Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2734-259X | ISSN (electronic): 2734-2603
Vol 6, No. 2 October 2022, pp 478 - 492

Analysis of Spatio-Temporal Pattern, Causes and Consequences of Fire Disaster in Kano Metropolis, Nigeria

Yunus S.[1,*] and Falola J. A.[2]
[1,2]Department of Geography, Faculty of Earth and Environmental Sciences, Bayero University Kano, Nigeria
Corresponding Author: *syunus.geog@buk.edu.ng

https://doi.org/10.36263/nijest.2022.02.0348

ABSTRACT

The threat of urban fire disaster has been and is still a serious problem in Kano metropolis resulting to increased risk exposure of human and properties, thereby rendering the metropolis unsafe for business, residence and recreational activities. This study examined the spatio-temporal patterns of fire disaster and it causes and consequences. The study adopted a mixed method integrating quantitative and geospatial data from various sources. Fire incidents data (2009-2019) was obtained from the records of the existing fire stations and subjected to Global Positioning System (GPS) surveying for spatial mapping. Three fire incident clusters were identified and selected within which questionnaire survey was conducted. Coefficient of Variance and simple percentages were used for the qualitative data analysis. The result revealed the influence of space-time relationships in fire disaster recurrence throughout the period of study. Annual incident trend indicated general increase in occurrence of fire disaster. Seasonally, the trend revealed the highest incidents during the cool and dry season (32%). Diurnally, there were more fire incidents in the morning (26%) and evening hours (24.7%) than in the early night hours (8.8%) due to low temperatures especially during the cool and dry season. Electric related problems and negligence constituted the dominant causes of fire disaster which is being responsible for about 36% and 73% of the total incidents recorded respectively. Residential and commercial landuses experienced the highest number of fire disaster with about 72% and 14% respectively. It is concluded that recurrence of fire disaster in Kano metropolis is influenced by space-time relationship and landuse. Massive enlightenment campaign on fire disaster prevention and preparedness measures should be embarked on especially within the high population density residential areas, stressing on negligence and electric related faults as the two major causes of fire outbreaks within the metropolis.

Keywords: Incident Density, Space-time Relationship, Landuse, Fire hub, Fire Season

1.0. Introduction

The twenty-first century has been referred to as the first 'urban' century because majority of the world's population lives in what has been classified as 'urban areas' (UN-Habitat, 2009; UNDESA, 2014; OECD, 2015). In 2014, 54% of the world population (around 3.8 billion people) lived in urban areas which occupies 0.5% of the world's total land area, but accounted for about 70% of economic activities, 60% of energy consumption, 70% of global waste and 70% of greenhouse gas emissions (UNDESA, 2014). By 2050, about 66% of world population was projected to live in urban areas, with the highest rates of urban growth expected in low and middle-income countries including India, followed by China and Nigeria, accounting for 37% of projected growth (UNDESA, 2014). The rapid urban expansion alongside large informal settlements are continuously posing significant challenges for the governance of urban areas and resulting into increased urban pressure, conflict potential, risk to various disasters and fire outbreaks (Avis *et al.*, 2016). Urbanization has been identified as an opportunity and a major global risk which has resulted into convergence of many types of risk and disasters (specifically fire outbreaks) in different cities of the world (UNDESA, 2014; WEF, 2014; Menya and K'Akumu, 2016).

Frequent fire disasters in urban residents and markets of different cities in Nigeria have become a major concern to urban planners, researchers, disaster managers and other stakeholders (NEMA, 2006; Oladokun, 2010). Kano Metropolis is not an exception because there have been recurrent fire disasters on almost all landuse types at varying intensities both spatially and temporally. The recurrent fire incidents have led to destruction of lives and properties worth billions of Naira with continuous increased risk to fire disaster. Several studies have been conducted in different parts of the world specifically focusing on the spatial and temporal distribution of urban fire disaster, causes and consequences, location of fire service stations, fire disaster response, service coverage analysis, location allocation analysis, risk estimation and analysis using various data types and methods including geospatial, statistical and mixed types (Habibi *et al*., 2008; Asgary *et al.*, 2009; Mahmud and Indriasari, 2009; Nisanci, 2010; Hacioğlu, 2010; Corcoran and Higginson 2011; Ceyhan *et al*., 2012; Jennings, 2013; Xin and Huang, 2013; Wuschke *et al.*, 2013; Yagoub and Jalil, 2015). In Nigeria, several related studies on similar subject matter have also been conducted (Oladokun and Ishola, 2010; Oladokun *et al.,* 2012; Ogundele *et al.*, 2013; Oladokun and Emanuel, 2014; Adekunle *et al.*, 2016; Adamu and Yunus, 2016; Ayuba *et al*., 2016; Dogondaji *et al.*, 2017; Yunus, 2019a; Yunus, 2019b among others). However, in Kano Metropolis, the few studies conducted focused on market fires (Umar, 2013; Maigari, 2014; Yunus, 2021), spatial distribution of fire incidents (Salisu, 2007), distribution of fire stations, causes and consequences of fire outbreaks (Isa *et al*., 2016). The studies have not adequately addressed the spatio-temporal patterns of the recurrent fire disaster with respect to various landuses, causes, consequences and their influencing factors. This therefore remains the focus of this study.

2.0. Methodology

2.1. Study area

Kano metropolis is located between longitudes 8^0 25' E to 8^0 40' E and latitude 11^0 50' N and 12^0 10' N. The metropolis comprises of eight (8) local government areas (Dala, Fagge, Gwale, Kano Municipal, Nassarawa, Tarauni and parts of Kumbotso and Ungoggo) (Maigari, 2016). The metropolis covers a total area of about 499 km^2, with an urban area of about 137km^2. The extent and distribution of the metropolitan local governments is presented in Figure 1.

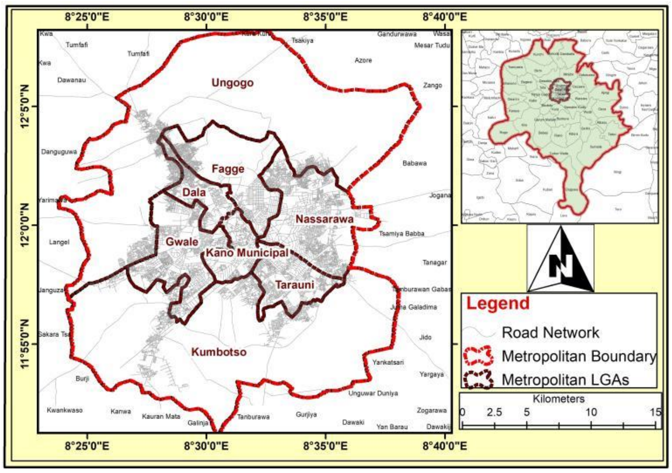

Figure 1: Kano metropolis

Kano metropolis is one of the fastest growing urban centres in the West African sub-continent both economically and population wise. It is the most populous area in northern Nigeria, and next to Lagos and Ibadan (Barau, 2005). Kano Metropolis with the projected population of about 4, 331, 790 (NPC, 2013) by 2018 has in few decades undergone drastic transformation and growth. The accompanying increase in intensities of human activities is making proper management difficult resulting in degraded environment (Barau *et al.*, 2015), and increased risk of various disasters. The growth of the metropolis is attributed to many factors. Apart from being the State capital, there has been increase in population through natural birth, immigration, sitting of educational institutions and location of industries/ large markets (Ayila *et al*., 2014). There is considerable variation in residential density across the metropolis. It has a population density of nearly 7, 000 people per sq km. The urbanized area is mainly concentrated in the six core LGAs (Dala, Municipal, Nassarawa, Gwale, Fagge, and Trauni) with a density of approximately 19, 000 inhabitants per sq km in about 145 sq km. This area due to population concentration, intensities of socioeconomic activities, demand and utilization of various energy sources during different seasons is found to be the most affected by fire outbreaks. The fire risk level is higher within the core area compared to the outer LGAs, (Kumbotso and Ungoggo) which are much larger in extent and encompass rural areas and settlements but less dense.

Kano Metropolis is exposed to a wide range of natural and human induced disasters. While some of these disasters are rapid, others are slow-onset, all resulting in loss of lives, property and degradation of environment. These disasters occur in form of flooding, epidemics, dam failure, building collapse, accidents (road and air crashes), bomb explosion, communal clash, fire disaster (residential, commercial and industrial landuses), air crashes, amongst others. The threat of urban fire is a serious problem in the metropolis with fires being responsible for deaths, injuries and destruction of properties worth billions of Naira. Frequent fire disasters in crowded urban residences and market structures, have become a major concern to urban planners, researchers and other stakeholders. This is the reason for the current study.

2.2. Materials and methods

This section presents the data types and sources, instruments and methods of data collection, sampling techniques and methods of data analysis.

2.2.1. Data types and collection techniques

Quantitative data of the available and accessible fire disaster incident record (2009-2019) comprising of incident's attributes including date and time of occurrence, landuses affected, estimated damages (counts of structures/materials and monetary value), cause or trigger, turn-out and arrival time, duration of response exercise, and number of life lost among others were obtained from the daily records of each of the existing fire stations within the metropolis. The choice of incidents record of this period was because about 75% of the existing fire stations were available (except Danladi Nasidi station) and the records from 2009-2019 were more readily available, accessible, consistent, legible (to some extent) and adequate. Additionally, absolute locational attributes (longitude and latitude) of the incidents were captured through GPS surveying for spatial analyses. Furthermore, quantitative data was equally collected from some of the affected households and neighborhood through questionnaire survey which provided data about the causes of fire outbreaks from the people's perspective. Landuses and land cover data (Raster format) was obtained from World View satellite image of 2018 with 30 cm spatial resolution. The data collection techniques employed by this study included fire incident record consultation, GPS surveying, Geo-spatial data capture (in vector and Raster format) and questionnaire survey.

2.2.2. Population and sampling methods

All the existing state fire stations within the metropolis were purposively considered, and only incidents from January, 2009 to September, 2019 were purposively considered for the study. This is because about 75% of the incidence record of the stated period was existing, available, accessible, consistent, legible (to some extent) and adequate. For the questionnaire survey, cluster sampling method was used to select the three (3) major fire incident clusters identified within the study area (Figure 2).

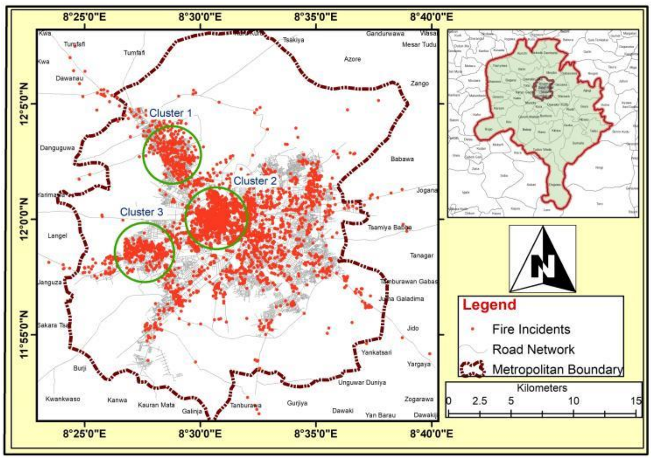

Figure 2: Fire incidence clusters in Kano metropolis (2009-2019)

The purpose was to obtain responses from the affected residents and neighborhood about their knowledge and perspectives of the causes of fire outbreaks. The three selected clusters include Kurna (366 incidents), the City center cluster (1200 incidents) which is tagged as 'fire hub' and Rijiyar Zaki (351 incidents).

2.2.3. Methods of data analysis (spatial and temporal analysis)

Incident Density analysis using the spatial analyst tool in Arcmap 10.8 was conducted to identify fire incident densities with respect to geographic space and in relation to surrounding landuses. It calculates the count of an incident per unit area, in this case, the density/frequency per square kilometer. From this analysis, most vulnerable landuses can easily be identified because of the rate of fire disaster recurrence on the landuse within a defined distance. Places with highest density of incidence within the shortest distance are referred to as Hotspots or high-density zones. On the other hand, large expense of geographic space (landuses) with few recurrence rates is referred to as Coldspots or low-density areas.

In terms of the temporal analysis, incident trend analysis was conducted to identify the pattern and influencing factors of fire recurrence within the study area. Temporal analysis was conducted on the basis of annual incident trend, seasonal and diurnal trend. This is to have a synoptic view of the pattern of the incidents at different time of the day, seasons and at annual level. The results from trend analysis were presented in graphs and charts. Factors influencing the patterns with respect to time were identified and discussed. Statistical analysis such as analysis of coefficient of variance and frequency was used to determine the causes and consequences of fire disaster.

3.0. Results and Discussion

3.1. Spatio-temporal pattern of fire incidents

Space and time relationship (spatio-temporal relationship) in the analysis of fire disaster recurrence is very fundamental for understanding the influence of time on the distribution of fire disaster and that of space on the times of fire recurrence within an area. From the analysis conducted, it was found that the spatio-temporal relationship of fire disaster recurrence within Kano metropolis remains inseparable because there has been consistent pattern throughout the study period. The result (Figures 3 and 4) revealed a major fire clusters within the city center (high density residential area) throughout the study period including the years with the highest and lowest fire incidence record (2013 and 2015) and a dispersed pattern at the outskirts.

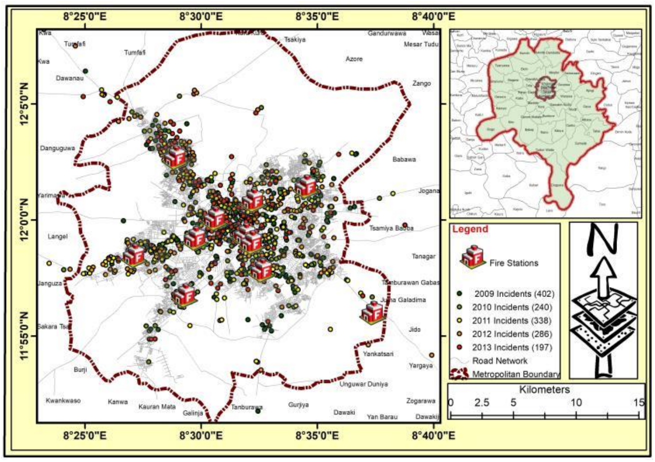

Figure 3: Spatio-temporal relationship of fire disaster recurrence from 2009-2013

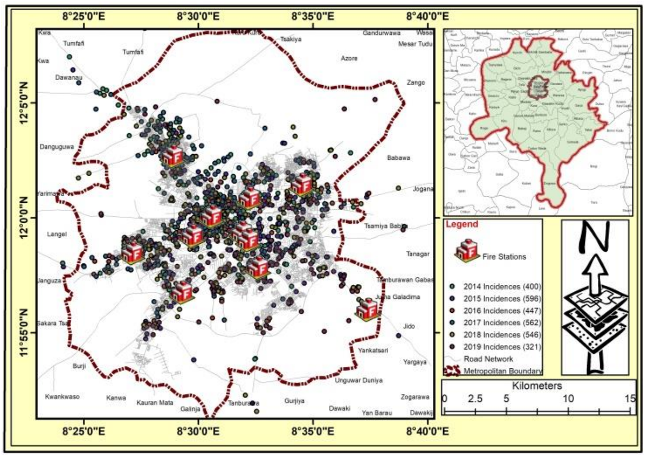

Figure 4: Spatio-temporal relationship of fire disaster recurrence from 2014-2019

Furthermore, similar pattern was identified throughout the study period with some cumulatively emerging clusters at largely residential areas around Kurna Asabe (Northwestern part), Rijiyar Zaki (Southwest) and Bompai in the Northeastern part of the metropolis from 2009-2013 (Figure 3). In the most recent time (2014-2019), two more clusters emerged around Dorayi and Sharada axis (Figure 4) indicating an increase in the number of fire clusters over time. This clearly signifies a direct relationship between space and time in fire disaster recurrence within the metropolis. This finding is similar to that of Zhang *et al.* (2018) who identified five spatio-temporal clusters within dwelling areas in Nanjing (China).

3.2. Incidence density analysis

Five (5) different neighborhoods were hierarchically identified based on the recurrence of fire incidents per unit area, in this case one square kilometer (1km^2). The categories were; very high density, high density, Medium density, low and very low-density zones (Figure 5). The result revealed that, the very high incident density zone which covers approximately about 61km^2 have experienced about 2285 incidents (which is equivalent to 53% of the total incidences recorded) within the study period. This, by implication, signifies that there are about 40 fire outbreak incidents per square kilometer (1km^2). This qualifies the area as 'fire epicenter' based on the realized incident density. Areas around Dala, Jakara, Gwammaja within the city center and parts of Kurnan Asabe, Kabuga Housing Estate (Janbulo) and Rijiyar Zaki constitute the very high incident zones (Figure 5).

This is followed by high and medium density areas (covering about 68km^2 and 70km^2) which experienced 670 and 195 incidents with equivalence of about 10 and 5 incidents per square kilometer (1km^2) respectively. The low and very low incident zones have wider aerial coverage with very few incidents (about 1-2 incidents of fire outbreaks per square kilometer) usually common toward the outskirt from the city center. This is similar to the findings of Strydom and Savage (2016) in South Africa.

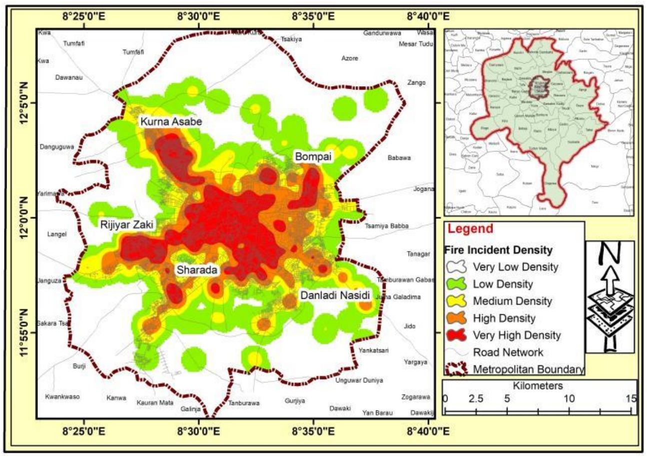

Figure 5: Fire incidence density map of Kano metropolis (2009-2019)
Source: Field Survey, 2019 and Data Analysis, 2020

The overall result (Figure 5) shows a direct relationship between residential/population density and recurrence of fire disaster. In other words, the more the population concentration and residential density, the higher the recurrence rate of fire disaster. Furthermore, highest concentrations of fire disaster are found within the high density residential landuses rather than commercial, educational and industrial areas. This signifies that landuse intensity is another factor that influences recurrence of fire disaster within Kano metropolis. This finding is similar to that of Young (2013) in China.

3.3. Temporal analysis of fire incidents (2009-2019)

3.3.1. Annual incident trend analysis

Incident trend analysis establishes relationship between fire disaster recurrence and time. This study examined the trend of fire incidences on annual, seasonal and daily basis throughout the study period (2009-2019). Figure 6 depicted a sinuous pattern of fire disaster occurrence using third order polynomial trend line (mostly used when data fluctuate with time). The trend line indicated an R^2 value of 0.721 signifying a good fit of the line to the data. It is evident that year 2015 recorded the highest number of fire incidences (13.8%), followed by 2017 and 2018 with 12.9% and 12.6% respectively (Figure 6). This generally indicates that the number of fire disaster occurrence within the metropolis has been on the increase in the recent time (2014-2018). This is due to many factors, but majorly increases in power supply, electric surge, nature and intensity of utilization of electricity especially during the cool and dry, and hot and dry seasons. The decline in the number of incidents in 2016 maybe probably due to improved nature of electricity utilization or massive sensitization campaign by the state fire service. It was expected that the number of incidences in 2019 would be very high, however, it was low because the data collected stopped at the month of September and did not capture part of the *Hunturu* season ('Fire Season') which usually records very high number of incidents.

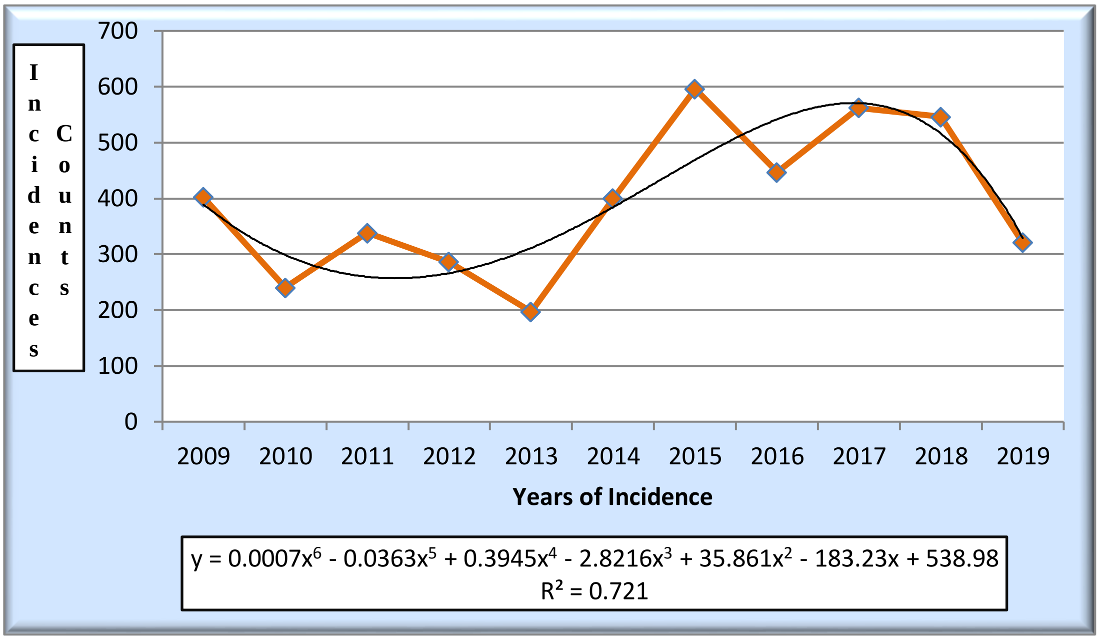

Figure 6: Annual trend pattern of fire incidence in Kano metropolis (2009-2019)

In contrast to rise in fire incidence recurrence from 2014-2019, there was decline between 2009 and 2013 (although not consistently) with 2013 recording the least number of incidents (4.6%), followed by 2010 (5.7%). The findings of Strydom and Savage, (2016) revealed variation in the trend of fire outbreaks in South Africa, while that of Yao and Zhang (2016) depicted similar temporal patterns of fire recurrence among the major dwelling areas. Addai *et al.* (2016) found a slightly different result were he observed same rate of fire incidents in Ghana from 2000-2010, and there was a sharp increase from 2011 to 2013 which was attributed to constant supply of electricity in the country throughout those years.

3.3.2. Seasonal variation and trend of fire disaster

Season is one of the major factor determining the recurrence rate of fire disaster in Kano metropolis. The study area is characterized by four (4) major seasons which are traditionally referred to as *Rani, Damina, Kaka and Hunturu* (i.e Hot and Dry, Warm and Moist, Warm and Dry and Cool and Dry seasons). Each of the seasons has its peculiarity and lasts for particular period, although there might be overlapping as a result of climate variability. Figure 7 depicts the seasonal pattern of fire disaster recurrence within the metropolis with highest number of fire incidents during the *Hunturu* season (32%), followed by *Damina* and *Rani* with 30.40% each, then *Kaka* (7.20%).

The *Hunturu* season in this regard is referred to as the 'fire season' because of the high rate of fire disaster recurrence (17.1%), while *Kaka* season usually records a lowest rate (11%) of fire recurrence. It should be noted that, *Hunturu* (Hammatan season) usually lasts for about 90-100 days, while the *Kaka* season only lasts for about 30-40 days annually. The recurrence rate signifies that the *Hunturu* and *Kaka* seasons experience not less than 17 and 11 fire incidences on daily basis respectively. *Damina* (Rainy season) in most cases usually records the lowest rate of fire disaster incident (8.8%). The major reason for rise in number of fire incidents in *Hunturu* is as a result of dryness and increase in the movement of the air which is accompanied by decrease in temperature. This results into increased ignitability of fire and the need for fire (to boil, cook and warm rooms) and electricity to power (in most cases) locally made heavy duty appliances for boiling and warming in order to adjust to the cold weather of the season. This results into electric surge and erratic outage which subsequently leads to fire outbreaks.

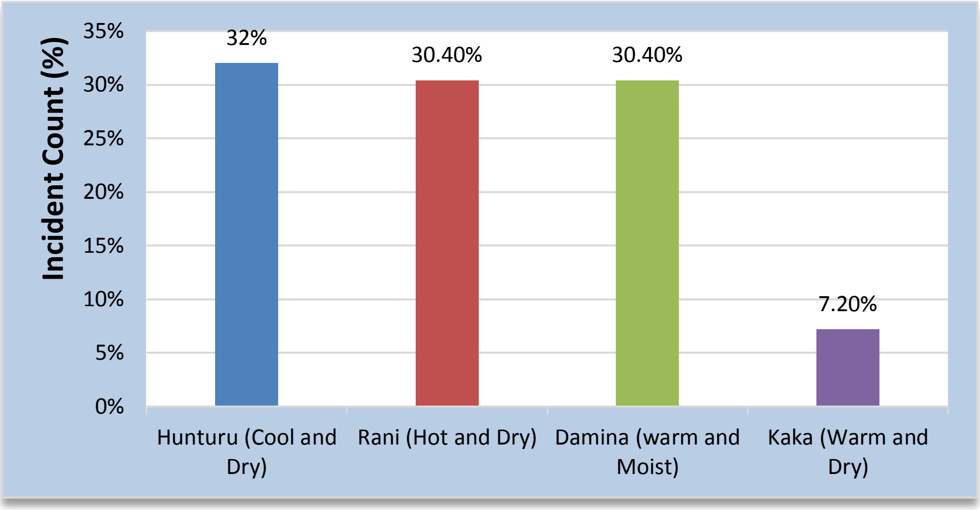

Figure 7: Seasonal variation of fire incidence in Kano metropolis (2009-2019)

The hot and dry season (*Rani*) which is almost opposite of the cool and dry season *(Hunturu)*, shares similar characteristics with regards to fire disaster recurrence rate (15.6%). This is also attributed to the rise in the utilization of electricity to power cooling appliances and refrigerators in order to adjust to the hot season. This finding is similar to that of Boateng (2013) and Strydom and Savage (2016) also examined the seasonal variations of fire recurrence. The general trend (Figure 8) showed a clear-cut difference between the incidents of 2009-2013 and 2014-2019. The number of incidents was higher during the later period than in the earlier. It is very important to note that there is general rise in the number of incidents across all seasons from 2014 to date except during *Kaka* season that reads averagely. The trend of fire incidents during *Kaka* season (across the study period) is generally low with less than 50 cases annually. This is due to low demand of electricity for cooling and warming during the season. However, in the same season, 2013 and 2014 recorded the lowest (about 8) and the highest (about 48) number of fire incidents respectively. On the other hand, the trend of the incidents during *Hunturu* and *Rani* seasons were generally high reaching to over 100 annually except in 2010 and 2013 in Hunturu and 2010, 2011, 2012 and 2013 in *Rani* respectively.

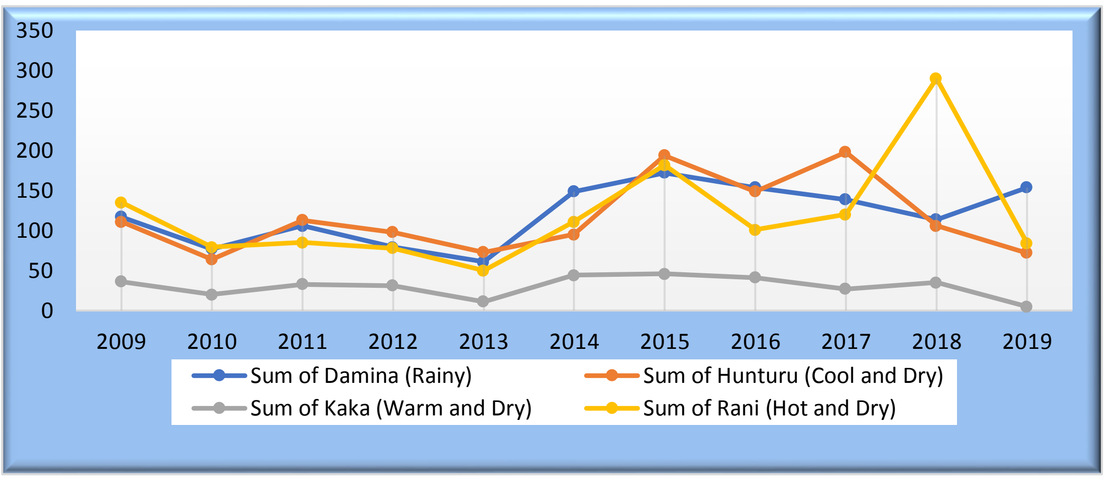

Figure 8: Seasonal trend of fire incidence in Kano metropolis (2009-2019)

3.3.3. Diurnal pattern and trend of fire incidents

The pattern of fire disaster occurrence in Kano metropolis also varies diurnally. For this study, times of the day were categorized into five (5) as morning (6:00am-11:59am), afternoon (12:00pm-15:59pm), evening (16:00pm-20:59pm), early night (21:00pm-23:59pm) and late night (00:00am-5:59am). Table

1 indicates that there were more fire incidences in the morning hours (26%), evening hours (24.7%) and afternoon (23.6%) than in the late-night hours (13%) and early night hours (8.8%). Morning, and evening hours experienced the highest fire outbreak recurrence rate because they are usually associated with lowest temperatures and regarded as peak hours for intense energy (electricity and fire) utilization especially for warming (during the cool and dry season) and cooling during hot and dry season. Morning hours are moments for cooking breakfast, boiling bathing water for students and workers in the family, and especially during *Hunturu* season, morning hours are moments for warming rooms using appliances and naked fire. The intensive utilization of electric appliances and naked fire for cooking, warming and boiling increases the risk of fire outbreaks.

Table 1: Diurnal pattern of fire incidences (2009-2019)

Year(s)	Times of the day					
	Morning	Afternoon	Evening	Early Night	Late Night	Not Stated
2009	121	92	102	42	33	12
2010	77	55	52	21	27	8
2011	93	85	78	17	61	4
2012	80	61	77	14	49	5
2013	48	55	55	17	10	12
2014	98	99	90	36	55	22
2015	164	131	139	51	92	19
2016	109	96	89	35	58	60
2017	117	137	162	56	79	11
2018	136	141	154	54	61	0
2019	84	74	77	42	43	1
Grand Total	1127	1026	1075	385	568	154

Source: Kano State Fire Service, 2019

Next is afternoon hours which experiences decline in temperature during the cool and dry season and rises during hot and dry season. Afternoon being the time for cooking lunch in almost all households is also associated with intensive energy utilization depending on the season. This increases the risk and recurrence rate of fire disaster. Fewer outbreaks were experienced during the early and late-night hours (9% and 13% respectively) due to lack of intensive utilization of electricity for cooking and boiling, only for warming or cooling of rooms depending on the season. Throughout the study period, there were more incidents in the morning than at other times of the day, except in 2013 and 2014 where afternoon and evening incidences outnumbered that of morning hours. High power consuming appliances (locally made electric cookers, room warmers and coolers) are mostly used extensively during this hour. This has resulted to ignition of fires which destroys properties and several lives.

Figure 9 depicts the diurnal trend of fire incidents from 2009-2019 in Kano metropolis. The result shows that, the trend of fire incidents during the early night hours is generally low throughout the study period with the highest number of incidents reaching to about 50 in 2015. However, on the other hand, the trend for morning and evening hours of the day were generally high with the highest number of incidents (in 2015) reaching to about 160 and 140 respectively. The highest number of incidents during evening hours was recorded in 2017 (about 160) followed by 2018 (about 150). Coincidentally, the highest and the lowest number of fire incidents during all times of the day (throughout the study period) were in 2015 and 2013 respectively.

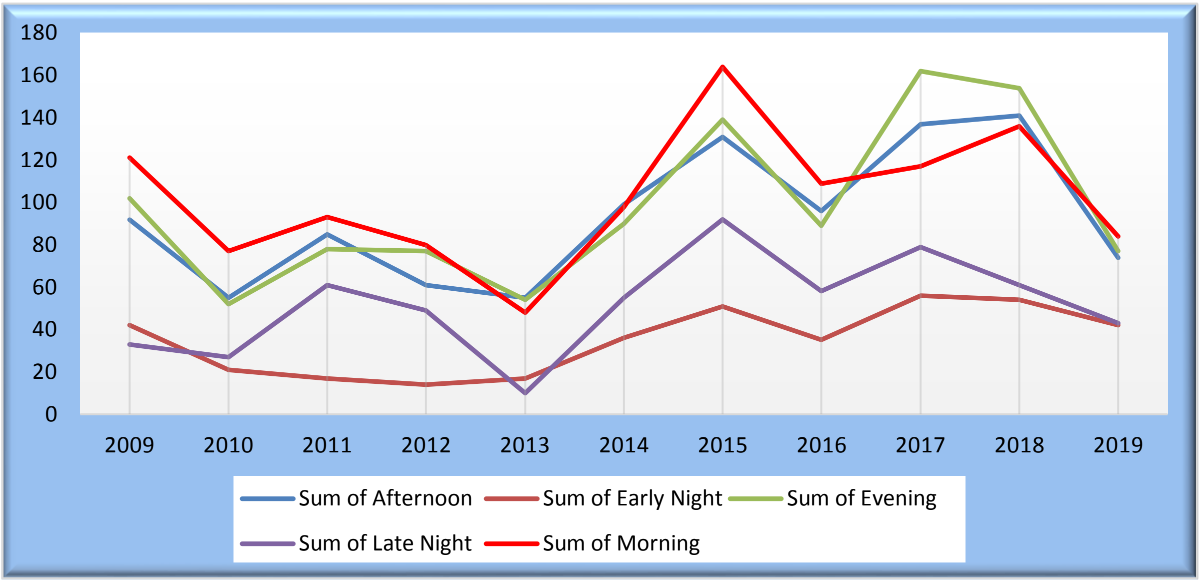

Figure 9: Diurnal trend of fire incidence in Kano metropolis (2009-2019)
Source: Kano State Fire Service, 2019 and Data Analysis, 2020

3.4. Causes of fire incidents (2009-2019)

Results about the causes of fire disaster based on the fire incident records obtained from the fire stations and the perspectives of the public/masses shows that electric related problems and negligence constituted the dominant causes of fire disaster. Incident records revealed electric sparks being responsible for about 36% of the total incidents recorded from 2009-2019 (Figure 10). While about 73% and 27% of the respondent indicated negligence and electric sparks as the major cause of fire disaster within the metropolis respectively (Figure 11).

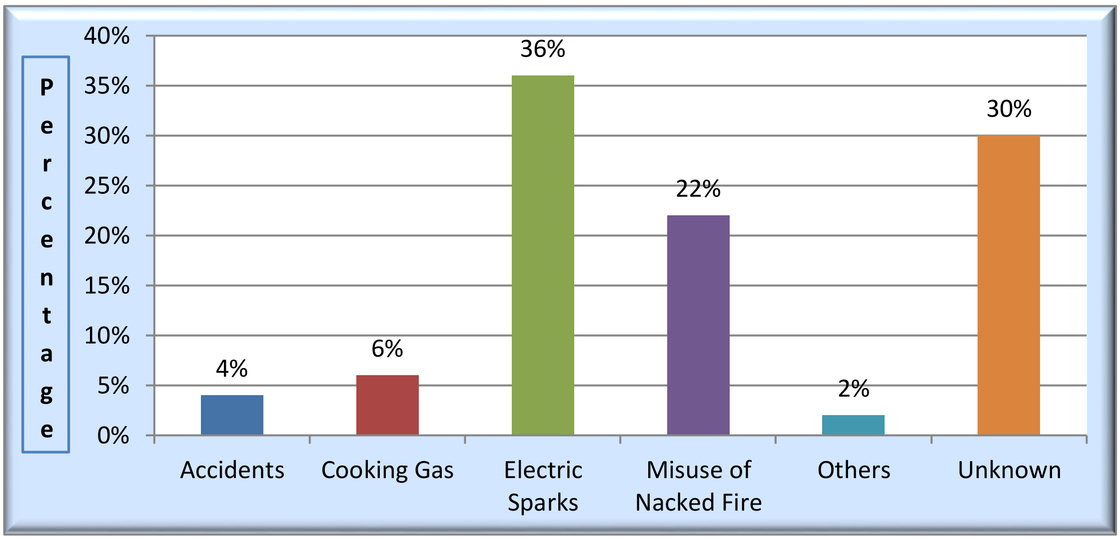

Figure 10: Major causes of fire outbreaks in Kano metropolis from KSFS record, 2009-2019

Several studies such as Simpson (2010), Boateng (2013), Koome *et al.* (2016), Isa *et al.* (2016) and Addai *et al.* (2016) come up with similar findings where electrical related problems comprising of old wiring, poor wiring, overloading of electrical circuits, heating appliances were the leading cause of domestic fires. On the contrary, Abu (2013) reported that 75% of fire outbreaks in Ghana were caused by smoking, 15% by ignorance, and 10% by accidents. Cooking gas and accident related outbreaks accounted for 6% and 4% respectively. It is however very important to note that the causes of about 30% of the total recorded incidences were unknown simply due to lack of proper/in-depth investigation by the fire service personnel either as a result of negligence or sometimes because of people's attitude/reactions towards the personnel due to the perceived lateness or incompetence. This therefore calls for motivating the personnel and also encouraging a more collaborative approach in response system to enable protection of the fire service personnel by the police during discharging their responsibilities. Other causes (as depicted in Figure 10) accounting for about 2% include fires caused by chemical related busting and excessive friction.

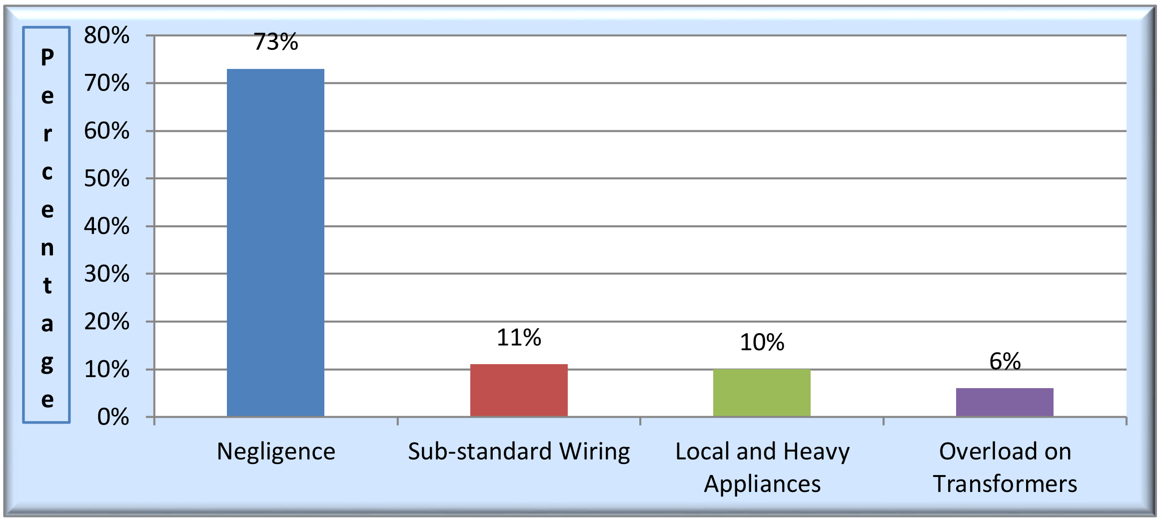

Figure 11: Major causes of fire outbreaks (affected residents and neighbourhood's perspectives)
Source: Field Survey, 2019 and Data Analysis, 2020

3.5. Consequences of fire incidents

Consequences of fire disaster are either expressed in material/structural terms (i.e expressed as count of items or properties destroyed), or in monetary terms. On the other hand, the resultant life loss and injuries (as part of consequences) are expressed as count/number of lives lost and injuries. The consequence in life loss and injuries can be directly from the people (public) or the firefighters. Additionally, injuries are further subdivided based on types and severity; physical or psychological, simple or complicated and cardiovascular or non-cardiovascular related injuries. In this work, consequences of fire outbreaks are broadly examined from five different dimensions i.e counts of consequences on landuses, structures/properties, life lost, injuries, and estimated losses in monetary terms.

3.5.1. Consequences based on landuses affected

The counts of properties or items affected by fire disaster were grouped into seven (7) classes, based on the landuses they are related to. These include; residential, commercial, health, educational, industrial, institutional and automobiles/others (Table 2). From Table 5, it is evident that residential and commercial landuses experienced the highest number of fire disaster throughout the study period. More than 70% of the total fire incidents recorded inflicted residential landuse (especially high-density residential area with low incomes around Jakara, Gwammaja and Dala), followed by commercial landuse (14%) and then properties including automobiles, generators and others accounted for only about 10%. This is because of residential and population density results into increased landuse intensity and therefore fire outbreaks.

Table 2: Landuses affected due to fire disaster (2009-2019)

Year	Commercial	Educational	Health	Industrial	Institutional	Automobiles/ others	Residential	Total
2009	70	2	0	4	5	97	224	402
2010	39	2	0	3	1	43	149	237
2011	60	3	1	2	4	44	219	333
2012	44	4	1	4	6	33	198	290
2013	47	1	0	3	5	29	112	197
2014	86	1	2	4	5	61	240	399
2015	83	3	1	5	8	50	445	595
2016	59	2	1	1	2	30	349	444
2017	61	6	4	0	7	26	457	561
2018	36	7	2	1	6	36	468	556
2019	20	5	1	4	0	12	279	321
Grand Total	605 (14%)	37 (1%)	13 (0.3%)	31 (1%)	49 (1%)	451 (10%)	3139 (72%)	4335 (100%)

Source: Kano State Fire Service, 2019 and Data Analysis, 2020

Additionally, residential areas were more vulnerable because they comprise about 80% of the total landuse area of the metropolis (at various density levels). This is followed by commercial area and activities which are the major activity people engage in within the metropolis. Educational, institutional and industrial landuses accounted for 0.9%, 0.11% and 0.7% respectively. The least affected landuse is the health related landuses which includes hospitals (both public and private).

3.5.2. Consequences based on structures/properties

With regards to the units of structures/properties destroyed, the result indicated that about 3136 rooms, a total of 2439 parlors, 2265 kitchens and 1837 toilets, 2006 shops/stores and 1705 offices were affected by fire disaster respectively (Figure 12). Others comprising of automobiles, generators and the likes reached to about 2030. The distribution of the affected properties/structures clearly shows that residential structures are the most affected followed by commercial and then administrative. Across the study period, rooms were the most affected with highest incidents in 2015 (over 400 rooms), 2017 (about 455 rooms) and 2018 (about 475 rooms).

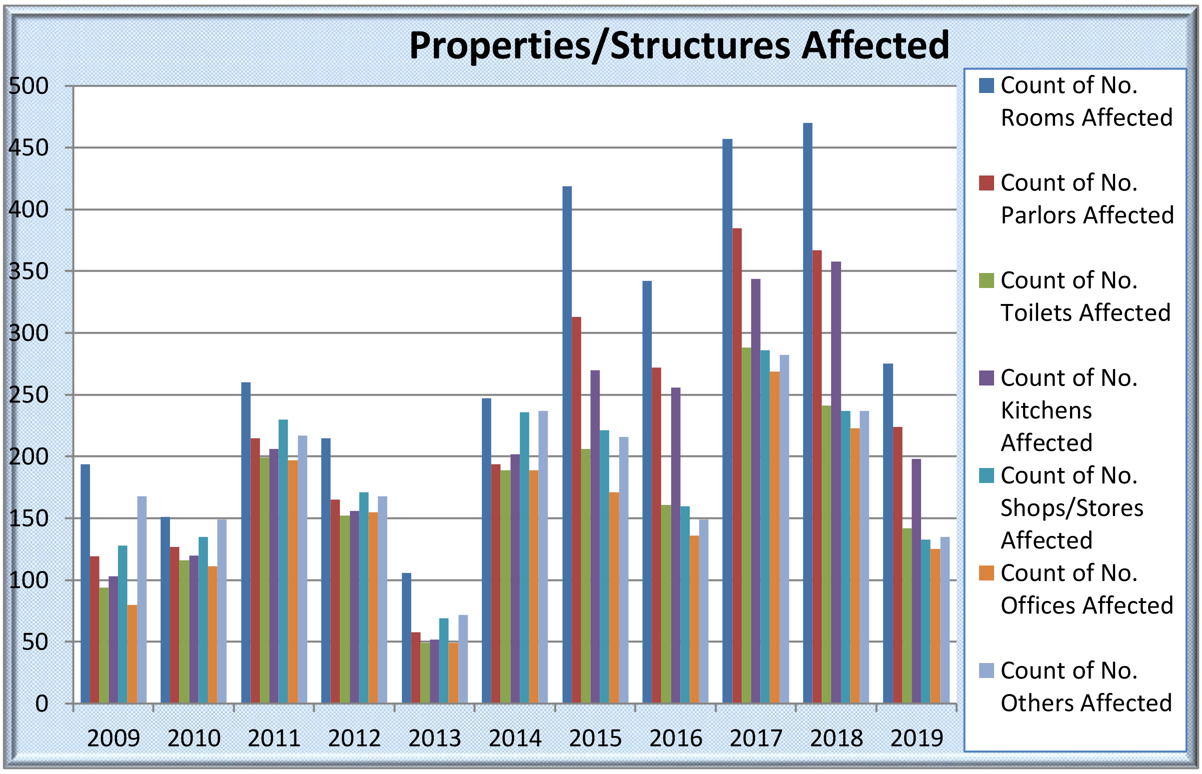

Figure 12: Structures/properties affected by fire outbreaks in Kano metropolis (2009-2019)
Source: Kano State Fire Service, 2019 and Data Analysis, 2020

3.5.3. Monetary loss, injury and deaths

Table 3 presents consequences of properties damaged in monetary terms, counts of life loss and injuries. The result indicates that year 2010 recorded the highest property damage worth over 1 billion Naira, with about 114 lives lost and more than 700 people injured. On the other hand, the highest number of life loss and injuries were recorded in 2013 along with property damage estimated to reach about four hundred and fifty-two million (N 452) Naira. It is also evident that none of the firefighters lost his/her life and only two (2) were injured for the last ten years. Result from the analysis of Coefficient of Variance indicated the number of estimated injuries as a result of fire outbreaks (54%) varied more than number of live loss and estimated monetary consequences. On the average, fire disaster accounted for 1,409 injuries, 263 life loss and property damage worth over 1 billion Naira within the study period.

Table 3: Consequences of fire disaster between 2009 and 2019

Year(s)	Estimated Damages (N)	Estimated Life Loss (Public)	Estimated Injuries (Public)	Estimated Life Loss (Firefighters)	Estimated Injuries (Firefighters)
2009	794,002,700	160	1023	0	0
2010	1,056,465,900	114	740	0	0
2011	600,700,000	73	892	0	0
2012	652,580,426	195	3140	0	0

2013	452,313,994	214	1976	0	0
2014	344,965,345	142	876	0	0
2015	546,434,190	144	523	0	0
2016	360,300,913	120	1655	0	0
2017	977,021,000	144	1959	0	0
2018	989,533,560	159	1665	0	2
2019	678,818,000	111	1055	0	0
Total	7,453,136,028	1576	15504	0	2
Mean	1,242,189,338	263	1,409	0	0
SD	250,971,766	39	762	0	1
CV (%)	20	15	54	0	

Source: Kano State Fire Service, 2019 and Data Analysis, 2020

4.0. Conclusions

It is concluded that recurrence of fire disaster in Kano metropolis is influenced by space-time relationship and landuse. Electricity related faults and negligence constitute the major triggers of fire disaster. It is therefore recommended that;

i. Massive enlightenment campaign should be embarked on by Kano State Fire Service (KSFS) and other related stakeholders especially within the high population density residential areas (city core) on fire disaster prevention and preparedness measures stressing on negligence and electric related faults as the two major causes of fire outbreaks within the metropolis.
ii. Redevelopment and regularizing of compacted settlements through enforcement of building codes, proper waste disposal and proper packing of vehicles along the narrow access routes should be undertaken by the planning department.
iii. The issue of electricity supply to such communities needs to be revisited because the lack of high voltage (230-240) supply to residents in such localities have resorted to making illegal connections, which have been identified as one of the major causes of shack fires thus contributing to the residents' vulnerability.
iv. Since seasonal variation is identified as one of the major factors influencing the occurrence of fire disaster, alternative strategies (utilization of solar-based modern appliances) for adjusting to the effects of various seasons should be developed in order to suppress the high recurrence especially during the morning, afternoon and evening hours of *Hunturu* (cool and dry season) and *Rani* (Hot and dry) seasons.
v. Risk reduction strategies should be employed by the fire service department in collaboration with the residents to reduce the risk of lives and properties especially within the risk hubs of the metropolis.

References

Adamu, Y. and Yunus, S. (2017). Spatio-Temporal Analysis of Urban Fire Incidences at Abuja Phase1, Nigeria. *Nassarawa Journal of Tropical Geography, 8*: 1864-1874.

Addai, E. K., Tulashie, S.K., Annan, J. and Yeboah, I. (2016). Trend of Fire Outbreaks in Ghana and Ways to Prevent These Incidents, *Safety and Health at Work*, 7 (2016): 284-292, http://dx.doi.org/10.1016/j.shaw.2016.02.004.

Adekunle, A., Asuquo, A., Essang, N., Umanah, I. I., Ibe, K. E., and Alo, A. B. (2016). Statistical Analysis of Electrical Fire Outbreaks in Buildings: Case Study of Lagos State, Nigeria. *Journal of Sustainable Development Studies*, 9 (1): 76-92.

Asgary, A., Ghaffari, A., and Levy, J. (2010). Spatial and Temporal Analyses of Structural Fire Incidents and their Causes: A case of Toronto, Canada. *Fire Safety Journal*, 45(1): 44–57.

Avis, W. R, Philip, A., Goodfellow T., Linda, H. Claire, M. Andrew, P, and Turner W. (2016). Urban Governance Topic Guide Suggested Citation. *Jaideep Gupte (IDS)University of Birmingham*, (November).

Ayila, A. E., Oluseyi, F. O., and Anas, B. Y. (2014). Statistical Analysis of Urban Growth in Kano Metropolis, Nigeria. *International journal of Environmental Monitoring an analysis*, 2(1): 50-56 (http://www.sciencepublishinggroup.com/j/ijema).

Ayuba, H. K., Aguocha, O., and Medugu, N. I. (2016). Fire Vulnerability Assessment of the Federal Capital City, *International Journal of Innovative Science, Engineering and Technology*, 3(5): 39–46.

Barau, A. S. Maconacchie, R., Ludinc, A. N.M. and Abdulhamid, A. (2015) Urban Morphology Dynamics and Environmental Change in Kano, Nigeria. *Land Use Policy*, 42: 307-317.

Barau, A. S., (2005). An Account of the High Population in Kano State, Northern Nigeria. Department of Geography, F.C.E., Kano.

Boateng, W. (2013). Electricity Company of Ghana Explains Causes of Fire Outbreaks. *Ghanaian Times*, Jan 24.

Ceyhan, E., Ertuğay, K. and Düzgün, Ş. (2013). Exploratory and Inferential Methods for Spatio-Temporal Analysis of Residential Fire Clustering in Urban Areas. *Fire Safety Journal*, 58: 226–239. https://doi.org/10.1016/j.firesaf.2013.01.024.

Corcoran, J., Higgs, G. and Higginson, A. (2011). Fire Incidence in Metropolitan Areas: A Comparative Study of Brisbane (Australia) and Cardiff (United Kingdom). *Applied Geography*, 31(1): 65–75. https://doi.org/10.1016/j.apgeog.2010.02.003.

Dogondaji A. Z, Ojonugwa E., Ibrahim A. A. and Mustafa A. (2017). P-Center Problem of Fire Stations in Sokoto Metropolis, *Asian Journal of Mathematics and Computer Research*, 18(3): 143-151, 2017.

Habibi K, Lotfi S, Koohsari MJ (2008). Spatial Analysis of Urban Fire Station Location by Integrating AHP Model and IO Logic Using GIS (A Case Study of Zone 6 of Tehran), *J. Appl. Sci.* 8(19): 3302-3315.

Hacioğlu C, (2010), Spatial Requirements of Fire Stations in Urban Areas: A Case Study of Ankara, A Thesis Submitted to the Graduate School of Natural and Applied Sciences of Middle East Technical University.

Isa, U. F., Liman, M. A., Mohammed, M. U., Mathew, O. S., and Yayo, Y. R. (2016). Spatial Analysis of Fire Service Station in Kano Metropolis, Nigeria. *IOSR Journal of Humanities and Social Science,* 21(9): 42–52. https://doi.org/10.9790/0837-2109014252.

Jennings, C. R. (2013). Social and Economic Characteristics as Determinants of Residential Fire Risk in Urban Neighborhoods: A Review of the Literature. *Fire Safety Journal*, 62(PART A): 13–19. https://doi.org/10.1016/j.firesaf.2013.07.002.

Koome, A. E. K., Wakhungu, J. W., and Omuterema, S. O. (2016). Analysis of Nature of Fire Hazards in Selected Locations of Kibera Slums of Nairobi County, Kenya, *International Journal of Social Science and Humanities Research*, ISSN 2348-3164 (online), 4 (4), pp: (358-363), Available at: www.researchpublish.com.

Mahmud, A. R., and Indriasari, V. (2009). Facility Location Models Development to Maximize Total Service Area. *Urban Issues in Asia*, SN 1S/April, pp.87-100.

Maigari A. I, (2014). Evolutionary Trend, Spatial Distribution of, and Issues Associated with Markets in Kano Metropolis: *Research on Humanities and Social Sciences*, Vol.4, No.28, 2014, ISSN (Paper) 2224-5766, pg:2225-0484 (Online), www.iiste.org

Menya, A. A., and K'Akumu, O. A. (2016). Inter-agency Collaboration for Fire Disaster Management in Nairobi City. *Journal of Urban Management,* 5(1): 32–38. https://doi.org/10.1016/j.jum.2016.08.001.

National Emergency Management Agency (NEMA, 2006). Industrial and Commercial Buildings Fire in Nigeria, NEMA, 2006.

Nisanci, R. (2010). GIS Based Fire Analysis and Production of Fire-risk Maps: The Trabzon experience, *Scientific Research and Essays* Vol. 5(9), pp. 970-977.

OECD (2015). The Metropolitan Century: Understanding Urbanisation and its Consequences. (Policy Highlights). Paris: OECD.

Ogundele, J.A., Arohunsoro, S.J., Jegede, A.O. and Oni, B.B. (2013).Evaluating the Operations of Emergencies and Disaster Management Agencies in Ekiti State, Nigeria. *Journal of Natural Sciences Research*, Volume 3, No.15, pg.132-138.

Oladokun, V. O. and Ishola, F. A. (2010). A Risk Analysis Model for Fire Disasters in Commercial Complexes in Nigeria," *Pacific Journal of Science and Technology*., vol. 11, no. 2, pp. 376-386, 2010.

Oladokun, V. O., and Emmanuel, C. G. (2014). Urban Market Fire Disasters Management in Nigeria: A Damage Minimization based Fuzzy Logic Model Approach. *International Journal of Computer Applications*, 106(17): 975–8887.

Oladokun, V.O. and Ishola F. A. (2010). A Risk Analysis Model for Fire Disasters in Commercial Complexes in Nigeria, Unpublished Msc. Thesis, Department of Industrial and Production Engineering, University of Ibadan, Ibadan, Nigeria.

Oladokun, V.O., Kolawole, A and Emmanuel, C. G. (2012). Risk Analysis Models of Fire Accidents in Nigeria Commercial Complexes: A Fuzzy Logic Approach," in *Proceedings of NIIE 2012 Conference*, Benin , 2012.

Salisu, A. U. (2007), Assessment of the Spatial Distribution of Fire Incidents from 2004 to 2006: A Case Study of Kano Metropolis. Unpublished Msc. Dissertation Submitted to the Department of Geography, Bayero University, Kano, Nigeria.

Simpson, DE. (2010). Fire Protection and Safety. A Presentation of Ghana National Fire Service (GNFS). Ashanti Regional Office at a Symposium of Building Technology Students Society (BTSS) Week Celebration, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, 24-27.

Strydom, S., and Savage, M. J. (2016). A Spatio-Temporal Analysis of Fires in South Africa. *South African Journal of Science*, 112(11–12): 1–8.

Umar, N. R. (2013). Fire Incident Emergency Response For Markets in the Metropolitan Kano , Kano State, Nigeria, Prs 312043 Regional Centre For Training In Aerospace Surveys (Rectas), December.

UNDESA (2014). World Urbanization Prospects: The 2014 Revision. New York: UNDESA.

UN-Habitat. (2009) Global Report on Human Settlements: Planning Sustainable Cities, Policy Directions. Nairobi: UN-Habitat.

WEF (World Economic Forum). (2014). Global risks 2015. Geneva: WEF.

Wuschke, K., Clare, J. and Garis, L. (2013). Temporal and Geographic Clustering of Residential Structure Fires: A Theoretical Platform for Targeted Fire Prevention, *Fire Safety Journal* 62(2013)3–12, http://dx.doi.org/10.1016/j.firesaf.2013.07.003.

Xin, J. and Huang C. (2013). Fire Risk Analysis of Residential Buildings Based on Scenario Clusters and its Application in Fire Risk Management. *Fire Safety Journal* 62(2013)72–78, http://dx.doi.org/10.1016/j.firesaf.2013.09.022.

Yagoub, M. M., and Jalil, A. M. (2014). Urban Fire Risk Assessment Using GIS : Case Study on Sharjah , UAE, 5(3), pg. 1-8.

Yao, J and Zhang X. (2016). Spatial-Temporal Dynamics of Urban Fire Incidents: A Case Study of Nanjing, China. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences,* Volume Xli-B2, 2016 Xxiii Isprs Congress, 12–19 July 2016, Prague, Czech Republic.

Yong, Z. (2013). Analysis on Comprehensive Risk Assessment for Urban Fire: The Case of Haikou City, doi: 10.1016/j.proeng.2013.02.195, *Procedia Engineering* 52 (2013) 618 – 623.

Yunus, S. (2019b). 'Response Delay Model: Bridging the Gap in Urban Fire Disaster Response System'. World Academy of Science, Engineering and Technology, Open Science Index 156, *International Journal of Humanities and Social Sciences*, 13(12), 1465 - 1470.

Yunus, S. (2021). Spatio-Temporal Analysis of Fire Outbreaks in Markets of Kano Metropolis, Kano State, Nigeria. Journal of Land Administration and Environmental Management, 1 (1): 1-8, 2021. ISSN: 2756-4088 (Online), 2408-6517 (Print). doi:https://doi.org/10.54222/ajlaem/v1i1.1.

Yunus. S. (2019a). Assessment of urban Fire disaster preparedness for Response Delay Modeling in Dutse town, Jigawa State, Nigeria. African Journal of Earth and Envi. Sci. vl 1, (2), pg 207-218, 2019. DOI: 10.11113/ajees.v3.n1.104.

Zhang, X. Yao, J. and Sila-Nowicka, K. (2018). Exploring Spatiotemporal Dynamics of Urban Fires: A Case of Nanjing, China. *ISPRS Int. J. Geo-Inf.*, 7, 7, (1-14); doi:10.3390/ijgi7010007.

Cite this article as:
Yunus S. and Falola J. A., 2022. Analysis of Spatio-Temporal Pattern, Causes and Consequences of Fire Disaster in Kano Metropolis, Nigeria. *Nigerian Journal of Environmental Sciences and Technology*, 6(1), pp. 478-492. https://doi.org/10.36263/nijest.2022.02.0348