Geospatial Information In Public Health: Using Geographical Information System to Model the Spread of Tuberculosis

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Key words: Tuberculosis, Cluster and spatial

SUMMARY

Currently, Nigeria is ranked fourth among the countries of the world with the highest burden of tuberculosis (TB) and new perspectives and ways of addressing TB treatment and control are needed as the disease continues unabated.

New technology, such as geographical information systems, may be useful in this process. This study therefore focused on identifying geographical areas where on-going tuberculosis transmission is occurring by linking Geographic Information Systems technology with tuberculosis diagnosis in communities in Ibadan, Nigeria. Retrospective data of TB incidence between 2004 and 2007 from the Health centers in Ibadan were cartographically mapped to show current trends in the spread of the disease and its geographic dispersion among those infected using ArcGIS 10.1 software, Satscan and Global Positioning System (GPS).

A total of 5579 cases were detected over the study period. The mean age for the entire affected population was 27.76 ± 8.46 (SD); 5400 (78.87%) patients were Adults while 179 (21.13%) were youth. The 'nearest neighbour distance analysis' indicated a clustered pattern of locations with Ibadan North West, South East, South West and North East characterized by overcrowding and poor quality housing conditions having increased likelihood of on-going transmission. This study therefore provides a preliminary synopsis of the uses of the Geographical Information Systems in the control of TB in Nigeria.

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1. INTRODUCTION

Infectious diseases remain a major cause of death worldwide and also represent an incalculable source of human misery. More than 95% of these deaths occur in developing world (Lolch, *et. al.*, 2003). The three major infectious diseases are human immunodeficiency virus/ acquired immunodeficiency syndrome (HIV/AIDS), tuberculosis and malaria. Tuberculosis is the most frequent cause of death from a single infectious disease in persons aged 15 – 49 years, causing a total of 2 – 3 million deaths annually (Enarson and Chretien, 1999). Tuberculosis (TB) is humanities greatest killer which is out of control in many parts of the world. The disease is preventable but it has been grossly neglected and no country worldwide is immune to it (Shrestha, *et. al*., 2005). It is still a major health concern worldwide and the disease spreads more easily in overcrowded settings and in the conditions of malnutrition and poverty (Mycal, *et. al.*, 2005). New perspectives and ways of addressing TB treatment and control are needed (Porter *et al.* 1999). These include different ways of implementing the World Health Organization's directly observed therapy short course (DOTS) strategy. The strategy emphasizes the importance of the creation and maintenance of a standard, well-managed health delivery structure through which to develop and maintain TB services. Putting this package into action is proving to be slow and difficult (WHO 1998), and there is a need to find ways of being flexible and creative in implementing the strategy. New technology, such as geographical information systems (GIS), may be useful in this process.

Geographical positioning system (GPS) and GIS certainly provide opportunities to identify problems produce hypotheses and further develop public health strategies for the control of infectious diseases like tuberculosis. So far, GIS has been applied to several communicable diseases, but there has been little work conducted on its uses in tuberculosis control (Beyers, *et. al.* 1996) particularly in Nigeria. Modeling tuberculosis (TB) transmission facilitates the understanding of spatial and temporal patterns of TB infection in a population. New perspectives and ways of addressing TB treatment and control are needed especially in Nigeria, given the increasing incidence of the infection and the fact that the country is ranked fourth in the global burden of the disease. Geographical Information System is a useful tool in disease control worldwide; hence the need for its application in TB control in Nigeria.

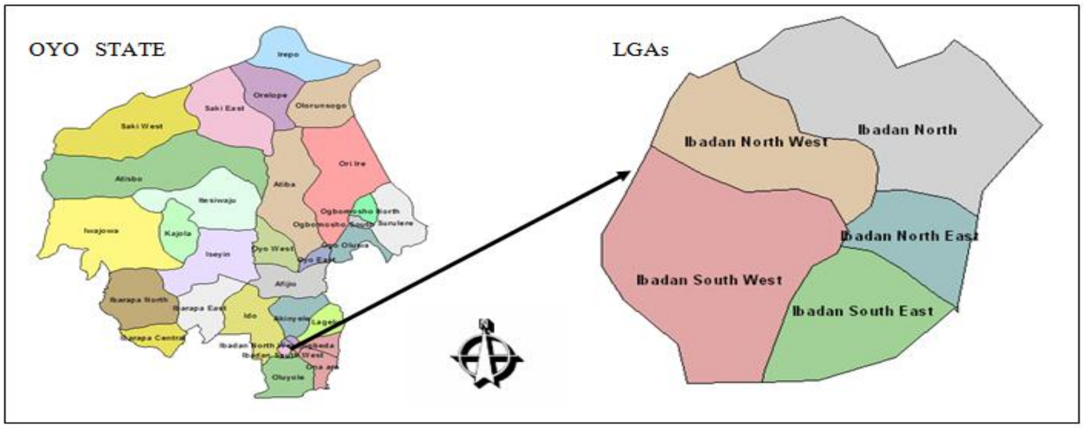


Figure 1 Map showing the Location of the study area

1.1 Study Area

The study covers Ibadan metropolitan city, which is the largest indigenous city in Africa, is the capital of Oyo state. It is made up of eleven local government areas five of which are within the inner city- Ibadan North-West, Ibadan North-East, Ibadan South-East, North Ibadan and Ibadan South-West. The remaining six encompassing local government areas are Akinyele, Lagelu, Egbeda, Ona-Ara, Oluyole and Iddo local government areas. Ibadan lies at latitude 7 ˚23' N and Longitude 3˚ 56'E. It is located at the transition zone between the forest and grassland areas of the country. The population of central Ibadan which is made of by the five Local Government Areas is 1,338,659 according to census result of 2006 covering an area of 128 square kilometer.

2. MATERIALS AND METHOD

Retrospective data of TB incidence between 2004 and 2007 from Jericho Chest Clinic, Ibadan were cartographically mapped to show current trends in the spread of the disease and its geographic dispersion among those infected in Ibadan North-West, Ibadan North-East, Ibadan South-East, Ibadan North and Ibadan South-West using ArcGIS 9.2 software and global positioning system (GPS), The database included names, age, gender, and addresses of the affected patients over the study period. Some data were eliminated either because of vague descriptions of location or because they could not be confirmed. The Latitude/Longitude coordinates of house and street data were determined by using the GPS (Global Positioning System) and Social survey. The database was converted into map layers within ArcGIS (Environmental Systems Research Institute, Redlands, CA, USA). A basic boundary map served as the base map and other features were generated from the satellite imagery.

Over the years, population and development of land in Ibadan have increased. As surrounding urban centers grow, proliferation into neighboring communities has become apparent and congested. New residents create need for the development of land for housing, schools, parks, and place significant strains on existing land cover and available natural resources. In order to monitor the spread in the city, a population percent change analysis was performed to determine the extent of land cover change over time.(Figure 3) A GIS analysis using a programme in ArcGIS 9.2 was performed to measure the distance between infected location and nearby points on the map. The degree of clustering of TB locations was assessed using the Average nearest neighbour distance method and yearly pattern differences were investigated. As previously mentioned, to reduce the size of the number of Tuberculosis Infection Locations analyzed. A subset of the study area was chosen; the 500x500m quadrangle. This area was chosen because most of the Tuberculosis Infection Locations for the study occurred in this area. The quadrangle was divided into 780 quadrants of 500 by 500 meters. This size was chosen because it encompassed a sufficient number of points for the analysis. Quadrants less than 500x500 meters combined too few points together in one quadrant, and a quadrant size of 1000 by 1000 meters, combined too many locations within one quadrant. All locations within this quadrangle were included in the analyses. Average nearest neighbor distance analysis was used to detect spatial point pattern.

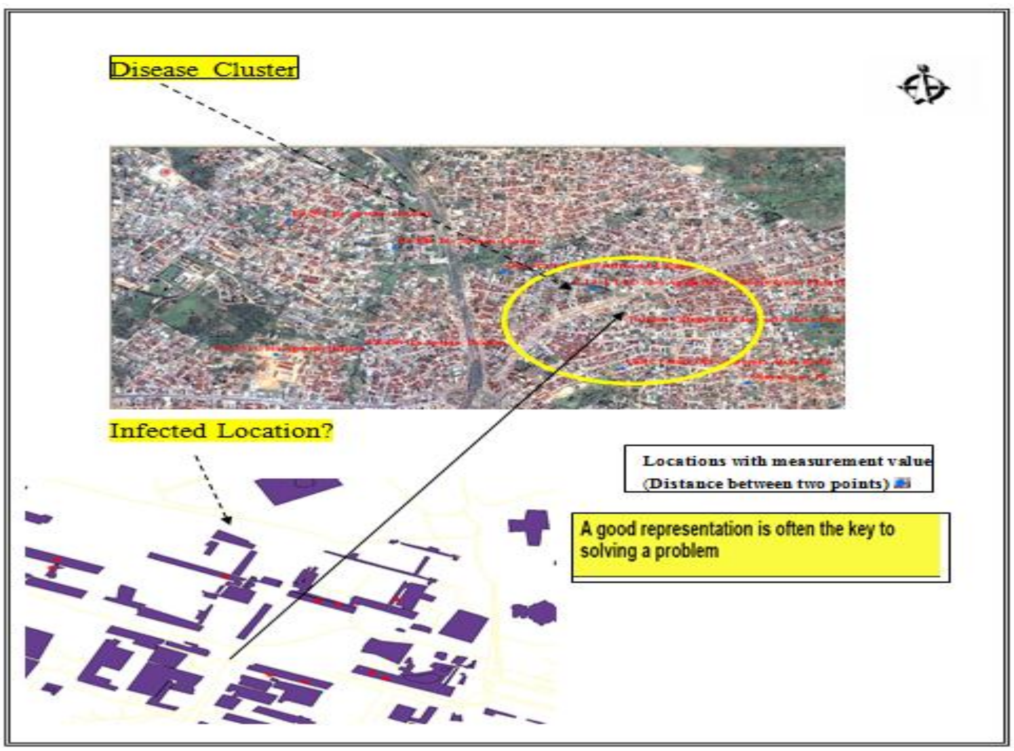


Figure 2 Showing spatial relationships between infected and non-infected points, Ibadan (2004-2007)

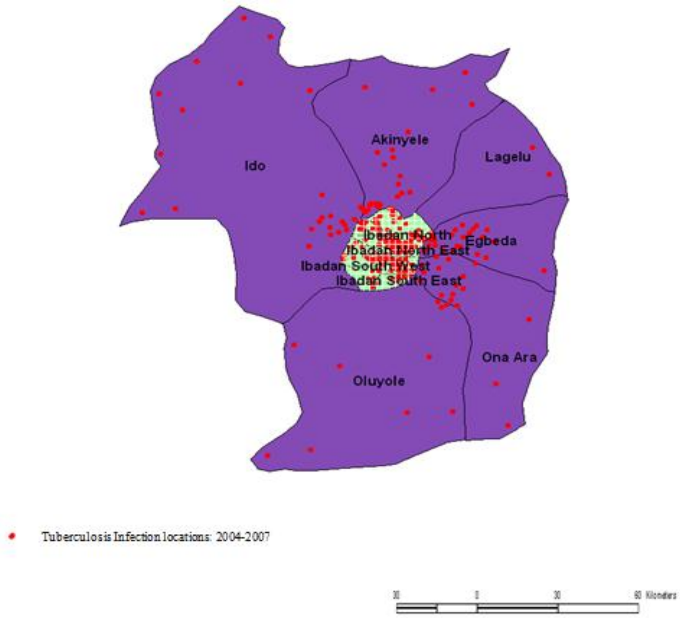


Figure 3 The quadrangle, showing the Tuberculosis Locations in the eleven Local Government area of Ibadan

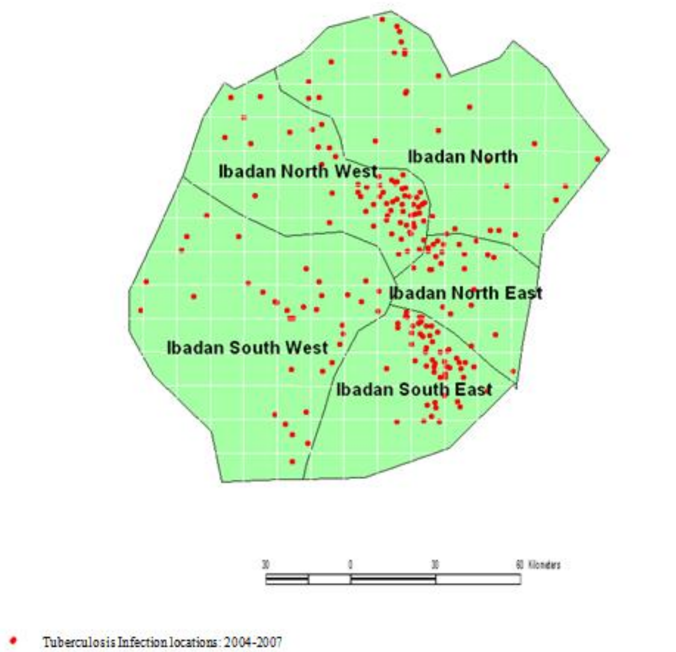


Figure 4 The quadrangle, showing the subset of Tuberculosis Locations of five Local Government areas

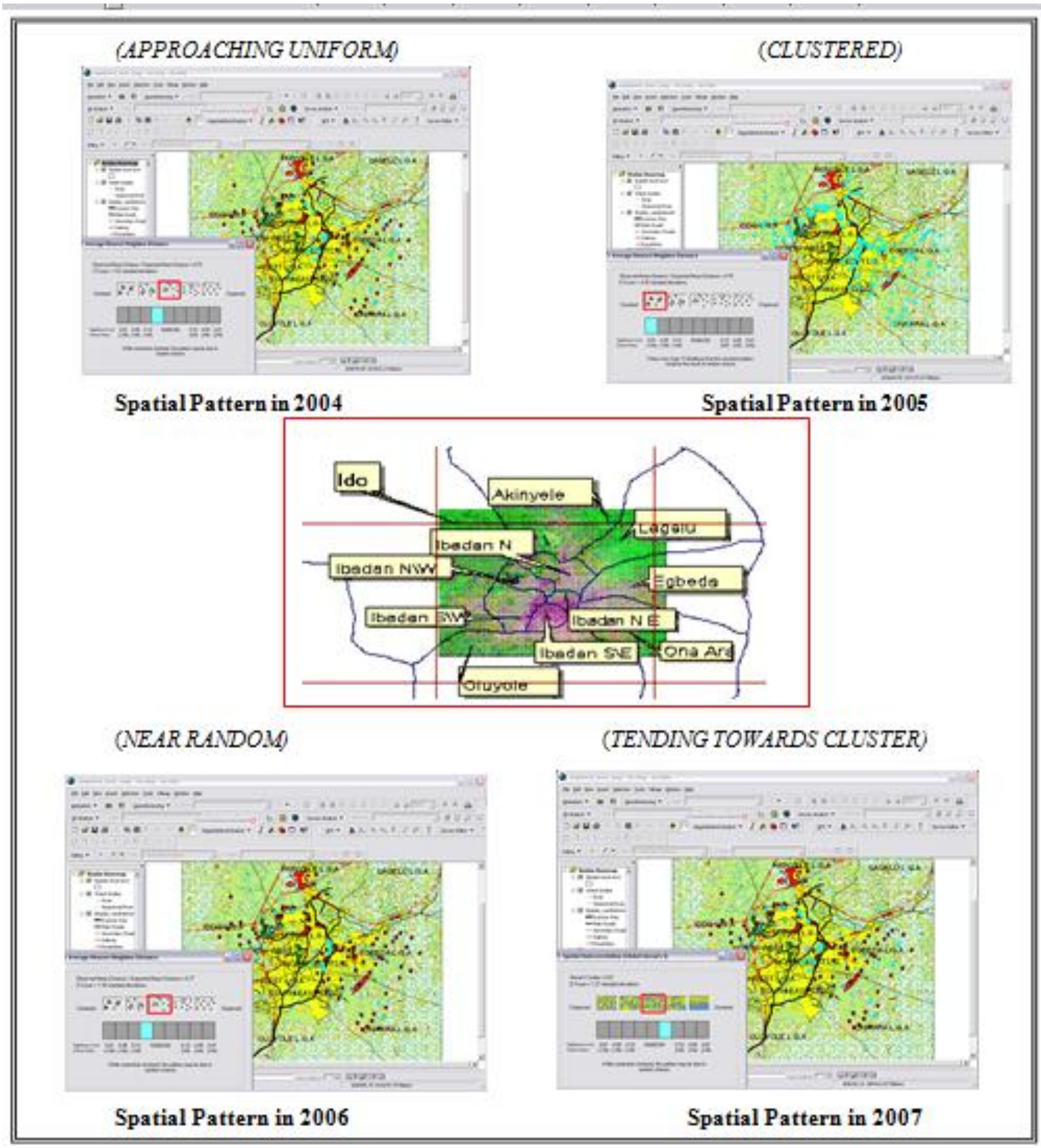


Figure 5 Average Nearest Neighbor Distance showing the distributional pattern of spread of TB in 2004, 2005, 2006 and 2007

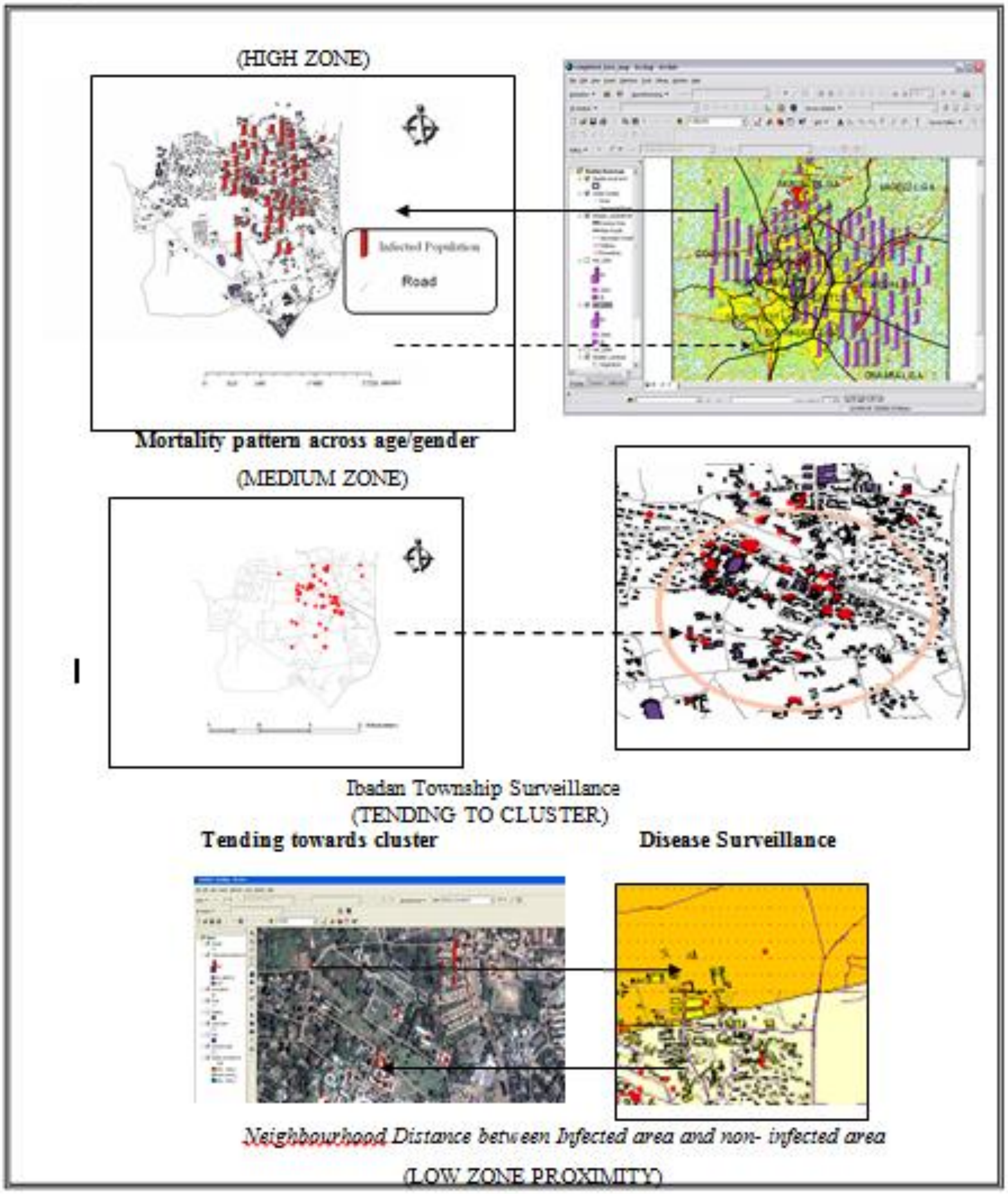


Figure 6 Spatial distribution of tuberculosis infection into low, medium and high zones

Table 1: Showing the number of confirmed cases of Tuberculosis in Ibadan

YEAR	POPULATION	CASES

1996-2004	1,694,961	12,217
2004-2007	5,084,791	17,448

Source: Jericho Chest Clinic, Ibadan.

Table 2: Showing the number of affected people in 2004-2007 in the five local govt areas.

LGA	2004	2005	2006	2007
South - East	114	212	155	217
North-West	174	188	163	292
South-West	169	154	195	185
North-East	153	163	170	178
North	54	76	88	96

Source: Jericho Chest Clinic, Ibadan.

Table 3: Nearest neighbor Index of the five local govt areas

Local Govt.	TB Infection record(Houses)	Nearest Neighbour(Houses)	Nearest Distance(m)	(mean) X-Coordinate	(mean)Y-Coordinate
South-East	1155	174	712.076	3.3544	7.6643
North-West	2614	824	656.662	3.6343	7.6432
South-West	1437	448	527.885	3.3419	7.6734
North-East	261	75	456.494	3.6111	7.5912
North	83	20	738.983	3.3431	7.6553

Source: Base map features were generated from Quick bird satellite imagery (0.6m resolution).

Table 4: Spatial distribution parameters of the five local govt areas

LGA	Population density	Nearest Neighbor Index	Pattern

South-East	11299	0.674	Near cluster
North -East	5317	0.533	Clustered
South-East	11299	0.674	Near cluster
South-West	7013	0.722	Tending to cluster
North -East	18614	1.1236	Near random
North	652	1.367	Approaching uniform

Table 5: Distance between TB infected area and non-infected area (m) in Ibadan North- East Local Government area.

Distance between TB infected area and non-infected area (m)	Nearest points to the infected areas in Ibadan North-East			Total
	Institution/Schools	*Commercial centers*	*Residential quarters*	
100-300	14	23	75	65
300-500	25	47	92	44

Table 6: Distance between TB infected area and non-infected area (m) in Ibadan South- East Local Government area.

Distance between TB infected area and non-infected area (m)	Nearest points to the infected areas in Ibadan South-East			Total
	Institution/Schools	*Commercial centers*	*Residential quarters*	
100-300	13	38	47	98
300-500	18	72	85	175

Table 7: Distance between TB infected area and non-infected area (m) in Ibadan North- West Local Government area.

Distance between TB infected area and non-infected area (m)	Nearest points to the infected areas in Ibadan North-West			Total
	Institution/Schools	*Commercial centers*	*Residential quarters*	
100-300	8	44	158	210
300-500	12	60	183	215

Table 8: Distance between TB infected area and non-infected area (m) in Ibadan South- West Local Government area.

Distance between TB infected area and non-infected area (m)	Nearest points to the infected areas in Ibadan South-West			Total
	Institution/Schools	*Commercial centers*	*Residential quarters*	
100-300	4	82	98	184
300-500	10	90	80	180

Table 9: Distance between TB infected area and non-infected area (m) in Ibadan North Local Government

Distance between TB infected area and non-infected area (m)	Nearest points to the infected areas in Ibadan North			Total
	Institution /Schools	*Commercial centers*	*Residential quarters*	
100-300	11	9	34	54
300-500	19	30	25	74

Table 10: Average movement of patients to and from Home, market and farm

Figures in parenthesis represent Standard Deviation (S.D.)

Direction of Movement		Purpose	Distance (Km)	Frequency in 3 months
From	**To**			
Home	Neighboring House	Work	0-15	63 (27)
Market	Farm	Rest	0-0.5	97 (40)
Farm	Neighboring farm	Materials exchange and business	0.6-15	1 (0.6)
Farm	Abattoir	Slaughter	0.5-3	0.6 (0.9)

Source: Field Survey of 100 patients, 2007

Table 11: Ibadan census data (1991 and 2006)

ID	LGA	LGA_HQ	1996_POP	2006_POP
1	Oluyole	Idi Ayunre	91527	265059
2	Ido	Iddo	53582	103261
3	Ona Ara	Akanran	123048	202725
4	Egbeda	Egbeda	129461	2815773
5	Akinyele	Moniya	140118	211359
6	Ibadan South West	Oluyole	277047	282585
7	Ibadan North West	Dugbe/Onireke	147918	152834
8	Ibadan South East	Mapo Hall	225800	266046
9	Ibadan North East	Bodija	135288	330399
10	Ibadan North	Agodi	302271	306795
11	Lagelu	Iyana-Offa	68901	147957

Source: Nigeria census 1996 and 2006

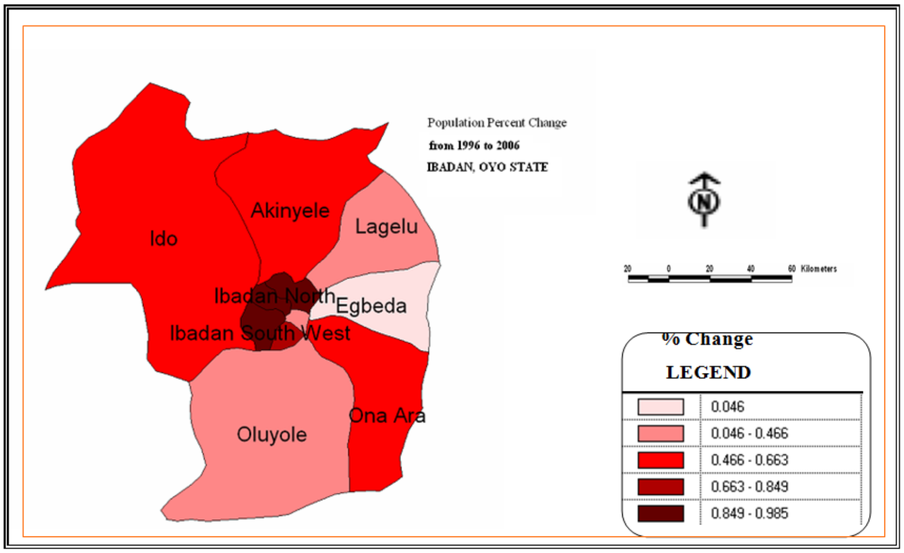
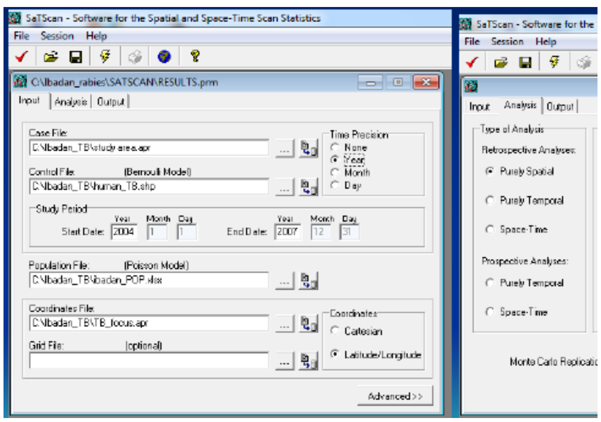


Figure 7 Population Change from 1991 – 2006(% change)



Central coordinates

Tuberculosis cluster Identity	Latitude (N)	Longitude (E)	Radius (Km)
Primary Cluster	7.39	3.89	15.03
Secondary Cluster	7.40	3.95	1.11

Figure 8 Satscan Software Cluster-Spatial Analysis

3. ANALYSIS OF RESULTS

A total of 5579 cases were detected over the study period. The mean age for the entire affected population was 27.76 ± 8.46 (SD). 579 (29.58%) was female and 5000 (70.42%) were male. 5400 (78.87%) patients were adult while 179(21.13%) were youth.

In order to reduce the size of the number of Tuberculosis Infection Locations analyzed a subset of the study area was chosen; the 500x500m quadrangle because most of the Tuberculosis Infection Locations for the study occurred in this area (Figure 3 and 4). Retrospective data of TB incidence between 2004 and 2007 from Jericho Chest Clinic, Ibadan were cartographically mapped to show current trends in the spread of the disease and its geographic dispersion among those infected in Ibadan (Table 1 and 2). The degree of clustering of TB locations was assessed using the Average nearest neighbour distance method and yearly pattern differences were completed (Figure 5).

The nearest neighbour distance analysis indicated a clustered pattern of locations (Table 4). Nearest neighbour Index of the interior Local government areas of Ibadan indicated a clustering neighbourhood spatial pattern of housing structure (Table3).
Furthermore, spatial distribution of tuberculosis infection was analyzed into zones (Figure 6).the result of the affected areas were grouped into low (0- 0.9%) medium (0.9%-1.8%) and high (1.8%-2.8%) areas.
The highest proportion of points with clustered TB occurred in the Ibadan North West, South East, South West and North East with the highest incidence. These areas; such as Gege, Orita Merin, Agbeni, Foko, Ogunpa, Idi arere, Popo-Iyemoja, Ayeye, Beere, Opoyeosa, Labiran, Adeoyo and Idiobi were characterized by overcrowding and poor quality housing conditions.

The distance between infected points and non-infected points are as shown in Table 5, 6, 7, 8 and 9. Field Survey of 100 TB patients were carried out to determine the average movement of patients to and from Home, market and farm with commercial centers and residential quarters within the nearest distance (Table 10).
In order to monitor the spread in the city, a population percent change analysis was performed to determine the extent of land cover change over time (Figure 7).

3.1 Discussion

The affected mean age (44.7 ± 17.3 (SD)) recorded in this study further confirms the age group most susceptible to pulmonary tuberculosis infection as asserted by Cadmus (2007). This showed that these groups were those at highest risk from the population studied. The results obtained are in agreement with the global picture in which the greatest incidence and mortality are concentrated in the economically most productive age group of the population (15-59 years) (Kochi, 1991). These age groups may therefore be responsible for further spread of the disease in the five LGAs which are within the inner city- Ibadan North-West, Ibadan North-East, Ibadan South-East, Ibadan North and Ibadan South-West.

It was observed that more males (70.42%) were documented to have TB in the community than females (29.58%). This finding is supported by the work of Uplekar, *et. al*. (2001) in which about 70% more male than female patients globally were said to suffer from Tuberculosis. This is further corroborated by the higher prevalence of TB in males over females in India with ratios varying from 1:3 to 1:5 (Chadha, 2005).

Notification rate values are twice as large for males as for females. A possible explanation could be that tuberculosis infection is directly and strongly related to HIV and risk behaviours like, alcohol and drug abuse, homelessness, among others, which are more frequent in the male population (Nunes, 2007).

However, it is known that women in poor countries confront more barriers than men in accessing health care services (Ayele, *et. al*., 2004) hence; the possibility of more cases of TB in women cannot be ruled out. This situation is also true in Nigeria where women are economically and educationally disadvantaged; hence, reduced opportunities to access health care. Therefore, women are less likely to be tested and treated for TB than men. Long *et al*. (1999) however, also believed that women are also less likely to develop TB infection.

This study uncovered geographical links to on-going tuberculosis transmission, enhancing traditional public health surveillance and a clustered pattern of infection was recorded. As such, with Ibadan North West, South East, South West and North East recorded the highest incidence. These areas could benefit from a more detailed evaluation to determine if it represents a real tuberculosis incidence cluster or if the cluster is caused by other factors, for instance, a better notification rate.

More so, a limitation encountered in this study was vague description of some addresses, which were as a result not included in the analysis. However, risk factors such as overcrowding and the fact that most points recorded in this location were ghettos constitute a plausible reason for this observation.

3.2 Conclusions and Recommendations

The case study of five Ibadan local governments which are within the inner city Ibadan North-West, Ibadan North-East, Ibadan South-East, Ibadan North and Ibadan South-West was thus an extremely small coverage of national records. Quantitatively, the model adequately describes the general spatial patterns of affected locations, but does not describe the interactions with environmental variables, or explicitly define terms of neighborhood effects. Thus, the results presented here are a poor predictor of future TB locations and any explanations need more robust statistical analysis to account for environmental conditions and seasonal changes. Because of these issues, a combination of spatial statistical methods should be used and any single should not be relied on.

Ideally, analysis that evaluates spatial clustering of all individuals at one moment in time and all locations for one individual over a time period should be used. In this way, questions of group cohesiveness and individual differences in movement patterns can be examined.

Further research should include a spatial weighting factor to account for variations in and the significance of environmental variables. Spatial adjacency of a set of environmental variables, consisting of human activities needs to be included in future analysis. Charges in the spatial pattern of affected locations over time need to be addressed due to human movement. Other spatial patterns and processes can be examined using techniques such as multi-response sequence testing, which can test for differences in distance moved between individual animals and groups of animals.

Due to inaccessibility of up to date survey maps of the area new streets may have been left out However, all the available data have been geo-referenced and the streets in which they fall have been identified. Land use maps are not up to date hence the type of structure presently occupying the area and land use cannot be identified without a reconnaissance survey. The use of GIS has not been fully integrated into the public health sector. Availability of data would go a long way to encourage researchers to fully delve into problems experienced within this sector because data is the bedrock of any analysis done with a GIS.

Our result shows that GIS can be used to classify the spread of tuberculosis; therefore, providing clues for its control measures particularly as it concerns point distribution of the disease in relation to the location and population density. Simultaneous use of GIS analysis and epidemiological surveillance will be an effective method for identifying instances of local transmission. Finally, further studies using GIS techniques will be required.

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