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Vulnerability Assessment of Spatial Distribution of Filling Station on the Environment in Gombe Metropolis Gombe State Nigeria

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ABSTRACT

The study analyzed the effects of spatial distribution of fuel stations on the environment in Gombe Metropolis, Nigeria. The coordinates of fuel stations were collected and analyzed using ArcGIS 10.1 to determine their spatial distribution and compliance with the Department of Petroleum Resource (DPR) standard. The results of the Nearest Neighbour Analysis showed a strong clustering of filling stations, with a mean distance of 281 meters between filling stations, which is less than the expected mean distance of 593 meters. There is a strong clustering of fuel stations within a distance of 400 meters, with 78 out of 84 fuel stations located within 400 meters of each other. Only 7.14 % of fuel stations are located at a distance greater than 400 meters. The study further indicated that the majority of the fuel stations (71 %) are located within 30 meters of residential areas which poses serious health risks. The clustering of fuel stations and their proximity to residential areas, and road networks can lead to traffic congestion, air pollution, fire hazards, and accessibility issues. The results of the study suggest that policymakers need to ensure that fuel stations conform to safety regulations set by DPR for sustainability.

Keywords: Vulnerability; Fuel station; Spatial distribution; Hazard.

INTRODUCTION

Fuel are primarily hydrocarbons containing Volatile Organic Compounds (VOCs) such as benzene, some of which are harmful and injurious to humans if in contact with skin and as well as exposure to it. Exposure to VOCs was reported to cause asthma, headaches, and mucosal symptoms (Steinemann, 2008; Ahmed *et al.,* 2014; Okwudili *et al.,* 2021). With oil products, residential areas close to fuel stations are at risk of fires, increased traffic, noise pollutants, waste, and wastewater pollution (Ioja *et al.,* 2010; Okwudili et al., 2021). Further, VOCs negatively affects the earth's biosphere, causing pollution and greenhouse gases emission into the atmosphere as well as destruction of ecosystem through oil spillage (Ahmed *et al.,* 2014; Okwudili *et al.,* 2021). The safety of lives, properties, and protection of the environment is therefore of major concern revolving around the petrol stations. Land-use activities along arterial highways are not been controlled and coordinated in certain large Nigeria cities, the area is vulnerable to risks such as traffic jam, pollution, accidents, fire explosions, and other environmental issues (Okwudili *et al.,* 2021).

In developing countries like Nigeria, the fast expansion of built-up and gas stations in mostly residential neighborhoods is alarming and raises concerns for a sustainable environment in addition to violations of land use agreements and environmental aesthetics (Amakiri-whyte *et al.,* 2021). Because of the continuous discharge of dangerous chemicals into the environment, this development has resulted in an increase in air pollution. Gasoline distribution to stations, tank

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breathing from temperature and pressure changes during vehicle refueling, emissions from loosely closed tanks, and leak damage from improper petroleum handling are some of the origins of these emissions (Isabel *et al.,* 2010).

According to Ayodele (2011) and Okwudili et al. (2021), filling stations are major cause of traffic issues such pollution, fire explosions, and traffic congestion in heavily urbanized areas. The variables, such location, size, and setback from the road, among others, determine how severe the problems. Unplanned growth leads to a number of risks, including pollution, traffic jams, and many other issues. This is due to the fact that physical conditions can influence the kind of business that is performed, but they can also have an impact on how well the firm performs. The necessity to comprehend the spatial distribution of the numerous filling stations in the Gombe metropolis served as the impetus for this study. What, where, and why are questions that geography had since the time of Eratosthenes, or the beginning of geography , been asking and can only be answered by conducting a thorough inquiry. The aim of the study is to evaluate the environmental effects of filling station distribution in relation to Department of Petroleum Resources (DPR) regulations in Gombe state, Nigeria..

MATERIALS AND METHOD

Study Area

This study was carried out in the Gombe metropolis located between latitude 11°4'0'' - 11° 14' 0N'' and Longitude 10°15'0'' - 10°20'30E''. It shares a common boundary with Akko L.G.A on the South Yalmaltu-Deba to the East and Kwami to the North. It occupies a total land area of about 56 km^2 (Figure 1). According to Koppen's classification of climate, Gombe state is classified as AW or tropical wet and dry climate. Gombe is located within the sub-Sudan climate zone.

Gombe metropolis is located within the lower Benue trough which is surrounded by the Pre-Cambrian complex to the east and south. The soil of the Gombe metropolis is the tropical ferruginous type (Abashiya *et al.,* 2017). Gombe is also a commercial hub for the Northeastern region of Nigeria, with a vibrant market for the exchange of goods and services. The state has several markets, including the Gombe main Market, Kumbiya kumbiya, and Pantami markets. Gombe have significant deposit of gypsum, which is used in the production of cement.

Methodology

A reconnaissance survey was carried out in the study area to familiarize the researcher with the area. Primary data used for the study were coordinates of filling stations and fire stations in the Gombe metropolis. Secondary data were obtained from other published sources; such as text materials, archives, theses, maps, online materials, articles, and journals which were all used to complement the already obtained primary data. GIS and statistical methods were used to analyze the locational information of filling stations in the metropolis. The GIS methods included Nearest Neighbour Analysis (NNA) and proximity analysis i.e., Buffer and Kernel-Density Analysis, while statistical methods such as simple descriptive statistics was used.

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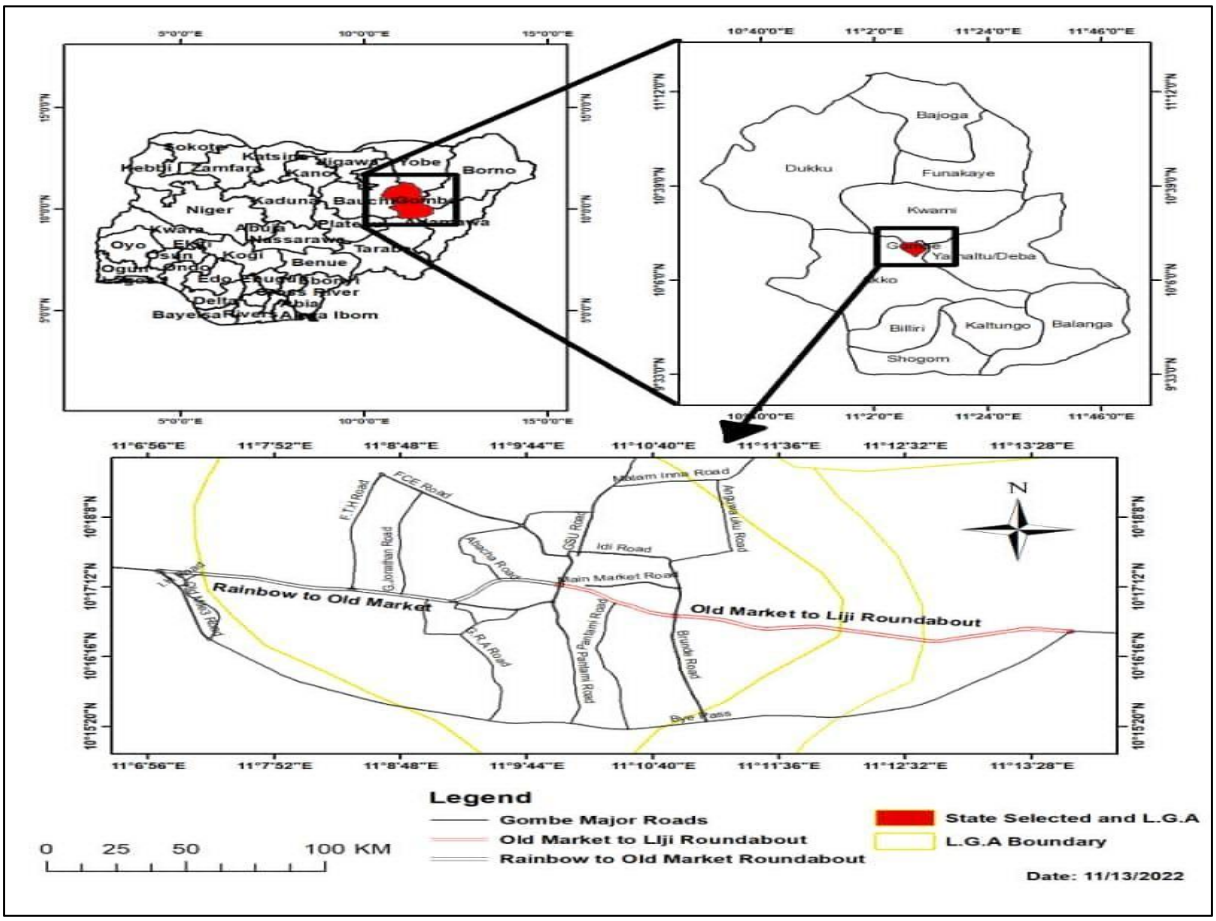

Figure 1: Map of the study area.

RESULTS AND DISCUSSION

Spatial Distribution of Filling Stations

The result of the spatial distribution of the 84 fuel stations in the Gombe metropolis showed that the fuel stations are not evenly distributed (Figure 2), rather they have a clustered distribution pattern given the z-score of 9.233 which is less than the critical normal z-score distribution. As observed in Figure 2, the distribution of filling stations in the study area is more concentrated on the western part of the study area as one moves from the Jekadafari area around the center of the study area towards Tunfure settlements. The z-score of -9.23 and the p-value of 0.00 in Figure 3 indicate that the observed mean distance and nearest neighbour ratio are significantly different from what would be expected based on chance alone. The negative z-score suggests that the observed mean distance is much smaller than the expected mean distance, and the p-value of 0.00 confirms that this difference is statistically significant. The observed mean distance of 280.82 meters for filling stations indicates that, on average, the distance between filling stations is 280.82 meters. The expected mean distance of 593.216 meters suggests that, based on theoretical or ideal models, the filling stations should be more spaced out than they are in reality. Also, the nearest neighbour ratio of 0.47339 is another indicator of the spatial distribution of filling stations. This ratio measures the degree of clustering or dispersion of the points in a given area. A value less than

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1 indicates clustering, while a value greater than 1 suggests dispersion. In this case, the value of 0.47 indicates strong clustering of filling stations.

The clustering of fuel stations in Gombe may lead to problems such as congestion, increased traffic, localized pollution and fire hazard. This corroborates Cristian and Constantina (2012) and Sulaiman (2019) in the study on buffer analysis and descriptive statistics on the proximity of Petroleum Filling Station (PFS) to residential buildings in the Bucharest suburbs, found that the high concentration of PFSs has led to malfunctions, highlighting a disadvantaged area due to environmental issues, unplanned development, overburdened infrastructure, and pollution of each environment component. Additionally, Olusegun *et al.* (2011) conducted a study on the locational distribution of PFSs and the underlying ramifications in Osun City, Nigeria's commercial density, and found that approximately 56% of PFSs in the area are clustered, which can jeopardize the safety of the region. Okwudili et al. (2021) also reported that in a BBC News of June 5, 2015, about 150 persons lost their life's as a result of fire explosion in fuel station at Accra Ghana due to clustering of fuel station in residential areas.

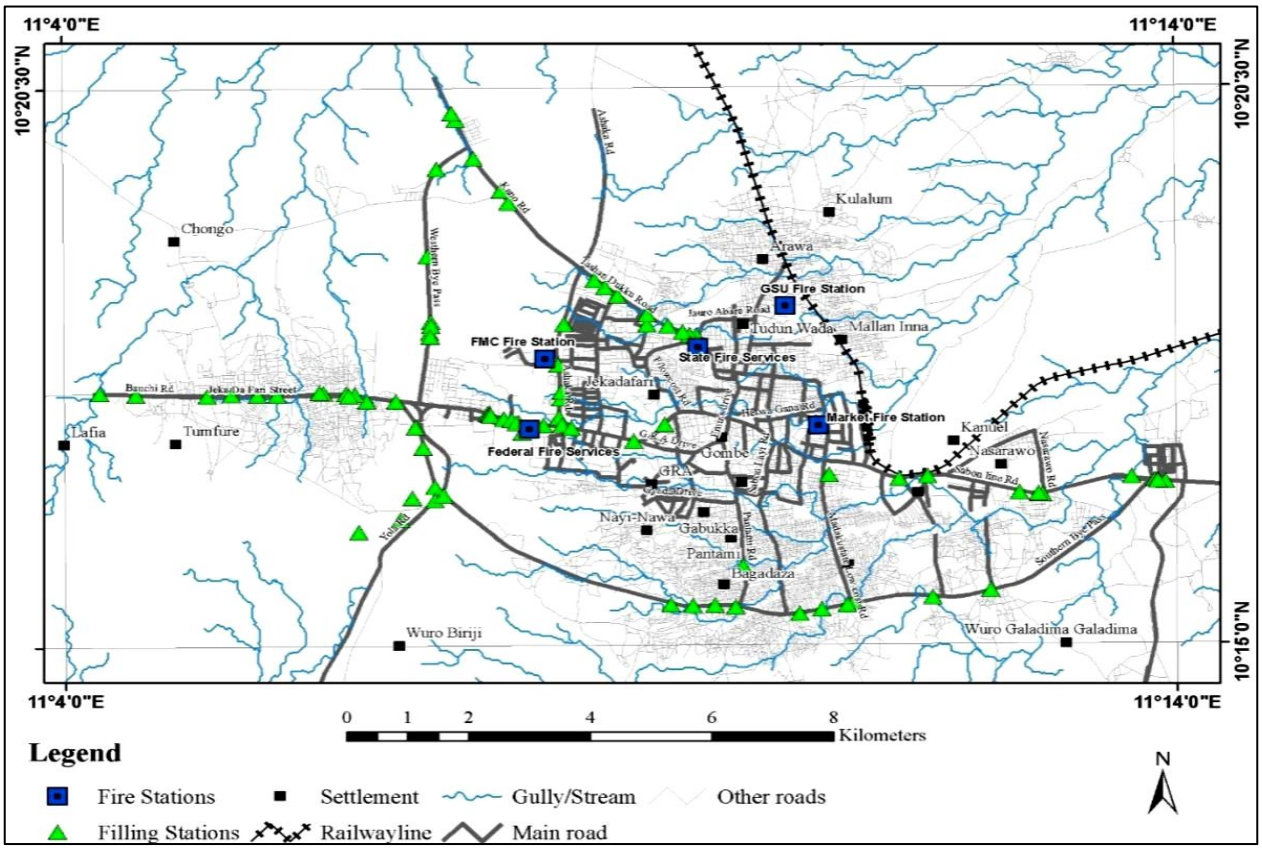

Figure 2: Spatial distribution of Filling Station in Gombe Metropolis.

Standard Distance between Filling Station

The result in Table 1 suggests that there is a strong clustering of fuel stations within a distance of 400 meters. Out of the total 84 fuel stations, 78 of them are located within a distance of 400 meters, which accounts for 92.86% of the total. On the other hand, only 6 fuel stations are located at a distance greater

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than 400 meters, which accounts for only 7.14% of the total. This result also indicated that there is only 7.14% conformity with the regulated standard of at least 400m distance to each other by DPR standard.

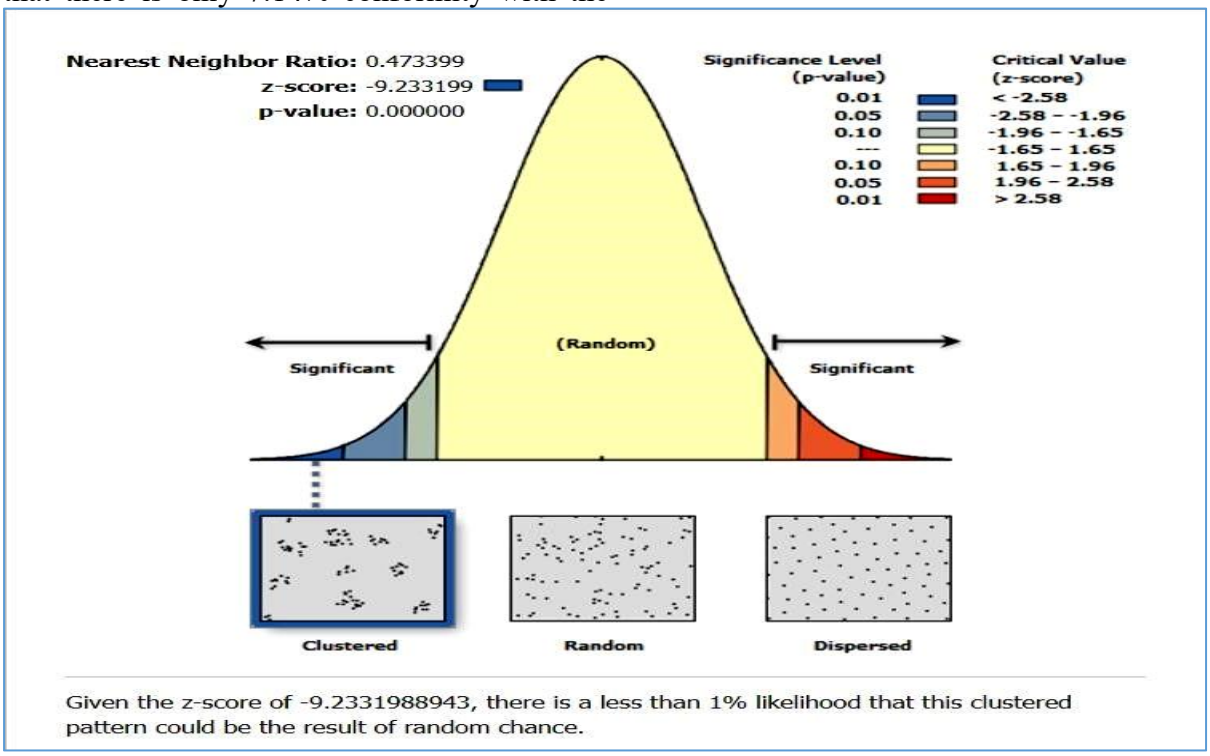

Figure 3: Nearest Neighbour Analysis of Filling Station.

Table 1: Buffer Distance between Filling Stations.

Distance	No. Stations	%
Less than 400 m	78	92.86
More than 400 m	6	7.14
Total	**84**	**100.00**

This clustering of fuel stations as observed in Figure 3 could potentially lead to issues related to traffic congestion, air pollution, and accessibility (Okwudili et al., 2021). For example, having too many fuel stations within a small area can lead to traffic congestion, especially during peak hours. It can also lead to increased air pollution due to the emissions from the vehicles waiting in line to get fuel. The non-clustered fuel stations that conform to the required standard of at least 400m apart from other fuelling stations as shown in Figure 5 are Jiri Brothers, H & H, Anib Baram, Lariski Integration, Jauro Yuguda, and Matrix State Low-cost road. Additionally, clustering of fuel stations in a particular area can also make it difficult for people living in other areas to access fuel stations easily. It could also result in a lack of competition and higher fuel prices in areas where there are fewer fuel stations. According to Ogundahunsi (2019), PFSs were haphazardly spread in Ilesa, Osun State, Nigeria, with some more being built. Filling stations along the road were found to be too close to one another; some were even built side by side, suggesting a greater likelihood of significant and wider impacts on the surrounding area. Furthermore, according to Ahmed et al. (2014), 45% of PFSs in Minna have setbacks of less than 30 meters from the road and residential areas, which is in violation of the Department of Petroleum Resources' (DPR) siting guidelines. Therefore,

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policymakers and town planners need to consider this clustering phenomenon of filling stations in the metropolis and come up with appropriate strategies to ensure that fuel stations are distributed in a way that is both efficient and accessible to all.

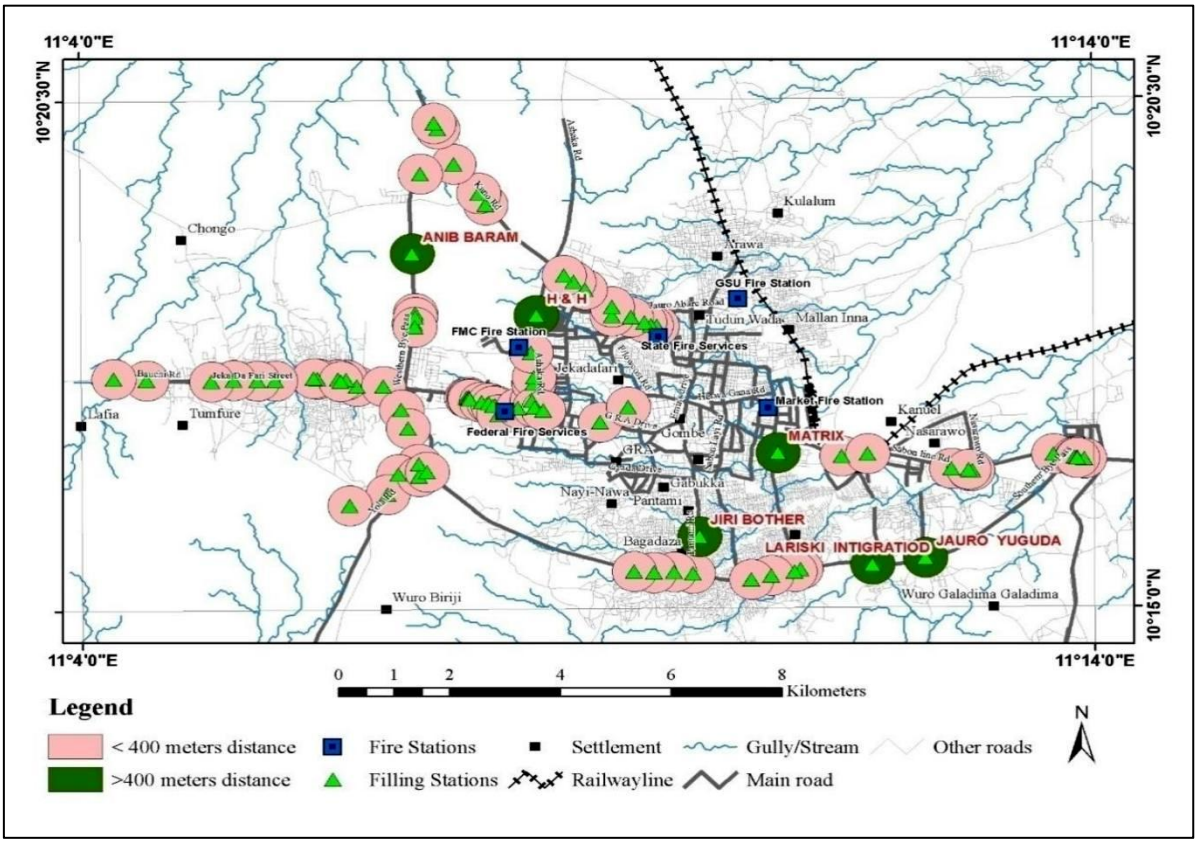

Figure 4: Filling Stations Conformity with Respect to Distance to Nearest Station.

Standard Distance of Filling Stations from Road Corridors

The result in Table 2 and Figure 5 showed that 39 % of filling stations are located within 15 meters of the road network, while 61% are situated at a distance greater than 15 meters. The proximity of filling stations to the road network has implications for accessibility, safety, and environmental issues. The proximity of filling stations to roads enhances accessibility for motorists but must be balanced with regulatory compliance. A study by Oladipo *et al*. (2017) emphasized that filling station locations within urban areas are optimized for accessibility but often violate spatial planning regulations, which could lead to health hazard. Filling stations located within 15 meters of the road network may be more accessible to motorists but can also pose potential risks such as the risk of fire explosion in the event of a collision.

Additionally, the proximity of filling stations to the road network may result in traffic congestion, especially during peak hours, which can cause air pollution and reduce the overall efficiency of the road network. On the other hand, filling stations located at a distance greater than 15 meters are less accessible to motorists, which can pose challenges for fuel suppliers and customers. However, this distance can provide a buffer zone that reduces the risk of fire explosion in the event of a

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collision and also reduces the likelihood of traffic congestion and air pollution. Filling stations near roads pose a significant fire hazard. According to Ahmed *et al.* (2020); Okwudili et al. (2021), inappropriate placement of filling stations in urban settings increases risks of fire outbreaks, especially due to vehicle collisions and spillage. Filling stations that conform to the required standard for road corridors are indicated in Figure 4.

Table 2: Filling Station Conformity to 15m Distance from Road Networks.

Distance from road	No Station	%
< 15 cm	33	39
> 15 cm	51	61
Total	84	100

According to Ebong *et al.* (2019), locating filling stations beyond minimum regulatory distances reduces the risk of fire and explosion while improving environmental safety. Overall, the distance of filling stations from the road network requires careful consideration by policymakers and planners. While proximity to the road network may facilitate accessibility, it can also pose safety risks and environmental problems. On the other hand, a greater distance from the road network may provide a buffer zone, but may also reduce accessibility to fuel stations. Policymakers and planners need to balance these factors to ensure that fuel stations are distributed in a way that is both efficient and accessible to all while minimizing the risks associated with their proximity to the road network.

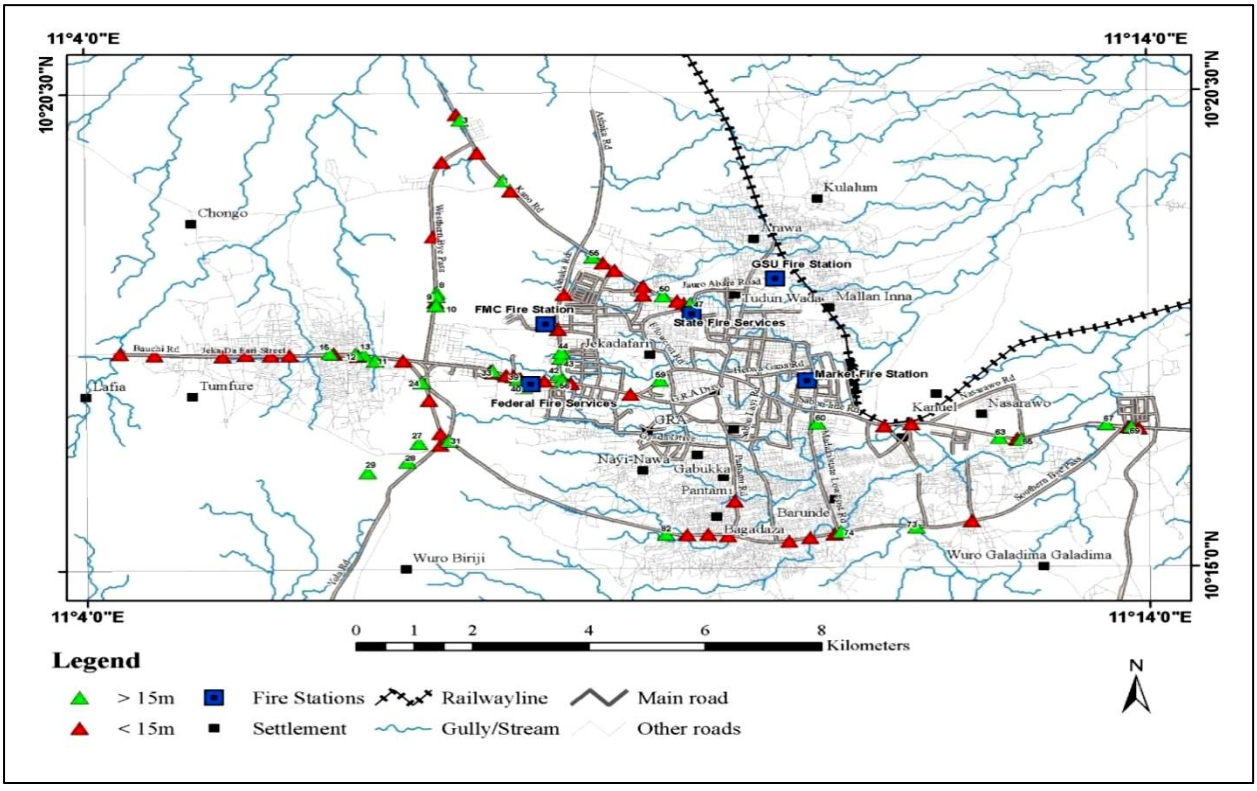

Figure 5: Filling Station Conformity with Respect to 15m Buffer Distance to Road.

Distance of Filling to Residential Areas

The result of the distance between the filling station and the road shows that 71.43% of the filling stations are located within 30 meters of residential houses, while only 28.57% of the fuel stations were located at a distance greater

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than 30 meters (Figure 6). This is of great concern as the proximity of fuel stations to residential areas can pose several risks to the health and well-being of individuals living in those houses. For instance, the emissions from vehicles filling up at the station can cause air pollution, which can lead to respiratory problems and other health issues. Additionally, there is a risk of fire explosion associated with filling stations, which can be particularly dangerous if the station is located too close to residential buildings. Similarly, Odipe *et al.* (2018) reported that the most of the fuel stations were near buildings, with 10 (3%) being near a school, 226 (76%) near retailers, 192 (65%) near residential houses, and 11 (4%) being near hospitals and pose serious health and environmental hazards to the people. The study reveals that PFSs are overly packed throughout the metropolis, resulting in cluster patterns that pose a major hazard to the town's heavily populated districts and are not constructed in compliance with existing norms. While filling stations are necessary for individuals to access fuel for their vehicles, it is important to ensure that they are located in a way that balances accessibility with safety and environmental concerns. Ulakpa *et al.* (2022) in their review of petroleum filling stations and their impact on the environment in Nigeria also reported that the majority of PFSs were located close to residents, with setbacks from the road and residential areas of less than 30 m in 90% of the filling stations. This may involve implementing policies to encourage the relocation of filling stations that are too close to residential areas or to require new filling stations to be located at a safe distance from residential buildings.

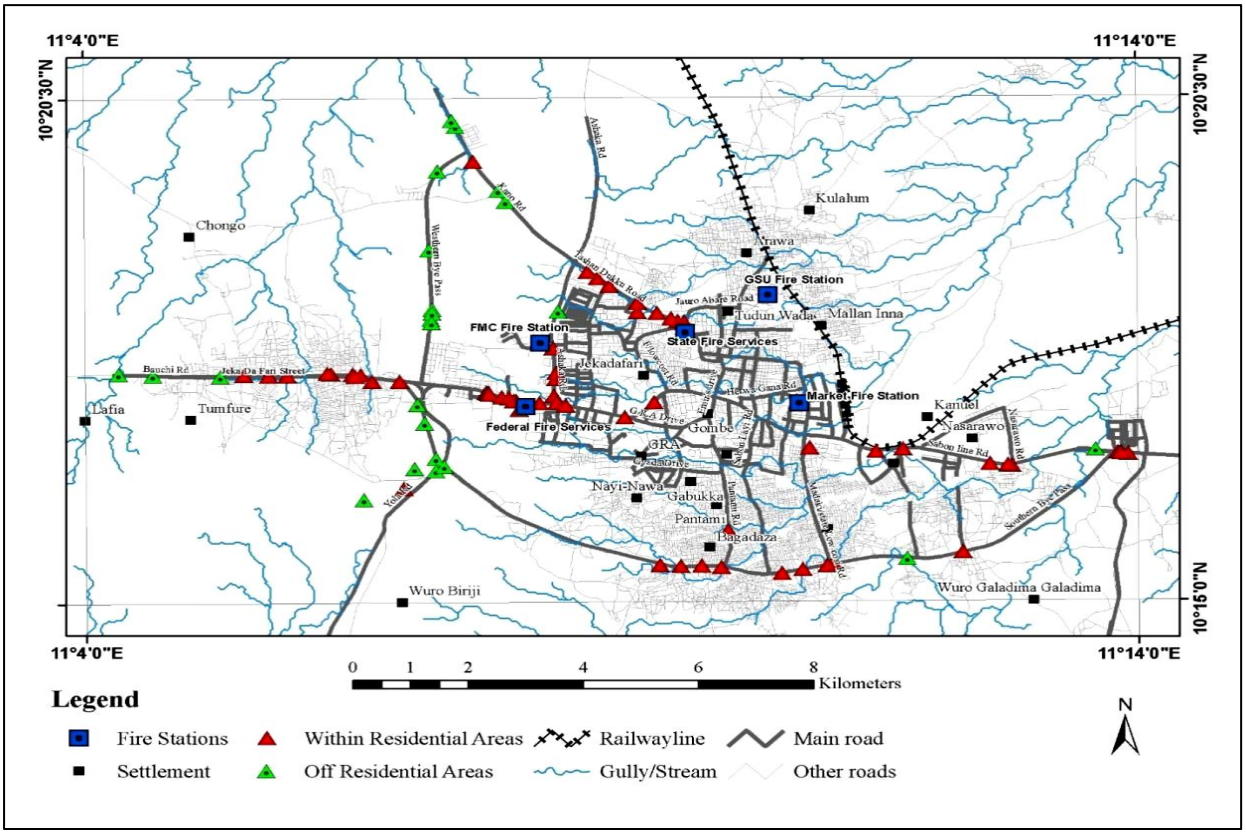

Figure 6: Offset of Residential areas from Filling stations.

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Distances of Filling Stations to Fire Services Stations

The statistics provided in Table 3 refer to the differences in distance between fuel stations and fire stations. The range indicates a wide variation in distances while the standard deviation suggests that the data is spread out around the mean. The variance of 2966112.05 indicates that the data is quite dispersed, with a significant amount of variability in the distances between fuel stations and fire stations. The standard distance between the filling station and the fire station is 2,700 m/2.7km. In terms of the implications of these statistics, it is important to note that accessibility to fuel stations is crucial for ensuring the smooth functioning of transportation networks. However, placing fuel stations too close to fire stations or other sensitive areas can pose safety and environmental risks (Figure 7).

Table 3: Statistics on Travel Distances to Filling Stations from Fire Stations.

Item	Value (meters)
Mean	2564.04
Maximum	7085.07
Minimum	132.70
Range	6952.37
SDV	1722.24
Variance	2966112.05

Similarly, According to Adewuyi (2020), fire stations' emergency response to filling stations shows that over half of the filling stations (60.8%) in the study region can be attended to promptly. As a result, the DPR Department and the Local Authority Town Planning should make sure that filling stations are positioned correctly to meet their established regulatory standards. Policymakers and planners need to carefully balance accessibility with safety and environmental concerns when determining the location of filling stations.

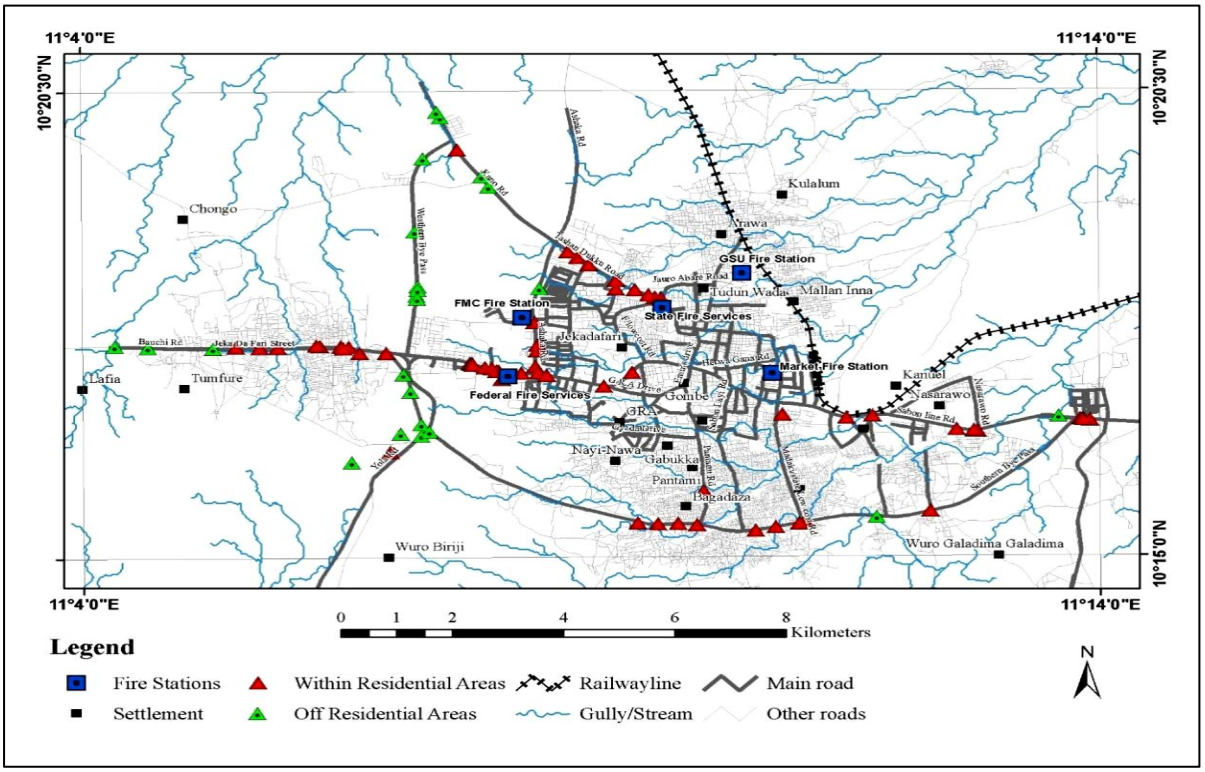

Figure 7: Distance of Filling Station to Fire Services Stations.

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Density of Filling Station

From Figure 8, the kernel density result indicated the clustering of filling stations in different areas of the Gombe metropolis. The density observed in the analysis ranges from 0 to 4.35 filling stations per square kilometer. The highest cluster of filling stations is in the range of 3.2-4.35 filling stations per square kilometer. This means that there are areas with a high concentration of filling stations – at least 3 to about 5 filling stations per square kilometer. The good implication for the high density of filling stations is that it could lead to competition among fuel stations and possibly lower prices for consumers. However, it could also lead to environmental concerns such as air pollution and traffic congestion. These high-density areas as observed in Figure 8 lie around Bauchi Motor Park and also have proximity to the Federal Fire Service Station in the metropolis. Similar findings were made by Adewuyi (2020), who found that only 35% of filling stations followed the 300-meter local authority standard interval, 7.2% followed the 400-meter DPR regulation standard, and only 32% had their dispensing pump at least 15 meters from the road. Based on these percentages, it can be inferred that standard regulations were not appropriately followed in the study area. The lowest cluster is in the range of 0 - 0.2 filling stations per square kilometer which covers areas within the outskirts of the town and some regions in the city centre. The low-density areas mean that there are many areas with limited access to fuel stations, which could result in inconvenience for drivers and potentially higher prices for fuel due to transportation costs. Overall, policymakers and planners need to carefully balance accessibility with safety and environmental concerns when determining the location of filling stations. Additionally, it's important to consider the distance between fuel stations and fire stations to ensure that emergency services can respond quickly in the event of an accident. Although filling stations and fire stations both have their roles very different. In case of a fire, a filling station is not equipped to respond to the situation or provide emergency assistance. Instead, fire stations are facilities that are specifically designed and equipped to handle emergencies, including fires and other types of disasters. In some cases, fire stations may be located near a filling station, as they are both considered essential facilities that serve the public. However, there is no inherent relationship between the two types of facilities beyond their shared importance to public safety. Petroleum production is a highly combustible substance, and as such, its exploration, transportation, unloading, storing, and selling points and facilities should not be taken for granted like other products. This is especially true in light of the prior discoveries. A WHO report from 2004 states that fire outbreaks linked to improper handling of petroleum production claim more than 2.3 million lives and damage more than 4.5 billion dollars' worth of property.

The clustering of fuel stations within a distance of 400 meters could lead to traffic congestion, air pollution, and accessibility issues. Policymakers and town planners need to consider this clustering phenomenon and come up with appropriate strategies to ensure that fuel stations are distributed in a way that is both efficient and accessible to all. The proximity of filling stations to the road network has implications for accessibility, safety, and environmental issues. Filling stations located within 15 meters of the road network may be more accessible to motorists but can also pose potential risks such as the risk of fire or explosion in the event of a collision.

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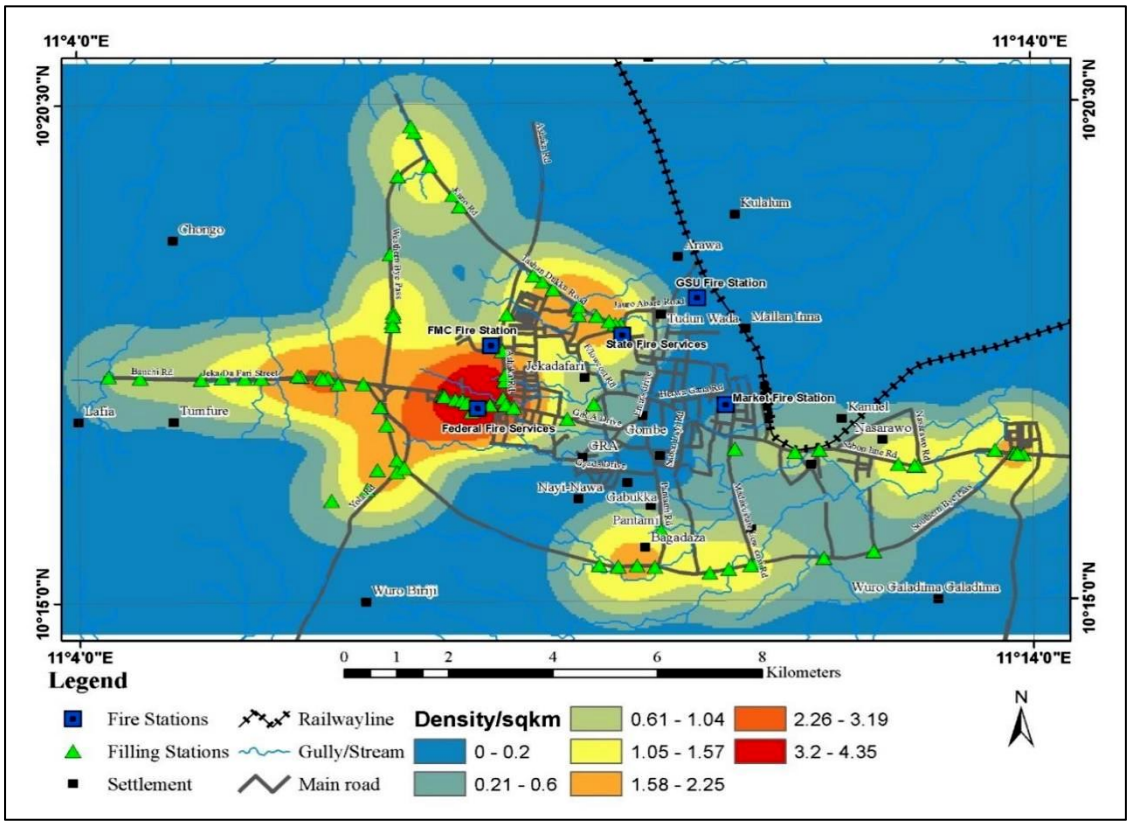

Figure 8: Kernel-Density of Filling Stations in Gombe metropolis.

CONCLUSION

The study analyzed the distribution pattern of filling stations in Gombe Metropolis using spatial analysis techniques. The results indicate that the filling stations in the study area are not evenly distributed and have a clustered distribution pattern. The observed mean distance between filling stations is 280.82 meters, which is much smaller than the expected mean distance of 593.216 meters. The nearest neighbour ratio of 0.47339 indicates strong clustering of filling stations, with 92.86% of the stations located within 400 meters of each other. The clustering of filling stations could lead to issues related to traffic congestion, air pollution, and accessibility. Therefore, policymakers and town planners need to consider this phenomenon and come up with appropriate strategies to ensure that fuel stations are distributed in a way that is both efficient and accessible to all. The study also analyzed the standard distance between filling stations and found that only 7.14% of filling stations conform to the regulated standard of at least 400 meters distance to each other.

Recommendation

. Implementation of regulations to ensure that filling stations conform to the regulated standards from other stations, road networks, settlements, and fire stations to reduce the risk of accidents and other hazards.

. Promotion of the use of alternative and cleaner energy sources such as solar and electric energy to reduce air pollution and improve the overall environmental quality of the area.

. Development of policies to encourage an even distribution of filling stations in the study area to address the issue of clustering.

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REFERENCES

Abashiya M., Abaje I.B., Iguisi E.O., Bello A.L., Sawa B.A., Amos B.B., Musa I. (2017) Rainfall characteristics and Occurrence of flood in Gombe Metropolis, Nigeria. Ethiopian Journal of Environmental Studies and Management, 10(1):44-54. ISSN: 1998-0507, doi: http://dx.doi.org/10.4314/ejesm.v10i1.5

Ahmed, A., Ibrahim, I., & Adepoju, J. (2020). *Urban fuel station placement: Accessibility and safety implications*. Journal of Urban Safety Studies.

Adewuyi, G. K. (2020) Assessment of Fire Service Station Response to Filling Stations Fire Outbreak and Vulnerable Healthcare Centers to Filling Stations in Urban Settlement. *International Journal of Research and Review*, 7(3): www.ijrrjournal.com, E-ISSN: 2349-9788; P-ISSN: 2454-2237

Ahmed, S., AbdulRahman, A.S., Kovo, A.S., Ibrahim, S. Okoro E.O. and Agbo, A.A. (2014). Health, Risk and Safety of Petrol Stations in Minna Town. An over View World Applied Sciences Journal. 32(4), 655-660.

Amakiri-whyte, B.H., Aselemi, A.E., Akpabio, M.U.A., (2021). Causes and Environmental Problems of Petrol Filling Stations in Residential Domain of Nigeria Town. *International Journal of Research and Scientific Innovation.* 8(1), 2321-2705.

Ayodele, S.J. (2010) spatial distribution of petroleum filling station in Kaduna North. Retrieved on 20th May, 2020. (Electronic resource). URL, WWW.srib.com/samuel

Ebong, S., Umoh, A., & Otu, I. (2019). *Safety distances in fuel station management*. Safety and Environment Review.

Ioja, C., Onose, D., Cucu, A., Ghervase L., (2010). Changes in water quality in the lakes along Colentina River under the influence of the residential areas in Bucharest. Selected Topics in Energy. Environment, Sustainable Development and Landscaping. pp. 164-169.

Isabel, M.C., Graciela, A., Monica, R.C., (2010). Evaluating emission from gas stations. Journal of environmental management. 6, 42-50.

Odipe, O.E., Lawal, A., Adio, Z., Karani, G. and Sawyerr, O.H.(2018). GIS-Based Location Analyses of Retail Petrol Stations in Ilorin, Kwara State, Nigeria. *International Journal of Scientific and Engineering Research*. (9), 790-794.

Ogundahunsi, D.S., (2019). Locational Analysis of Fuel Stations, in Ilesa, Osun State, Nigeria. International Journal of Development Strategies in Humanities, Management and Social Sciences. 4(2), 1-15.

Okwudili U., Eme C. C., Nwachukwu M. A., Babatunde A., Nwachukwu J. I. (2021) Proliferation of Petrol Stations as Indicative of Unsustainable Development in Owerri West County Nigeria. *Journal of Research in Environmental and Earth Sciences*. 7;11: 58-71. www.questjournals.org

Olusegun, A., Folakemi, O., Omotayo, S., et al., (2011). Assessment of Safety Practices in Filling Stations in Ile-Ife, South Western Nigeria. Journal of Community Medicine and Primary Health Care. 23, 9-15.

Steinemann, A.C., (2008). Fragranced consumer products and undisclosed ingredients. Environmental Impact Assessment Review. 29, 32e38

Sulaiman, Y., (2019). Analysis of Locational Compliance and Fire Safety Preparedness among Petrol Filling Stations in Dutse Town, Jigawa State. *Yunus Confluence Journal of Environmental Studies.* 13(1), 107-118.

Cristian I.I., and Constantina, A.T., (2012). Temporal analysis of incompatible land-use and land-cover: The proximity between residential areas and gas stations in Bucharest suburban area. Elsevier, *Procedia Environmental Sciences.* (14), 49 - 58.

Ulakpa R. O. E., Ulakpa W. C., Eyankware O. E. (2022) Petroleum Filling Stations and Their Impact on the Environment in Nigeria. *Journal of Environmental & Earth Sciences*, 4 (1), 1-14. DOI: https://doi.org/10.30564/jees.v4i1.4073.

World Health Organization (WHO, 2004) Safe piped water: Managing microbial water quality in piped distribution systems. Report by Richard Ainsworth