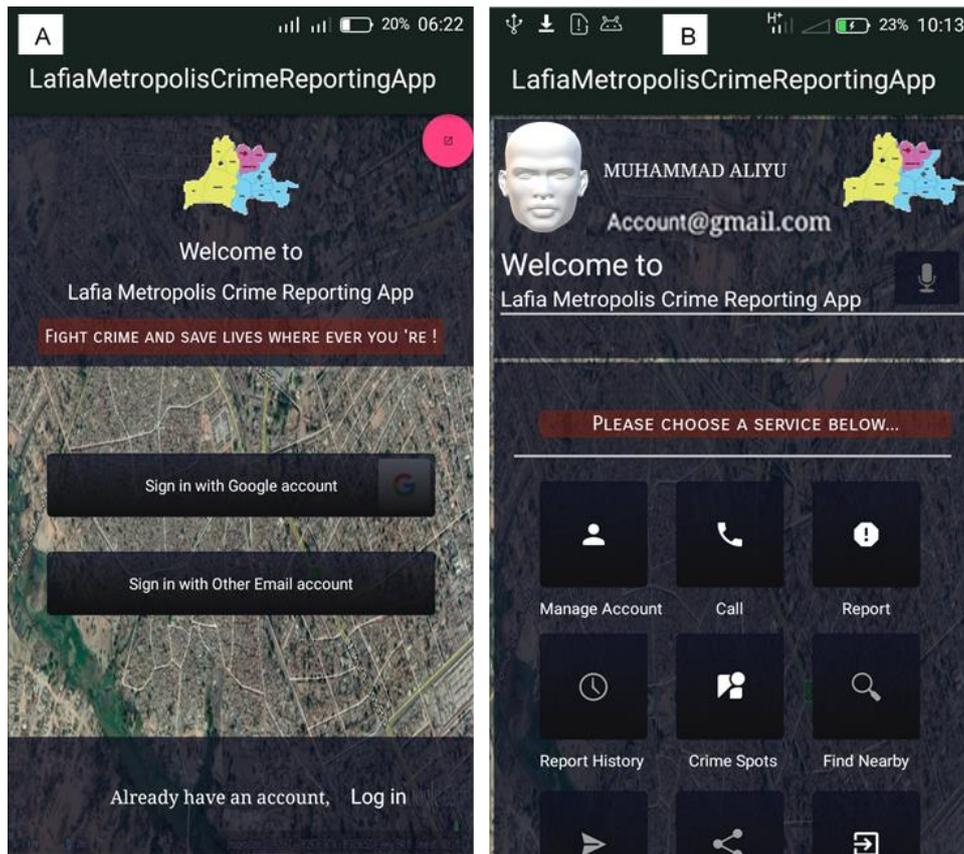


Figure 8. a. Log in Page

b. Home Page

The crime report page as shown in Figure 9 allows the user to fill in crime details of the crime to be reported. This feature will mostly be ideal in non-emergency situations where the reporter's life is not in any danger and he/she can narrate the

crime or give a tip to the Police. The reports sent are location-based; that is, the coordinate of the crime location is sent alongside the report.

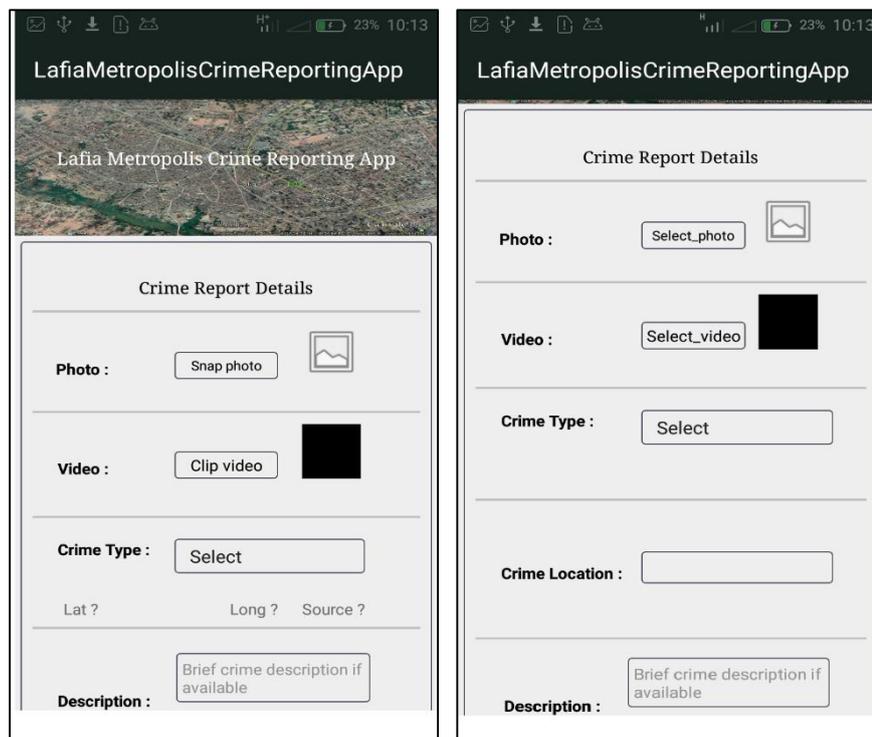


Figure 9. Crime Report Page

Intelligent Crime System

This web-based system serves as an interface for information extraction, prediction, and mapping. Figure 10 is the home page of the web-based system. As the background of this system, the Random Forest (RF) algorithm was used for prediction. Python has a standard library that implements the RF and that is used in this work for prediction. Random Forest is an ensemble algorithm based on decision trees; interested readers are referred to Yu, et al. (2014), Chen, (2019), and Belgiu and Drăguț (2016).

The crime data which was stored as a csv file was converted into a data frame in Python using a pandas object and the classification task implemented using inbuilt Random Forest on Scikit-Learn Library, referred to as the *Sklearn – Random Forest Classifier*. The Sklearn – Random Forest Classifier in Python fits n number of decision tree classifiers on various sub-samples of the dataset, controls the over-fitting of data and improves predictive accuracy. For example, if y is an attribute to be predicted and X the attributes used for prediction, then the classifier syntax used is given as follows:

```
from sklearn.tree import RandomForestClassifier
dt = RandomForestClassifier() #Object of classifier
dt.fit(X, y)
```

The crime dataset was split into two (75% test data and 25% training data). The Scikit-Learn's `model_selection` package that contains a class `test_train_split` method was employed to split the original dataset into training and testing dataset. The training data is used to identify all crime features, including the arrest status, the rate of a particular crime, and the crime location. As illustrated in Figure 10, a high rate of arrest of criminal elements can serve as deterrents to would-be offenders. The RF uses this feature to predict the likelihood of crime occurring. The higher the arrests, the lower the likelihood of crime.

The performance measure of the RF is given in Table 1. It has an accuracy of 80% and mean square error (MSE) of 0.033 after 10-fold cross validation.



Figure 10. Home Page

Table 1. Performance measure of RF

Measure	10-fold cross validation
Accuracy	80%
MSE	0.033

Crime Rate Prediction

This interface can predict the crime rate, and crime type likely to occur in a given time. This is achieved using the Random Forest algorithm. If the arrest status of a crime is low, it assumes the likelihood of repetition of the crime to be so, and it takes the average occurrence of the crime as the predicted value of crime for a given time. It requires the user to select two criteria to predict a possible number of crimes that are

likely to happen over a selected period, the crime category to predict and the period (day, month, year) of prediction. The interface for crime prediction is shown in Figure 11. The advantage of this prediction is that it helps in future policing planning, for example, how many patrols should be mounted, in which area, and what resources should be channelled to that location based on the prediction.

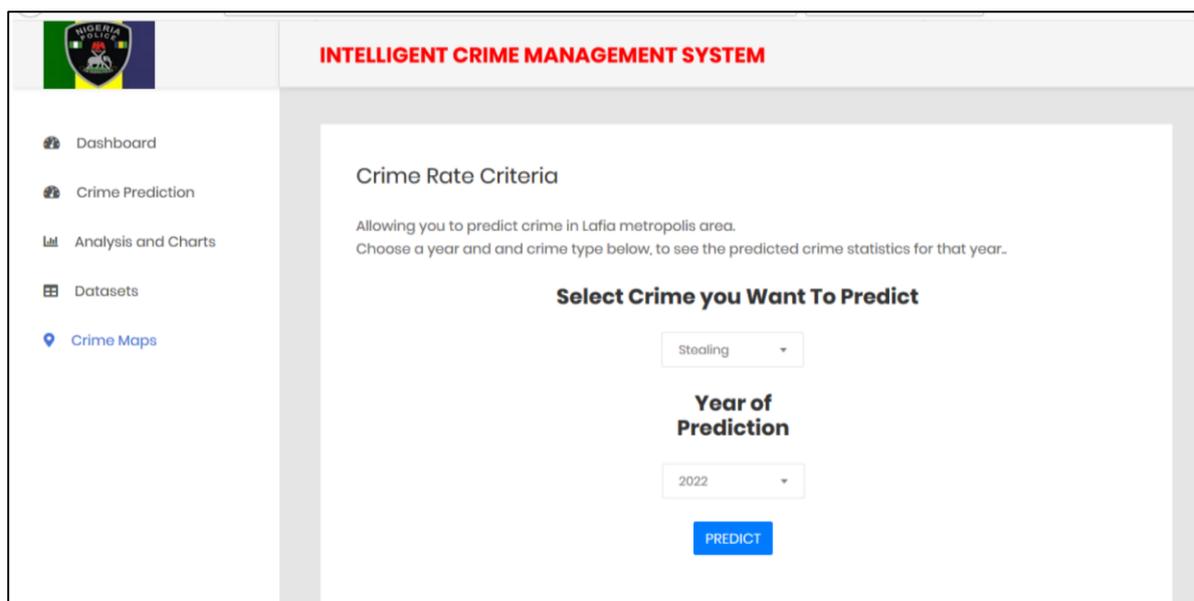


Figure 11. Crime Rate Prediction

Suppose 2022 is selected as a year and Stealing as a crime; the predicted result shows that a total of 52 stealing offenses are likely to be committed in the year 2022. The arrest status of stealing is very low but showed a steady rise over the years, so the algorithm picked the lowest stealing occurrence as a

likelihood to occur. The lowest is picked because the steady rise of the arrest status of stealing meant some police effort to curb the crime. Figure 12 shows the predicted result of the crime rate.



Figure 12. Predicted Crime Rate Result

CONCLUSIONS

Crime occurrence is not random and is spatially distributed in patterns; while some patterns are discovered, others are not. Crime has to be managed appropriately because of its complexity. Our findings show that the spatial pattern of crimes tended to be clustered around areas with a high student population (such as College of Agriculture, Poly); this could result from inadequate manpower and facilities/equipment for policing activities. So the system developed was able to report crime incidences either as an eyewitness or otherwise, store these crime incidences into a geospatial database created for the Police, use the stored data for prediction of crime rate, and provide a different visualization of the stored data in the form of maps. If developed, this system could compensate for

inadequacies of facilities/equipment and thereby help in fighting crime. The following are recommended, among others:

- i. That adequate cities and nation-wide crime mapping and analysis should be carried out. This will help alleviate the security challenges facing the country.
- ii. The Government should do more in the area of personnel recruitment and training, budgetary allocation, and policies that will drive technology for policing. This will enhance effective and efficient policing with improved police performance.
- iii. Areas with student density should have all-around security provision to minimize crime, especially armed

robbery, cult activities, rape, stealing, and other violent crimes.

- iv. The Police can increase their presence and reduce criminal activities by establishing mini police posts in communities (areas) where victims of crime have difficulty in reaching the police stations during an emergency due to long distance.
- v. The Police can partner with the people and communities by providing public security awareness program and community policing.

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