

Spatiotemporal Variation in Facility-Reported Malaria Burden in Kaduna Metropolis, Kaduna

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Abstract—Malaria remains a major public health challenge in Kaduna Metropolis despite the ongoing control intervention. This study examined the spatiotemporal variation in facility-reported malaria burden in Kaduna Metropolis from 2020 to 2025, which makes identification of disease burden important for surveillance and intervention. Annual RDT positive malaria records were obtained from 14 selected public and private healthcare, while malaria case rates were calculated per 1,000 projected LGA population. Kernel Density Estimation was used to map the spatial clustering of reported cases across the metropolis. The results revealed substantial variation in reported case rates across the study period, where Kaduna North recorded the highest rate in five of the six years, rising from 17.08 cases per 1,000 population in 2020 to 29.71 in 2024 before declining to 28.46 in 2025. Kaduna South peaked at 22.60 in 2023, while Chikun reached 9.53 in 2024. Igabi records showed an increase from 1.15 in 2024 to 1.85 in 2025. The spatial maps showed a persistent central hotspot around Jowako - Ashmed - Kabala - Tudun Wada corridor and adjoining areas from 2020 - 2024, followed by the emergence of a second hotspot along the southern metropolitan corridor of Television PHC, Makera, Kakuri Gwari, Romi and Gonin Gora in 2025. The findings demonstrate spatial persistence with temporal restructuring of facility-reported malaria burden. Routine GIS-based surveillance is therefore recommended to support geographically targeted malaria interventions and resource allocation.

Index Terms—Malaria case rate, spatiotemporal analysis, spatial clustering, Kernel Density Estimation, healthcare facilities, Kaduna Metropolis.

I. INTRODUCTION

Globally, Malaria is one of the leading public health concerns, with its burden concentrated in sub-Saharan Africa. Despite ongoing investment in vector control, diagnostic testing, antimalarial treatment and preventive interventions, overall progress towards

malaria elimination remains uneven. The World Health Organization (WHO) estimated 282 million malaria cases and 610,000 deaths globally in 2024, with the African Region accounting for approximately 94% of cases and 95% of deaths. Nigeria is among the countries that contributes to this burden where the WHO estimated approximately 68.5 million malaria cases and 184,900 malaria related deaths in Nigeria in 2024. This underscores the continuing public health significance of the disease and the need for more geographically targeted surveillance and control strategies (WHO, 2025).

Kaduna Metropolis represents a good setting for this investigation which contains variation in population concentration, settlement structure, infrastructure and healthcare access. Studies have confirmed that malaria remains a major health problem within the metropolis. Maina et al. (2017), in a facility-based study involving 305 participants at selected hospitals in Kaduna Metropolis, reported *P. falciparum* infection among 39.7% of those examined. Eke et al. (2026) reported malaria parasitaemia among 57.5% of 464 individuals seeking medical care across selected healthcare facilities in Kaduna Metropolis. These studies provide useful evidence of continuing malaria occurrence. However, their cross-sectional designs primarily describe infection among sampled healthcare users and do not demonstrate how the geographic concentration of healthcare facility reported malaria burden has changed across multiple years.

This represents an important knowledge gap for malaria surveillance and resource allocation. It is important to determine where reported burden is persistently concentrated, whether those concentrations remain stable and whether new clusters are emerging over time. The availability of routinely collected malaria records is valuable for longitudinal surveillance because they can reveal changes in the

spatial concentration of diagnosed cases even with the influence of healthcare seeking behaviour, facility accessibility, diagnostic activity and reporting completeness.

On this background, this study examined the spatiotemporal variation of facility-reported malaria burden in Kaduna Metropolis between 2020 and 2025. Specifically, it analyse the malaria cases rate and map the relative spatial concentrations of high and low reported malaria cases which reveals changes in the geographic configuration of malaria hotspots over the six-year period in Kaduna Metropolis. The study provides geographically explicit evidence that can support more targeted malaria surveillance, resource allocation and specific location control interventions within the urban area.

1.1 Study Area

The study was carried out in Kaduna Metropolis, Kaduna State, located between latitudes $10^{\circ}25' 00''$ and $10^{\circ}39'00''$ N and longitudes $7^{\circ}19'00''$ and $7^{\circ}39'00''$ E (Figure 1). The metropolis covers a landmass of approximately 450 km² (Oluwole and Tarfa, 2021), situated with elevation of 620amsl (Daful et al. 2020) and extends across Kaduna North, Kaduna South and parts of Chikun and Igabi Local Government Areas (LGAs).

According to the National Population Commission (NPC) (2006), the population of Kaduna metropolis is estimated to be 1,570,331 with an annual growth rate of approximately 2.4%. This figure comprises of data for the four LGAs making up the metropolis.

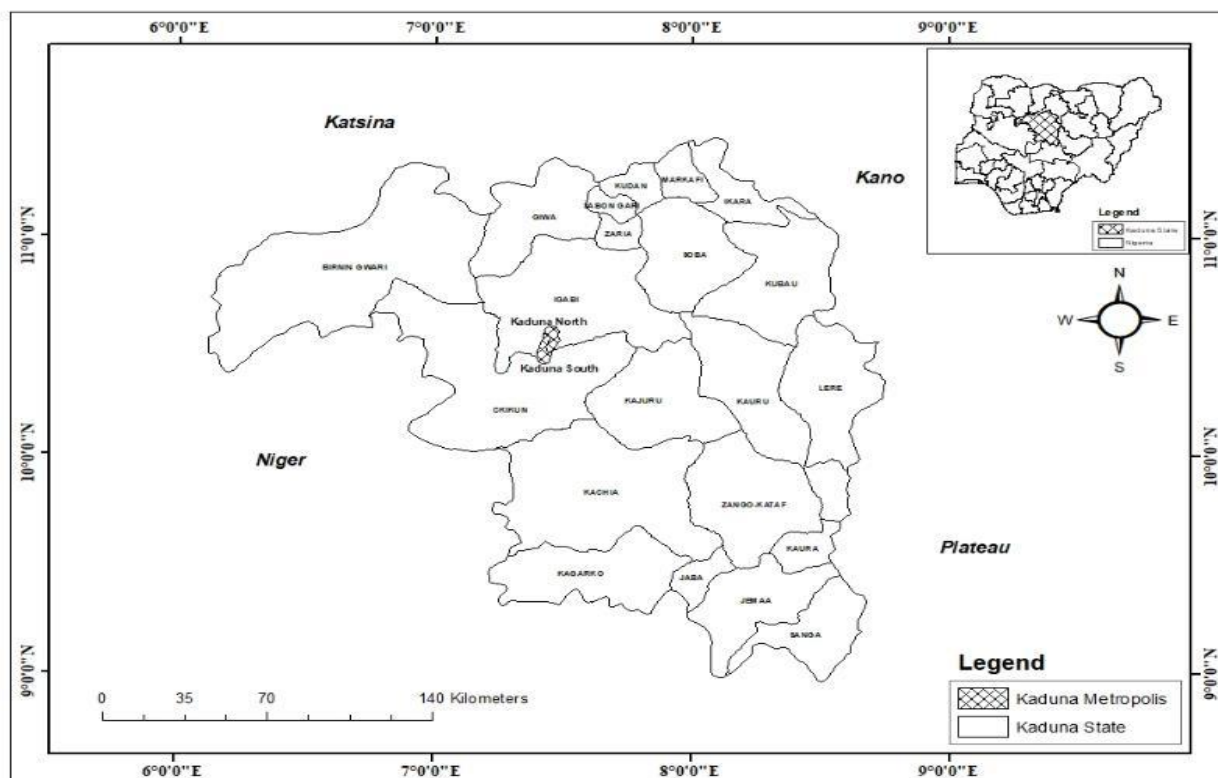


Figure 1: Kaduna state showing Kaduna Metropolis

Source: KASUPDA, (2025)

II. THEORETICAL FRAMEWORK AND LITERATURE

Theoretical Framework

The study is anchored on Disease Ecology Theory, which provides a geographical framework for

understanding disease as the result of interactions among human, disease agents, vectors and the environments. The foundation of the disease ecology is associated with medical geography with scholars like Jacquez (1996), Meade and Emch (2025). The theory is relevant to malaria because the survival and

reproduction of Anopheles mosquitoes are influenced by environmental conditions such as surface water, vegetation, drainage, rainfall and sanitation. Human activities can also modify these conditions through urban development, waste disposal, drainage alteration and water storage practices, thereby creating environments that may either support or restrict mosquito breeding.

Literature Review

In Nigeria, Ogunsakin et al. (2024) examined changes in malaria prevalence between 2000 and 2020 using GIS-based spatial and temporal techniques. Their analysis demonstrated considerable geographical variation in malaria patterns and applied Getis-Ord Gi* hotspot analysis to identify statistically significant clusters of relatively high and low malaria prevalence across different periods. However, its national-scale analysis does not capture the finer intra-urban dynamics that may occur among communities and healthcare service areas within individual Nigerian cities. Mohamed-Djawad et al. (2026) examined malaria surveillance data from 44 neighbourhoods in Libreville, Gabon, between 2012 and 2023 and identified substantial neighbourhood-level spatial and temporal heterogeneity. The study used local Getis-Ord Gi* statistics to distinguish hotspots and cold spots and emphasized the relevance of identifying persistent high-risk neighbourhoods for micro-stratified malaria control.

III. MATERIALS AND METHODS

Malaria records covering 2020 - 2025 were obtained from 14 selected public and private healthcare facilities as shown in Table 1, across the four LGAs, comprising RDT positive malaria cases obtained from facility registers and National Health Management Information System monthly summaries.

Geographical coordinates of the healthcare facilities were obtained using a handheld GPS and linked to their corresponding annual malaria records. Population data were derived from the National Population Commission (NPC) 2006 population census and projected annually to the study years using the annual population growth rate of 2.4%.

Table 1: Distribution of Selected Healthcare Facilities in the Study

LGA	Healthcare Facilities
Kaduna North	Jowako Specialist Hospital, Ashmed Specialist Hospital, Zakari Isa Memorial PHC, Unguwan Shanu PHC, Kabala Doki PHC, General Hospital Kawo.
Kaduna South	Television PHC, Makera PHC, Yusuf Dantsoho Memorial Hospital, Tudun Wada
Chikun	PHC Sabon Tasha; PHC Unguwan Romi; Gonin Gora PHC; Narayi PHC Bayan Dutse
Igabi	Rigachikun PHC

Annual LGA populations were projected from the 2006 NPC population using the exponential population-growth expression:

$$P_t = P_0 \times (1 + r)^t$$

For each study year, malaria records from the selected healthcare facilities within each LGA were aggregated, relative to the corresponding projected LGA population and expressed as per 1,000 projected population. The resulting measure was calculated as: Malaria case rate (MCR) = Annual RDT positive cases recorded at selected facilities ÷ Projected LGA population × 1000 (per 1,000 population)

3.1 Data Analysis

Healthcare facilities coordinates were imported into ArcGIS and linked with annual RDT positive malaria case counts for each year from 2020 to 2025. Kaduna Metroplis boundary and healthcare facilities locations were projected to WGS 1984 UTM Zone 32N coordinate system.

Spatial clustering was examined using Kernel Density Estimation, with the reported malaria case count associated with each healthcare facility serving as the analysis variable. The annual analyses were conducted for 2020, 2021, 2022, 2023, 2024 and 2025, enabling comparison of the persistence, expansion, contraction and emergence of high and low burden clusters over time.

IV. RESULTS AND DISCUSSION

Spatiotemporal Variation in Reported Malaria Case Rate

The malaria case rates as shown in Table 2 for Kaduna North consistently recorded the highest rates, increasing from 17.08 cases per 1,000 population in

2020 to a peak of 29.71 in 2024 before declining slightly to 28.46 in 2025. The burden revealed from 2023 – 2025 may indicate drivers such as dysfunction drainages, open waste dump, and poor sanitation within Kaduna Metropolis. It aligns with Dimkpa et al. (2025), that's these spatial variations may be influenced by environmental factors like inadequate drainage infrastructure, accumulated refuse dumps, and poor sanitation.

Kaduna South also in Table 2 showed higher fluctuation declining from 5.40 in 2020 to 4.55 in 2021 and rising to 22.60 in 2023 before subsequently declining to 16.05 in 2025. This may reflect changes in malaria occurrence as well as differences in healthcare utilization, diagnostic activity and reporting across the selected facilities. It aligns with Ogunwale et al. (2024), that health-seeking behavior and routine healthcare centres diagnostic services varies.

Chikun in Table 2 showed an increased from 1.53 cases per 1,000 population in 2020 to a peak of 9.53 in 2024 before falling to 7.68 in 2025. For Igabi LGA, available data recorded 1.15 cases per 1,000 population in 2024, increasing 1.85 per 1,000 in 2025. The absence of records from 2020 - 2023 reflects gaps in routine healthcare reporting, reasons include reduced healthcare attendance and diagnostic testing during the COVID-19 period, staff transfers, healthcare facility renovation, missing registers, or reporting interruptions. This assumption aligns with Ogunwale et al. (2024), who noted that healthcare utilization and formal malaria diagnosis vary with accessibility, cost and service-related constraints.

Table 2: Facility-reported malaria case rates by LGA, 2020 - 2025

LGA	Year	Total Cases	Projected Population	MCR (per 1,000)
Kaduna North	2020	8,679	508,162	17.08
	2021	9,009	520,358	17.31
	2022	9,471	532,846	17.77

	2023	10,563	545,635	19.36
	2024	16,598	558,730	29.71
	2025	16,283	572,139	28.46
Kaduna South	2020	3,030	561,346	5.40
	2021	2,618	574,818	4.55
	2022	8,104	588,614	13.77
	2023	13,624	602,741	22.60
	2024	9,398	617,207	15.23
	2025	10,141	632,024	16.05
Chikun	2020	794	518,889	1.53
	2021	3,478	531,342	6.55
	2022	2,769	544,095	5.09
	2023	4,057	557,153	7.28
	2024	5,438	570,525	9.53
	2025	4,485	584,217	7.68
Igabi	2020	N/A	600,396	N/A
	2021	N/A	614,805	N/A
	2022	N/A	629,561	N/A
	2023	N/A	644,670	N/A
	2024	760	660,142	1.15
	2025	1,253	675,991	1.85

Source: Authors' analysis 2026.

Spatial Distribution of Malaria Hotspots 2020 - 2025

The 2020 map as shown in Figure 2 shows a principal hotspot in central Kaduna North around Jowako Specialist Hospital (2,921 recorded cases), Ashmed Specialist Hospital (3,444) and the Kabala Doki PHC area. The high confidence core extended across Shaba, Maiburji, Kabala and Tudun Wada/Nupawa. A separate hotspot appeared around General Hospital Kawo (2,314 cases), with a transitional zone between Kawo and the central cluster. Lower confidence hotspot areas extended south toward Makera PHC (3,030 cases), Kakuri Gwari and Barnawa. The northern periphery around Rigachikun and southern Chikun, including areas around Sabon Tasha, Gonin Gora and Romi, were mapped mainly as cold spots. However, for Igabi no records were available for 2020, so the apparent cold-spot pattern around Rigachikun should therefore not be interpreted as evidence of low malaria burden in Igabi.

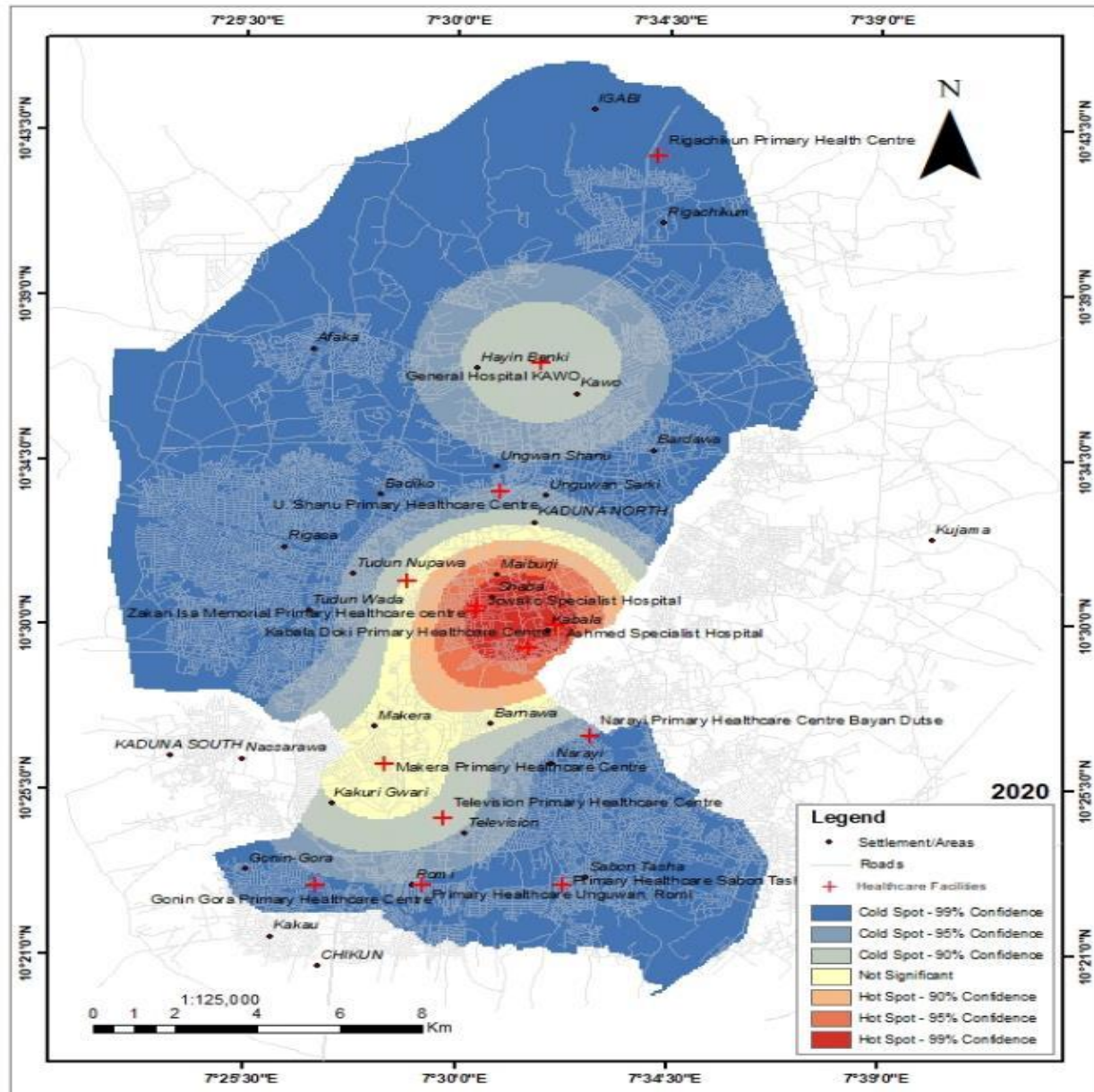


Figure 2: Hotspot analysis of reported malaria cases in Kaduna Metropolis, 2020

Source: Author's analysis (2026)

In 2021 as shown in Figure 3, total recorded cases across healthcare facilities increased from 12,503 to 15,105. The main hotspot expanded into a more elongated north - south corridor covering Tudun Wada, Shaba, Maiburji and Kabala. Ashmed Specialist Hospital (3,902 cases) and Jowako Specialist Hospital (3,211) together accounted for

approximately 47.1% of recorded cases. Narayi PHC (1,618 cases) formed part of a transitional zone extending toward Narayi and Barnawa. The southern Chikun remained predominantly within cold-spot classes. As in 2020, the apparent cold-spot pattern near Rigachikun shows coldspot

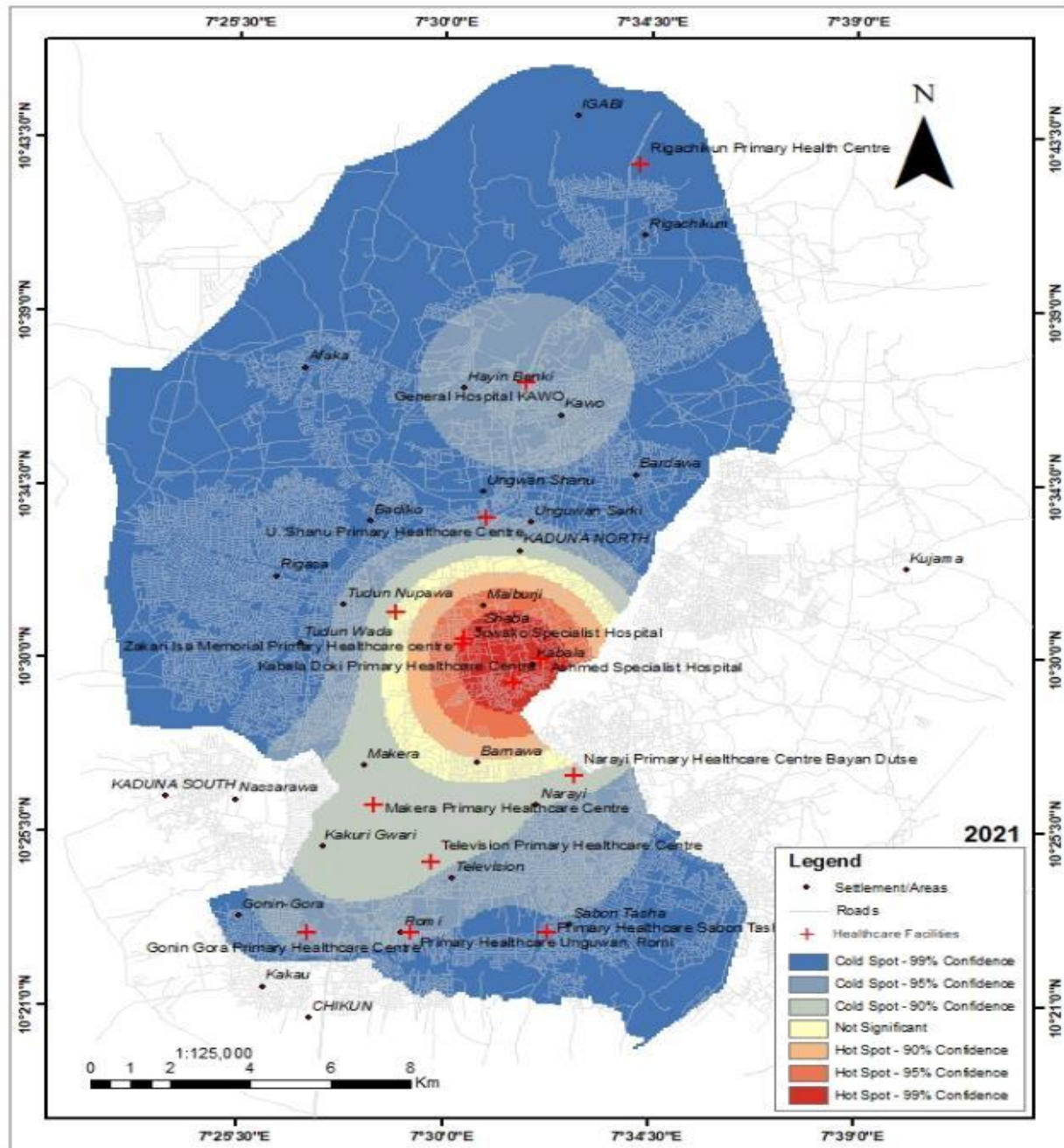


Figure 3: Hotspot analysis of reported malaria cases in Kaduna Metropolis, 2021

Source: Author's analysis (2026)

The 2022 map in Figure 4 retains a central hotspot around Yusuf Dantsoho Memorial Hospital (4,470 cases), Ashmed Specialist Hospital (4,010), Jowako Specialist Hospital (2,841) and Zakari Isa Memorial PHC (895). Together, these four facilities recorded 12,216 cases, approximately 60.0% of the 20,344 cases recorded across the healthcare facilities. A separate localized hotspot appeared around General

Hospital Kawo (1,725 cases). Transitional hotspot zones extended south toward Makera and Television and east toward Narayi, Barnawa and Kakuri. The northern periphery around Rigachikun and the southern areas around Sabon Tasha, Goini Gora and Unguwan Romi were largely represented by coldspot classes.

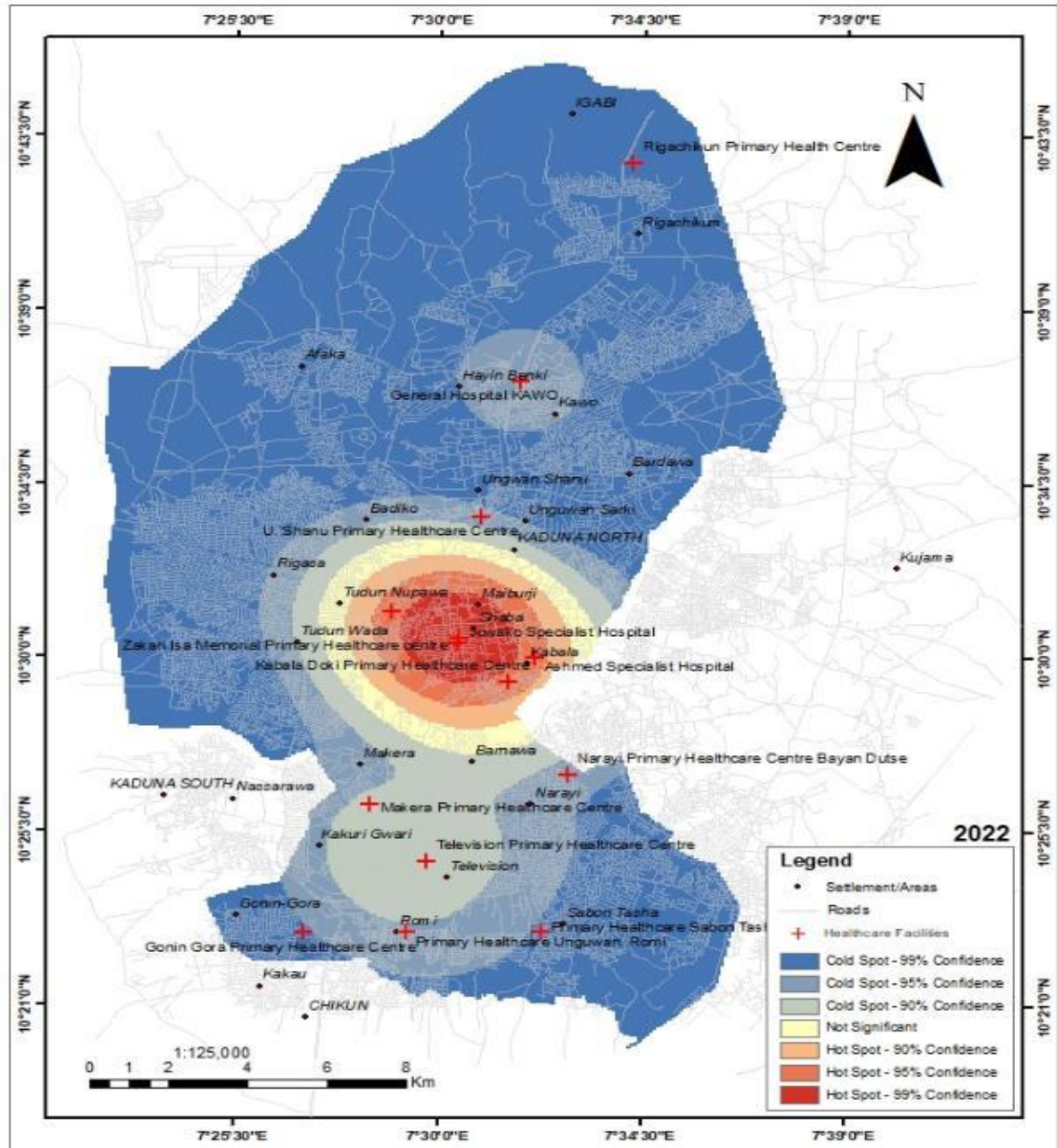


Figure 4: Hotspot analysis of reported malaria cases in Kaduna Metropolis, 2022

Source: Author's analysis (2026)

In 2023 as seen in Figure 5, the central cluster increased in 2023. Yusuf Dantsoho Memorial Hospital recorded 9,801 cases, Ashmed Specialist Hospital 4,518 and Jowako Specialist Hospital 3,841, together with Zakari Isa Memorial PHC (851), these facilities recorded 19,011 cases, or approximately 67.3% of the

28,244 cases recorded in the three LGAs. The central hotspot expanded around Tudun Wada/Nupawa and adjoining Kaduna North neighbourhoods. Television PHC, Makera PHC and Narayi PHC remained within transitional zones. The map depicts Rigachikun and the southern Chikun corridor mainly as coldspot areas.

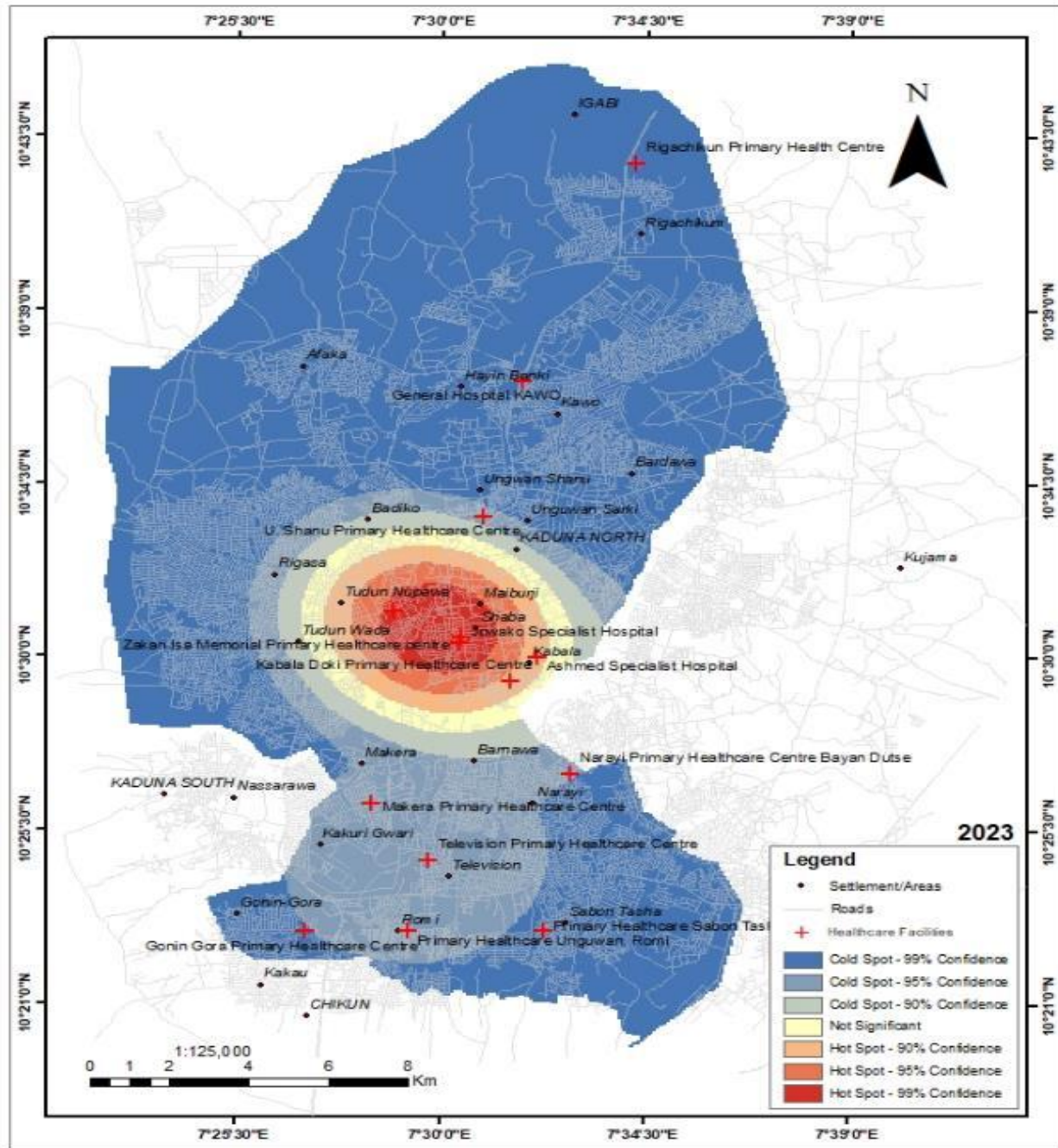


Figure 5: Hotspot analysis of reported malaria cases in Kaduna Metropolis, 2023

Source: Author's analysis (2026)

In 2024, Figure 6 reveals primary hotspot remained centred on Kaduna North. Jowako Specialist Hospital recorded 3,981 cases, Ashmed Specialist Hospital 4,500, Kabala Doki PHC 2,439 and Unguwan Shanu PHC 2,726. The surrounding hotspot covered parts of Shaba, Maiburji, Kabala, Tudun Wada/Nupawa and Unguwan Sarki. Transitional zones extended toward

General Hospital Kawo in the north and toward Television, Makera, Narayi and Romi in the south, indicating that high clustering was not confined to the central core. Across the four LGAs, the available facilities recorded 32,194 cases in 2024. Although Rigachikun had 760 recorded cases, the broader northern area was mapped as a coldspot zone.

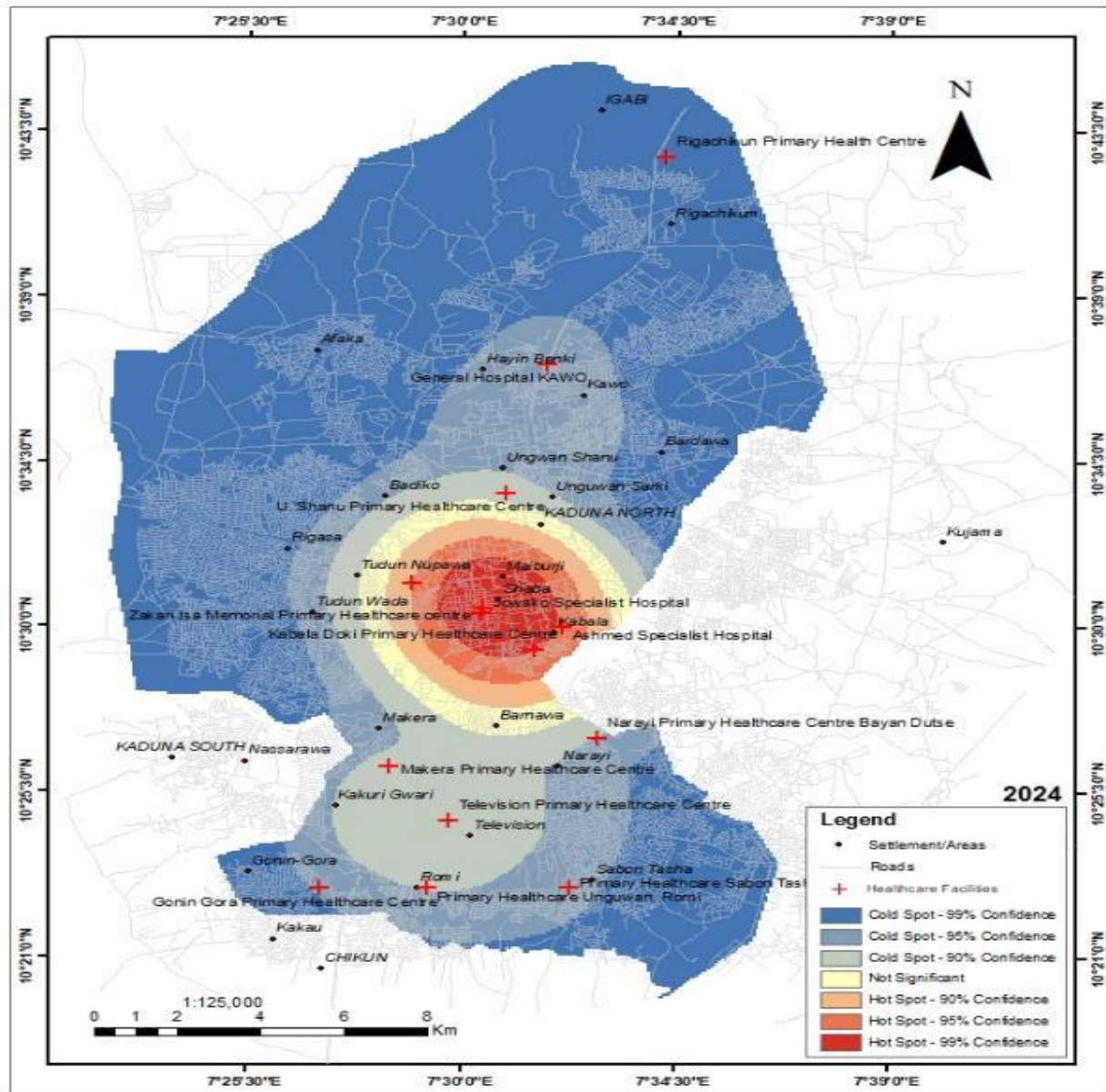


Figure 6: Hotspot analysis of reported malaria cases in Kaduna Metropolis, 2024

Source: Author's analysis (2026)

The 2025 map in Figure 7 reveals a notable change from the central pattern of the earlier years. The primary hotspot persisted in Kaduna North around Jowako Specialist Hospital (4,153 cases), Ashmed Specialist Hospital (4,901), Kabala Doki PHC (1,152) and Ungwan Shanu PHC (1,529), extending toward Tudun Wada and Badiko. A second hotspot emerged along the southern metropolitan corridor around Television PHC (3,002 cases), Makera PHC (2,637)

and PHC Ungwan Romi (930), extending across Television, Kakuri Gwari, Gonin Gora and Romi. Narayi and Barnawa formed intermediate areas between the two clusters. Rigachikun PHC recorded 1,253 cases while remaining within a mapped coldspot zone. The healthcare facilities recorded 32,162 cases in 2025, which is similar to the 32,194 recorded in 2024, despite the visible redistribution of the mapped clusters.

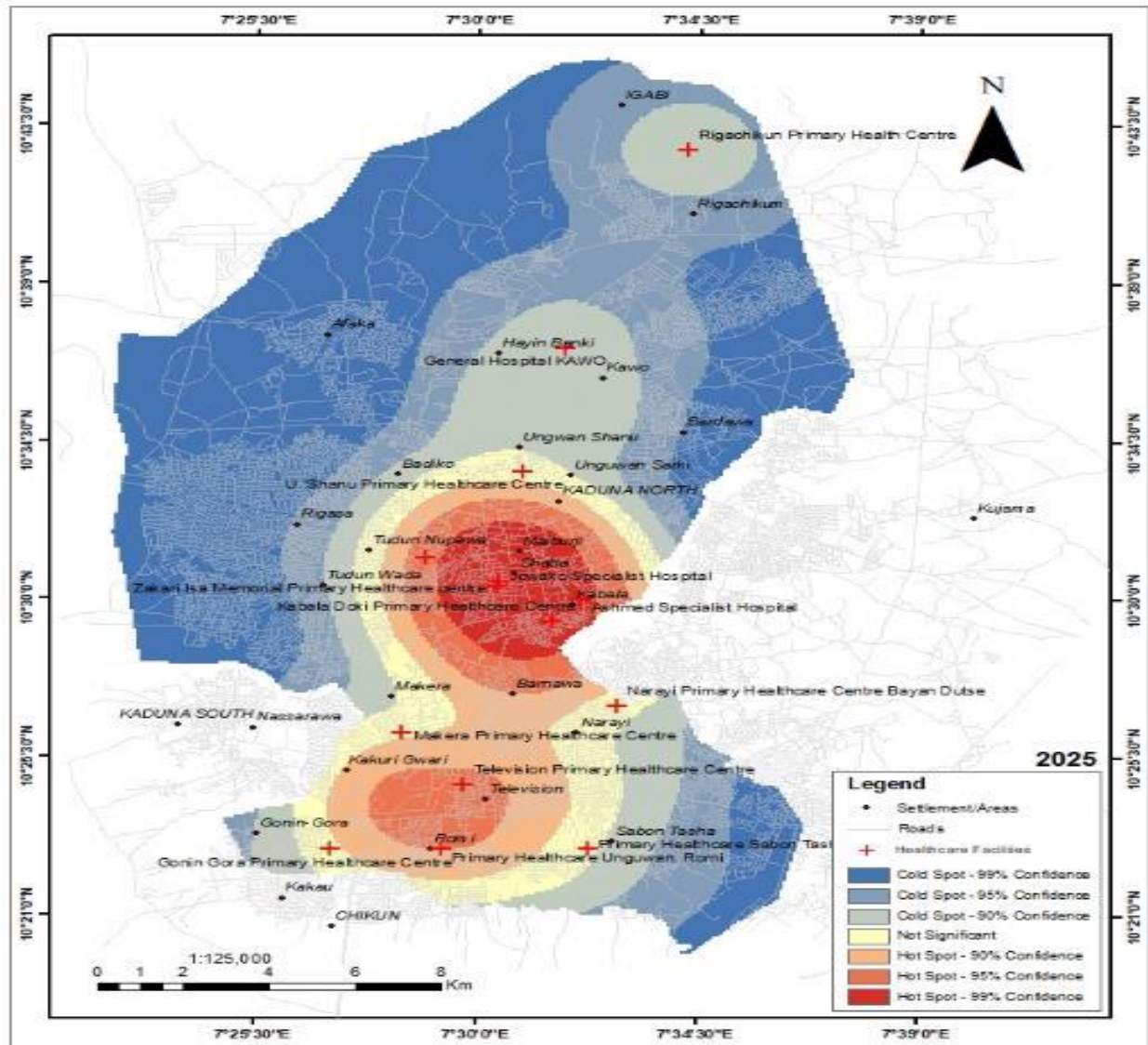


Figure 7: Hotspot analysis of reported malaria cases in Kaduna Metropolis, 2025

Source: Author's analysis (2026)

Generally, the observed spatial concentration suggests relatively stable underlying environmental and socio-economic conditions that may continue to favour a higher burden of reported malaria cases. Likewise, the emergence and strengthening of the southern hotspot may reflect increasing urban expansion, population growth, changing land-use patterns, inadequate drainage infrastructure and varying housing conditions, which have been identified as factors capable of influencing the spatial distribution of malaria burden in urban environments. The findings are consistent with ogunsakin et al. 2024; Savi et al.

2024 in their study, that malaria burden can vary substantially within urban areas.

V. CONCLUSION AND RECOMMENDATION

This study examined facility-reported malaria case rates across four LGAs and mapped spatial clustering of reported cases across Kaduna Metropolis between 2020 and 2025. Kaduna North generally recorded the highest case rates and contained the most persistent central hotspot. Kaduna South experienced a pronounced rate peak in 2023, while Chikun reached its highest rate in 2024. The 2025 spatial map showed

a shift from a predominantly central hotspot to a dual-cluster pattern, with a second cluster emerging along the southern metropolitan corridor. These findings demonstrate that reported malaria burden varies across both administrative units and neighbourhoods over time.

The Kaduna State Ministry of Health and the Kaduna State Primary Health Care Board should routinely geocode facility malaria records and repeat hotspot analysis annually to identify persistent and emerging clusters. Surveillance and diagnostic capacity should be reviewed in the central hotspot areas and the southern corridor identified in 2025. Health authorities should also improve completeness and consistency of facility reporting and expand routine data coverage beyond the selected facilities.

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