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ORIGINAL ARTICLE

Assessment of tuberculosis case notification rate: spatial mapping of hotspot, coverage and diagnostics in Katsina State, north-western Nigeria

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Abstract

Tuberculosis (TB) is prevalent in Nigeria, and Katsina, along with other 12 states in the country, accounts for a high proportion of unnotified TB cases: constituting the high priority-intervention States in the country. Interventions focused on TB detection and coverage in the state could benefit from a better understanding of hotspot Local Government Areas (LGAs) that trigger and sustain the disease. Therefore, this study investigated the spatial distribution of TB Case Notification Rates (CNRs), diagnostics and coverage across the LGAs. Using 2017 to 2019 TB case finding data, the geocoordinates of diagnostic facilities and shapefiles, a retrospective ecological study was conducted. The data were analysed with QGIS and GeoDa. Moran's I and LISA were used to locate and quantify hotspots. The coverage of microscopy and GeneXpert facilities was assessed on QGIS using a 5 km and 20 km radius, respectively. The CNR in the state, and 29 of the 34 LGAs, increased steadily from 2017 to 2019. Hotspots of high CNRs were also identified in 2017 (Moran's I=0.106, p-value=0.090) and 2018 (Moran's I=-0.020, p-value=0.370). While CNRs increased along with presumptive TB rates across most LGAs over the years, the positivity yield and bacteriological and Xpert diagnostic rates decreased. Bacteriological and GeneXpert coverage were 78% and 49% respectively. Additionally, only 51% of the state's population lived within 20km of a GeneXpert facility. These results suggest that TB program interventions had some positive impact on the CNR, however, diagnostic facilities need to be equitably distributed and more innovative approaches need to be explored to find the missing cases.

Keywords: Tuberculosis, Case Notification Rates, Spatial Analysis, Hotspot, Katsina State, Nigeria.

INTRODUCTION

Tuberculosis (TB), the leading cause of death globally among adults by a single infectious agent, has plagued humans for millennia (1). Despite being a preventable and curable disease, an estimated 10 million people fell ill with TB in 2019, and over 1.4 million people died because of the infection. The disease burden varies significantly across countries with a range of 5 to 500 cases per 100,000 population and a global average of 150 cases per 100,000. Eight countries (Bangladesh, China, India, Indonesia, Nigeria, Pakistan, Philippines, and South Africa) accounted for over two-thirds of the total cases of the disease in 2018 (2).

Nevertheless, global efforts to combat the disease have yielded slow but progressive dividends, with an estimated 58 million deaths averted through TB diagnosis and treatment over the last two decades. To sustain these achievements and reach the World Health Organization (WHO) goal of ending TB in 2030, current efforts need to be stepped up (3), and one of the crucial steps in TB elimination is case finding (CF) or detection. TB CF or detection, an entry point into the TB treatment cascade, refers to the use of a systematic approach in identifying presumptive TB cases through screening and establishing diagnosis using one or more diagnostic tests (4). The case notification rate (CNR) provides an indication of how effective TB programs are at finding people with active TB and diagnosing them correctly (5).

In 2018, Nigeria accounted for an estimated 4.3% (429,000 cases) of the global TB cases, and over 162,000 deaths. Over the past two decades, the reported incidence of TB has stagnated despite efforts made by the government and non-governmental agencies (6). Despite having the highest total number of cases in Africa, only 24% (106,533 notified cases) of cases in the country were reported in 2018. Underreporting of confirmed cases and underdiagnosis have been identified as the two significant challenges responsible for this gap (3). Within the country, Katsina State accounts for a significant proportion of unnotified cases in the country and together with 12 other states, including the Federal Capital Territory, the state accounted for over 50% of unnotified cases across Nigeria. Therefore, the National Tuberculosis, Leprosy and Buruli Ulcer Control Program (NTBLCP) prioritised these states for an intensified intervention package, including active case-finding. As part of the 2014 National Strategic Plan for TB elimination, a structured laboratory network system along with new diagnostic equipment were introduced in the country (7); however, this has been significantly limited by the uneven distribution of healthcare centres providing TB services and inadequate infrastructure (8).

Advances in spatial technology and its use in disease surveillance has aided in providing a better understanding of the epidemiology of diseases (9). The Geographic Information System (GIS) used in TB surveillance has enhanced TB CF and provided vital information for targeted control efforts in different parts of the world such as the United States of America (10), Bangladesh (11) and The Gambia (12). A spatial analysis of the distribution of the disease alongside the facilities providing TB services can guide the NTBLCP and other stakeholders in Nigeria on the allocation of resources for case-finding activities. Information on access to TB services, TB case notifications and treatment can provide useful insight into where TB cases are ”missed”. Therefore, we carried out a study on TB mapping for Katsina State incorporating analysis of bacteriological and expert diagnostics as well as coverage using clinical surveillance data for the years 2017 to 2019.

MATERIALS AND METHODS

Study design

This study employed a retrospective ecological study design which allows for secondary analysis of aggre-

Supplementary information The online version of this article (Tables/Figures) contains supplementary material, which is available to authorized users.

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gate data. The study covered the Local Government Areas (LGAs) in Katsina State, Nigeria.

Study setting

Katsina State, one of the 36 States of the Federal Republic of Nigeria, is situated in the Sahel Savanah of the North-Western region of the country. The state covers a land area of 24,192 square km, and its capital is in Katsina LGA (14). The state is relatively flat and lies within the tropics between latitude 11°00' to 13°25N and Longitude 6°45' to 9°05E and it is bounded by Kano and Jigawa states to the east; Kaduna state on the South; Zamfara state on the west and shares international borders with the Republic of the Niger on the North (15).

The state is further divided into 34 LGAs (Figure 1) with an estimated population of over 7.8 million consisting slightly more of males (50.8%) than females (49.2%) (16). The capital of the state, Katsina LGA, has the highest population, and together with three other LGAs (Daura, Funtua and Kankara) they account for 17.4% of the entire state population. An estimated 56.4% of the state's population live below the national poverty line of 376 Nigerian Naira per day (17) and about 90% of the State population dwell in rural settlement with food and cash crop farmers and cattle rearers making up a large proportion of the state's workforce (14).

The state has 422 health facilities, supported by the State Tuberculosis, Leprosy and Buruli Ulcer Control Program (STBLCP), providing TB diagnostic services across the 34 LGAs, but only 10 of the facilities provide TB diagnostic services using the Xpert MTB/RIF® (18).

Data collection

We obtained aggregated routine data at the LGA level from the quarterly TB monitoring and evaluation exercise conducted by the STBLCP. The Katsina STBLCP coordinates the activities of LGA TB control programs and collaborates with implementing partners to implement the program, supporting 422 health facilities across the state. The quarterly facility-level TB case finding data from 2017 to 2019 across the health facilities were obtained from the Katsina State Ministry of Health through Katsina STBLCP. These data were used for the calculation of Case Notification Rates (CNR) and other variables. The population and population density data used as denominators were acquired from the Nigeria Bureau of Statistics. For spatial analysis of CNR, presumptive, diagnosed TB cases and other secondary variables in the LGA, we obtained and utilized the coordinates of health facilities providing TB diagnostic services and digital maps of the state from the Nigerian Health Facility Registry (19) and Geographical Administrative Areas (GADM) (13) respectively. Choropleth maps were produced for 2017 to 2019 using QGIS software.

Spatial Autocorrelation and TB clusters/hotspots identification and classification

The GeoDa software was employed for spatial analysis. The spatial autocorrelation tool, Global Moran's Index (Global Moran's I) was used to assess the overall pattern and trend of TB CNRs. Global Moran's I statistics is a correlation coefficient that assesses the extent to which the variable(s) of geographical units are similar or dissimilar. It works with the null hypothesis that the attribute being analysed is randomly distributed across all geographical units. The index is bounded by -1.0, and 1.0 with a Moran's I value of -1.0 indicating perfect dispersion, 0 indicating perfect randomness and 1.0 indicating perfect clustering (20). In addition, Local Indicators of Spatial Autocorrelation (LISA) was used to locate and characterise clusters of geographical units with high (hotspots) and low (coldspots) TB CNRs. A significance level of 5% was used for the LISA and Moran's I test.

Coverage Analysis

The QGIS software was used to estimate the proportion of the population covered by TB diagnostic services. The population density, obtained from WorldPop, was analysed with geo-coordinates of facilities providing TB diagnostic services to estimate the proportion of people covered by TB services using a 5km radius by applying a 0.045° buffer to create a 5km catchment area for each facility. The catchment areas were dissolved to avoid double counting of the population in overlapping catchment areas (e.g., populations residing within the 5km catchment area of two or more facilities). The layer was subsequently clipped to the boundaries of Katsina to discard catchment areas outside state boundaries. Similarly, the coverage of Xpert MTB/RIF® (GeneXpert) facilities was calculated using a wider radius of 20km.

Ethical considerations

Anonymized aggregated dataset at the LGA level by the Katsina STBLCP was utilized in this study. The Katsina State Ministry of Health Research Ethical Review Committee approved this study (Ref: MOH/ADM/SUB/1152/1/374). Consequently, the Research Ethics Committee of KIT Royal Tropical Institute, The Netherlands granted a waiver since the data were anonymized and it would not be necessary to obtain consent from each of the participants.

RESULTS

Descriptive Case Notification Rates Analysis

From 2017 to 2019, the TB CNR in Katsina state increased from 62 to 98 cases per 100,000 population. CNRs gradually increased over these years in all LGAs except in Dutsinma, Jibia, Katsina, Kankia, Kusada and Rimi LGAs (Figure 2). Bakori (631%, 2017 CNR=29 cases per 100,000 population) had the highest proportional increase in CNR over the three years in the state. The number of notified cases also increased over the three years. Interestingly, higher rates were initially reported in the northern part of the state, but by 2019 this had shifted to the south.

In 2017, 4,894 TB cases were notified, with the highest CNR in Katsina LGA (177 cases per 100,000 population) and the lowest in Zango LGA (15 cases per 100,000 population). The distribution of CNRs across the LGAs of the state was not symmetrical and had a median of 49 cases per 100,000 population with an interquartile range (IQR) of 35 cases per 100,000 population. In 2018, Kaita LGA had the lowest CNR (11 cases per 100,000 population) while Charanchi had the highest (221 cases per 100,000 population). The distribution of the 2018 CNR across the LGAs of the state was not symmetrical and had a median of 49 cases per 100,000 population with an IQR of 43 cases per 100,000 population. In 2019, the lowest CNRs were in Kusada and Sandamu LGAs (20 cases per 100,000 population), while the highest was observed in Funtua LGA (232 cases per 100,000 population). The distribution of the CNR across the LGAs of the state was asymmetrical, with a median of 78 cases per 100,000 population.

Presumptive TB Rate and Positivity Yield

In 2017, Zango LGA had the lowest rate of presumptive TB case per 100,000 population while every other LGA had less than 800 presumptive TB cases per 100,000 population except for Funtua (1,214) and Katsina LGAs (854). In 2018, low rates of presumptive TB case per 100,000 population were seen in Kaita (52), Baure (107), Musawa (122) and Mai'adua (131), while the highest rates were seen in Katsina (1,190), Batsari (1,110) and Charanchi (1,051). In 2019, low rates of presumptive TB cases per 100,000 population were seen in Danja (260), Rimi (297) and Daura (325), while the highest rates were seen in Katsina (2,119), Sabuwa (1,793) and Funtua (1,623). The highest increase in presumptive rates in 2019 occurred in the Central and Southern parts of the state (Katsina, Sabuwa and Funtua had presumptive rates of 2,119, 1,793 and 1,623, respectively).

The number of presumptive TB cases increased by almost 100% between 2017 to 2019, with the highest rise in Katsina, Kankara and Bakori LGAs, however, a decline in the number of presumptive cases was reported in Rimi and Kankia LGAs over the three years. Contrastingly, the increasing trend slowed down in the northern part of the state, where no LGA had over 400 presumptive TB cases per 100,000 in 2017. Daura, Zango and Sandamu LGAs in the northern region had a consistent presumptive TB rate below 400 presumptive TB cases per 100,000 for all three years. A total of 71,303 presumptive TB cases were identified across the entire state, out of which 56,304 clients had a bacteriological test for TB (45% Xpert Test, 55% Smear Microscopy Test and <1% TB LAMP/LF-LAM Test).

The new and relapse TB cases reported in the LGAs also increased over the three years from 4,894 in 2017 to 7,711 in 2019. The presumptive TB rate and cases consistently increased over the three years by over 100% in Bakori, Baure, Kankara, Zango, Mai'adua, Sabuwa, Matazu, Danja and Faskari LGAs.

The positivity yield, however, had an opposite trend, and decreased across the state. All LGAs had a lower yield in 2019 compared to 2017 except for Rimi, Kankara, Matazu, Ingawa, Daura, Funtua and Danja). Three LGAs (Matazu, Dandume and Sabuwa) maintained very low positivity yields over the years. The state's positivity yield was 16% in 2017, with the lowest yield in Matazu (6%), and the highest yield in Kafur and Mashi (34%). In 2018, the positivity yield in the state was 14%, the lowest was in Matazu (6%) and the highest in Mai'adua (39%). The positivity yield for the state in 2019 was 11%. Dandume, Jibia, Kusada and Sandamu had the lowest (5%) compared to Danja (24%) that had the highest positivity yield.

Bacteriological Diagnostic Rates

The proportion of TB cases diagnosed using a bacteriological method of diagnosis decreased from 51% in 2017 to 44% in 2019. While the bacteriological diagnostic rates in southern Katsina decreased over three years, those in central and northern Katsina increased. Kusada and Zango LGAs had the highest diagnostic rates in all three years, while Charanchi had the lowest. Of the 31,304 presumptive TB cases that were identified in 2017, 5,015 were diagnosed with TB (19% Xpert test, 23% Smear Microscopy test and 58% Clinical Diagnosis). In 2018, the number of presumptive cases increased to 35,088 with a corresponding increase in the number of persons diagnosed (5,210), out of which 23% were diagnosed using Xpert test, 24% Smear Microscopy test and 53% Clinical Diagnosis. Similarly, out of the 7,711 persons diagnosed with TB in 2019, 17% were confirmed as TB cases using GeneXpert, 27% through Smear Microscopy test, <1% using TB LAMP/LF-LAM Test and 56% were diagnosed clinically.

TB CNR Cluster/Hotspot identification

In 2017, a cluster of low CNR (coldspots) was observed in the LGAs along the north-eastern international border between the state and the Niger Republic (Baure, Zango and Mai'adua) as well as Sabuwa LGA, which share a border with Kaduna state. In addition, a cluster of high CNR (hotspots) were observed in LGAs which share a border with or near the state capital (Jibia, Kurfi and Batagarawa). Interestingly, Funtua LGA, which had a high CNR, was surrounded by LGAs with low CNRs, and Safana LGA, which had a low CNR, was surrounded by LGAs with higher CNRs. However, the spatial autocorrelation of CNRs across the state was weak and not significant (Moran's I: 0.106, p-value: 0.090). In 2018, hotspots were seen around Kurfi and Batagarawa LGAs. Like 2017, Safana LGA with a low CNR was surrounded by LGAs with high CNRs. The spatial autocorrelation analysis in 2018 showed weak dispersion, although this was not significant (Moran's I: -0.020, p-value: 0.370). In 2019, some LGAs with low CNRs (Faskari, Dandume and Danja) in the southern part of the state were surrounded by LGAs with high CNRs. These three LGAs shared interstate boundaries with Kaduna. The spatial autocorrelation analysis observed this year showed a weak but higher dispersion compared to 2018. However, this was also not significant (Moran's I: -0.171, p-value: 0.080) (Figure 3).

Coverage Analysis

Coverage analysis using a clipped and dissolved 5km (0.045°) buffer showed that 22% of the state's population was over 5km away from a TB diagnostic facility. The facility density for the state was five facilities per 100,000 population with a range of 3 (Baure, Bindawa Daura and Musawa LGAs) to 12 (Sabuwa LGA) facilities per 100,000 population across the LGAs. Kankara (25%) had the least coverage while the entire population of Katsina LGA lived less than 5km away from a TB diagnostic facility. Five LGAs (Batagarawa, Dandume, Dutsi, Sandamu and Sabuwa) had over 90% coverage. Using a 20km radius (0.180°) buffer for GeneXpert coverage, the result showed that 49% of the state's population lived over 20km away from a GeneXpert facility. Two LGAs (Safana and Baure) had 0% coverage, and eight others had coverage of less than 25% (from <1% in Danja to 24% in Kankara). Most of the LGAs with a GeneXpert facility had more than 90% coverage, except Kankia LGA (71%). More than half (60%) of the GeneXpert facilities were in Central Katsina (two in Katsina LGA and one each in Rimi, Jibia, Dutsinma and Danmusa LGAs), while the northern and southern parts of the state had two (20%) (Figure 4).

DISCUSSION

The study showed that TB CNRs across the LGAs of the state increased in the three-year period. This could be explained by the efforts by the NTBLCP to improve case notification across 12 states, including Katsina state, which accounted for over 50% of unnotified cases in 2015 (7). In addition, several interventions have been implemented in the state over these years in collaboration with the lead implementing partner, KNCV Tuberculosis Foundation (KNCV), to increase case finding as well as CNRs. Some of the notable approaches used in the interventions include Patent Medicine Vendors (PMVs) and community volunteer, contact investigators and Wellness on Wheels (WoW) or Mobile Care for TB Screening and Diagnosis (21). However, despite the steady increase in CNR over the last three years, no LGA in the state has met the target of 287 notified cases per 100,000 population set by the NTBLCP in its national strategic plan in any of the three years (7).

The maps generated in this study showed that LGAs with a high population size and density were more likely to have higher CNRs across the years. This corroborates previous studies that showed that CNRs are directly related to population size or density (22–24). Interestingly, some LGAs with a small population size and density (Sabuwa, Charanchi and Kurfi) were seen to have high CNRs, which shows that TB cases relative to population size could vary greatly across regions irrespective of population size or density (25).

While CNRs increased along with presumptive TB rates across most LGAs in the state over the years, the positivity yield, bacteriological diagnostic rate and Xpert diagnostic rate decreased. The slight increase seen between 2017 and 2018, and the spike in 2019 in the presumptive TB rates could suggest positive yields from efforts of the STBLCP and KNCV in active case finding (ACF) or the implementation of a more sensitive (but less specific) screening procedure (26). ACF usually includes approaches targeted at contacts of persons with active TB or mass screening of asymptomatic persons in the community and has been shown to increase the number of TB cases and CNRs in Katsina and other states in Nigeria (27)(28) as well as in other developing countries (29,30).

Remarkably, LGAs along the international border between the state and the Niger Republic and LGAs with high poverty rates were seen to have consistently lower presumptive TB rates in all three years compared to other LGAs. Communities along international borders are often characterised by the paucity of diagnostic facilities (31) which could explain the pattern observed. A framework by the Zero TB initiative asserts that a low positivity yield provides an indication that the wrong population might be being tested while a yield greater than 10% suggests that only the highest risk individuals or those with more advanced active disease are evaluated or screening tools with high sensitivity are used. A high positivity yield could also be observed in the early phase of implementing effective active case finding strategies; however, this usually decreases over time (26). The increase in presumptive TB rates and TB CNRs, and the decrease in positivity yield observed in this study could be attributed to the various cases finding strategies implemented by the state TB program and implementing partners. These strategies employ screening tools with lower sensitivity and target populations with a high TB risk. The low sensitivity enabled identifying a higher number of presumptive cases that turn out to be TB negative after being tested with a diagnostic tool. Conversely, three LGAs (Matazu, Dandume and Sabuwa) maintained very low positivity yields over the years, and this could suggest under-detection.

In 2018, the bacteriological diagnostic rate for Africa was 65% (3) which is higher than that of Katsina state and half of the LGAs in the state in 2018 and 2019. Similar studies conducted in other low- and middle-income countries attribute low bacteriological diagnostic rates to improper documentation, improper referral, the inability of the presumptive case to produce sputum, overworked laboratory staff, stockouts of the commodities required to perform the test, and faulty equipment (32–34). The decrease in bacteriological diagnostic rate over the years in combination with identification of an increasing number of presumptive cases accessing care in the limited diagnostic facilities whose number remained relatively unchanged over the three years, suggests that the available diagnostic resources were insufficient for the increased demand.

The state's Xpert diagnostic rates for the three years were slightly higher than the national rate of 16.8% reported in a study conducted by Gidado et al. However, these rates were less than 50% in most LGAs despite the adoption of Xpert MTB/RIF® as a primary diagnostic tool for TB in Nigeria in 2016 (35). This possibly points to the limited capacity of the machine. For instance, each Xpert machine can run four samples every two hours (3,36) for eight hours a day. Hence, an Xpert facility can perform approximately 5,840 tests per year without considering any downtime. With a total of ten Xpert machines in the whole state, it could only run 82% of the 71,303 samples collected from presumptive cases in 2019. This implies that the diagnostic facilities currently available are overburdened, in addition to being geographically inaccessible to a significant proportion of the population, and leaves clinicians with the option of a clinical diagnosis or sputum smear microscopy, which are less sensitive and specific (33).

Past studies have shown that the distance to health facilities significantly affects the utilization of various health services in Nigeria (37,38). Similar spatial patterns were also observed between the distribution of TB CNR and facility density and diagnostic facility coverage in this study. The distance to diagnostic facilities often has an inverse relationship with TB CNR. People living in areas furthest from TB diagnostic centres face the challenge of covering long distances to get to these facilities (22). Despite 78% of the population living within 5km of a microscopy facility and an average of five facilities per 100,000 population across the state (which translates to 2.5 facilities per 50,000 which is more the target of 1 facility per 50,000 population set by the NSP-TB), microscopy facilities are inequitably distributed. An example seen was in Kankara and Katsina LGAs where both had high populations and CNRs but two extreme "5km coverage for microscopy facilities" (Kankara=25% and Katsina=100%) and different microscopy facility densities (Kankara=4 and Katsina=6 facilities per 100,000 population). The lack of diagnostic facilities in Kankara LGA could explain the low rate of bacteriological diagnosis and high rate of clinical diagnosis in the LGA. Clinical or empirical diagnosis of TB has a sensitivity of 16% to 44.4% and a specificity of 86.9% to 95.3% and has serious negative consequences for the individual and the health system based on a multicounty diagnostic trial conducted in some low- and middle-income countries (39). Some of these negative consequences include exposure to the risk of adverse reaction to TB drugs, catastrophic expenditure, unnecessarily overstretching of scarce resources for health, and the incorrect estimation of disease burden, which could lead to inequitable distribution of resources during planning (40).

The coverage of Xpert facilities was more inequitable with the entire population of two LGAs and 75% of eight LGAs outside the 20km radius of any Xpert diagnostic facility. However, the pattern of distribution of Xpert corresponds slightly with the CNR hotspots observed in 2017. The last Xpert diagnostic site in the state was activated in 2016 (18), and this could explain the pattern of distribution of these facilities and the CNR observed in 2017. Most parts of LGAs along the state's borders with the Niger Republic and Sokoto State were not covered by available diagnostic services. A similar pattern was observed in communities along international borders in Ethiopia (31).

This study has its limitations. Facility coverage analysis was based on population coverage without considering the capacity of each diagnostic facility or travel time to the facility. Secondly, presumptive and confirmed TB cases may access services in other LGAs outside theirs, which could lead to misclassification. In addition, some data fields were missing, for example, the data for an entire LGA (Safana LGA) was missing in 2018 and, therefore, excluded from the analysis for that year. Furthermore, the LGA-level estimates of TB prevalence were unavailable, making it impossible to compare the CNR and the actual burden of TB. It is important to also note that aggregate data was used for this study as such, findings from this study might not be applicable at individual to avoid ecological fallacy.

CONCLUSIONS

We carried out mapping on TB CNR, presumptive cases, bacteriological and expert diagnostics, as well as coverage between 2017 and 2019 in Katsina State, Nigeria. We believe that this study identifies high-priority LGA hotspots to guide NTBLCP and STBLCP TB interventions, including coverage and diagnostics. These results suggest that TB program interventions had an impact on the CNR. However, diagnostic facilities need to be equitably distributed and more innovative approaches need to be explored to find the missing cases.

Furthermore, Studies adopting qualitative and quantitative approaches using the geocoordinates of the residence of confirmed TB cases are recommended as these would provide detailed insights into the distribution of CNRs and more information on missed cases.

INFORMATION

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Contributions. MM: Conceptualized the study, conducted literature review and study reporting. MvG: Provided technical input in study methodology and carried out data analysis and management. OJA: Contributed to study conceptualization, literature review and also drafted the manuscript. SO: Provided technical input in study methodology and data analysis and management. HO: Provided technical input in study conceptualization and methodology. TB: Provided technical input in study conceptualization and methodology. SO: Provided technical input in study conceptualization and literature review. AY: Provided technical input in data analysis and management. MG: Provided technical input in study conceptualization and methodology.

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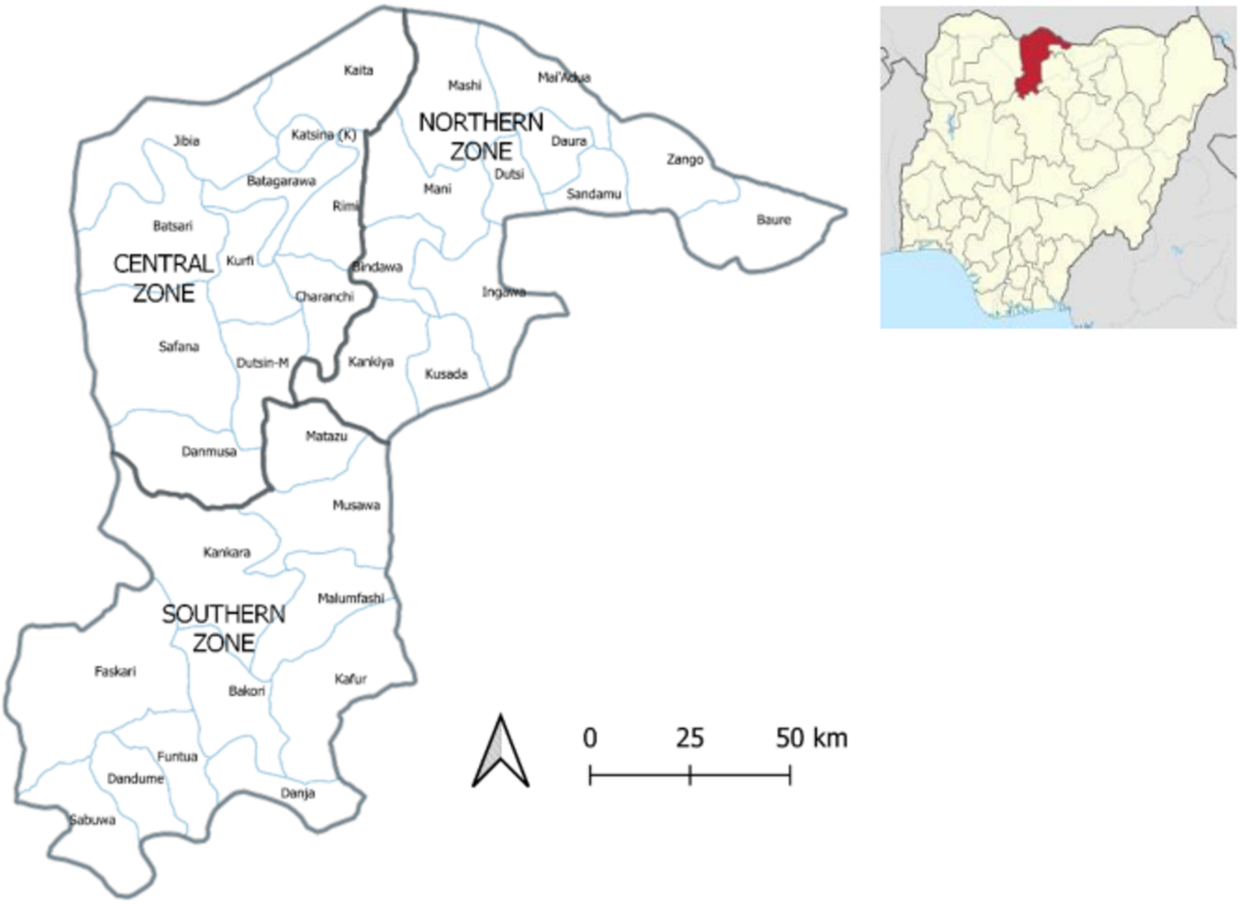

FIGURE 1: Map of Katsina State showing the 3 geopolitical zones and 34 LGAs (13).

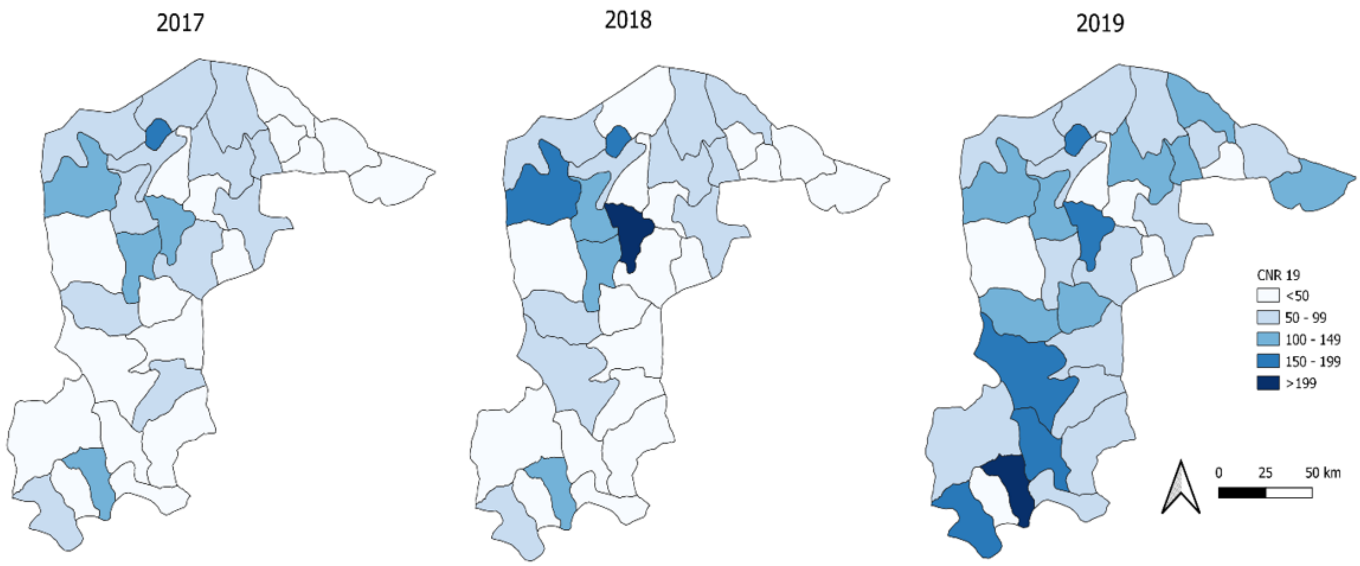

FIGURE 2: Summary of Case Notification Rates in Katsina State from 2017 to 2019.

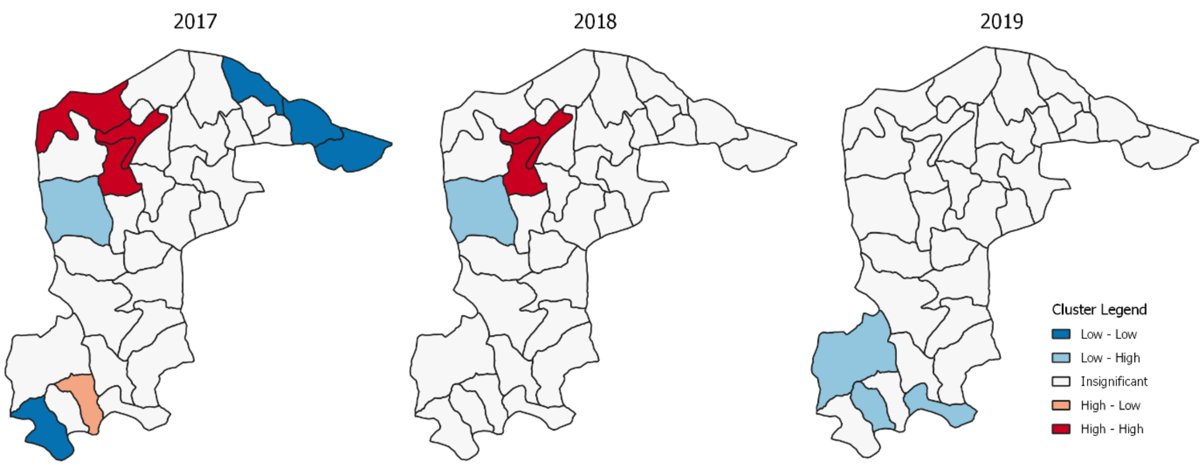

FIGURE 3: Summary of CNR LISA analysis from 2017 to 2019.

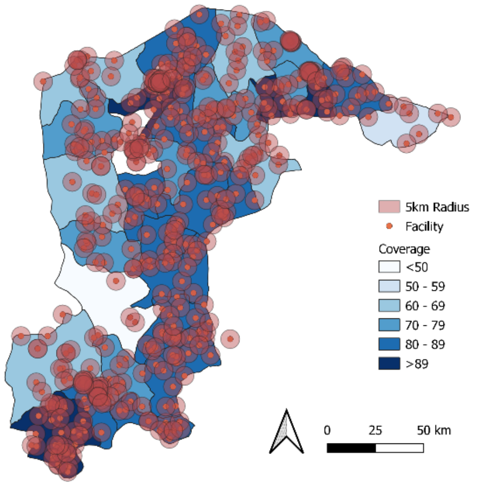

FIGURE 4: Maps showing the proportion of the population within 20 km radius of facilities providing GeneXpert diagnosis and 5 km radius of facilities providing TB sputum smear microscopy services.

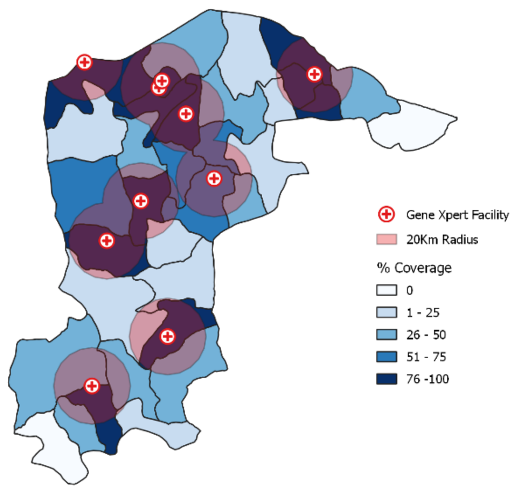

FIGURE 5: Maps showing the proportion of the population within 20 km radius of facilities providing GeneXpert diagnosis and 5 km radius of facilities providing TB sputum smear microscopy services.