

An Assessment of the Trend and Periodicity of Fire Disasters in Sokoto Metropolis, in Nigeria

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ABSTRACT

Global trends indicate that both natural and man-made disasters are on the increase and more people are being affected. This study assessed the trend and monthly distribution of fire disasters in the Sokoto metropolis. Data on monthly records were collected from the Sokoto State Fire Service Department for 2000-2023. Monthly meteorological data for wind speed, sunshine maximum and minimum temperature were collected from the Nigerian Meteorological Agency (NIMET) spanning the period of 2000-2023. Trends were calculated using the Mann-Kendall test. Also, multiple linear regression was used to examine the contribution of weather variables to fire disasters. Results revealed an upward trend. The fire frequency is surging on a trend with positive both monthly and annually. The magnitude of the trend produced statistical P-values of 0.000 for January, February and March while P-values of <0.0001 were observed on an annual basis. The findings revealed that the critical time for fire incidences are afternoon hours. The result indicates that February, March, January and December constitute the fire disaster-prone period and correspond to the cold dry and hot dry months in the area. Also, maximum temperature accounts for (R² = 0.049), minimum temperature (R² = 0.103), wind speed (R² = 0.004) and Sunshine hours accounted for about (R² = 0.017). There is a need to educate and sensitise the residents through mobile telephony, radio and television broadcasts on the high-risk months identified. Additional fire stations in cluster patterns of distribution should be set up and more fire-fighting personnel should be recruited.

Keywords: Emergency; Fire Disaster; Trend, period and Climatic variables

INTRODUCTION

Global trends indicate that both natural and man-made disasters are on the increase and more people are being affected. The most vulnerable are the poor who are exposed to various disaster risks[1]. Fire disasters are very common in both developed and developing countries. They have diverse causes which are either man-made or natural. Overall, fire disasters are higher during the dry period and sometimes festive events when the demand for electricity or use of fire is high[2][3][1]. Weather and human activities change with the seasons of the year, and so do the incidence, causes and severity of fires. Daily fire incidence is at its highest in the spring while in tropical area Nigeria especially the daily high frequency of fire cases is recorded during the dry season[2]. According to[4], meteorological factors and

the breaking out of fire are closely related. The most important climatic factors that influence the degree of risk of forest fires are air temperature, precipitation, relative humidity, wind and droughts[5][6]. Fire outbreaks in urban areas in northern Nigeria (including Sokoto metropolis which is the study area) are surging and have become disasters that are very difficult to predict when compared to the listed other disasters. A perusal of fire events is: The statistics about fire accidents in Sokoto metropolis between the years 2000 and 2017 suggest that fire accidents in this city tend to be more happenings, more destructive and more complicated. In this context, the periodic assessment of fire outbreaks is quite significant in urban fire planning and the making of fire regulations. This can be the means of promoting coordinated social and economic development in the city. Sokoto Central Market was burnt down by fire in 2006 and about 10 billion Naira worth of properties were destroyed in the inferno (SSDFS, 2006). A report from Sokoto State Fire Service reveals that out of the 423 cases of fire disasters recorded in 2011 within the metropolis, 6 people lost their lives. Available information from Sokoto State Fire Services in 2008 estimated property saved is about N106,312,460.25 while the property destroyed amounted to N58,741,25231 and 11 people lost their lives. Most recently in 2021 fire razed part of Sokoto Central Market and about 4357 traders were affected.

The frequency and similarity of fire disasters recorded across various urban centres in Nigeria in the last decade have become a major cause of concern for all stakeholders in disaster management[2]. Evidence has shown that many activities that influence fire incidence change with the season of the year. In the United States, the winter season increases the need for heating and warm weather tends to bring people and their behaviours outdoors[3] Seasonal forecast of fire probability can provide information for priority areas at a temporal scale which allows planning and fire mitigation actions ahead of the fire event is very crucial[7] Since the incidence of fire in buildings is a major threat to the safety of occupants and properties therein, particularly, where inflammable materials are commonly used[8] it has been confirmed by several scholars[2][9] that the following disasters; flood, earthquake, cyclone and extensive cause upheavals in a physical social and economic context where they occur. Most of the literature on fire disasters revealed that a gap exists between the magnitude, frequency and the level of preparedness whenever such disaster strikes[10]. Analysis of urban vulnerability to fire in China[4] attributed to urbanization process, population experience remarkable increase of modern buildings. According to[11] in Africa, the frequent occurrence of major fire accidents in commercial buildings, shopping malls, and markets has become a serious threat to the fragile economy of most countries. The occurrence of disasters and emergencies in Nigeria has increased in frequency and intensity, especially in recent times. A report in Nigeria (NEMA, 2006) shows many major markets and commercial buildings have been gutted by fire which resulted in the loss of lives and properties worth several billions of naira. A related development[12] confirmed that most market fires are attributed to shop-owners' carelessness in handling electrical appliances, faulty electric wiring and storage of inflammable substances in unsafe manners. Despite the importance of fire for the development of human society but constitutes a significant threat to life and property in urban and rural areas[13]. A study conducted by[14] in the Kano metropolis has linked the high frequency of fire to the increase in residential, commercial, industrial and institutional land uses leading to urban expansion. Study in Ibadan[2] attribute it to the physical expansion of the built-up area that took place without any strategic planning or official development management while in the city of China was attributed with the acceleration of industrialization, urbanization, and Marketization[15]. According to[16] Australia is the driest and most drought-prone continent the fire season persists for 4–7 months during the dry season most of the continent is experienced and confirmed that settlement of the continent by the Aboriginal people increased the incidence of fire, as did the European settlement in the eighteenth century. In Dar es Salaam the situation was a result of fire safety measures in buildings are inadequately provided and, in cases where they are provided, are not well maintained[17]. Analysis of fire disasters in the twentieth century attributed the increase to industrial, technological, military development, as well as the increasing number of armed conflicts[18]. The study conducted by[14] in the

city of kano and concluded that simultaneous increase in population and settlement expansion of the town has a direct effect on the increase in emergencies services.

The objective of this study is to assess the magnitude (number of occurrences per year) and the temporal distribution (monthly distribution over the 12 months of the year) of fire disasters in the Sokoto metropolis from 2000 to 2023. The choice of the year 2000 is based on the reason that political governance became stable in Nigeria after the inauguration of a new Federal Constitution in 1999. The motivation to conduct this study is simple; Sokoto metropolis by its location and history serves as the marshalling centre for most large businesses in Nigeria whose catchment areas cover the north-western portion of the country as well as the landlocked Nigèr Republic. Fires also inflict adverse consequences on the natural environment[12]. These include contamination of the air via the fire plume and its subsequent diffusion, deposition of particulate on soil and water, contamination of soil and water from fire suppression runoff, which might contain toxic or hazardous materials and direct exposure to soil and water from hazardous materials are dangerous human and environment[12].

METHODS

Study Area

The Sokoto Metropolis is located between Latitudes $12^{\circ} 46'N$ to $13^{\circ} 08'N$ and Longitudes $5^{\circ} 14'E$ to $5^{\circ} 30'E$ (Figure 1). A larger section of the city is located on top of a 300-metre hill that slopes gently into plains that fringe the city almost all around. The climate is typically Tropical Continental Hinterland and thus it is located in a sunny environment where at least six hours of sunlight should be expected daily. The mean annual temperature is $28^{\circ}C$ indicating it is in a hot climate; but in December and January, night and early morning temperatures could be far below $20^{\circ}C$. Also, during April and May, the temperature rises to about $40^{\circ}C$ and thus the area becomes very hot. The dry dusty and fast-moving Tropical Continental (cT) *Harmattan* dominates the city for about five months and unleashes its impacts on residents. The total annual precipitation of the Sokoto area is 680 mm per annum; as result, the city's environment is always dry. Relative Humidity is 46.83%; there are only four months in the year (June to September) during which the humidity of the air goes beyond 60%. Aside from dryness, the environment is windy; the mean wind speed for the year is $1.56\ m^2$ but between November and February it could rise above $2.5\ m^2$.

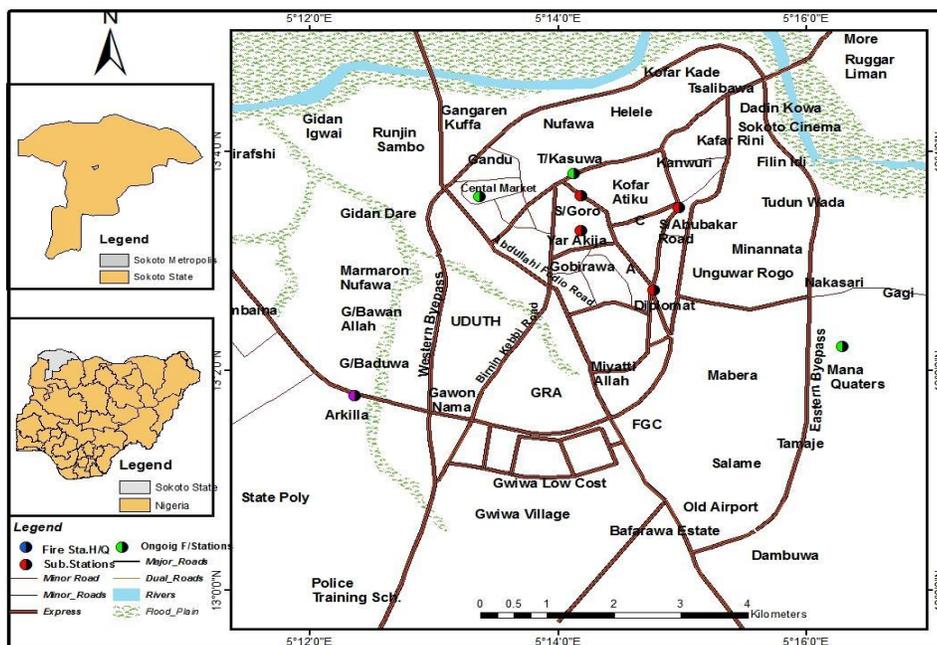


Figure 1. The Study Area

Sokoto has always remained as an administrative capital of a new state bearing its name for all the five State creation exercises in Nigeria's political history (i.e. in 1967, 1976, 1987, 1991 and 1996). Notably, Sokoto metropolis serves as the transportation and distribution hub of people goods and services in north-western Nigeria especially trade across the Sahel to the Mediterranean coast. Concluding, Sokoto has been experiencing very astronomical population growth, since the creation of the state in 1967. There have been very rapid surges in residential, commercial, industrial and institutional land uses leading to the city sprawling. The simultaneous increase in population and settlement expansion of the metropolis should be expected to have direct effects and indirect effects on the occurrence of disasters such as fire outbreaks.

Data Collection

Data on reported monthly fire outbreaks (most of which resulted in disasters) in Sokoto metropolis spanning the 2000 to 2023 time period were collected from Sokoto State Fire Service. Monthly maximum and minimum, wind speed, and sun Shine hour Temperature, for the period were also collected from the Achieve of Nigerian Meteorological Agency (NIMET). The time series of frequency of fire disasters was calculated using the Mann-Kendall test [27]. The Mann-Kendall statistical test for trend is used to assess whether a set of data values is increasing over time or decreasing over time and whether the trend in either direction is statistically significant. Mann–Kendall positive value determines an inclining trend whereas its negative value indicates a declining trend and is statistically significant when the p-value is less than 0.05 [28].

Multiple Regressions Model

Multiple regression was used to evaluate the contribution of meteorological parameters independent variables also called predictor or explanatory variables on frequency of fire disaster (dependent variables). In multiple linear regression, a linear combination of two or more predictor variables is used to explain the variation in a response. In essence, the additional predictors are used to explain the variation in the response not explained by a simple linear regression fit. Regression techniques are the most widely used statistical techniques employed on a large variety of problems in the field of applied research.

According to [20] fires can be triggered or exacerbated by lightning, high winds, earthquakes, volcanoes, floods and deliberate setting of fire by human beings. Lightning is the most significant natural contributor to fires affecting the building environment. [21] demonstrate the general causes of residential fire outbreaks in cities of northern Nigeria they include the geographical location of the city; the weather condition in an area i.e. the prevailing season; nature and direction of the wind in the region; nature of building materials commonly used to construct residences; circumstances prevailing during the period of fire outbreak. [22] have been more specific in identifying the frequent causes of fire outbreaks in urban areas; they list frequent power outages, electric power surges, electrical sparks, illegal connection to the electricity grid, the use of improper electrical fittings, substandard cooking and heating gadgets, indoor use of electric generators, and negligence in the use household electrical appliances, leaving children at home without supervision, storing up fuel (petrol) at home, Arson and ignorance of fire safety measures. However, the rapid material-intensive growth patterns of the twentieth century have adversely affected the environment, which in turn has made many groups (especially the poor), more vulnerable to fire disasters [11].

In the United states, [3] reported that incendiary and suspicious acts (including arson), cooking and carelessness with open flames are the leading causes of fires. These causes have a common thread to human activity and human error. They concluded that most of these fires were likely preventable. [23]

provided steps for dealing with an outbreak of a fire when it occurs, and conclude that considerations of the problem of fire (protection and prevention) planning process in all buildings and should be included from conceptual stages of the design this reduces the magnitude of the disaster see [Figure 1](#) for the stages. Another safety measures, [\[24\]](#) put forward that fire protection should start from architectural and engineering phases of building and concluded that, when planning for new cities and neighbourhoods, town planners should consider access for fire fighting personnel, their vehicle and equipment to freely manoeuvre and effectively control fire. Studies conducted by [\[25\]](#) highlighted road accessibility as part of the challenge of fire fighting control in Sokoto Metropolis.

Overloading of the electrical appliance on the same fuse and improper electrical installation in homes and workplaces [\[26\]](#). Add that in the process of urbanization and industrialisation in West Africa, large quantities of combustible fuel are being stored in residential premises because the supply of electricity has been insufficient as well as infrequent; this has led to an increase in fire hazards. From the foregoing discussion, naturally-induced fire disasters such as those caused by earthquakes, volcanic eruptions etc are not common. So, it is easy to conjecture that many of the fire outbreaks in Nigeria have human causes. This situation forms the crust of fire disaster occurrence among Nigeria's population of over 190 million. Literature review on fire disaster preparedness draws substantive conclusion that fast growth in urban places of developing country from small to cities leads to increased risks of fire disasters as well. Despite the frequency and magnitude of the fire disasters urban dwellers are rarely prepared to save life and properties [\[10\]](#).

The devastating effects of fires disasters in Nigeria in the last four decades must be reviewed for argument. The most devastating fire disaster in the nation's history occurred on 18th October 1998 in Jesse, Delta State (southern Nigeria) when a petroleum pipeline exploded and claimed 1,082 lives on a single day [\[22\]](#). The second deadliest outbreak occurred on January 27, 2002, when military-grade high calibre munitions exploded at the Nigerian army's cantonment in Ikeja (Lagos) and killed 800 people as well as rendering more than 10,000 people homeless. Aside from southern Nigeria whose fire disaster may be categorised industrial, the northern part of the country had not been spared of the menace. The ultra-modern bus terminus in Jos (Plateau State, Central Nigeria), the multi-million Naira Sabon Gari Market in Kano metropolis have all been gutted down by the fire. Central Market, The situation is not different in the study area (Sokoto metropolis); records of the Sokoto State Fire Service reveal that in 2008 alone while the property was estimated to be worth ₦59 million (the equivalent of \$2,124 million property were salvaged, some ₦106 million (the equivalent of \$38,160 million) were lost to fire and 11 people died. Fire disasters are quite devastating in Africa's most populous nation; also the 4,000-stall Sokoto Central Market was 95% reduced to ashes in 2006.

RESULTS AND DISCUSSION

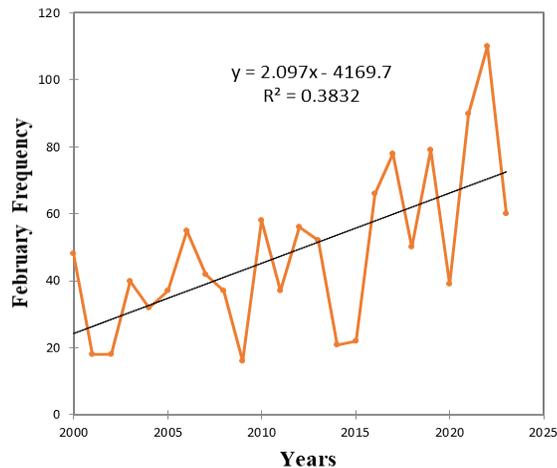
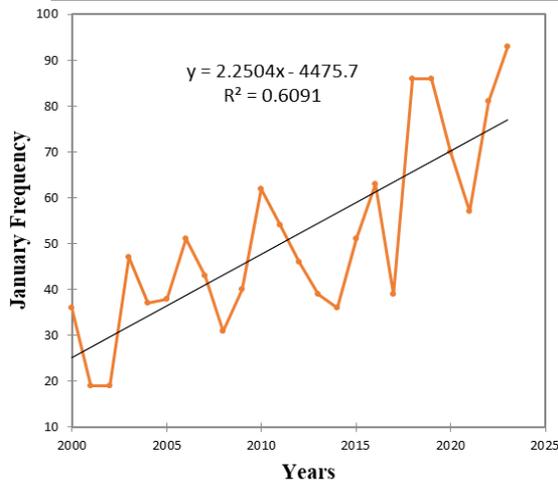
Trend Analysis of Fire Disaster

The results of the trend analyses were presented on monthly and periodic incidences of fire disaster ([Table 1](#)). The frequency patterns of fire disaster denote significant positive trends at a 95 % confidence level. However, there are three months out of twelve months these include April, July and August that P-values is greater than alpha (0.05). Significant trends are found for monthly reported cases and annual. The finding revealed no negative trends are detected for the period of observed from 2000 2023 ([Table 1](#)). The trend in the following months April June and August showed insignificance as the P-values are greater than alpha (0.13, 0.31 and 0.13) respectively. The findings indicate a significant positive trend on annual basis with values P-values of <0.0001. The progress of fire incidences yearly this calls for great concern by all stakeholders to curb the menace of urban fire outbreaks. The statistical significance trend was detected with Sen's slope estimation to determine the magnitude of the trend as presented in [Table 1](#). The magnitude was very high in first and the quarter of the year during period under study.

The purpose of the Mann-Kendall (MK) test (Mann 1945, Kendall 1975, Gilbert 1987) is to statistically assess if there is a monotonic upward or downward trend of the variable of interest over time. A monotonic upward (downward) trend means that the variable consistently increases while downward trend confirmed the variable is decreases over the time. Figure 2 and 3 (monthly trend fire disasters) displays that there high variability of the outbreaks of fire outbreaks in Sokoto city despite the nature of upward trend from January to December.

Table 1. Kendall stau Statistics of Monthly and Annual

Months	Kendall's tau	Sen's slope	S	Var(S)	p-values	alpha
January	0.57	2.15	157.00	1620.33	0.00	0.05
February	0.45	2.15	122.00	1620.67	0.00	0.05
March	0.43	1.62	116.00	1606.67	0.00	0.05
April	0.23	0.76	62.00	1616.00	0.13	0.05
May	0.50	0.83	137.00	1613.67	0.00	0.05
June	0.35	0.50	95.00	1618.33	0.02	0.05
July	0.15	0.28	42.00	1619.33	0.31	0.05
August	0.23	0.25	61.00	1606.33	0.13	0.05
September	0.42	0.44	111.00	1600.33	0.01	0.05
October	0.45	0.76	122.00	1612.67	0.00	0.05
November	0.55	1.19	148.00	1610.00	0.00	0.05
December	0.50	2.00	132.00	1578.00	0.00	0.05
Annual	0.71	11.68	195.00	1624.33	< 0.0001	0.05



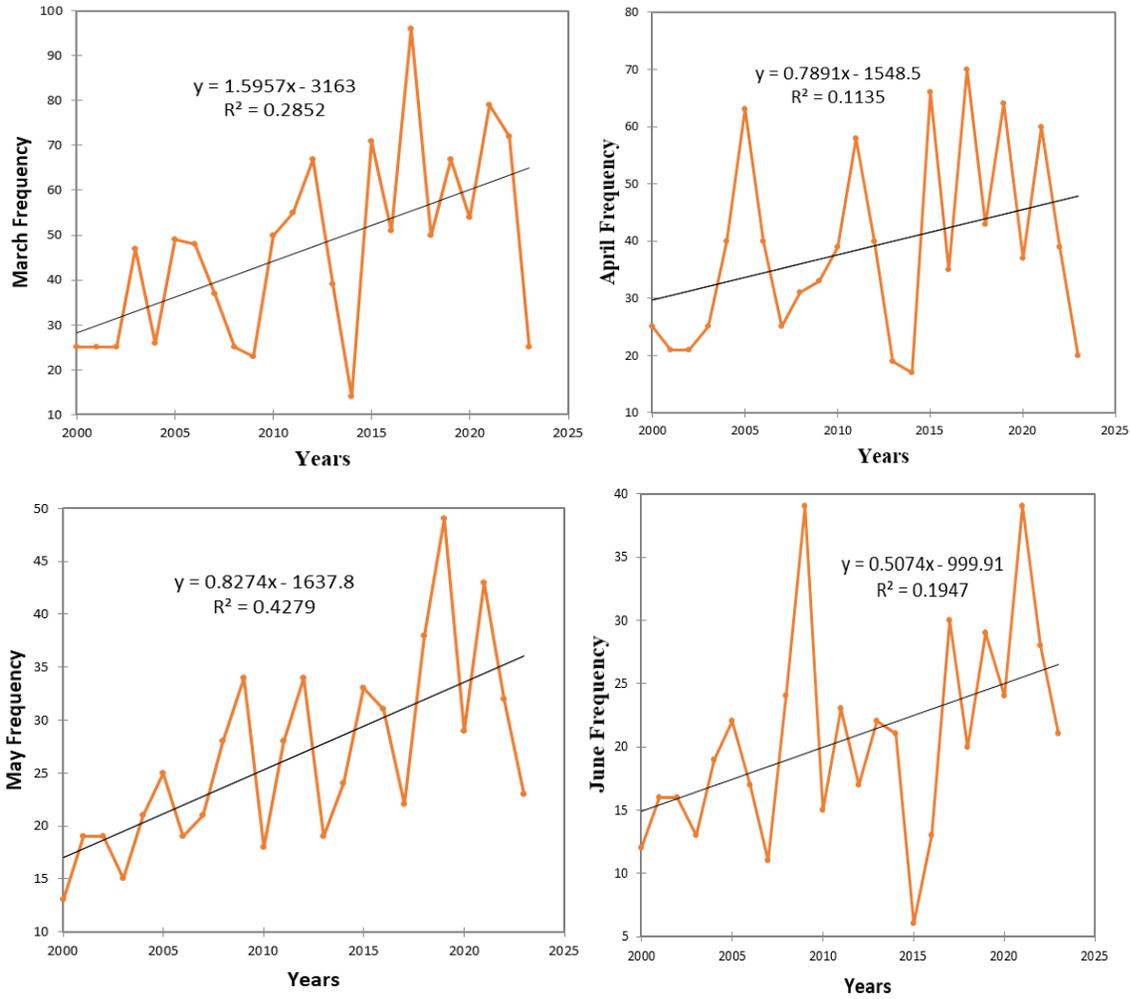
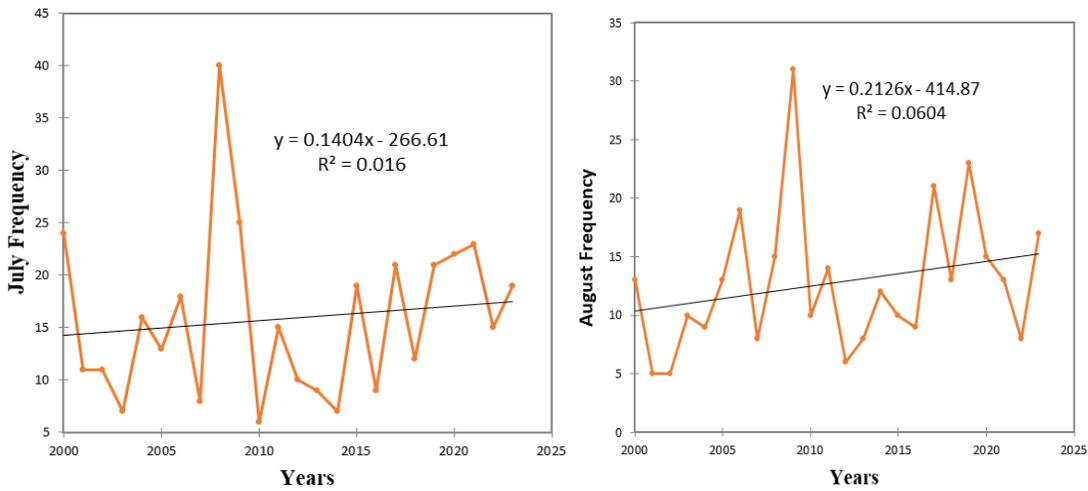


Figure 2. Monthly Trend of Fire Incidences January to June



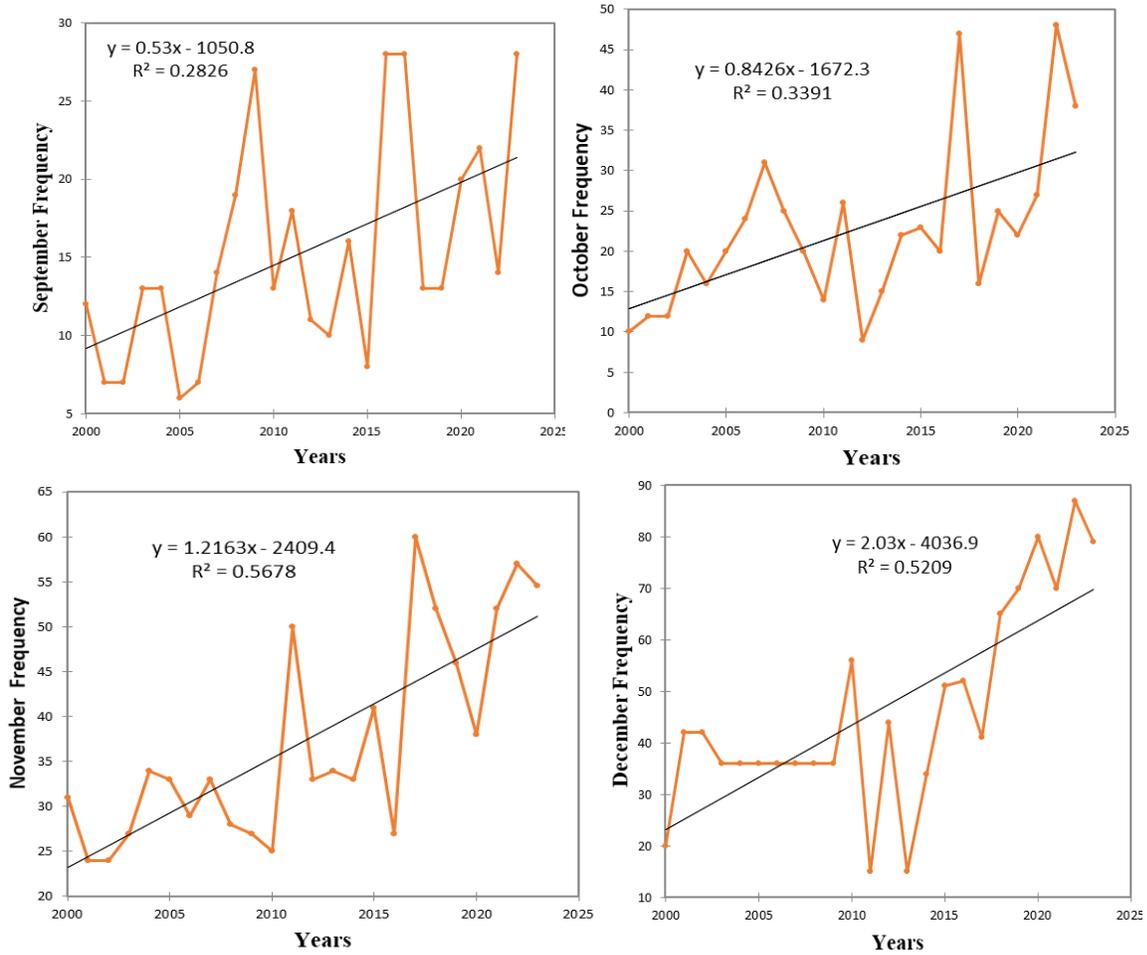


Figure 3. Monthly Trend of Fire Incidences July to December

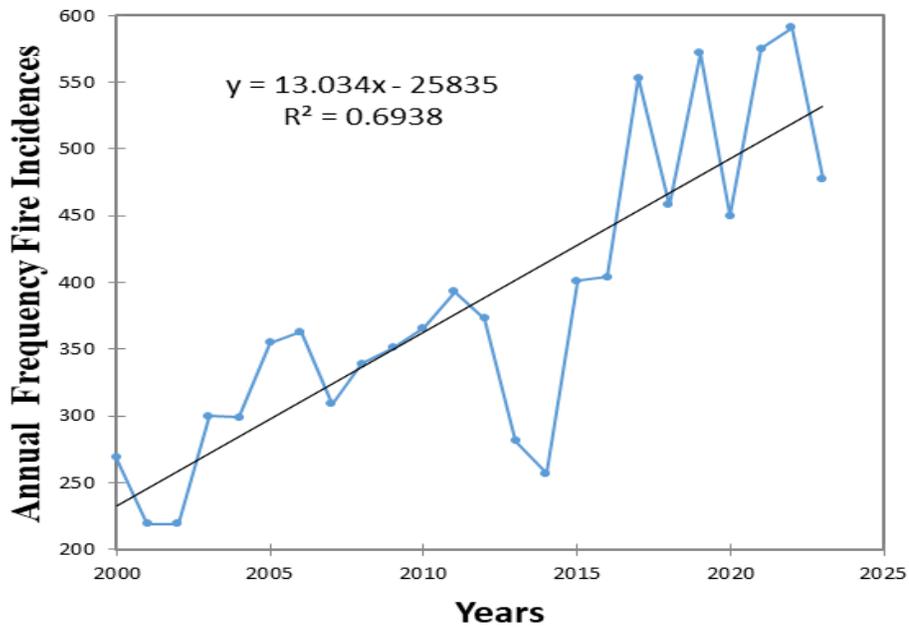


Figure 4. Annual Trend of Fire Incidences

Relationship Between Meteorological parameters and fire Disaster

The relationship between meteorological variables and incidences of fire disasters was observed. The findings (Table 1&2) reveal evidence of a correlation between the meteorological parameters and incidents of fire disasters. Further analysis reveals a weak relationship between weather parameters and fire cases with Maximum Temperature having a correlation value of 0.221, Minimum Temperature with -0.320, wind speed with -0.063 and sunshine hours with 0.131. Negative relationships mean that as x values increase, y values decrease or vice versa. The results further confirm that weather parameters could be included as contributing factors to fire outbreaks in the study area. This finding is in line with [11] who reported that high temperatures and wind increase the magnitude and intensity of fire. Figure 8 also revealed the contribution of each meteorological variable. It could be deduced that minimum temperature accounts for ($R^2=0.103$), maximum temperature ($R^2= 0.049$), Sunshine hours ($R^2= 0.017$) and wind speed ($R^2= 0.004$). This shows that minimum temperature contributes 10.3% and maximum temperature also contributes 4.9% to fire incidences in the study area. The findings could be attributed to the reason why most of the fire cases were experienced during the night period. Another important factor is the harmattan season where the frequency of fire cases increases and the maximum temperature reduces. Wind speed accounted for 0.04% while sunshine hour explained 1.7% of the variation of fire disasters (Figure 5).

Table 2. Accuracy measures of the regression Model

Statistics Measures	Tmax	Tmin	Wind Sped	Sunshine
R ²	0.049	0.103	0.004	0.017
Adjusted R ²	0.045	0.099	0.000	0.014
MSE	10.678	10.532	2.324	1.098
RMSE	3.268	3.245	1.525	1.048
DW	0.357	0.378	0.663	1.289

Table 3. Matrix Correlation between Frequency of fire case and weather variables

Variables	Fire Cases	Tmax	Tmin	Wind Speed	Sunshine Hours
FIRE CASES	1.000				
TMAX	0.221	1.000			
TMIN	-0.320	0.142	1.000		
Wind Speed	-0.063	0.053	-0.065	1.000	
Sunshine Hours	0.131	0.155	0.065	0.032	1.000

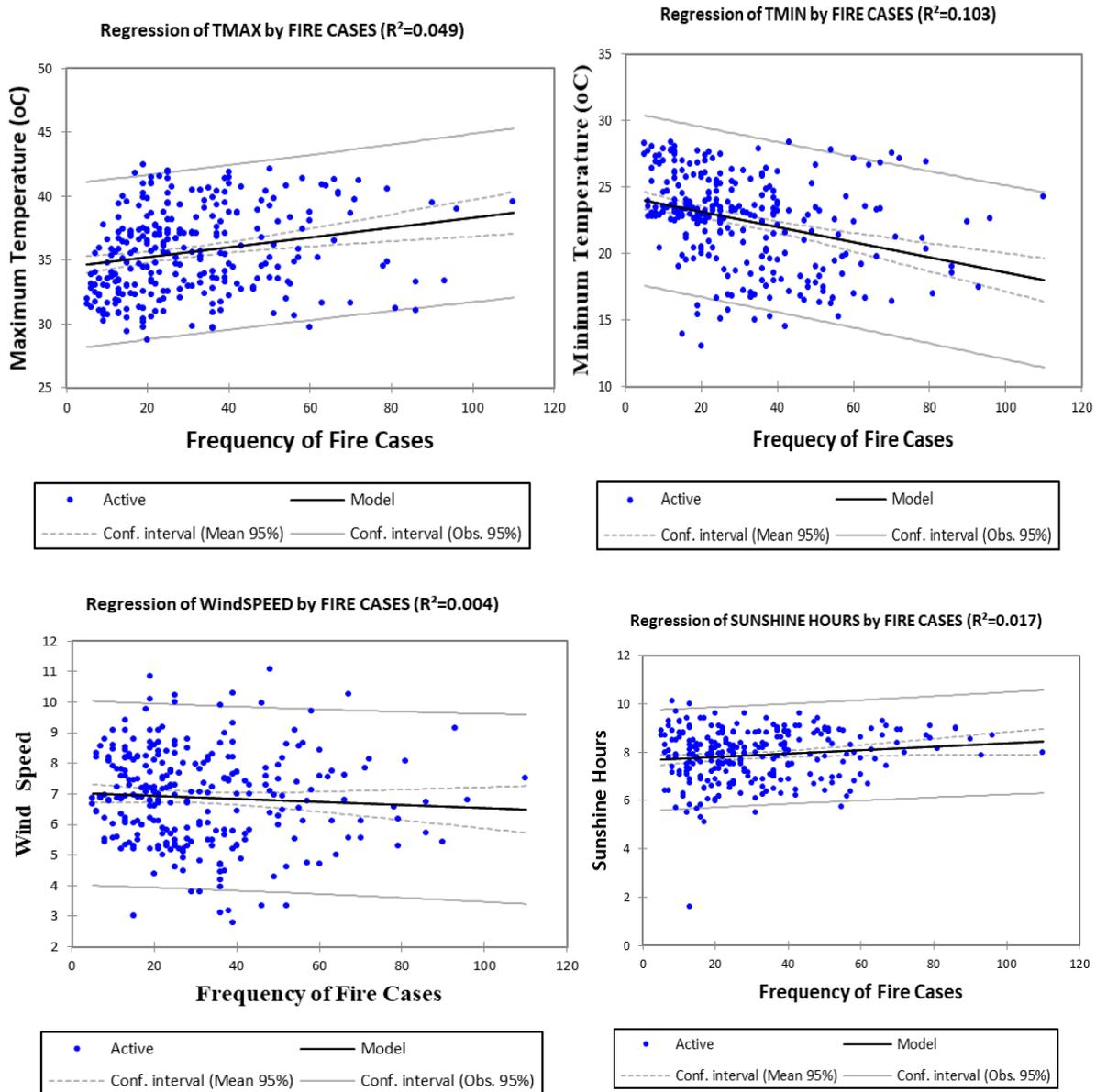


Figure 5. Linear regression between meteorological variable and Fire incidences

Periodic Analysis of Fire Disaster

A fire incident is a devastating event that can be avoided with enough knowledge of how and the likely period of the high frequency[30]. The pattern of the occurrences of fire disaster in OSokoto metropolis varies diurnally. For this study time of the day were categorized in Five (5) as morning (6am – 11:59am), afternoon (12:00pm -15:59pm), evening (16:00pm- 20:59pm), early night (21:00 -23:59pm), and late night (00:00 5:59am) . The analysis presented in Figure revealed that afternoon hours experienced the highest fire outbreak occurrence rate because they are usually associated with higher temperature, and intense solar radiation. Further analysis for morning and evening hour’s fire cases could be related lowest temperature and regarded as peak hour for intense energy utilization especially for morning hour during the cool and dry season and cooling during the hot and dry season. Figure revealed in each of the months during year 2022 incidences fire occurred during day hours. The monthly and

annual variation of fire count data reported during 2000–2023 were presented in [Figures 10](#) and [11](#). The results revealed that February, March, January and December recorded the highest cases of fire disasters.

The rise in the outbreaks in February, March, January and December can be attributed to climatic factors (high wind speeds, low Relative Humidity and the relatively low temperature in December, January and February). Conceivably, the first two factors directly and indirectly contribute to the eruption and spread of residential fire while the low temperature induces the need to do much heating. Indeed, [\[25\]](#) has opined that there is a significant relationship between the seasons of the year and fire outbreaks in the Sokoto metropolis. The result is in agreement with studies conducted by [\[31\]](#) in Botswana and Namibia which observed a shift in seasonality of increased fire occurrences mainly during the dry season.

February ranks first over the period under study. This is contrary to the popular belief that December and January were critical and that reported cases are always higher. The result based on the analysis of the monthly frequency of fire cases revealed that August recorded the lowest number of cases. This could be as a result of the prevailing weather conditions where energy demand is very low when compared to critical months observed. The results illustrate that much of the surging is coming from the weather conditions in the cold-dry and hot-dry seasons of the city (February, March, January and December period). The result of the seasonal pattern of the occurrences of fire outbreaks as opined by [\[2\]](#) could be used for guiding the operation of fire personnel in making decisions concerning safety awareness and emergency response.

However, the annual ([Figure 8](#)) displays variations of the yearly outbreaks of fire outbreaks in Sokoto city; the lowest total numbers were recorded in 2008 and 2009 while the highest was in 2022 followed by 2023. There is an indication that the yearly magnitude of fire disasters is showing a surging trend. The finding is in line with [\[1\]](#) who reported that the global trends of fire disasters (both natural and man-made) are increasing and the worst affected were the vulnerable people from developing nations. Changes in both residential and commercial building contents, as well as in construction materials and methods, have had a significant impact on fire cases. The study conducted by [\[32\]](#) showed that residential land uses have the highest occurrence of fire incidences followed by educational and transportation land uses. It is easy to conclude from [Figure 10](#) that there is a dangerous surge in the trend of fire outbreaks in the city which should be worrisome to all residents. Other contributing factors are unstable electricity supply to residents, very rapid urbanization; negligence on the part of residents and illegal electrical connections

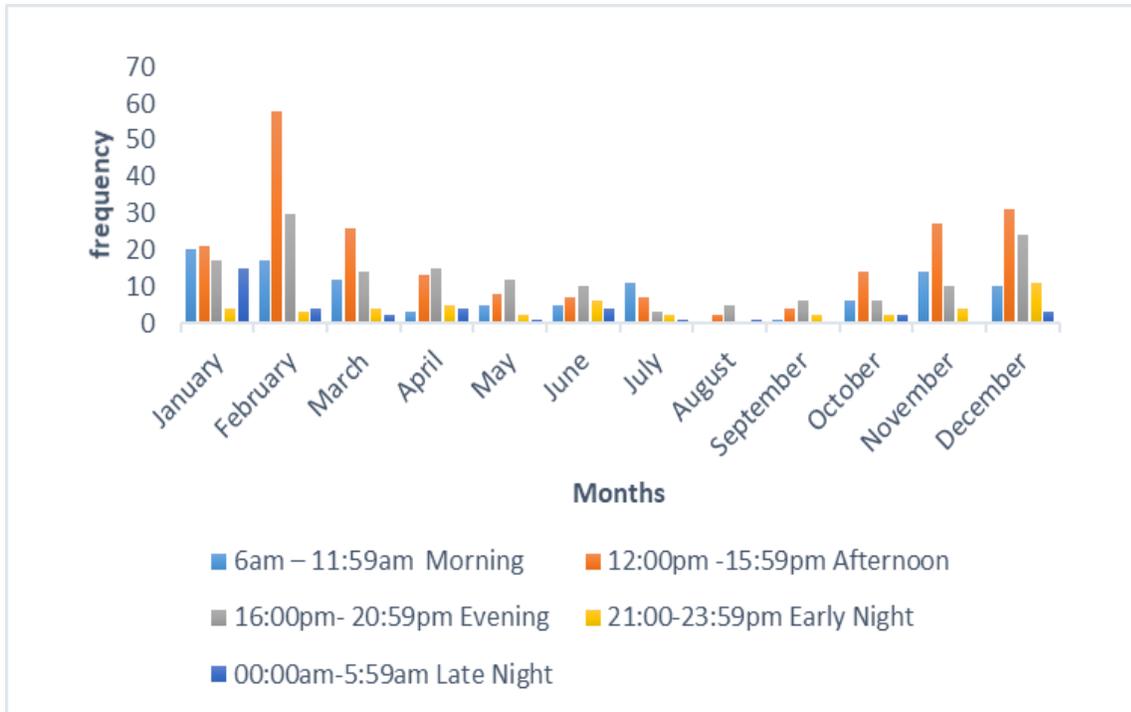


Figure 6. Diurnal Pattern of 2022 Monthly Fire incidence in Sokoto Metropolis

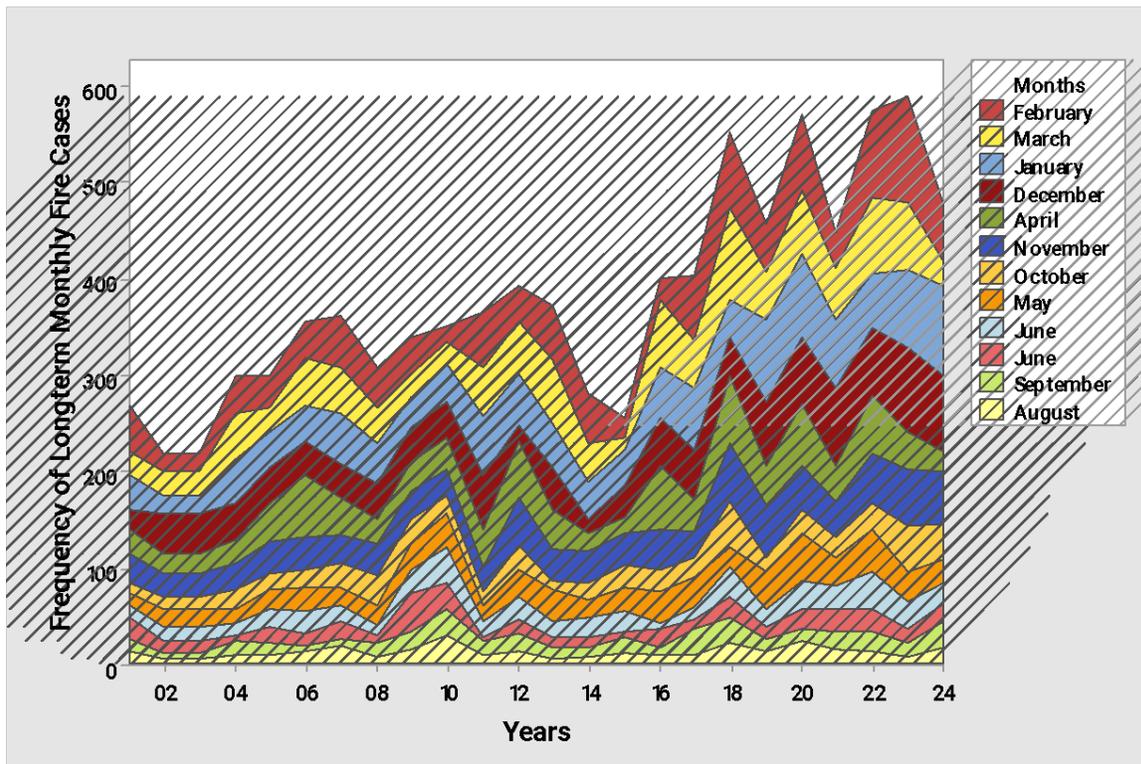


Figure 7. Monthly Magnitudes of Fire Disasters in Sokoto Metropolis: 2000-2023

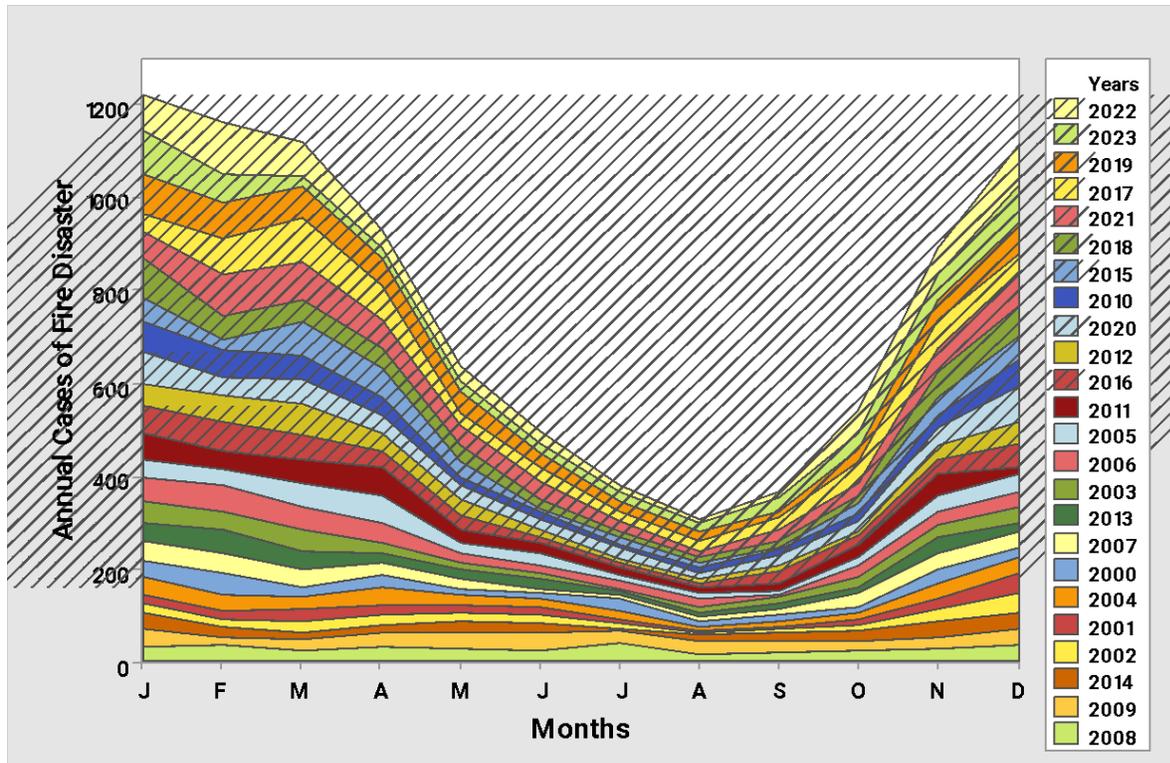


Figure 8. Yearly Magnitudes of Fire Disasters in Sokoto Metropolis: 2000-2017

CONCLUSION

The study reveals that the frequency of fire outbreaks in the Sokoto metropolis is increasing; the majority of the outbreaks occur during the long dry season prevailing in the area; the fire-prone months are majorly January, February, March and April; but sometimes November, and December also join the chorus. The surging fire outbreaks have been impacting the Sokoto State Government to divert her inadequate financial resources for fire-fighting, providing disaster relief and rehabilitation to victims and the environmental destruction. Thus, the socio-economic development of the city is being hindered. The study recommends the following as a panacea; since the fire outbreak-prone months have been identified, and the fact that the menace is surging, different safety measures should be adopted. Additional fire stations in cluster patterns of distribution need to be set up just as more fire-fighting personnel are needed. Finally, the study recommended the investigation of the spatial distribution of fire outbreaks in the study area.

DECLARATIONS

Conflict of Interest

We declare no conflict of interest, financial, or otherwise.

Ethical Approval

On behalf of all authors, the corresponding author states that the paper satisfies Ethical Standards conditions, no human participants, or animals are involved in the research.

Informed Consent

On behalf of all authors, the corresponding author states that no human participants are involved in the research and, therefore, informed consent is not required by them.

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