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Spatial epidemiology of tuberculosis in the high-burden counties of Kisumu and Siaya, Western Kenya, 2012–2015

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SUMMARY

BACKGROUND: Effective management of tuberculosis (TB) and reduction of TB incidence relies on knowledge of where, when and to what degree the disease is present.

METHODS: In a retrospective cross-sectional study, we analysed the spatial distribution of notified TB incidence from 1 January 2012 and 31 December 2015 in Siaya and Kisumu Counties, Western Kenya. TB data were obtained from the Division of Leprosy, Tuberculosis and Lung Disease, Nairobi, Kenya, as part of an approved TB case detection study. Cases were linked to their corresponding geographic location using physical address identifiers. Spatial analysis techniques were used to examine the spatial and temporal patterns of TB. Assessment of spatial clustering was carried out following Moran's *I* method of spatial autocorrelation and the Getis-Ord Gi* statistic.

RESULTS: The notified TB incidence varied from 638.0 to 121.4 per 100 000 at the small area level. Spatial analysis identified 16 distinct geographic regions with high TB incidence clustering (GiZScore $\geqslant$ 2.58, $P <$ 0.01). There was a positive correlation between population density and TB incidence that was statistically significant (rs = 0.5739, $P = 0.0001$).

CONCLUSION: The present study presents an opportunity for targeted interventions in the identified subepidemics to supplement measures aimed at the general population.

KEY WORDS: TB; incidence; high-burden; spatial analysis; epidemiology

TUBERCULOSIS (TB) REMAINS one of the world's deadliest diseases despite great advances made over the past two decades; at the end of 2016, there were an estimated 10.4 million new TB cases and 1.5 million deaths due to TB worldwide.[1] However, TB incidence and the related burden vary considerably from country to country. Kenya is ranked 15th among the 22 high-burden countries that contribute 80% of the global burden; in Africa, it is ranked number five out of the 15 listed countries.[2] In-country data also reveal geographical variations in TB burden. For example, the Nyanza Region (encompassing Siaya and Kisumu Counties) in Western Kenya has the highest TB burden, with an estimated incidence of 500 cases per 100 000 population.[3] Some portions of the region, including areas around Kisumu City, report an incidence of up to 700 cases/100 000. The region also suffers a concurrent human immunodeficiency virus (HIV) burden that is nearly 3–4 times the nationally reported average of 5.9% (24.8% in Siaya County and 19.9% in Kisumu at the end of County 2015).[4]

Effective management of TB and reduction of incidence rates relies on knowledge of where, when and to what degree the disease is present. TB control programmes in Kenya have mostly focused on detecting and treating index cases.[5,6] TB is primarily spread through close contact with diseased individuals (mostly household contacts). Hence, programmes need to identify areas with increased TB occurrence so as to employ aggressive prevention measures (such as active case finding), which reduce the time available for transmission of *Mycobacterium tuberculosis* to others, thereby decreasing incidence. The problem is that data to determine geographical populations with higher risk of acquiring TB disease are not readily available.

Disease mapping using geographical information systems (GISs) is a tool widely used in epidemiology to identify population groups with a higher risk of sickness or premature mortality to guide public health intervention.[7] Over the last two decades, there has been increased application of GISs in the context of public health and research.[8–11] In the case of TB, researchers have used GISs over the last two decades to study this infectious disease.[12–16] For example,

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GISs have been used to analyse the transmission patterns of *M. tuberculosis* in Linyi City, China, during 2005–2010.[12] In urban West Africa, GISs were used to investigate and identify TB clusters in the Greater Banjul Region in Gambia.[14] Comparable GIS techniques have been applied in Madagascar[15] and India[16] to understand disease prevalence and risk factors, and to guide control measures.

Despite the demonstrated utility of GISs in TB prevention and control programmes, we found limited evidence of its application in Kenya, particularly with more granularity, even if such information can enhance the effectiveness of interventions. Since 2012, Kenya has been implementing an electronic TB register system (TIBU), for which complete data were available for 2012–2015.

The objective of the present study was to investigate the spatial clustering patterns and temporal variations of TB notification in the high-burden counties of Siaya and Kisumu, Western Kenya.

METHODS

Study setting

Siaya and Kisumu Counties are made up of 13 subcounties, 65 county Assembly Wards and 340 sublocations (lowest formal administrative units in Kenya) over a combined surface area of 5301 km^2 along the shores of Lake Victoria (Figure 1).

Data source

Population data

The population of Kisumu and Siaya Counties is estimated at 1 811 213 (respectively, 968 909 and 842 304) according to the latest national census conducted in 2009. Population estimates for each year were estimated using a growth rate of 2.7% in 2012 and 2013 and 2.6% in 2014 and 2015 based on projections from the Kenya National Bureau of Statistics (KNBS).

Tuberculosis data

We included TB cases between 1 January 2012 and 31 December 2015 residing in Siaya and Kisumu Counties. TB cases were diagnosed using sputum smear microscopy, Xpert® MTB/RIF (Cepheid, Sunnyvale, CA, USA), culture and/or abnormal radiography in the presence of symptoms. Laboratory-confirmed positive results and clinically diagnosed TB patients were included in the analysis. Individual patient data were linked to a corresponding geographic location (sublocation) using physical addresses. The sublocation is the lowest formal administrative unit in Kenya. To eliminate biases associated with smaller denominators (when calculating percentages and rates), we further aggregated the summarised data points at the sublocation level to the ward level. Typically, a ward comprises several sublocations that yield an almost equal population size within each subcounty. The notified incidence rate (NIR) for each ward was then normalised using the population sizes for each ward, i.e., NIR = (number of reported TB cases per year/population) $\times$ 100 000.

Ethics and consent

This work was performed collaboratively under protocols approved by the Kenya Medical Research Institute (KEMRI; Nairobi, Kenya), Walter Reed Army Institute of Research (WRAIR; Silver Spring, MD, USA) and the Centers for Disease Control and Prevention: KEMRI SSC#2094, WRAIR# 2102, and CDC #6450 respectively. Additional ethical approval was granted by the Maseno University (Kisumu, Kenya) Ethical Review Committee (MSU/DRPI/MUERC/000162/15). Access to county-level TB data were granted as part of the above approved TB case detection study.

Spatiotemporal trends and spatial autocorrelation of notified tuberculosis

Spatial analysis techniques within ArcGIS v 10.3.1 (Environmental Systems Research Institute, Redlands, CA, USA) were used to generate maps to examine the temporal pattern of TB NIR. We used the global Moran's I statistic[17] to assess the presence and nature of TB spatial autocorrelation (or dependency) for each of the years. A calculated value of $G_i^* \geqslant 1.96$ indicates that the ward and its neighbouring wards had a notified TB incidence rate that was statistically significantly higher than that of other wards.

Tuberculosis clusters and hotspots analysis

We relied on two local measures of spatial association within ArcGIS v 10.3.1 to indicate where the clusters or outliers were located and which type of spatial correlation was most important.[18] Anselin Local Moran's I allowed us to detect core clusters/outliers of wards with unexplained extreme TB values using random variation, and to classify these into 'hotspots' (high values next to high, HH), 'coldspots' (low values next to low, LL) and spatial outliers (high among low, HL or vice versa, LH).

Furthermore, we used the local Getis-Ord statistic, Gi*, to provide additional information indicating the intensity and stability of core hotspot/coldspot clusters. The output of the hotspot analysis tool is GiZScore and GiPValue for each feature. The higher the GiZScore, the more intense is the clustering. A GiZScore score near zero indicates no apparent spatial clustering. A calculated value of Gi* $\geqslant$1.96 (95% significance level, P <0.01) indicates that the ward and its neighbouring wards have a TB rate that is statistically significantly higher than that of other wards.[19]

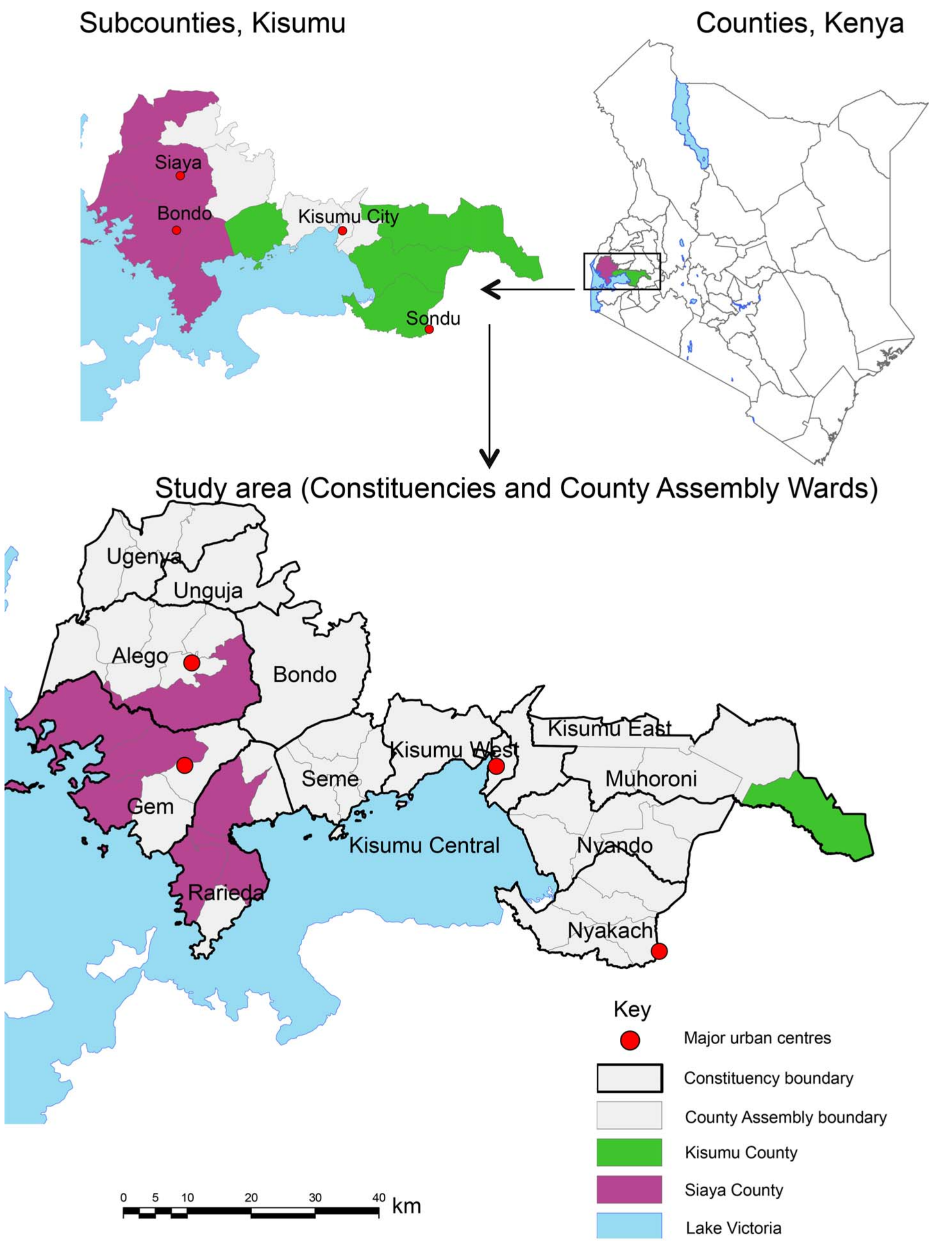

Figure 1 Map showing location of study area and administrative boundaries (county, subcounty and ward assembly).

Statistical analysis

We computed population-based ratios for each ward strata, which were grouped using level of urbanisation and population density. We first tested for data normality and used the Spearman's test to correlate the TB rate to population density. The Wilcoxon rank-sum was used to compare the average TB rate in urban and rural wards.

RESULTS

Descriptive analysis of tuberculosis cases

A total of 23 374 TB cases were extracted from TB registers in Siaya and Kisumu Counties from 2012 to 2015. In the spatial analysis of the 23 374 cases reported, 20 804 cases (89.4%) were geocoded to the study area. Losses were due to missing locator information, inconclusive addresses or addresses confirmed to be outside the study area (Figure 2).

Spatial and temporal patterns of tuberculosis cases

The TB notified incidence rate (annualised average) over the 4-year period was 259.5/100 000 (230.3/100 000 females, 293.9/100 000 males). The TB cases were distributed within the two counties, 13 subcounties and all 65 wards. There was an evident temporal variation in the NIR—from 310.6/100 000 in 2012 to 213.8/100 000 by the end of 2015. At the county level, the average NIR over the 4-year period was 304.3/100 000 in Kisumu County and 213.3/100 000 in

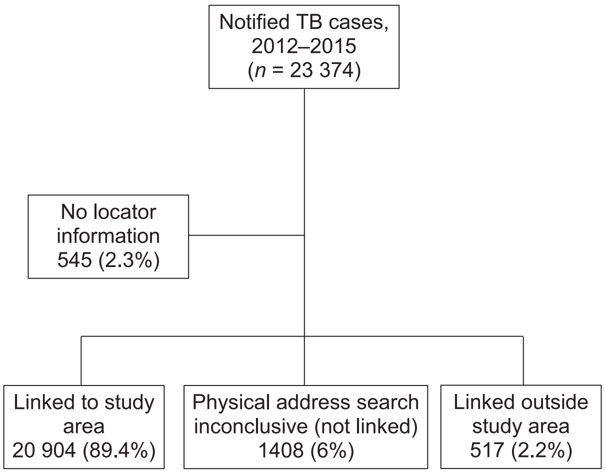

Figure 2 Percentage of geo-coded TB cases. TB = tuberculosis.

Siaya County. The higher rates in Kisumu County than in Siaya County was replicated over the 4-year period. At the small area level, the NIR (annualised average) varied from 638.0/100 000 in Market Milimani to 121.4/100 000 in Masogo/Nyango'ma ward.

In general, areas around Kisumu City such as Market Milimani Ward (638/100 000), Manyatta B Ward (570/100 000) and Railways Ward (493/100 000) recorded higher TB rates than the rest of the study area. The average TB rate was 3.9 in the urban wards and 2.2 in the rural wards (Wilcoxon rank-sum, $P = 0.0001$). There was a positive correlation between population density and rate of TB, which was statistically significant (rs = 0.5739, $P = 0.0001$). An isolated high rate was also observed in South-East Nyakach (bottom right ward of the study area), with 459.4/100 000. Figure 3 shows the spatial variations of TB rates between 2012 and 2015 in Siaya and Kisumu Counties.

Table 1 presents the notified TB incidence from 2012 to 2015, complemented by rates of new smear-positives, extra-pulmonary TB (EPTB), TB-HIV, and general mortality rates at county and subcounty levels. The rate of EPTB varied from 72.1/100 000 in Kisumu Central to 23.0/100 000 in Nyando, both in Kisumu County. The rate of new smear-positives ranged from 184.4 in Kisumu Central, Kisumu County, to 64.1 in Ugunja, Siaya County. The proportion of TB-HIV was 65.4% (13 667/20 904), which translated into a rate of 169.4/100 000 for the study area. At the subcounty level, TB-HIV positivity varied from 255/100 000 in Kisumu Central to 96.6/100 000 in Muhoroni, both in Kisumu County. The average mortality among TB patients over the 4-year period was 24.2/100 000. The rate of treatment failures ranged from 23.1/100 000 in Kisumu Central, Kisumu County, to 3.2/100 000 in Ugenya, Siaya County. Variations at the ward level are presented in Appendix Table A*.

* The appendix is available in the online version of this article, at http://www.ingentaconnect.com/content/iuatld/ijtld/2019/00000023/00000003/art000 .....

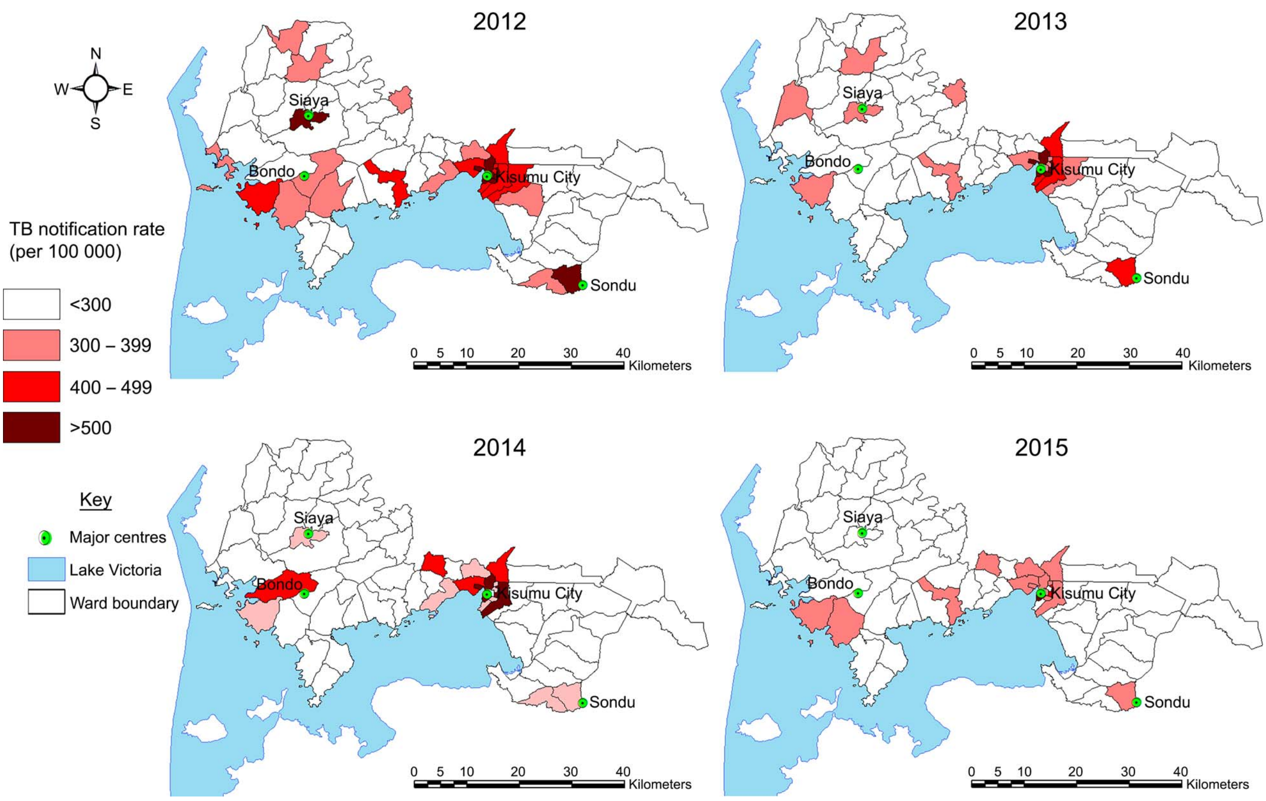

Figure 3 Spatial trends in TB incidence by ward/100 000 population, 2012–2015. TB = tuberculosis.

Table 1 TB notification rates/100 000 population in Kisumu and Siaya Counties, Kenya

	TB/100 000 population				Cases/100 000 population					
	2012	2013	2014	2015	TB rate*	EPTB	New smear-positive	TB-HIV†	Mortality	Treatment failures
Siaya and Kisumu (study area)	310.6	260.0	257.5	213.8	259.5	41.5	106.4	169.4	24.2	10.1
Kisumu County	370.4	302.1	300.1	249.3	304.3	43.9	126.5	191.1	24.6	11.4
Kisumu Central	563.9	492.1	402.5	345.5	448.6	72.1	184.4	255.0	23.2	23.2
Kisumu East	461.4	381.7	375.4	309.4	380.4	56.5	154.7	249.8	28.0	15.0
Kisumu West	366.8	264.0	392.1	306.3	332.1	47.1	139.8	202.9	28.3	13.9
Muhoroni	167.4	152.1	173.2	119.3	152.6	22.9	72.1	96.6	13.0	5.1
Nyakach	339.9	267.1	264.6	217.5	271.1	35.7	90.7	188.7	27.5	4.1
Nyando	279.7	198.6	208.3	167.0	212.3	23.0	97.7	141.8	21.9	6.0
Seme	308.7	247.5	253.3	263.7	267.9	34.8	123.9	189.7	38.9	4.4
Siaya County	248.8	216.6	213.5	177.1	213.3	39.0	85.8	147.0	23.7	8.8
Alego	261.4	252.1	230.0	136.6	218.7	40.1	76.3	150.2	27.9	6.3
Bondo	291.7	248.2	265.7	208.8	252.9	45.7	103.8	176.0	25.7	12.1
Gem	252.9	196.8	189.8	187.1	206.0	37.2	92.5	143.1	22.5	9.8
Rarieda	162.4	153.1	172.2	156.0	160.9	31.5	63.3	114.9	19.6	10.1
Ugenya	310.0	252.3	215.5	210.7	246.0	46.0	100.6	162.7	29.6	3.2
Ugunja	183.0	177.5	162.9	152.1	168.5	29.1	64.1	110.2	14.0	5.8

* Combined TB rate (2012, 2013, 2014 and 2015).
† HIV-positive cases/100 000 population.
TB = tuberculosis; EPTB = extra-pulmonary TB; HIV = human immunodeficiency virus.

Tuberculosis spatial autocorrelation/dependency

The global spatial autocorrelation analysis showed positive spatial autocorrelation (global Moran's $I >$ 0) in TB incidence from 2012 to 2015 ($P < 0.001$; Table 2). The highest Moran's I indices were observed in 2012 (Moran's $I = 1.217$, $P < 0.001$).

Figure 4 shows the core TB clusters/outliers based on Anselin Local Moran's I. The latter showed core clustering of high TB incidence wards next to high ones (HH) to be consistently located in the Kisumu Central Region composed of 11–13 wards over the 4-year period. HH clusters in 2012 to 2015 were relatively stable and included mainly wards around Kisumu City. The spatial analysis also showed a core 'coldspot' cluster of low-next-to-low (LL) wards consisting of 1–7 wards over the 4-year period. The Local Indicators of Spatial Association (LISA) cluster maps showed that, over time, there had been an increase in LL areas in the study area.

Tuberculosis hotspot detection and analysis

The hotspot analysis identified 16 primary hotspots (GiZScore $\geqslant$ 2.58, $P < 0.01$) over the 4-year period and two coldspots (GiZscore $\leqslant$ –2.58, $P < 0.01$) in 2015 (Figure 5). The hotspots were predominantly clustered around Kisumu City. The OrdGi* statistic also revealed a secondary intensity hotspot cluster (GiZScore 1.96–2.58, P <0.05 standard deviations [SDs]) in 2012 (Kabonyo/Kanyagwal) and two secondary intensity hotspot clusters (GiZScore 1.96–2.58 SDs) in 2014 (West Kisumu and Kabonyo/Kanyagwal).

DISCUSSION

We provided an analysis of the spatial and temporal variations of notified TB incidence within a high-burden population. Our analysis goes beyond current broad characterisations at national and regional levels[1,20] to local variations at county, subcounty and ward levels.

We found the variation in TB occurrence to be striking; the estimated notified TB incidence in some wards was 10 times that of others, the rate of new smear-positives varied up to 14 times, whereas treatment failure rates varied up to 40 times. These results could be effectively used for successful TB control programmes, even as more detailed individual-level investigations are done in the identified areas to evaluate the most important determinants of disease distribution.

We observed that the high notified TB incidence rates were mainly around the main towns of Kisumu, Siaya and Bondo for all the years except in 2015,

Table 2 Analysis of high/low clustering for different years using Getis-Ord Gi* statistics global spatial autocorrelation analyses for the tuberculosis rate in Siaya and Kisumu Counties, 2012–2015

Year	Observed	Expected	Variance	*Z* score	*P* value	Interpretation
2012	1.217947	−0.015625	0.00492	17.58677	<0.001	Clustered
2013	1.178259	−0.015625	0.00484	17.15353	<0.001	Clustered
2014	0.875971	−0.015625	0.00499	12.62123	<0.001	Clustered
2015	0.993379	−0.015625	0.00498	14.29390	<0.001	Clustered
Annualised average	0.556123	−0.015625	0.00479	8.257480	<0.001	Clustered

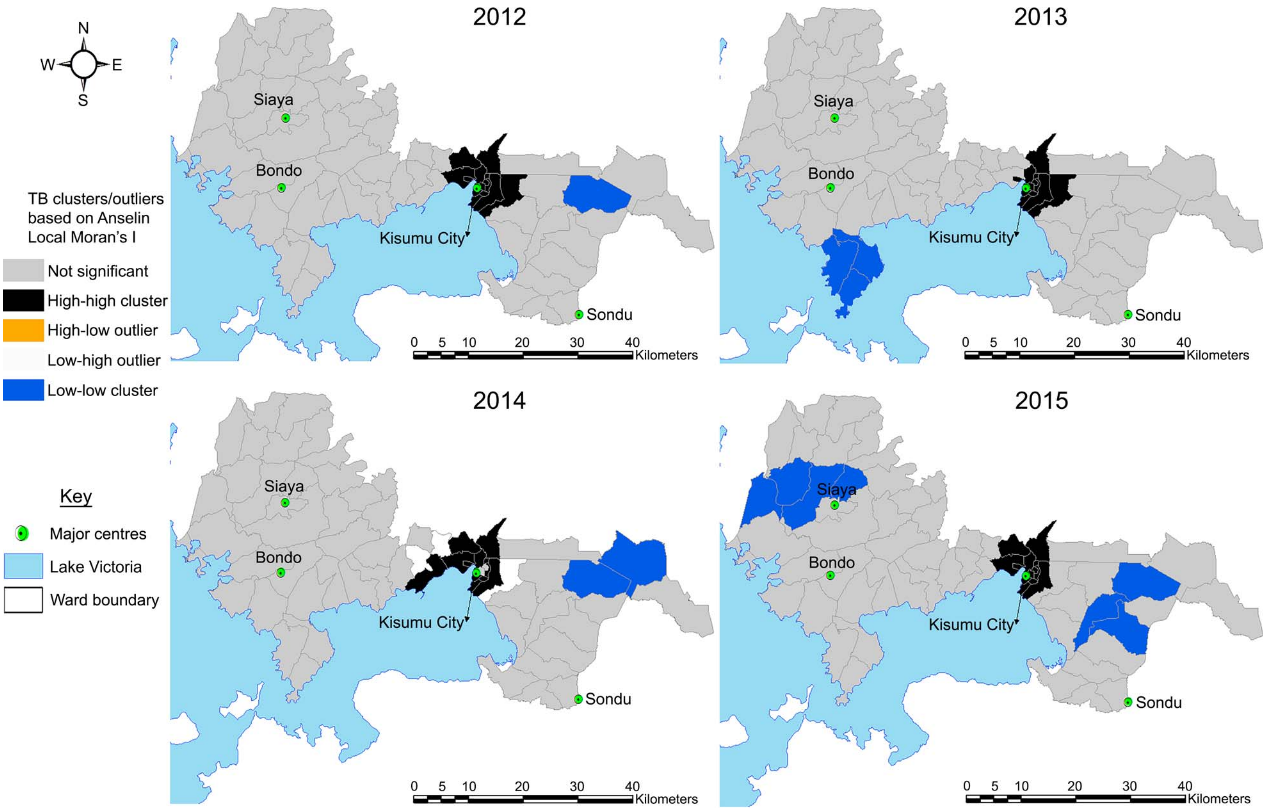

Figure 4 TB clusters/outliers based on Anselin Local Moran's *I*, 2012–2015. TB = tuberculosis.

when the TB rates around Siaya and Bondo decreased. Our results are consistent with those of other studies associating high TB occurrence with towns that have experienced increased urbanisation and immigration.[21–23] We also observed high TB rates in the southern part of Kisumu County, which borders the neighbouring Homa Bay County (South-East Nyakach). This area is located close to an

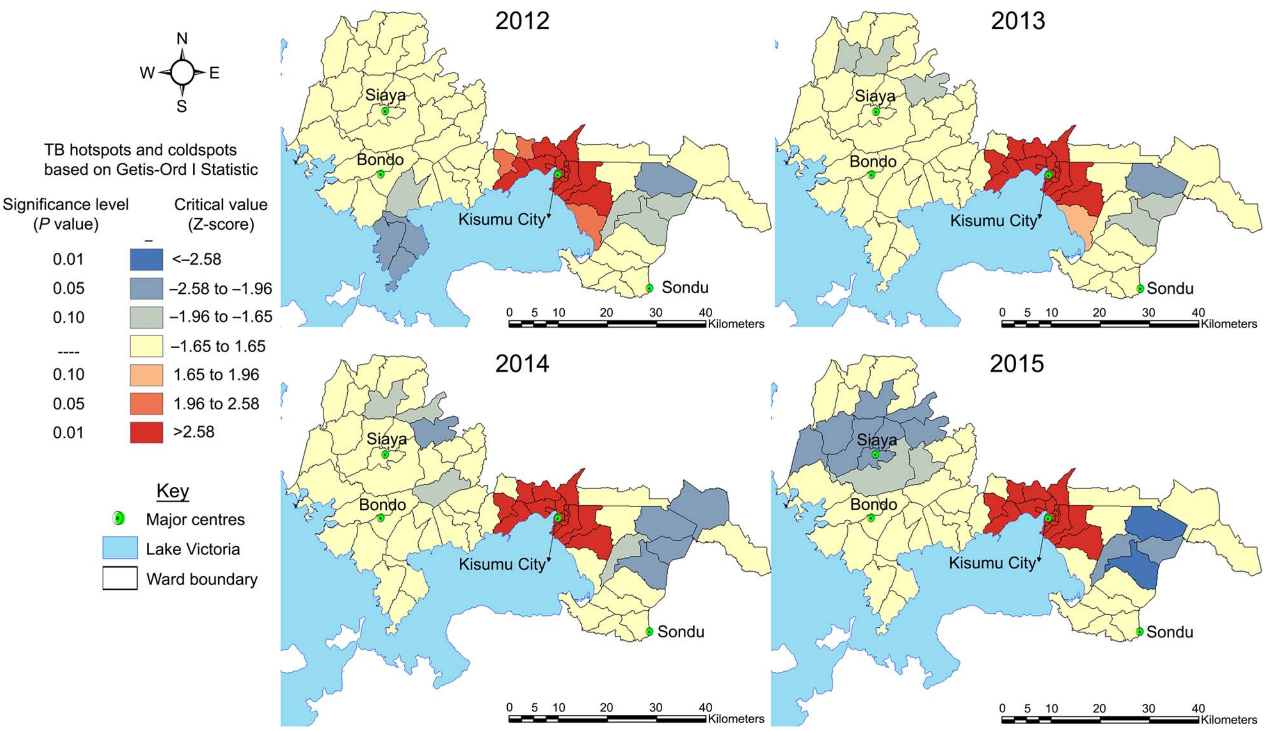

Figure 5 TB cluster type and intensity based on the Getis-Ord Gi* *Z* score (SD). TB = tuberculosis; SD = standard deviation.

industrial town (Sondu) that has grown due to the Sondu Miriu power plant. Sondu town also acts as a transport hub between neighbouring Kericho and Kisii towns. This could explain the higher TB rates in this region as a result of the high population of workers and traders in the town.

The present study showed that the spatial distribution of TB in Siaya and Kisumu Counties was non-random, and clustered with a significant Moran's *I* for each year. Local G_i* detected 16 wards with significant spatial clusters for high incidence of TB. The fact that the identified hotspots remained localised and stable over the 4-year period suggests ongoing TB transmission in these areas. Extreme *P* values clearly showed that the identified clusters were statistically significant.

While our study demonstrated the utility of GIS in our setting, it had limitations. First, we relied on passive surveillance data and could not therefore exclude the possibility of underreporting, considering that not all those who presented with TB sought care. There is also a possibility that some facilities (particularly private ones) did not submit their data to TIBU.

However, our study also had strengths. First, we used the ward level as a unit of analysis and included urban and rural settings, which helped to improve our understanding of the spatial epidemiology of the disease in a wider geographic context. In addition, the 4-year period enabled us to assess the spatial pattern and stability of clusters of the disease in the study area. With complete 2012 data as baseline, results from the present study could serve as a geographic early-warning disease surveillance system in the future, particularly if similar data are mapped in real time.

CONCLUSION

Identification of concentrated subepidemics within generalised epidemic settings presents an opportunity for targeted interventions to supplement measures aimed at the general population.

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Conflicts of interest: none declared.

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APPENDIX

Table A Notification rates/100 000 population in Kisumu and Siaya Counties, Western Kenya, 2012–2015

	Year				Cases/100 000 population					
County assembly ward	2012	2013	2014	2015	TB rate*	EPTB	New smear-positive	TB-HIV†	Mortality	Treatment failure
Study area average	310.6	260.0	257.5	213.8	259.5	41.5	106.4	169.4	24.2	10.1
Kisumu County	370.4	302.1	300.1	249.3	304.3	43.9	126.5	191.1	24.6	11.4
Kisumu Central total	563.9	492.1	402.5	345.5	448.6	72.1	184.4	255.0	23.2	23.2
Kondele	420.3	354.6	303.5	256.6	332.0	49.1	142.1	201.9	18.5	13.0
Manyatta B	725.2	608.9	521.3	440.7	570.9	65.2	323.6	289.4	32.6	24.7
Market Milimani	798.0	737.1	526.9	504.2	638.0	138.3	203.8	298.4	26.7	34.0
Migosi	480.8	331.6	336.5	319.3	365.5	67.3	128.9	213.0	26.9	12.3
Nyalenda A	530.4	532.0	391.2	323.8	441.9	71.6	151.7	280.7	22.8	29.1
Nyalenda B	465.2	466.5	338.3	282.3	385.9	57.6	163.8	252.2	18.5	30.2
Railways	585.7	538.9	530.3	330.7	493.9	70.0	215.8	304.2	24.8	21.6
Shaurimoyo Kaloleni	505.3	366.9	271.8	306.7	360.4	58.0	145.8	200.1	14.5	20.8
Kisumu East total	461.4	381.7	375.4	309.4	380.4	56.5	154.7	249.8	28.0	15.0
Kajulu	459.7	412.0	416.6	324.4	401.8	64.2	147.4	242.5	26.6	19.6
Kolwa Central	481.2	419.9	511.6	374.7	446.1	49.0	220.6	296.9	21.7	24.5
Kolwa East	443.5	313.0	197.9	229.1	293.4	56.4	96.1	209.9	35.5	1.0
Kisumu West total	366.8	264.0	392.1	306.3	332.1	47.1	139.8	202.9	28.3	13.9
Central Kisumu	412.7	300.0	425.9	363.5	375.4	39.1	162.6	203.5	21.6	19.8
Kisumu North	395.6	294.1	366.7	299.9	338.3	47.0	132.3	213.5	35.2	10.7
North West Kisumu	278.2	172.9	403.1	314.3	293.2	50.1	135.5	181.9	24.1	13.0
South West Kisumu	380.7	289.0	372.9	247.5	321.5	52.2	128.6	213.0	32.1	12.1
Muhoroni total	167.4	152.1	173.2	119.3	152.6	22.9	72.1	96.6	13.0	5.1
Chemilil	186.9	146.1	132.9	154.2	154.7	14.4	67.3	99.4	8.0	4.8
Masogo/Nyang'Oma	141.1	166.1	75.6	105.2	121.4	18.6	59.0	79.3	18.0	3.8
Miwani	137.1	120.0	260.0	88.7	151.4	23.0	74.1	98.8	8.2	1.6
Muhuroni/Koru	236.4	193.4	206.3	196.1	207.7	34.2	101.9	123.2	20.0	13.5
Ombeyi	135.3	134.7	191.0	52.4	127.7	24.2	58.2	82.4	10.6	1.5
Nyakach total	339.9	267.1	264.6	217.5	271.1	35.7	90.7	188.7	27.5	4.1
Central Nyakach	271.2	183.7	172.6	174.5	199.5	33.8	88.2	131.1	21.4	4.9
North Nyakach	194.8	229.2	275.8	142.5	210.2	30.0	90.1	141.8	22.3	1.4
South East Nyakach	621.5	483.8	368.0	375.5	459.4	43.7	121.6	324.0	43.7	6.6
South West Nyakach	325.9	270.3	329.4	202.5	281.0	26.9	80.8	200.2	28.2	2.6
West Kisumu	286.0	168.3	177.5	192.6	205.2	44.1	72.9	146.7	22.0	5.1
Nyando total	279.7	198.6	208.3	167.0	212.3	23.0	97.7	141.8	21.9	6.0
Ahero	291.3	196.7	208.3	136.7	206.8	29.2	98.2	136.8	26.1	5.2
Awasi/Onjiko	266.3	181.9	181.7	159.8	196.4	22.4	92.0	130.2	18.0	7.9
East Kano/Wawidhi	208.2	129.9	116.5	64.2	128.2	14.1	60.3	79.5	11.5	0.0
Kabonyo/Kanyagwal	281.5	254.7	243.6	246.5	256.2	17.8	116.2	169.6	32.0	10.7
Kobura	351.1	229.9	291.3	227.8	274.0	31.6	121.6	192.9	21.9	6.5
Seme total	308.7	247.5	253.3	263.7	267.9	34.8	123.9	189.7	38.9	4.4
Central Seme	410.7	310.4	264.7	361.2	336.1	45.0	149.4	254.7	47.9	5.7
East Seme	264.6	265.8	246.9	248.5	256.2	28.7	115.8	171.2	40.0	3.1
North Seme	251.0	166.3	248.3	181.5	211.4	30.6	106.6	143.2	28.8	4.4
Siaya County	248.8	216.6	213.5	177.1	213.3	39.0	85.8	147.0	23.7	8.8
Alego total	261.4	252.1	230.0	136.6	218.7	40.1	76.3	150.2	27.9	6.3
Central Alego	203.1	186.0	161.4	102.1	162.1	24.4	44.5	117.6	28.0	5.0
North Alego	191.8	157.6	177.9	55.2	144.4	30.7	57.3	95.2	17.4	2.0
Siaya Township	525.2	357.4	397.3	230.8	374.9	82.7	114.4	257.1	44.8	12.4
South East Alego	254.0	242.4	242.5	151.5	221.6	44.5	79.1	151.5	29.9	7.5
Ukwala	169.7	211.7	181.6	217.2	195.4	41.8	77.3	124.4	26.1	4.2
Usonga	224.6	357.6	219.4	62.9	214.1	16.3	85.0	155.3	21.2	6.5
Bondo total	291.7	248.2	265.7	208.8	252.9	45.7	103.8	176.0	25.7	12.1
Central Sakwa	423.8	345.1	318.9	327.8	352.9	48.7	153.8	275.4	33.2	28.8
North Sakwa	390.7	282.4	217.0	159.9	260.0	50.9	108.6	172.2	18.1	8.7
South Sakwa	342.2	228.4	275.5	301.6	286.7	61.2	114.7	202.6	37.3	15.3
West Nyakach	164.8	238.8	172.9	126.4	175.1	27.8	80.0	117.9	16.0	0.8
West Sakwa	208.4	142.3	482.0	229.8	266.9	53.6	95.7	168.6	30.7	7.9
West Uyoma	189.6	74.5	201.9	156.8	155.8	26.4	76.7	105.5	12.8	12.8
Yala Township	327.8	392.9	276.8	192.2	295.7	57.6	119.1	203.5	27.8	10.6
Yimbo East	285.9	281.5	180.8	176.2	229.7	39.2	81.7	162.7	29.4	12.3
Gem total	252.9	196.8	189.8	187.1	206.0	37.2	92.5	143.1	22.5	9.8
Central Gem	225.0	207.6	180.3	147.0	189.2	32.6	84.8	132.3	24.2	4.7
East Gem	190.6	149.1	124.1	138.2	149.9	30.5	68.2	102.3	19.7	5.4
North Gem	272.3	262.4	243.2	212.6	247.0	45.1	104.8	170.8	26.0	8.3
South Gem	231.2	174.7	173.1	208.1	196.5	48.2	89.9	134.4	21.2	11.0
West Asembo	305.0	168.8	175.2	173.3	204.3	39.0	78.6	137.8	21.5	16.1

Table A (*continued*)

County assembly ward	Year				Cases/100 000 population					
	2012	2013	2014	2015	TB rate*	EPTB	New smear-positive	TB-HIV†	Mortality	Treatment failure
West Gem	221.0	228.7	173.9	139.1	189.7	32.7	92.6	135.5	21.5	10.2
West Yimbo	324.7	186.4	258.7	291.1	265.1	32.0	128.7	188.7	23.4	13.3
Rarieda total	162.4	153.1	172.2	156.0	160.9	31.5	63.3	114.9	19.6	10.1
East Asembo	152.0	219.1	229.5	117.1	179.1	29.7	54.7	131.1	21.0	8.1
North Uyoma	169.9	131.4	128.1	177.2	151.7	32.4	70.1	117.2	13.6	13.6
South Uyoma	180.0	87.6	152.8	219.0	160.4	39.8	75.1	119.5	17.1	13.7
West Alego	163.7	176.0	177.0	111.5	156.5	22.8	55.9	107.6	20.0	2.8
West Ugenya	146.5	151.5	173.7	155.2	156.9	33.0	60.8	98.9	26.4	12.5
Ugenya total	310.0	252.3	215.5	210.7	246.0	46.0	100.6	162.7	29.6	3.2
North Ugenya	300.8	232.8	275.5	246.4	263.5	36.9	103.4	169.9	33.7	3.3
Ugunja	391.8	321.5	226.1	196.4	281.7	57.2	111.7	191.6	31.7	2.3
West Seme	237.4	202.5	145.0	189.4	192.9	43.7	86.7	126.5	23.4	3.9
Ugunja total	183.0	177.5	162.9	152.1	168.5	29.1	64.1	110.2	14.0	5.8
East Ugenya	165.2	157.7	200.2	175.3	174.8	30.9	59.5	108.7	13.2	10.3
Sidindi	234.0	235.0	178.9	139.5	195.7	35.3	66.2	138.7	15.4	6.3
Sigomere	149.9	139.8	109.6	141.5	135.0	21.0	66.8	83.3	13.5	0.8

* Combined TB rate (2012, 2013, 2014 and 2015).
† HIV-positive cases/100 000 population.
TB = tuberculosis; EPTB = extra-pulmonary TB; HIV = human immunodeficiency virus.

RÉSUMÉ

CONTEXTE : Une prise en charge efficace de la tuberculose (TB) et une réduction de son incidence reposent sur le fait de savoir où, quand et à quel degré la maladie est présente.

MÉTHODE : Dans une étude transversale rétrospective, nous avons analysé la distribution spatiale de l'incidence notifiée de la TB du 1e janvier 2012 au 31 décembre 2015 dans les comtés de Siaya et Kisumu, dans l'Ouest du Kenya. Les données relatives à la TB ont été obtenues de la Division de la Lèpre, de la Tuberculose et des Maladies pulmonaires, Nairobie, Kenya, dans le cadre d'une étude approuvée de détection de cas de TB. Les cas ont été reliés à leur emplacement géographique correspondant, grâce aux identifiants de leur adresse de domicile. Des techniques d'analyse spatiale ont été utilisées afin d'examiner les profils spatiaux et temporels de la TB. L'évaluation du regroupement spatial a été réalisée en suivant la méthode de Moran *I* d'autocorrélation spatiale et la méthode statistique de Getis-Ord Gi*.

RÉSULTATS : L'incidence notifiée de la TB a varié de 638,0 par 100 000 habitants à 121,4 par 100 000 au niveau de zones géographiques restreintes. L'analyse spatiale a identifié 16 régions géographiques distinctes avec une incidence de TB élevée (GiZ Score $\geqslant$ 2,58 ; $P <$ 0,01). Il y a eu une corrélation positive entre la densité de la population et l'incidence de la TB, qui a été statistiquement significative (rs = 0,5739 ; P = 0,0001).

CONCLUSION : Les résultats de cette étude présentent une opportunité d'interventions ciblées au sein des sous épidémies identifiées, pour compléter les mesures destinées à la population générale.

RESUMEN

MARCO DE REFERENCIA: El tratamiento eficaz de la tuberculosis (TB) y la disminución de su incidencia depende de los conocimientos sobre dónde, cuándo y en qué grado está presente la enfermedad.

MÉTODOS: En un estudio trasversal retrospectivo se analizó la distribución espacial de la incidencia de TB notificada del 1° de enero del 2012 al 31 de diciembre del 2015 en los condados de Siaya y Kisumu, en el oeste de Kenia. Los datos sobre la TB se obtuvieron de la División de Lepra, Tuberculosis y Enfermedades Respiratorias, Nairobi, Kenia, en el marco de un estudio aprobado de detección de casos. Se vincularon los casos con su correspondiente localización geográfica mediante identificadores de direcciones físicas. Se utilizaron técnicas de análisis espacial con el fin de examinar las características temporales y espaciales de la TB. Los conglomerados espaciales se evaluaron mediante los estadísticos *I* de Moran de autocorrelación espacial y el Gi* de Getis-Ord.

RESULTADOS: La incidencia de TB notificada osciló entre 638,0 y 121,4 por 100 000 habitantes en una pequeña escala. El análisis espacial definió 16 regiones geográficas diferentes con alta incidencia de TB, en conglomerados (índice Z de Gi $\geqslant$2,58; $P <$ 0,01). Se encontró una correlación positiva entre la densidad de población y la incidencia de TB, con significación estadística (rs = 0,5739; P = 0,0001).

CONCLUSIÓN: Los resultados del estudio ofrecen la oportunidad de intervenciones dirigidas a las subepidemias detectadas, en complemento de las medidas dirigidas a la población general.