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Spatio-Temporal Pattern of Tuberculosis Cases in Jos Metropolis, Nigeria, 2019 - 2022

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Abstract

In Nigeria, Plateau State, with its capital Jos Metropolis (JM), is one of 14 high Tuberculosis (TB) burden states with an increasing TB occurrence. There are no reported spatio-temporal studies from JM, therefore, it is not known how TB spatio-temporal clusters may impact TB transmission in JM. Spatio-temporal patterns of TB cases in JM were analysed in this study. Identifying such patterns may help towards the development of TB prevention and control strategies in the JM. Coordinates from Polling Unit Locator (PUL) at the Independent National Electoral Commission (INEC) website were used to geolocate TB cases to their nearest Polling Units within an Electoral Ward (EW). SaTScan software was used to identify space-time TB clusters through a retrospective space-time analysis based on the discrete Poisson model. The TB cases mapped were 4,897 over the study period (2019-2022). Three significant (primary) spatiotemporal TB clusters were identified, with one of them occurring within the 2021-2022 time period. Thirteen EWs were present within the primary cluster (LLR = 436.95, RR = 2.68 and P-value = 0.001). The clusters were located in the central areas of the northern parts of the JM. These spatio-temporal TB clusters can potentially serve as a source of further spread of TB infection and disease to other locations in JM. Due to the space-time nature of these clusters, timely and targeted interventions, particularly in the affected areas, are required to limit and prevent the further spread of TB within the Jos Metropolis.

***Keywords**: Electoral Ward, Nigeria, Polling Unit Locator, Space-Time Clusters, Spatio-Temporal Pattern, Tuberculosis.*

Introduction

Nigeria has been classified by the World Health Organization (WHO) as one of the 30 high burden Tuberculosis (TB) countries of the world [1] with TB persisting as a significant public health problem in the country [2-4]. About 371,000 notified TB cases were reported in 2023 in Nigeria [5]. Jos Metropolis (JM) is the capital of Plateau State (PLS) in Nigeria and the state is ranked as the 14th high TB burden state [3] and since 2018 TB cases have been on

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the rise [6]. In PLS, despite a high rate of success for TB treatment of about 80%, the case detection rate (CDR) has remained low at 26% [7].

One of the effective approaches to active case finding (ACF), a TB control strategy [8, 9], that could improve TB CDR is the application of spatial analysis to identify TB clusters. In Nigeria, studies on spatio-temporal pattern of TB are limited [10, 11]. The only one such study from PLS was on spatial and temporal distribution of TB infection at the level of local government area (LGA) [11] and this was an ecological study. There are no studies from JM on the spatio-temporal pattern of TB.

Understanding the spatio-temporal pattern of TB in a locality could aid in targeted TB prevention and control. The aim of this study was to identify the spatio-temporal pattern of TB cases in JM. If high-risk cluster areas and the periods in which they occur can be identified in JM, they could be targeted for enhanced TB interventions to reduce the TB burden.

Materials and Methods

Study Site

Jos Metropolis, the capital city of Plateau State, is the study site and lies between latitudes 8°24' N and 10°30' N and longitudes 8°32' E and 10°38' E, and with a population of 478,609 [12], it is the 11th largest Nigerian city. The metropolis is comprised of Jos North (JN) and Jos South (JS) Local Government Areas (LGAs). These two LGAs are among the 17 in the state. Each LGA is divided into Electoral Wards (EWs) by the Independent National Electoral Commission (INEC) [13]. There are 14 EWs in JN - Naraguta A, Jenta Apata, Abba Na Shehu, Garba Daho, Ali Kazaure, Ibrahim Katsina, Jenta Adamu, Jos Jarawa, Tafawa Balewa, Naraguta B, Sarkin Arab, Tudun Wada-Kabong and Vanderpuye, Gangare. In JS there are 12 LGAs EWs - Zawan A, Gyel A, Kuru A, Zawan B, Gyel B, Bukuru, Giring, Kuru B, Vwang, Du, Shen, Turu (Figure 1).

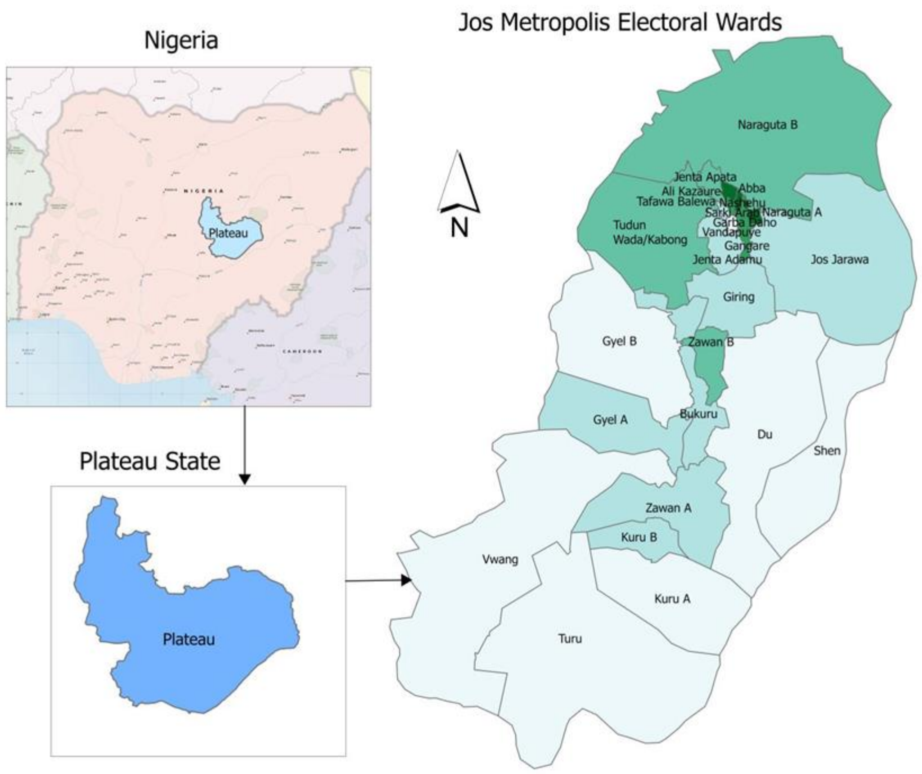

Figure 1. The Study Area - Jos Metropolis with its Electoral Wards

Study Population

Patients diagnosed with TB and who had their records captured in TB Treatment Registers (TBTR) at TB treatment (DOTS) units constituted the study population. The Nigeria National Tuberculosis and Leprosy Control Programme (NTBLCP) guidelines of 2015 [14] provides the case definition for TB; and a positive GeneXpert (Xpert) is considered as confirmed TB. The inclusion criteria for this study were: Cases of TB with a complete or incomplete physical address information and who reside in JN and JS of JM.

Study Design

The study design was retrospective, and retrospective purely spatial and time-space analyses were performed using geospatial techniques.

Types and Sources of Data Collected

Patients' geolocation (coordinates) in the EWs, shapefiles (EW boundaries and rasta data) were the spatial variables collected. The source of data was the TBTRs where TB diagnosis and treatment data were recorded and includes variables such as gender, age, forms of TB (extrapulmonary or pulmonary), HIV status of patients, TB treatment outcomes, type of TB case (drug sensitive or drug resistant) and patients' physical address which may either be complete or incomplete.

The TBTRs is kept in the archives of the Plateau State TB and Leprosy Control Programme (PLSTBLCP), an agency of the Plateau State Ministry of Health (PLSMOH), with the former being the state arm of the Nigeria's National TB and Leprosy Control Programme (NTBLCP). Routine TB data is collected by DOTS Officers at EW level and collated at LGA and state levels by TB LGA Supervisors and State TB Control Officers.

Determining Electoral Wards Population

The old EWs were 20 in JN and 20 in JS but the current INEC EWs consist of 14 in JN and 12 in JS [13]. The Nigeria National Population Commission (NPC) [12] and INEC [13] do not have a current population data for the current EWs. Thus, this data was determined from a newly created shapefile containing the current EWs, created in an ArcGIS Pro 3.5.3 environment, by merging some of the old EWs boundaries. This merging was done using the administrative level 3 (Ward boundaries) shapefile from GRID3 [15] and administrative level 2 (LGAs) shapefile from GADM [16]. The population data for the all 26 current EWs in JN and JS for the year 2019 was extracted in ArcGIS using the new shapefile and the 2019 WorldPop raster data [17]. Next, the obtained estimated Worldpop population for 2019 was then used as the baseline population for determining the projected population counts for the following years. So, using each preceding year's population count as the baseline population, the projected population for 2020, 2021, and 2022 were determined. The World Bank data [18] on the annual population growth rates for Nigeria, which remained constant at 2.1 percent from 2019 to 2022, was used in determining each year's projected population.

TB Cases Geolocation

Using the PU Locator (PUL), each TB patient was geolocated to the PU closest to their residence within their EW, using the available address information, their localised residential area or a popular landmark near their residence. The current PUs and EWs are already well demarcated for election purposes in all LGAs at the State and Federal levels by INEC. In JM, some residential areas or houses don't have complete house numbers and street names (although their localised residential area or nearby landmark is usually known), making it logistically difficult to trace patients to their homes, and this was why all patients were geolocated to their closest PUs using the PUL. This PUL found at the INEC website [13] gives the X and Y coordinates of each TB case.

Data Management and Data Analysis

Microsoft Excel spreadsheet was used for data entry, and with the exception of the physical addresses needed for geolocation, all TB data were deidentified. The spatial geographic unit of analysis was the EWs and this was used because it is one of the levels at which TB interventions are carried out in Nigeria [3]. To get each EW TB CNR per 100,000 of the population, the total number of notified TB cases in that EW in a given year was divided by the projected population for that year, then multiplied by 100,000.

Spatial Autocorrelation Analysis and Mapping

The test for spatial autocorrelation analysis (global Moran's) and mapping TB spatial pattern were performed in ArcGIS. To determine the extent of TB cases spatial clustering, a global Moran's Index ranging from +1 to -1 was applied, with positive and negative values indicating clustering and dispersion, and 0 meaning no clustering, respectively. A Z-score of > 1.96 or <-196, and a P-value < 0.05 indicate a significant Moran's *I* global autocorrelation test statistic.

Purely Spatial and Space-Time TB Cluster Analyses

In order to identify spatial and space-time TB clusters, retrospective purely spatial and retrospective space-time analyses based on the discrete Poisson model [19] were performed, using the SaTScan software version 10.1 (*https://www.satscan.org/*). The input files used for the analyses were: case file containing the total number of TB cases per EW, the population file containing the projected population for each EW, and the coordinate file containing each EWs X, Y centroids points.

Based on Monte Carlo simulations/replications [19], SaTScan uses the Monte Carlo hypothesis testing and calculates the Poisson generalised likelihood ratio (LLR) test for each cluster. The null hypothesis in this study was that there is no TB cluster in the study area and TB disease is randomly distributed across the area. The test identifies the clusters or localised areas with a rate of an event/disease that is significantly different from that of the surrounding area. Clusters with the maximum LLR were selected as the primary (significant) clusters and all others were considered as secondary clusters. For reporting secondary clusters, the criteria used were - hierarchical most likely cluster and no geographical overlap [19].

SaTScan, by using systematically moving circular scan windows across a geographical study area, detects windows (clusters or localised areas) of varying sizes. The window size was set at 50% of the total population under consideration, the simulation was set at 999, the significance level (P-value) was set at 0.05 for the null hypothesis in this study, and for the space-time analysis, the time frame was set from 2019 to 2022 with a time precision of one year. The Kulldorf scan statistics computes the relative risk (RR), likelihood ratio (LLR) and P-value for each scan window.

Results

Characteristics of the TB Cases

This study covered the period January 2019 to December 2022 and 4897 patients who met the inclusion criteria were recruited for the study. The median age (IQR) of the patients was 66 years (54-81) with children aged 0-15 yrs being only 0.5%, and majority of the patients were males (64%). Pulmonary TB was commonest form of TB (91%) and 18% (848/4585) of the patients tested positive for HIV. Of the total notified cases of TB, 90% (4401/4897) were new cases and 1% (61/4897) were DRTB cases.

Tuberculosis Case Notification Rates

Over the 4-year period (2019 - 2022), the overall mean TB CNR for JM was 117 per 100,000 of the population, and overall, the CNRs increased over the study period (Table 1 and Figure 2). The lowest CNRs were seen in the EWs in the southern part of JM (JS). The highest CNRs were recorded in the EWs (Naraguta A, Garba Daho, Ibrahim Katsina, Abba NaShehu, Tudun/Wada Kabong, Jenta Apata, Ali Kazaure, Gangare and Sarkin Arab) in the northern part of the metropolis (JN). Most of these EWs are centrally located in JN - Garba Daho, Ibrahim Katsina, Abba NaShehu, Jenta Apata, Ali Kazaure, Gangare and Sarkin Arab (Table 1 and Figure 3).

Table 1. Tuberculosis case notification rates for Electoral Wards in Jos Metropolis, 2019 – 2022

Electoral Wards	**Year 2019**			**Year 2020**			**Year 2021**			**Year 2022**			**2021-2022**
	TB Cases	**EW Pop**	**TB CNR**	**TB Cases**	**EW Pop**	**TB CNR**	**TB Cases**	**EW Pop**	**TB CNR**	**TB Cases**	**EW Pop**	**TB CNR**	**TB CNR***
Jos North													
Abba NaShehu	20	2885	693	30	2946	1018	32	3007	1064	29	3071	944	932
Ali Kazaure	18	4666	386	22	4764	462	43	4864	884	40	4966	805	639
Garba Daho	17	3196	532	6	3263	184	20	3332	600	23	3402	676	500
Gangare	27	5258	514	34	5368	633	16	5481	292	24	5596	429	465
Ibrahim Katsina	11	2734	402	9	2791	322	11	2850	386	15	2910	515	408
Jenta Adamu	45	26244	171	35	26795	131	27	27358	99	35	27932	125	131
Jenta Apata	40	14033	285	43	14328	300	75	14629	513	45	14936	301	350
Jos Jarawa	80	79972	100	79	81651	97	90	83366	108	124	85117	146	113
Naraguta A	22	5107	431	35	5214	671	43	5324	808	47	5436	865	697
Naraguta B	159	126297	126	210	128949	163	251	131657	191	264	134422	196	170
Sarkin Arab	10	2316	432	9	2365	381	12	2414	497	14	2465	568	471
Tafawa Balewa	8	2698	297	5	2755	182	2	2813	71	3	2872	104	162
TudunWad/ Kabong	143	83900	170	165	85662	193	215	87461	246	213	89297	239	213
Vanderpuye	0	3750	0	1	3829	26	2	3909	56	3	3991	75	39
Sub-total	600	363056	165	683	370680	184	839	378464	222	879	386412	227	200
Jos South													
Bukuru	50	59988	83	43	61248	70	69	62534	110	55	63847	86	88
Du	47	136429	34	38	139294	27	45	142219	32	47	145206	32	31
Giring	52	58336	89	39	59561	65	67	60812	110	56	62089	90	89
Gyel A	27	31015	87	35	31666	111	37	32331	114	42	33010	127	110
Gyel B	33	49893	66	37	50941	73	41	52011	79	32	53103	60	69
Kuru A	8	49440	16	6	50478	12	7	51538	14	15	52621	29	18

Kuru B	15	20945	72	12	21385	56	20	21834	92	24	22292	108	82
Shen	11	19995	55	4	20415	20	13	20844	62	8	21281	38	44
Turu	40	70854	56	26	72342	36	36	73861	49	49	75412	65	52
Vwang	64	65402	98	55	66775	82	60	68178	88	56	69609	80	87
Zawan A	51	69621	73	45	71083	63	55	72576	76	77	74100	104	79
Zawan B	57	22685	251	53	23161	229	64	23648	271	73	24144	302	264
Sub-total	455	654603	70	393	668350	59	514	682385	75	534	696715	51	70
Total	**1055**	**1017659**	**104**	**1076**	**1039030**	**104**	**1353**	**1060849**	**128**	**1413**	**1083127**	**130**	**117****

EW = Electoral ward, Pop = population, TB = Tuberculosis, CNR = Case notification rate per 100,000 of the population.

**Mean TB case notification rate for each EW over a 4-year period (2019-2022).*

*** Overall mean TB case notification rate over a 4-year period (2019-2022) for Jos Metropolis.*

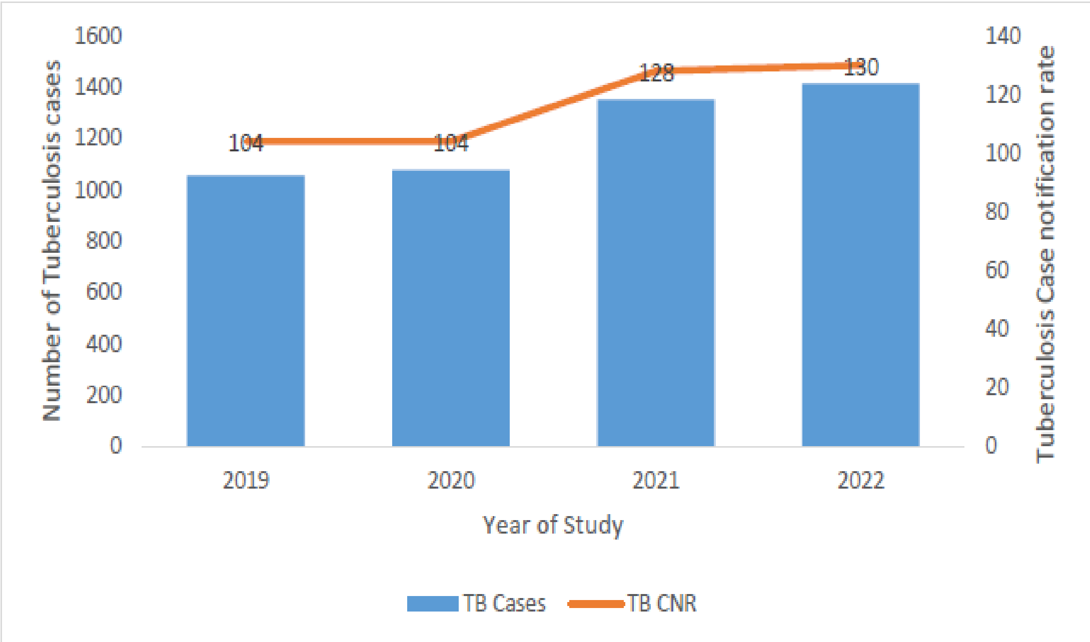

Figure 2. Tuberculosis cases notification rate (CNR) and Number of Tuberculosis cases and in Jos Metropolis, 2019 - 2022

Tuberculosis Spatial Pattern

Figure 3 (a - d) shows the TB spatial patterns for 2019 - 2022, with the northern part of the JM having the EWs with highest CNRs.

Global Spatial Autocorrelation

Over the period 2019 to 2022, there was a strongly positive spatial autocorrelation of the TB cases (global Moran's I = 0.925860, P-value = 0.0001) and for each individual year 2019, 2020, 2021 and 2022, the Moran's I and P-values were: 0.874624 and 0.0001; 0.926799 and 0.0001; 0.938986 and 0.0001; and 0.894014 and 0.0001, respectively. These results indicate that TB cases distribution in the EWs of JM was spatially clustered than would be expected by chance alone.

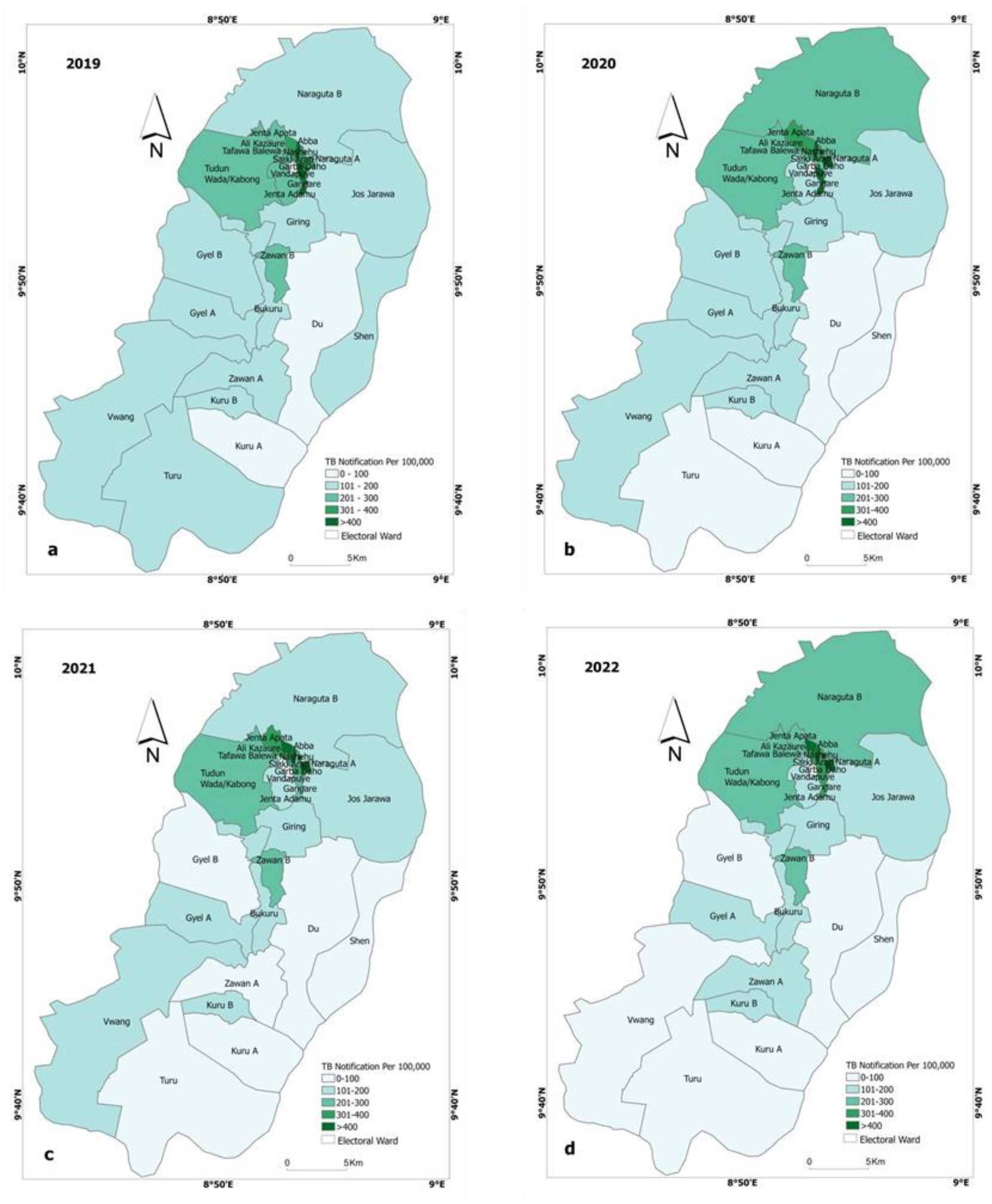

Figure 3. Spatial distribution of Tuberculosis case notification per 100,000 of the population in Jos Metropolis, 2019 - 2022

Spatial Analysis

In the purely spatial analysis, for each of the four years, one primary (A) and one secondary (B) significant TB clusters were identified (Figure 4), with the primary ones in JN and secondary ones in JS. The primary clusters also contain the EWs with the highest CNRs - Naraguta A, Garba Daho, Ibrahim Katsina, Abba NaShehu, Tudun/Wada Kabong, Jenta Apata, Ali Kazaure, Gangare and Sarkin Arab (Table 1 and Figure 4).

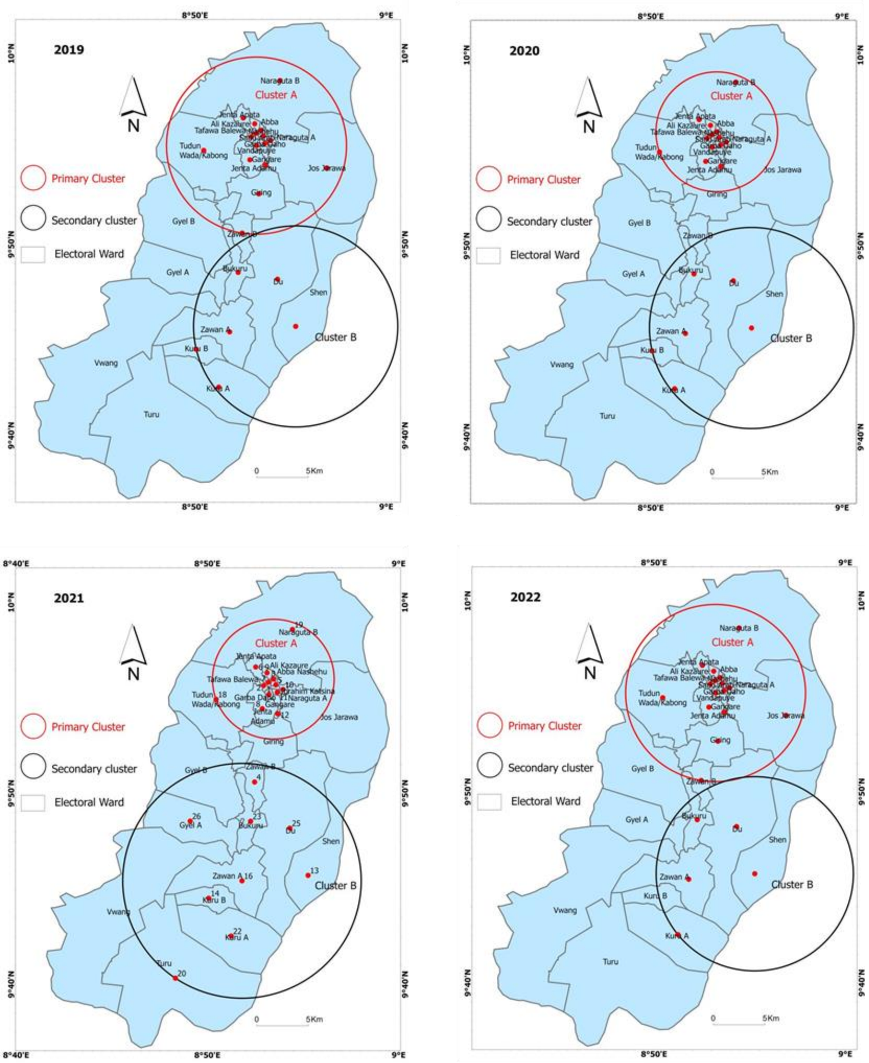

Figure 4. Purely spatial Tuberculosis clusters in Jos Metropolis, 2019 - 2022

Spatio-Temporal Analysis

From 2019 to 2022, four TB clusters were identified with three of them (A, B, and C) significant (Figure 5). Thirteen EWs were present within the significant primary cluster A in the time frame January 2021 - December 2022 (LLR = 436.95, RR = 2.68 and P-value = 0.001) and these were – Naraguta A, Naraguta B, Garba Daho, Ibrahim Katsina, Abba NaShehu, Vandpuye, Tudun/Wada Kabong, Jenta Apata, Ali Kazaure, Gangare, Tafawa Balewa, Jenta Adamu, and Sarkin Arab (Table 2).

Table 2. Spatio-Temporal Clusters of Tuberculosis in Jos Metropolis from 2019 to 2022

Time frame	Type of cluster	Number of EW locations in a cluster	Radius of a cluster (Km)	Observed Cases	Expected Cases	LLR	RR	P-value
Jan 2021 - Dec 2022	A	13	5.8	1504	694	436.95	2.68	0.001
Jan 2019 - Dec 2020	B	6	9.7	330	841	233.51	0.35	0.001
Jan 2019 - Dec 2019	C	11	3.0	218	85	73.97	2.63	0.001
Jan 2019 - Dec 2019	D	2	5.0	60	95	7.37	0.63	0.073

EW = Electoral ward, 1 = Primary (Significant) Cluster, 2 - 4 = Secondary clusters, LLR = Log likelihood ratio, RR = Relative risk

Primary cluster A, with a radius of 5.80 Km, encloses secondary cluster C, which has a radius of 2.96 Km (Figure 5).

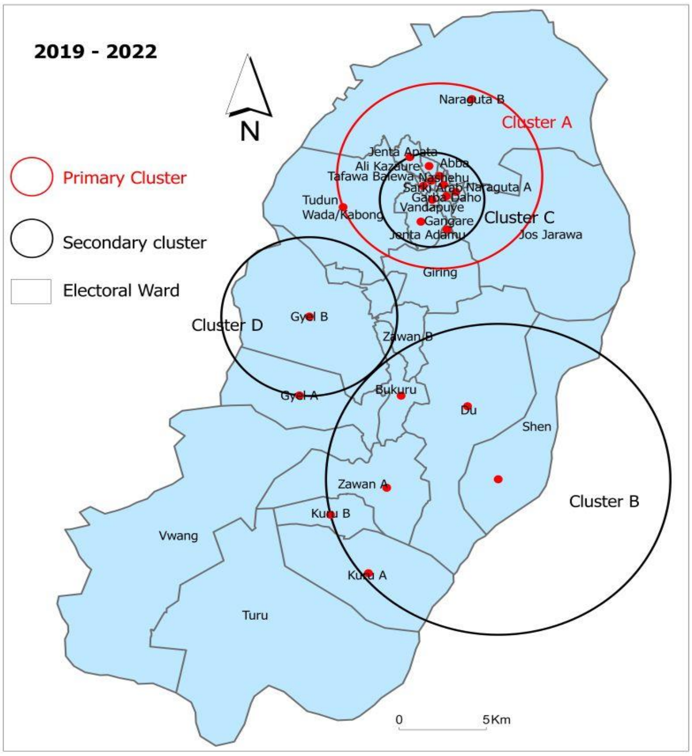

Figure 5. Tuberculosis Spatio-temporal clusters in Jos Metropolis, 2019 – 2022

Discussion

In this study, both TB cases spatial and spatio-temporal patterns in JM were explored. The spatial distribution of TB cases and the significant purely spatial TB clusters were predominantly found in the central areas of the northern part of JM. Within these clusters were the EWs - Naraguta A, Garba Daho, Ibrahim Katsina, Abba NaShehu, Tudun/Wada Kabong, Jenta Apata, Ali Kazaure, Gangare and Sarkin Arab. These EWs were also located within the significant (primary) space-time clusters (with time frame Jan 2021-Dec 2022) and they had the highest CNRs. Overall, just as reported in other studies [20-22], the findings in this study indicate spatial heterogeneity in the distribution of TB cases both across geographical space and over time.

The identification of a significant spatio-temporal cluster between January 2021 - December 2022 (two years), suggests that the factors driving TB transmission may have become more pronounced over time. The persistence of significant TB clusters in the same locations of the above EWs within those two years may suggest a sustained TB infection/disease transmission. This may imply that over time, TB has the potential to spread from this cluster to the other areas of JM, especially the southern part (JN), where the TB CNRs are relatively lower.

Several factors have been identified as drivers of TB transmission. According to the United Nations, overcrowding—a key indicator of a slum and a marker of poverty and social deprivation—is one such factor [23]. Some areas in the EWs (Tudun Wada and Gada Biu in Tudun Wada/Kabong EW, Angwan Rukuba in Naraguta B EW and Jenta Adamu EW itself), which are within the identified significant TB space-time cluster, have been identified by one study as areas of urban slum of Jos city with high levels of overcrowding and poverty [24].

It is thought that TB clusters and hotspots are observed in overcrowded and impoverished settings due to the natural spatial dependence of TB incidence/occurrence, attributed to the airborne nature of its transmission, which is enhanced by overcrowding [25]. Also, malnutrition, which is usually associated with poverty, could result in a weakened immune system and hence TB disease susceptibility [26].

These study findings could be utilised in the planning and implementation of TB prevention and control through the optimal allocation of scarce resources by the Nigerian TB control programmes and by TB programmes in other resource-limited countries. One study [27] showed that, instead of using a uniform approach to TB prevention and control, targeted interventions which focus on geographic areas dominated by clusters will be more effective. Given the space-time nature of the identified significant TB cluster, timely intervention is necessary to limit and prevent further TB transmission within the metropolis.

The Jos Metropolis bus and train terminal is in close proximity to some of the EWs - Abba NaShehu, Naraguta A, Ali Kazaure, Garba Daho, Sarkin Arab, Gangare and Ibrahim Katsina, identified in the space-time clusters. This terminal is also within the Jos Terminus market, and both are known to be densely populated and overcrowded. A systematic review [28] showed that Tuberculosis transmission and incidence are enhanced in overcrowded/ densely populated settings. Our study findings that areas located within TB clusters are were those associated with densely populated and impoverished areas of Jos Metropolis [24] is similar to a spatio-temporal study finding from Nairobi in Kenya [29]. In the Nairobi study, the authors reported that most of the TB cluster locations were in poor and high population densities areas. Also, another spatio-temporal study from greater Banjul in The Gambia, in West Africa showed that TB clusters were in the most densely populated areas and areas with some of the highest TB incidence rates of [30] which was similar to our study findings.

In this study, we leveraged an already available INEC Electoral Wards polling unit locator (PUL) to geolocate the study patients, an approach that has not been used before, at least in our setting. Other researchers in Nigeria could utilise this geolocation approach for an initial exploratory geospatial mapping and analysis of TB and other disease conditions instead of using a hand-held GPS for real-time geolocation. This approach has the advantage of being cost-effective, logistically easier and convenient.

This study was unable to look at potential risk factors that might help explain the space-time clustering of the TB cases in some EWs of the metropolis. Another limitation was that patients who lacked any form of address (complete or incomplete) or whose localised residential area is not known, and who were therefore excluded from the study, might have biased the observed spatial pattern.

Despite this study’s limitations, its results can be used to target the areas with significant TB clusters and the highest CNRs for more effective TB prevention and control. This will require optimal allocation of resources, including healthcare workers, TB diagnostic facilities and treatments. In addition to these, there should be increased TB surveillance, focused and intensive health education campaigns on TB prevention measures, and, where improvement in other socio-economic parameters like improved housing conditions.

Conclusion

The EWs in the central areas of the northern part of JM had the highest TB case notification rates and these also had significant purely spatial as well as spatio-temporal TB clusters. In view of the space-time nature of these clusters, there is an urgent need for timely and targeted interventions to limit and prevent further spread of TB in JM from these clusters.

Conflict of Interest

All Authors declare that they have no competing interests.

Ethical Approval

Ethical approval for this study was given by the Plateau Specialist Hospital and permission for use of the TB data was given by the Plateau State Ministry of Health.

Author Contributions

AOE: Conceptualisation, design and writing original draft; AOE, IG: Analysis and Interpretation; AOE, IG, OMU-E, M-JEE and FRT: Data curation, Writing – Review & Editing; IG and FRT: Supervision.

All authors approved the final manuscript before submission and take responsibility for its content.

Data Availability

Available on request.

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References

[1]. World Health Organization (WHO), 2023, Global Tuberculosis Report 2024. Retrieved from https://www.who.int/teams/global-programme-on-tuberculosis-and-lung-health/tb-reports/global-tuberculosis-report-2024/tb-disease-burden/1-1-tb-incidence

[2]. KNCV Nigeria, 2023, Tuberculosis in Nigeria. Retrieved from https://kncvnigeria.org/nigeria-is-among-the-14-high-burden-countries-for-tb/

[3]. Ogbudebe, C., et al., 2023, Identifying Hot Spots of Tuberculosis in Nigeria Using an Early Warning Outbreak Recognition System: Retrospective Analysis of Implications for Active Case Finding Interventions. *JMIR Public Health Surveill*, 9, e40311, Doi: 10.2196/40311.

[4]. Federal Ministry of Health (FMOH), 2019. Draft 2019 Annual TB Report. Retrieved from https://www.health.gov.ng/doc/Draft-2019-NTBLCP-Annual-report-22032020.pdf

[5]. National Tuberculosis, Leprosy and Buruli Ulcer Control Programme (NTBLCP), 2023. Retrieved from https://ntblcp.org.ng/resources/2023-annual-tb-report/

[6]. Federal Ministry of Health (FMOH), 2019, Draft 2019 Annual TB Report. Retrieved from https://www.health.gov.ng/doc/Draft-2019-NTBLCP-Annual-report-22032020.pdf

[7]. Plateau State Tuberculosis and Leprosy Control Programme (PLSTBLCP), 2019, Quarterly report on tuberculosis case finding. *National Tuberculosis and Leprosy Control Programme*.

[8]. World Health Organization (WHO), 2006, Building on and enhancing DOTS to meet the TB-related millennium development goals. Retrieved from http://apps.who.int/iris/bitstream/handle/10665/69241/WHO_HTM_STB_2006.368_eng.pdf?sequence=1

[9]. World Health Organization (WHO), 2008, Implementing the WHO Stop TB Strategy, a handbook for national TB control programmes. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK310745/pdf/Bookshelf_NBK310745.pdf

[10]. Teibo, T. K. A., Berra, T. Z., Alves, Y. M., Tavares, R. B. V., Olayemi, O. A., Arcêncio, R. A., 2025, Surveillance of tuberculosis incidence and mortality through spatio-temporal analysis in Oyo

State, Nigeria. *PloS one,* 20(7), e0311739, https://doi.org/10.1371/journal.pone.0311739

[11]. Kefas, I. B., Isiko, I., Okoro, L. N., Isa, H., Asingwire, J. M., Manankong, J. P. I., et al., 2024, Spatial and temporal distribution of tuberculosis infection in Plateau State, Nigeria, A descriptive ecological study. *Student's Journal of Health Research Africa,* 5(12), 13, https://doi.org/10.51168/sjhrafrica.v5i12.1413

[12]. National Population Commission (NPC), 2010, Population distribution by sex, state, LGA senatorial district, 2006 Population and Housing Census, Priority Table Volume III. Retrieved from http://catalog.ihsn.org/index.php/catalog/3340/download/48521

[13]. Independent National Electoral Commission (INEC), PUL, 2025, Polling Unit Locator. Retrieved from https://cvr.inecnigeria.org/pu

[14]. Federal Ministry of Health (FMOH), 2015, National tuberculosis, leprosy and Buruli ulcer management and control guidelines. Retrieved from https://www.health.gov.ng/doc/NTBLCP-TBL_BU-Management-Control-guidelines-2015_050315.pdf

[15]. GRID 3, 2021, GRID 3 Data Hub for Nigeria (NGA). Retrieved from https://data.grid3.org/datasets/0824aded5f5a4d39b10871c667aa8ccf_0/about

[16]. GADM, 2025, Retrieved from https://gadm.org/data.html

[17]. Worldpop, 2019, Retrieved from https://hub.worldpop.org/geodata/summary?id=28030

[18]. World Bank, 2023, Nigeria population annual growth rates. Retrieved from https://data.worldbank.org/indicator/SP.POP.GROW?locations=NG

[19]. Kulldorff, M. A., 1997, Spatial scan statistic. Communications in Statistics, *Theory and Methods*, 26:1481-1496.

[20]. Dangisso, M. H., Datiko, D. G., Lindtjørn, B., 2015, Spatio-Temporal Analysis of Smear-Positive Tuberculosis in the Sidama Zone, Southern Ethiopia. *PloS One,* 10(6): e0126369, Doi:10.1371/journal.pone.0126369.

[21]. Tadesse, S., Enqueselassie, F., Hagos, S., 2018, Spatial and space-time clustering of tuberculosis in Gurage Zone, Southern Ethiopia, *PloS One,* 13(6): e0198353. https://doi.org/10.1371/journal.pone.0198353

[22]. Asemahagn, M. A., Alene, G. D., Yimer, S. A., 2021, Spatial-temporal clustering of notified pulmonary tuberculosis and its predictors in East Gojjam Zone, Northwest Ethiopia. *PloS One,* 16(1):e0245378, https://doi.org/10.1371/journal.pone.0245378

[23]. World Health Organisation (WHO), 2018, WHO Housing and health guidelines. *Geneva: World Health Organization,* Licence:CC BY-NC-SA 3.0 IGO. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK535289/

[24]. Lekwot, V. E., Yakubu, A. A., Kwesaba, D. A., Sahabo, A. A., 2015, An analysis of inner city decay, A study of some selected slums in Jos Metropolis, Plateau State, Nigeria. *International Journal of Scientific and Technology Research,* 4(2), 171–176.

[25]. Im, C., Kim Y., 2021, Spatial pattern of tuberculosis (TB) and related socio-environmental factors in South Korea, 2008-2016. *PloS One,* 16(8), e0255727, https://doi.org/10.1371/journal.pone.0255727

[26]. Centers for Disease Control and Prevention (CDC), 2025, Tuberculosis. Retrieved from https://www.cdc.gov/tb/hcp/clinical-overview/tuberculosis-disease.html#:~:text=How%20it%20spreads,Disease%20rates

[27]. Dowdy, D. W., Golub, J. E., Chaisson, R. E., Saraceni, V., 2012, Heterogeneity in tuberculosis transmission and the role of geographic hotspots in propagating epidemics. *Proc Natl Acad Sci U S A,* 109(24), 9557-9562, Doi: 10.1073/pnas.1203517109.

[28]. Lee, J. Y., Kwon, N., Goo, G. Y., Cho, S. I., 2022, Inadequate housing and pulmonary tuberculosis, a systematic review. *BMC public health,* 22(1), 622. https://doi.org/10.1186/s12889-022-12879-6

[29]. Maore, N. K., Kirui, N. K., Kireki, O., Ogutu, O., Owino, M., Ogaro, T., et al., 2018, Spatial and

temporal distribution of notified tuberculosis cases in Nairobi County, Kenya, between 2012 and 2016. *East African Medical Journal*, *94*(10), S28-S40, https://doi.org/10.4314/eamj.v94i10.

[30]. Touray, K., Adetifa, I. M., Jallow, A., Rigby, J., Jeffries, D., Cheung, Y. B., Donkor, S., Adegbola, R. A., Hill, P. C, 2010, Spatial analysis of tuberculosis in an urban west African setting: is there evidence of clustering? *Trop Med Int Health*, 15(6), 664-672, Doi: 10.1111/j.1365-3156.2010.02533.x.