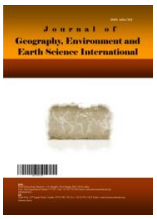

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GIS-Based Emergency Fire Response for Minimization of Fire Outbreaks in the Greater Accra Metropolis, Ghana

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Authors' contributions

This work was carried out in collaboration among all authors. Author EY conceptualized designed and drafted the final draft. Authors IS and EKN provided relevant resources, supervised, prepared the first draft, reviewed and edited the manuscript. Authors VK, NS, FKA, SOYA and EAGK acquired data, analyzed, edited and assisted in the interpretation of results. All authors read and approved the final manuscript.

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ABSTRACT

The study report assessed the geographic distribution of existing fire stations in the Accra Metropolitan Area (AMA). It further sought to evaluate the spatial coverage for each fire station under predefined sustainable response times. Information on fire stations and incidents, access to

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sources of water and settlements were purposively obtained and visualized in Arc Map 10.6 with the multiple buffer tools. GIS web application was developed to integrate reporters and fire stations within the AMA for an efficient and effective response to emergency cases related to fire outbreaks. Results suggest that GIS application is essential to fire management as it significantly improved response time to 15 minutes, reducing causalities as well as damaged properties if the strategy is adopted. Results proved a response time of 15 minutes is feasible in the study area if the proposed strategy is adopted. The study presents this management system as one that could be easily be deployed to other stations across the country. The platform provides details on the location, the magnitude of the fire incident among other relevant details. This study would regulate and minimize risks associated with fire outbreaks which are often accompanied by both direct and indirect consequences and could facilitate early reporting using mobile collection devices.

Keywords: Emergency fire response systems; Geographic Information System (GIS); web based application; Accra.

1. INTRODUCTION

Emergency management are strategies put in place to facilitate risk prevention and minimization of impacts emanate from several disasters. [1] defined Emergency management as the discipline where science, technology, planning and management are employed with the sole aim of dealing with harmful situations. [2] developed a white paper (199) entitled: "Emergency Planning and Response Systems" categorized Emergency management activities into five stages, namely; planning, mitigation, preparedness, response and recovery. [3] argued that developing countries have weak preparedness and response to disaster management. Emergency response is usually handled at the local level by first respondents such as fire departments, police, medical professionals and municipalities. In mitigating the impacts of disasters in developing countries, the International decade for National Disaster Reduction (IDNDR) was established [4,5]. Specific objectives set-out for IDNDR entailed developing a roadmap for disaster management. This blueprint constituted sharing methods for risks and disaster assessments, prediction, prevention and mitigation of natural disasters.

Fire outbreak is a menace to both developed and least developed countries [6,7] reported that 75% of fire outbreaks in Ghana are caused by smoking, 10% resulting from accidents, whilst and 15% occurred as a result of ignorance. [8] argued that poor electrical materials and appliances were the main causes of fire outbreaks in Ghana. Unskilled or inexperienced personnel who handled or operated for some agencies or individually could be faulted in some cases. Most electricians who did not attain any form of formal education underwent in-service training to equip themselves. Learning on the job over a given period propels most local electricians to carry out major projects including installation of electrical materials for houses, firms and companies. Some companies and house-owners with the sole aim of cutting down production cost go in for inexperienced or unskilled individuals which later results in such outbreaks. The affordability of their prices has led to several citizens purchasing their services regardless of whether they are qualified or not especially amongst low-income earners [9]. Educated electricians are abreast with the dangers associated with fire, its prevention and safety measures as compared to low level education individuals. Moreover, low-income earners are most likely to incur such incidents due to indulgence in activities that may lead to fire outbreaks. Amongst these activities are: open fires, not equipping homes with the necessary and appropriate fire prevention materials [10]. Additionally, some arsonist in some case scenarios highlighted by [11], have sabotaged the central government by initiating fires to destroy state properties, aimed at showing their displeasure or compelling the central government to attend to prioritize their needs.

The underlying philosophy of any emergency response agency is to respond as quickly as possible to disasters, aimed at reducing loss of lives, personal and public properties worth millions or billions. Time is an essential variable in developing emergency response systems [12]. It is often associated with the ratio of fatal to serious injuries. The time difference between a fire outbreak and a response to firefighting is directly proportional to property loss, as a result of the fire outbreak. The success in the management of an emergency depends on

resources, systems, and personnel. Resources are required at the planning, response and recovery phases. These components need to be identified according to the responding agencies and the types of emergencies encountered. In addition to resources, good systems such as the development of an emergency operation plan, an incident command system, and a warning system to facilitate the emergency management activities should be implemented. The systems essentially specify the roles, functions, and responsibilities of each responding agency in relation to emergency situations. The emergency response personnel serve as the link between the resources and the systems because they are trained to practicalize or use systems and resources during emergency scenarios. From the public's perspective, the response time begins when the appropriate authorities are notified of a fire incident. The community then assesses the efficiency or inefficiency of the fire service in relation to the response time, used to remedy the situation. Delayal in response time results to a flashover, accounting for increasing number of deaths and loss of properties. To avoid the impact of flashover, it is prudent to adopt fire service response time, regulated by service standard.

Response periods (time taken) have been identified as a measure of emergency performance. Within the context of emergency response, the rate taken to complete various mitigation activities varies. For instance, time is taken to respond immediately to distress calls, reaching out to emergency scenes, time to extinguish fire, time to execute the operation, time to leave the emergency scene, time to return to the fire station among others. Here, it is assumed the shorter the duration taken by service providers to respond to emergencies, the better their performance in the execution of tasks. [13] outlined some reflex time sequence for managing fire. These sequences composed of:

Dispatch time: The duration required to receive and process an emergency call;

Turnout time: The duration from when units acknowledge notification of the emergency to the beginning point of response time;

Response time: The commencement period where units are en route to the emergency incident and end when units arrive on the scene;

Access time: The amount of time required for the crew to move from where the apparatus stops to where the emergency exists; and the amount of time required for fire department units to set up, connect hose lines, position ladders, and prepare to extinguish the fire.

We sought to establish a geographic information system (GIS) based fire emergency response for GNFS where maximum coverage and time places a crucial role. ESRI termed GIS as a computer-based technology that links geographic information (location of objects) to descriptive information (what the objects entail or look-like) [2,13]. GIS enables users to visualize, manipulate, analyze and display spatial data by linking maps to databases. In the case of fire emergencies, GIS facilitates accurate location of the fire incident, fire hydrants in the area and access to the shortest routes, aimed at reducing emergency response time. Examples of GIS map layers that fire departments use are streets, fire hydrants topography, fire station location, satellite or aerial imagery, fire demand zones and public occupancies [2]. Interestingly, GIS is a useful tool for efficient and effective use of geographic data.

1.1 Application of GIS in Facility Location

According to the Webster's Dictionary, location can be termed as a position in space, and an area marked off for a specific purpose. Contextually, a location problem would involve identifying a specific position or place for a specific function. There are several common types of location problems, associated with GIS. The most common type involves the measurement of where something exists. Given adequate time, it is possible to measure the location of virtually anything on the earth surface (i.e., *location measurement problem*). The second type involves the search for an appropriate location for an activity (i.e., *locational search problem*). It is common to refer to the locational search problem as a facility location problem. This type of problem can involve the placement of one activity (*for instance; a retail store*) or the placement of a set of interrelated facilities (*Example: fire stations to serve an urban area*). Such problems are considered as single and multi-facility location problems. The problem of optimal facility location when applying GIS has also been extensively studied. [14] applied GIS to determine the location and subsequent allocation of emergency response vehicles in Iowa in the United States. The authors used GIS to estimate and compare response times

between a proposed site and an actual response time for existing sites.

Several authors have suggested some initial factors that need to be considered prior to conducting any analysis of a potential fire station site is the development of response time standards. This is often done by conducting time analysis with GIS software. The response time standard serves as a base for selecting better potential sites before considering other factors. [15] meticulously reviewed several studies linking GIS and facility location. He concluded that GIS has the ability to support a wide range of spatial queries that aid optimum allocation of a location. By and large, the primary importance of GIS application in all forms of emergency service operation is to reduce response time, especially for emergency case scenarios [16]. The delay between the fire brigade's departure and arrival on the scene of the fire incident is a key indicator of service operational effectiveness and efficiency.

1.2 Problems Related to Maximum Coverage

Facility location problems involve the location of facilities to economically serve clients and the citizenry. The objective of the optimization problem is to choose a subset of locations at which to place facilities to minimize the cost of serving clients. The objective of the set covering problem is to minimize the cost of a facility location to obtain a specified coverage level (i.e., reachability from a location to a client), as discussed by [17]. Although the set covering determines the number of facilities needed to guarantee 100 percent coverage, a decision maker's allocated resources may be insufficient to construct all the facilities that the model determines. Location goals must then be shifted to maximize the coverage the available resources can provide. This is however known as the maximal covering problem [15]. As a variant of the set covering problem, the maximal covering problem seeks to maximize the amount of demand covered within the acceptable service *S* by locating a fixed number of facilities. The main difference between the two problems is that all demand must be met (covered) in the set covering problem, whereas some demand may be left unmet (uncovered) in the maximal covering problem [4,16].

Over the past few decades, Ghana has been plagued by increasing and disastrous fire emergencies. The Ghana National Fire Service (GNFS) was established across several cities to educate the general public on fire safety and prevention measures, as well as combating emergency fire outbreaks that may hamper lives and several properties. Fire outbreaks are recurrent and costly to the state. Fire incidents exacerbate poverty in the country as several people lose start-up capital or income, personal properties along with other health implications. The country recorded a total of 1,986 fire incidents in 2006 [18]. In 2013, Ghana recorded a total of 2,201 fire outbreaks in the first quarter alone, with an estimated loss of USD $8 million dollars' worth of properties [19,20]. Presently, most areas within the central business district areas have suffered the most frequent fire outbreaks. Citing instances like; the Accra Kokomba market fire in April 2014, which destroyed over 5000 stores rendering more than 700 persons jobless [20]. In Kumasi, which is considered the largest open-air market site in West Africa [21], about 300 shops were razed down by fire in February 2014, leaving more than 500 traders jobless [22]. The complete loss of the Central Medical Stores (CMS) in Tema in 2015 [23] is an excellent example of the financial and human health costs of Ghana's urban fires. Such disasters affect cost as well as operational capabilities of the health and pharmaceutical industry. The Ghana National Fire Services (GNFS) was widely blamed for poor emergency fire response. Some attributed the failure to overcrowding and traffic congestion which make the movement of fire trucks and personnel extremely difficult. GNFS enumerates many challenges including inadequate numbers of personnel and insufficiently equipped fire trucks, unreliable water supply, poor placements and non-existent fire hydrants, coupled with outdated emergency communication infrastructure. A significant reduction in the number of fire outbreaks and the corresponding damages will require a multi-faceted approach.

Despite the frequency, severity and cost of fire outbreaks, limited scientific research exists on the problem. In the event of a fire outbreak, effective control depends on the ability of the GNFS to respond within the shortest possible time with the right equipment (functional fire trucks with fire retardants and so on), and well-trained personnel with access to timely information regarding the geographic location of fire incidents. [24] identified the optimal route from existing fire stations to any fire event as well as the closest fire hydrants. By allowing queries

to locate the closest fire hydrants, the study provided one important tool for improving fire response in Ghana. However, their study did not evaluate the efficiency of the current system of fire service stations to geographical coverage. We examined the geographic distribution of existing fire stations in the Accra Metropolitan Area (AMA). The present study sought to evaluate the spatial coverage for each fire station under predefined response times. The rationale behind this study was to assess how GIS applications can be used to effectively manage emergency cases or fire incidences. Prudent management of fire outbreaks using geospatial techniques could go a long way to minimize casualties, save lives and properties, among other benefits. Therefore, the present study attempted to answer the following research questions: (i) What is the geographic coverage of fire stations in Accra Metropolitan Area? (ii) What are the locations of sources of water in the study area? (iii) In what way can the reporter and fire service be integrated for effective fire response.

2. MATERIALS AND METHODS

2.1 Study Area

The Accra Metropolitan Area (AMA) is located between longitude 05°35'N and on latitude 00°06'W. The area extends about 25km from the east to the west and about 12km from the north to the south. It is the regional capital of the Greater Accra Region serves at the capital of the Republic of Ghana. AMA has a total land area of about 139,674 square kilometers, bounded with Ga South Municipal to the West, La Dadekotopon Municipal to the East and Ga West Municipal to the North with the Gulf of Guinea at the South according to the Ghana Statistical Service [25]. The AMA is entirely urban. Presently, the population of the study area stands at 2,514,005 according to the GSS 2020 Annual Report.

The Accra Metropolitan Area is the economic hub of the Greater Accra Region and the rest of the country. It hosts manufacturing industries, oil companies, financial institutions, telecommunication units, tourism, education, health institutions, among other key establishments. Residents in the city are engaged basically in the primary, secondary and tertiary sectors of the economy. Predominant activities in the study area constitute trading, construction, fishing, farming, service industry, manufacturing among others. The indigenous people until recently were mostly engaged in fishing and farming [25].

2.2 Methodology

2.2.1 Data collection

This research made use of questionnaires to survey the perception of the general public in the AMA regarding fire incidents. Data from the questionnaires were analyzed using SPSS (version 16.0). A sampling size of 420 (constituting the general public and GNFS personnel) was designed for this study. The target population constituted shop owners, traders/market women, retailers and wholesalers, landlords, health and financial personnel, electricians and so on. Tesano, North Kaneshie, Mamobi, Korlebu, Kanda, East Legon and Adabraka were the selected areas, used for the study due to the recurrent incidence of fire cases recorded in these areas. Secondary data was acquired from the Remote Sensing and Geographical information system laboratory of the University of Ghana.

2.2.2 Secondary data

Data on fire incidents for the year 2018 was obtained from the RSGIS lab. The fire incidence for the Accra Metropolitan Area was then extracted. The Ghana shapefile data acquired from RSGIS Lab's website was used to extract the region of interest (ROI), thus, Accra Metropolitan Area. The coordinates for the fire service stations in AMA was retrieved from the RSGIS website and mapped.

ArcGIS 10.6 was used to perform proximity analysis (multiple buffer), coupled with the generation of other topographical maps. Web ArcGIS was used to develop a web application that links the reporter to the fire service. Statistical Package for the Social Sciences (SPSS) software version 16.0 was used to present results using descriptive statistics against the causes of fire incidents as well as areas, susceptible to fire incidents in AMA.

2.3 Data Analysis

Data on fire incidents, water sources and the location of fire stations were imported into ArcGIS 10.6 (Arc map). Resultant maps were created to visualize the data. Upon generation of the maps, proximity analysis was conducted to determine the distance of various fire stations to

the nearest town or location. The multiple buffers in the proximity analysis tool were used. Here, each ring in the buffer indicated fire stations that were located within/away from the 2km radii.

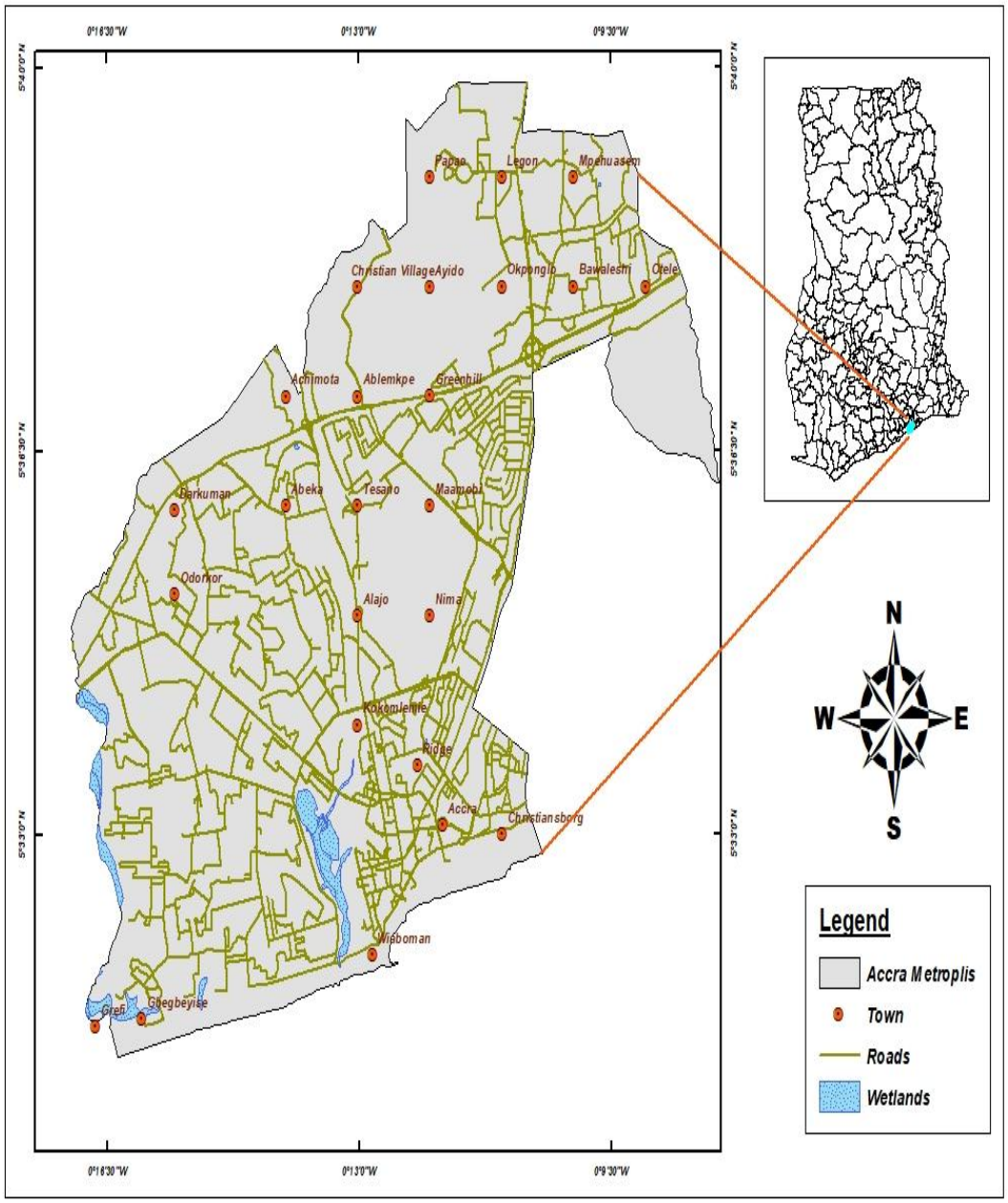

Fig. 1. Map of the study area: Accra Metropolitan Area (AMA), Ghana

Table 1. Description and type of datasets used for the study

Type of Data	Acquisition Date	Source
District Boundaries	N/A	RSGIS lab's website
Water coverage	2016	Town and country planning unit
Fire incidents	2018	RSGIS lab's website

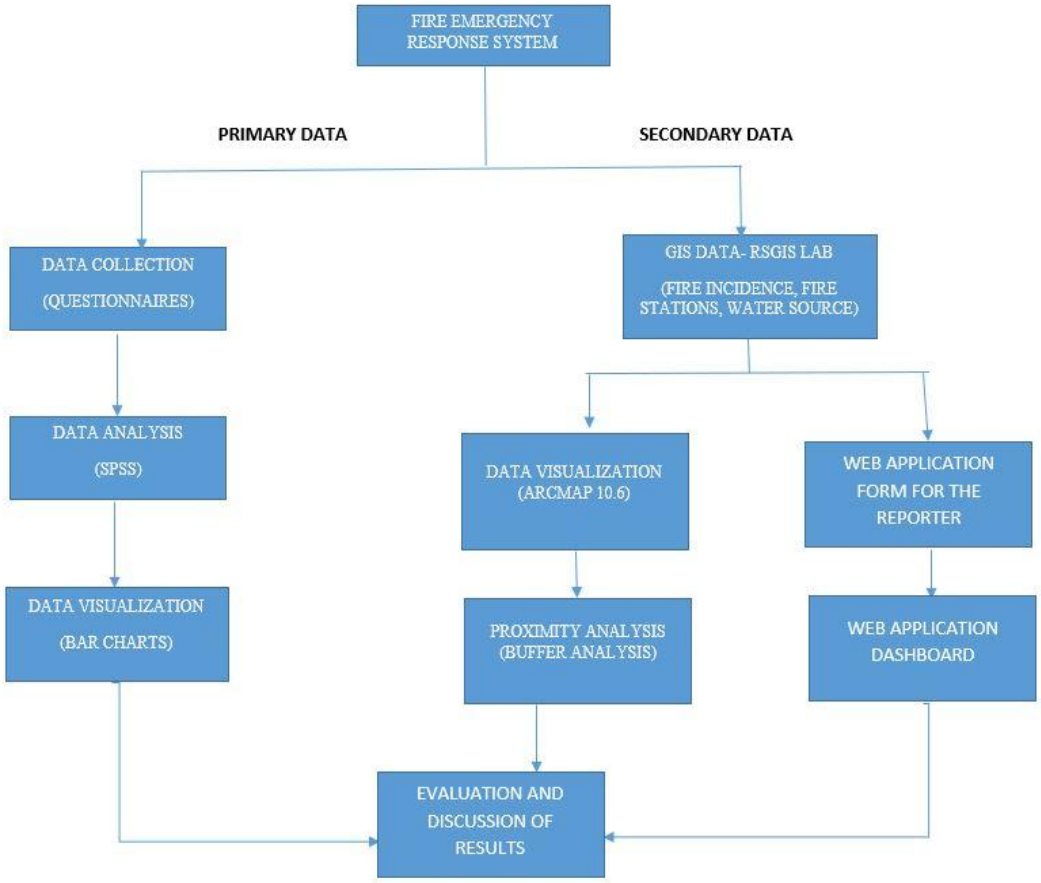

Fig. 2. Flow diagram and framework for the study

2.3.1 Web application

ArcGIS 10.6 was used to design the map for the web application. The AMA shapefile was imported into arc map. An attribute table was created for the map with the fields (reporter name, community, risk magnitude, area class, thus, residential, commercial, industrial and so on as well as reporting time and status). These fields help the reporter key in important details of the fire incident. The town's shapefile was overlaid on the AMA shapefile and then imported into ArcGIS web. ArcGIS web application was used to create the web application form which links the reporter and the fire service station dashboard. This helps the reporter key in important information or attributes of the fire incident's location. The dashboard was also created in the web application to collate all the reports from the field. It is hosted by the fire station and constitutes real-time report location map which includes optimal routes to the incident location from the fire service station and the status of the fire, thus, if extinguished or not.

3. RESULTS

3.1 Demographic Characteristics of Respondents

The distribution below (Table 2) presents the demographic characteristics of respondents in AMA. It is evident that 20% of respondents had an age range between 10-20 years; fifty percent of respondents, constituting 210 people had an age range of 21-30 years. On the other hand, 30% of respondents were above the age of 30 years. In terms of educational status, most of the respondents somewhat had attained high school education, with few being considered as illiterates due to their inability to read and write. 10% of the respondents had no formal education; five percent had basic (primary) education; 55%

had attained high school education whereas thirty percent had obtained tertiary education. Based on these findings, it could be concluded that most respondents were literates. Additionally, it can be observed that a greater number of respondents lived in North Kaneshie, Mamobi, Korle-Bu and East Legon, whilst the least number of respondents lived or worked at Tesano. The demographic characteristics of respondents are presented in the table (Table 2) below.

The illustration (Fig. 3) below depicts some common causes of fire, revealed by respondents within the selected communities of the study area.

Table 2. Biodata of respondents in AMA

Variable	Frequency (n=420)	Percentage (%)
Age		
10-20	84	20
21-30	210	50
31-40	84	20
Above 41	42	10
Educational status		
No formal education	42	10
Basic Education	21	5
Senior High School	231	55
Tertiary Education	126	30
Respondents' location		
Adabraka	50	11.9
East Legon	60	14.3
Kanda	50	11.9
Korle-Bu	60	14.3
Mamobi	60	14.3
North Kaneshie	100	23.8
Tesano	40	9.5
Internet users		
Yes	39	9.3
No	381	90.7

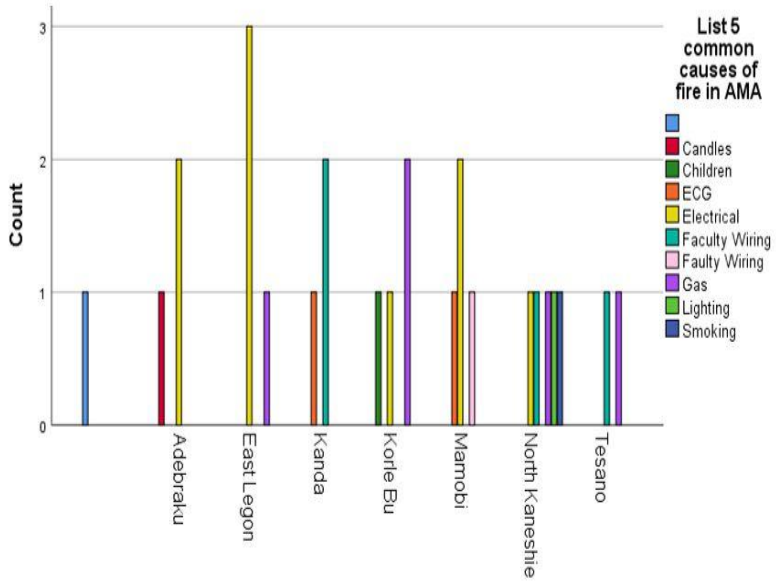

Fig. 3. Causes of fire outbreak in the study area

3.2 Reporting of Fire Incidents to Emergency Agencies

The illustration (Fig. 4) below shows respondents' preferred mode of contacts during emergencies in the event of a fire outbreak. It is observed that the respondents from Mamobi preferred to report fire incidents to the police service rather than the fire service. Residents in this community asserted the police service responded to emergency calls faster than the GNFS.

3.3 Distances between Fire Stations and the Areas in AMA

The buffer tool in ArcMap was used to create buffers, illustrating areas close to the various fire stations using the multiple ring buffer tool in the analysis library (Arc toolbox). It is observed that most of them fell within the 2 km radii from the fire stations. Also, some of these locations were 6 km away from the fire stations as shown in the figure below:

4. DISCUSSION

4.1 Common Causes of Fire

Respondents were required to list and rank 5 causes of fire. Faulty electrical wiring ranked first among a list of other causes as the main cause of fire outbreak among the selected communities used for this study. Leakage of gas placed second followed by candles left unattended to or placed near combustible materials, ECG (i.e., fluctuations in voltage/power during the transmission process) and so on. [7] reported that 75% of fire outbreaks in Ghana are caused by smoking, with 10% attributed to accidents and 15% to ignorance. [8] argued that poor electrical materials and appliances are the main causes of fire outbreaks in Ghana. Personnel from the GNFS who were interviewed advised against children playing with candles or candles being left unattended or placed near combustible materials, mobile phones should not be brought to the kitchen where there are inflammable substances. In recent times, improper installation of electrical wiring and faulty appliances has led to an increase in fire outbreaks. This could be attributed to inexperienced or unqualified people who underwent in-service training. Smoking materials, lighted tobacco products, mostly cigarettes are the leading cause of fatal fires. Typically, abandoned or discarded smoking materials ignite trash, mattresses and bedding, or upholstered furniture, with the majority of fatal smoking-related fires starting in the bedroom, living room, family room or den. Unattended cooking represents another common cause.

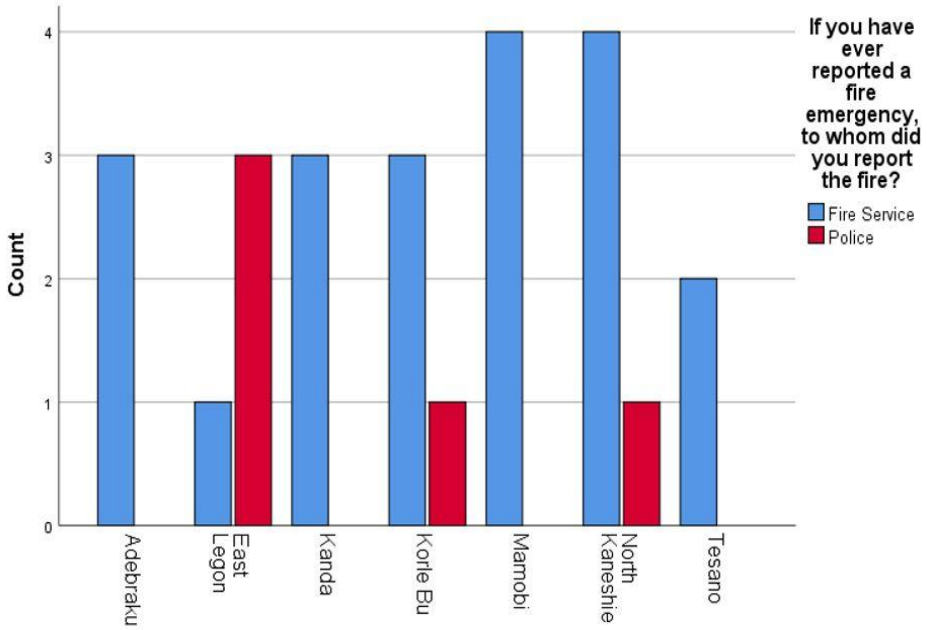

Fig. 4. Reporting fire outbreaks to state institutions

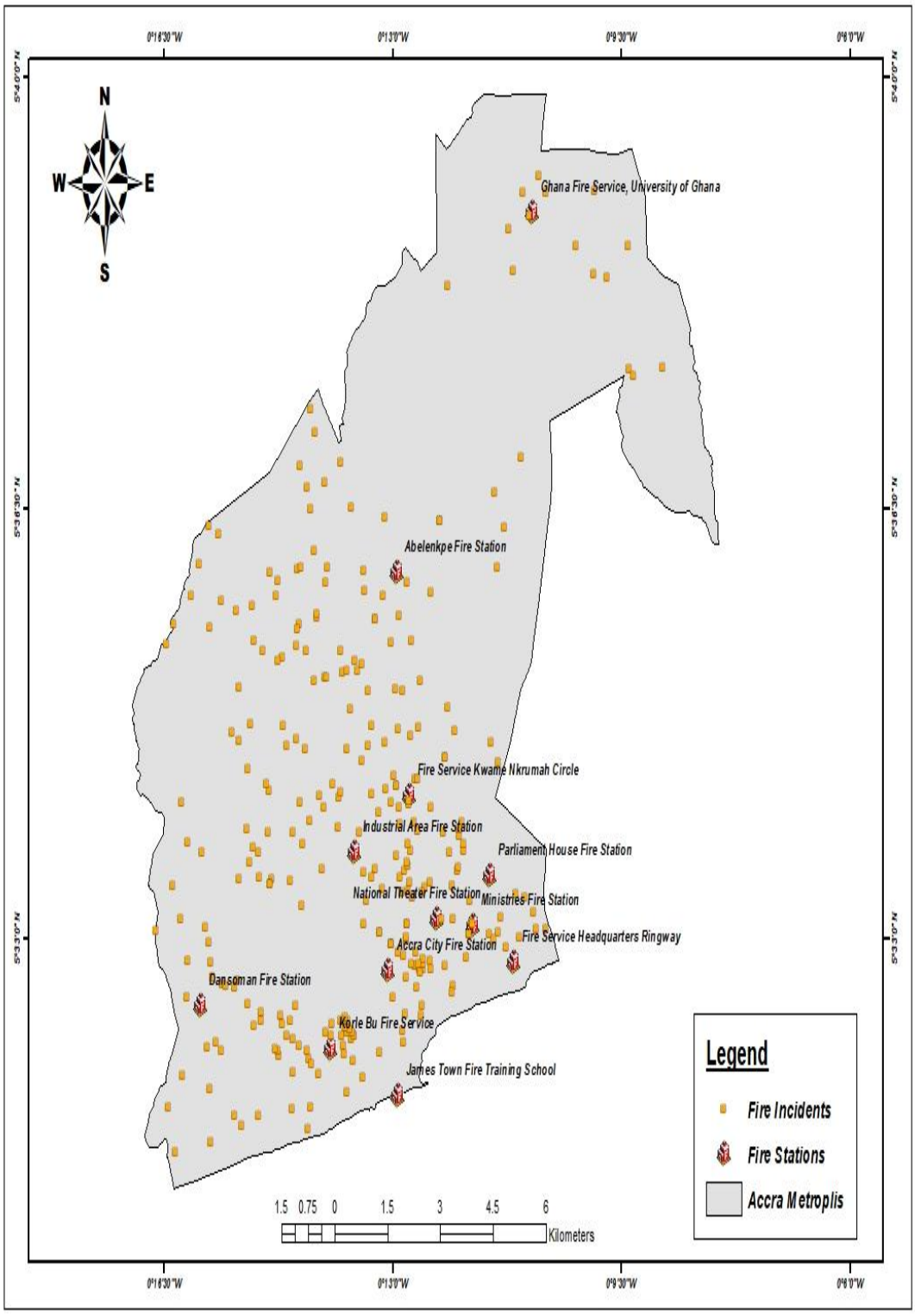

Fig. 5. Recorded fire incidents in 2018, and their proximity to fire stations in AMA

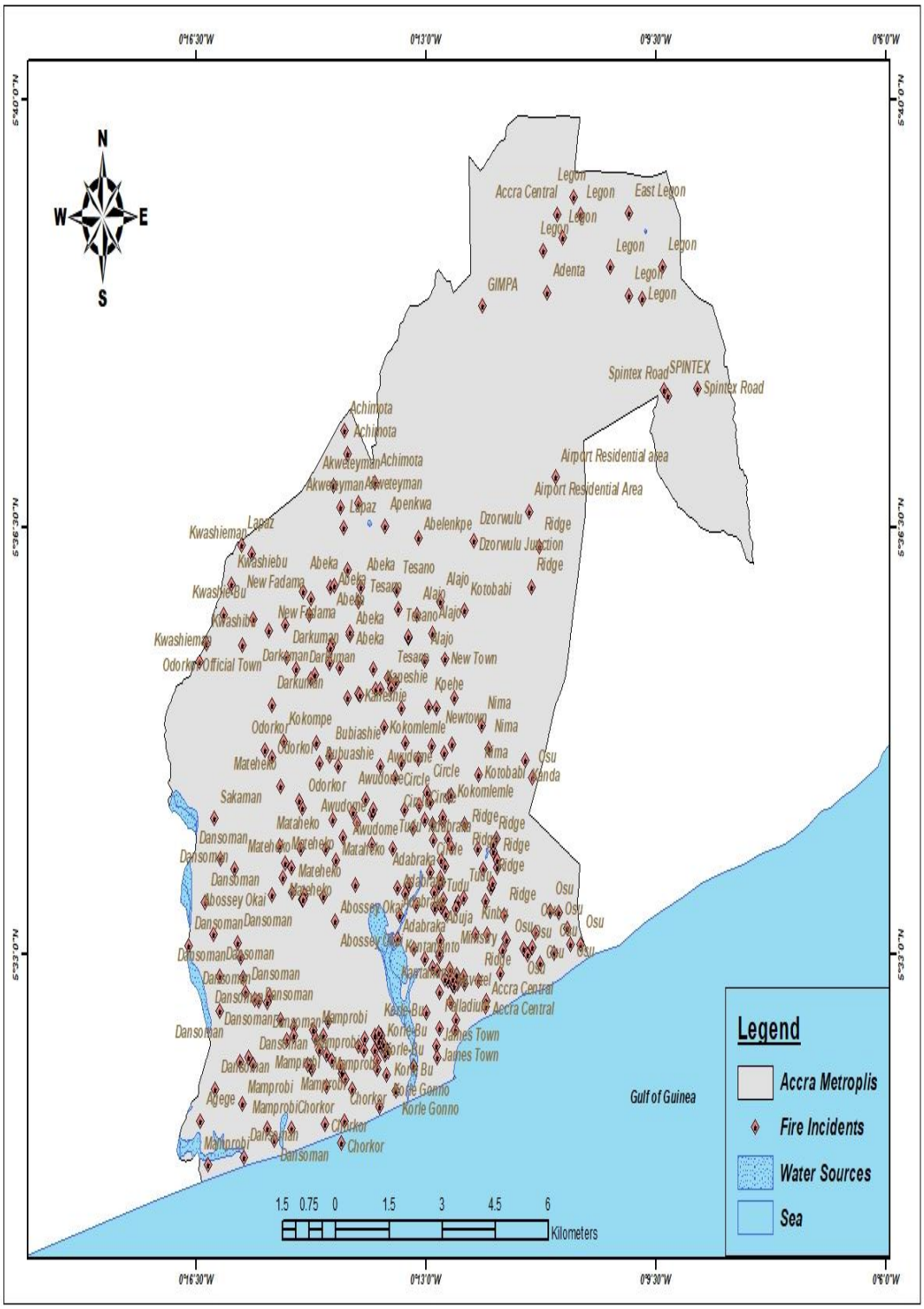

Fig. 6. 2018 recorded fire incidents in emergency zones, and their proximity to water sources

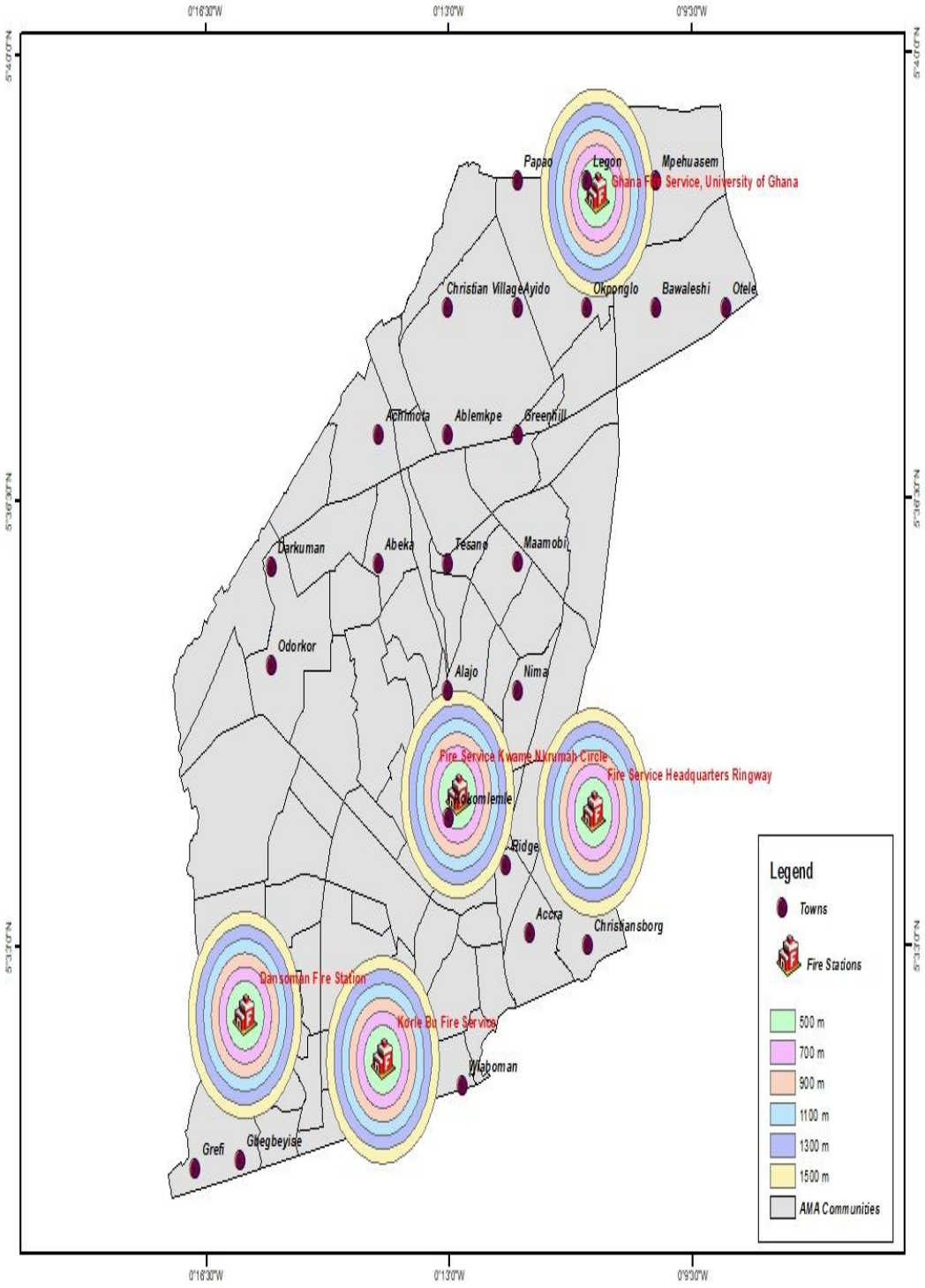

Fig. 7. Distance between fire stations and communities in AMA

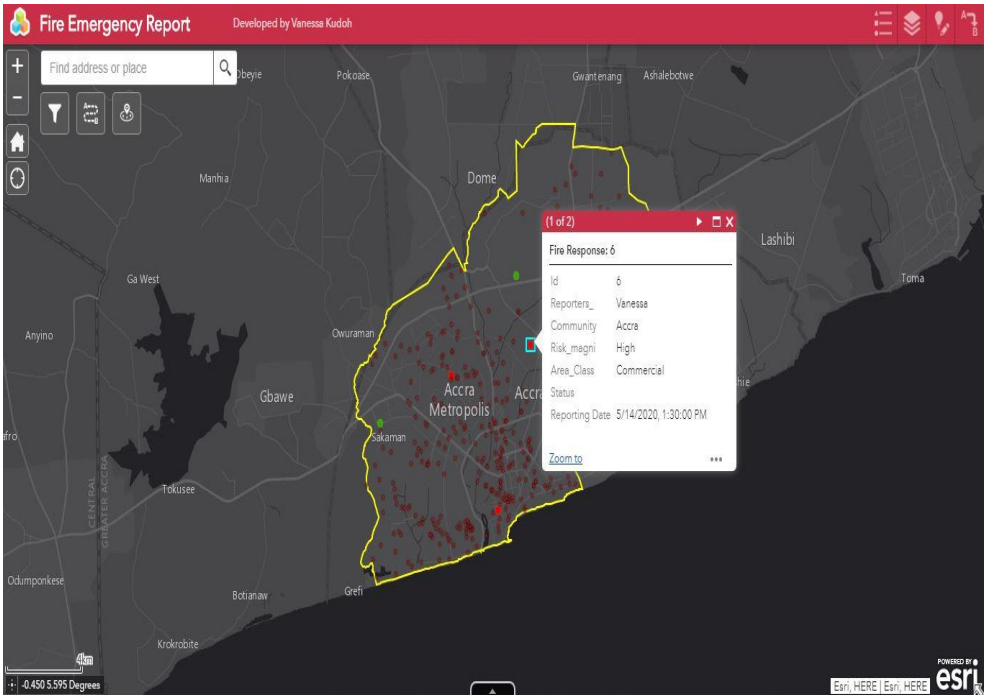

Fig. 8. Web based application for emergency fire response

People get distracted by children, pets or visitors, sometimes forgetting that they left food on fire. There is no safe period to leave cooking unattended. The level of carelessness or negligence displayed by most citizens is alarming. GNFS periodically hold programs to sensitize the public on the causes of fire outbreaks along with some safety and protective measures during emergencies.

4.2 Fire Emergency Response

According to GNFS, the standard time for responding to emergency cases, related to fire incidents is 4 minutes. Personnel from the GNFS interviewed across the various stations in the selected communities admitted their inability to meet the said response period. They asserted that the average response time during emergencies ranged between 10 and 15 minutes. In contrast, the general public argued the said period stated by the GNFS was untrue, stating it takes over 20 minutes for the GNFS to arrive at a fire incident. The GNFS attributed delays to poor road networks, inaccessible routes, inaccurate locations and the problem of maximum coverage. They further revealed that they largely depend on reporters for locations. Therefore, inaccurate information or reportage often resulted in delays or failure to meet the expectation of the general public. When asked why GPS was not applied to track or spot locations, they revealed they had not been educated in the use of such applications. Additionally, they asserted only most of their stations had no GIS platforms except the national headquarters that seeks to introduce such applications across fire stations in the country. The GIS application was initially introduced to some officials who by observation, had neither heard nor seen such application. Moreover, officials who recognized the GIS application revealed the GNFS currently does not employ GIS in its emergency response although they look forward to it in the near future. Fig. 8 shows a web application that facilitates accurate information given by reporters to the fire service, in the event of a fire outbreak.

4.3 Fire Incidents in 2018 and their Proximity to fire Stations in AMA

The figure (Fig. 5) below illustrates areas, ensigned with fire incidents and fire stations as at 2018. It could be observed that the southernmost part of Fig. 5 is enshrined with fire stations as compared to the north zone. Here, the fire incidents in the study area show most communities lack quick access to fire stations due to their proximity (distance) to these units

coupled with traffic congestions which hamper responses. This resulted in more lives and properties, destroyed as a result of fire incidents, recorded in 2018. The concentration of fire stations is not evenly distributed across the Accra Metropolis as depicted in the figure above. Some areas within the Metropolis like Odorkor, Darkuman, Glefe and Gbegbeyise are deprived of fire stations whilst areas like Adabraka, Osu, Ridge, East Legon, Cantonments among others have more stations (highly localized). The uneven distribution of fire stations results in coverage problems. Fire stations tend to travel long distances (usually beyond 20km) to reach fire incidents. This influences response periods, thereby amplifying causalities and properties. For instance, the fire stations at the University of Ghana fire service and Ablemkpe travel as far as 6km to reach areas such as Odorkor and Darkuman due to traffic congestion and road inaccessibility. It often takes more than 30 minutes to reach such locations during an outbreak. There are also communities with maximum coverage yet experience fire outbreaks.

4.4 Fire Emergency Zones and their Proximity to Sources of Water

Figure 6 shows areas with fire incidents within the selected communities in the study area. Since such communities lack quick access to fire stations due to their proximity to the nearest fire station, coupled with traffic congestions. Lives and properties worth millions were lost to the fire incidents recorded in the 2018 report. Fig. 6 shows recorded incidents in various emergency fire zones and their proximity to water. Fig. 6 shows only few areas have access to water sources. These areas are the coastal areas (southern areas) as compared to the central and northern part of the study area. Proximity to a waterbody is essential during the extinguishing process.

4.5 GIS Web Application Integrating both the Reporter and the fire Service for Effective Fire Response

The present study developed a GIS web application (Fig. 8) that integrates reporters and the various fire stations within AMA for efficient and effective response to emergency incidents. Education plays an instrumental role in the successful implementation of GIS web-based application. Literacy rate in Ghana in the year 2000 stood at 57.9% according to [25]. The rate increased to 71.50% in 2010, further rising to 79.04% in 2018 according to [26]. The rate is projected to increase further based on several policies and investments, initiated by the Government of Ghana since the year 2000. For instance, implementation of the Capitation Grant, delivery of free school uniforms and sandals, provision of free text books, construction of Community Day Senior High Schools among others. Additionally, the introduction of the Free Senior High School policy has significantly improved enrolment at various levels in Ghana's basic educational system. Considering the threshold or people engaged in this study in the selected communities where fire incidents are recurrent, the distribution above (Table 2) shows respondents (90%) had attained some level of education. Hence, once this system is implemented, a large section of the citizenry if not all, have the needed capacity to operate or report emergency cases using the web-based application. Moreover, access and availability of internet services are key towards the implementation of this platform. Internet users according to World Bank data [27] rose from 0.83% of Ghana's population in the 2002 to 39% in 2019. The current rate is projected to rise further between 46%-48%.

Despite the constraints through distances to emergency zones, poor transportation networks and traffic congestions, the web application presents a proactive opportunity to minimize direct and indirect consequences that may emanate from fire outbreaks. The reporter initially makes an early report using the mobile Arc collector by providing relevant details which include the location, class of residence, magnitude of the fire and other useful information. The information provided upon submission is displayed on a dashboard at the national or regional level. The information presented is then forwarded to the nearest fire station, providing quick and accessible routes among other details to remedy the situation. The system adopts a top-down approach to information dissemination during an emergency scenario during the initial stage in the emergency response or management process.

5. CONCLUSION

The present study assessed the geographic distribution of existing fire stations in the Accra Metropolitan Area (AMA). It further sought to evaluate the spatial coverage for each fire station

under predefined response times. The rationale behind this study was to assess how GIS applications can be used to effectively manage fire outbreaks. Findings revealed the application of GIS in response to fire management significantly improves response time. It equally serves as an essential tool for reducing causalities as well as damaged properties. Results proved a response time of 15 minutes is feasible in the study area if the proposed strategy is adopted. Nonetheless, additional time of preparation (5 minutes) may be required for effective service delivery. Findings show fire service trucks or vehicles at a speed of 80 km/h would be appropriate to provide services over the entire study area. In addition, an emergency fire service delivery plan/strategy was developed. Findings illustrated in this study can be implemented extensively by all fire service stations across the country. In this study, we further proposed suitable maps and web applications to facilitate firefighting operations in inaccessible parts of the study area. This adaptive measure would enable fire fighters to gain access to inner communities to avert consequences incurred from fire incidents. Proximity and an accessible road network were designed to locate/determine the fastest routes to fire spots and service areas at a specified period and distance (speed). We recommend an improvement in existing road networks in the study area. This in effect, would effectively realize the full prospect of the mitigation measures, proposed in this study. Due to pressure on existing fire service stations, the Government of Ghana should site new fire service station in areas such as Odorkor and Darkuman for quick and easy fire response time, aimed at solving the problem of long-distance coverage. The Ministry of Interior (MoI) and Ministry of Finance (MoF) should allocate funds for the integration of geospatial technology for effective fire emergency response across the country. A comparative study could be carried out to compare and contrast handling of fire outbreaks with or without GIS applications.

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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