Geospatial Information in Public Health: Using GIS to Model the Spread of Tuberculosis

OLOYEDE-KOSOKO S.O.A
DEPARTMENT OF GEOINFORMATICS
FEDERAL SCHOOL OF SURVEYING
P.M.B 1024 OYO

&

AKINGBOGUN, AYOOLA AKINOLA
Pointmile Geotech,Lagos

ayo.akingbogun@yahoo.com
oloyedekosoko@yahoo.co.uk

The Influence of Spatial Structure on Disease Transmission, Prevalence and Treatment

INTRODUCTION

Infectious diseases remain a major cause of death worldwide. 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).

- 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.

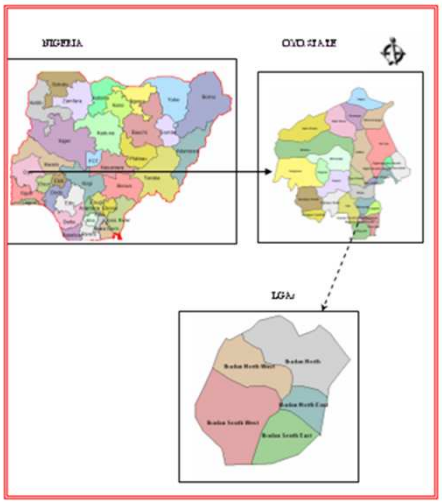
New technology, such as geographical information systems, may be useful in this process. This study therefore focused on identifying geographical areas where on-going tuberculosis transmission is occurring by linking Geographic Information Systems technology with tuberculosis diagnosis in communities in Ibadan, Nigeria

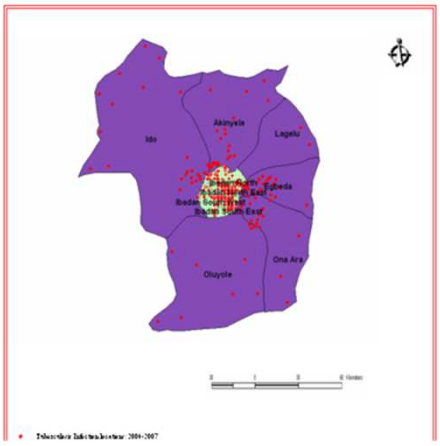
Study Area

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-

North
North-West
North-East
South-East
South-West

Diagram showing the location of the study area





DATA AQUISITION

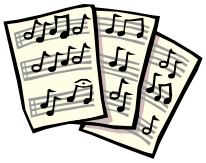
- Data of TB incidence between 2004 and 2007 from five Health centers in Ibadan were cartographically mapped to show current trends in the spread of the disease and its geographic dispersion among those infected using ArcGIS software, Satscan and Global Positioning System (GPS)

- Five hospitals were visited:
  - One teaching hospitals
  - two private hospitals
  - two community hospital

Data (January 2004 to December 2007) on TB patients were captured from case files/records available in the Records offices of these hospitals.

GEOGRAPHIC

INFORMATION



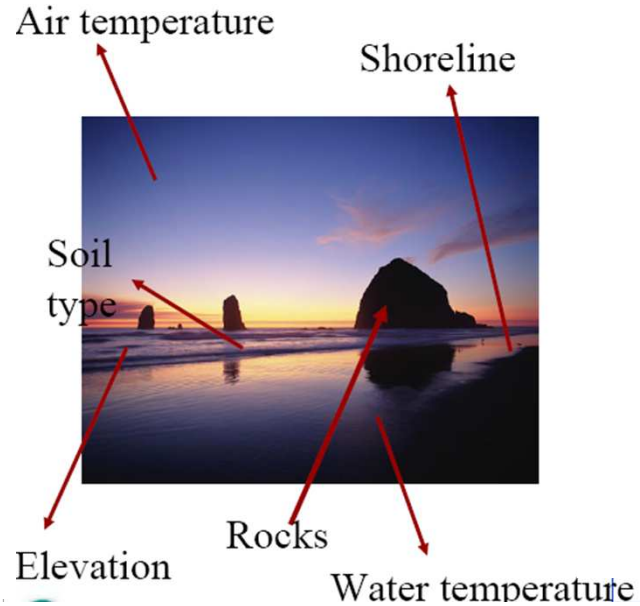
SYSTEM

ASSEMBLY OF COMPUTER <u>HARDWARE</u> AND <u>SOFTWARE</u> DESIGNED TO *CAPTURE, STORE, MANIPULATE, ANALYZE* AND *DISPLAY* DATA THAT ARE REFRENCED TO A SPECIFIC PART OF THE EARTH SURFACE.

Three types of Models

- Real World
- Computer representations
- Visualizations

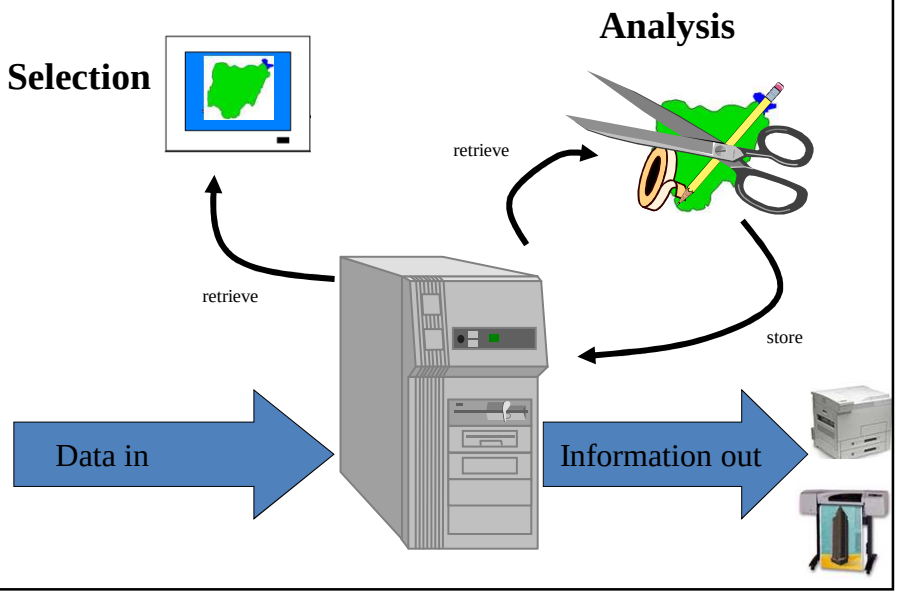
Real World



DATA ACQUISITION FOR GIS

* **Land Surveying**
* **Photogrammetry**
* **Remote Sensing**
* **Cartography**
  - **Scanning**
  - **Digitizing**

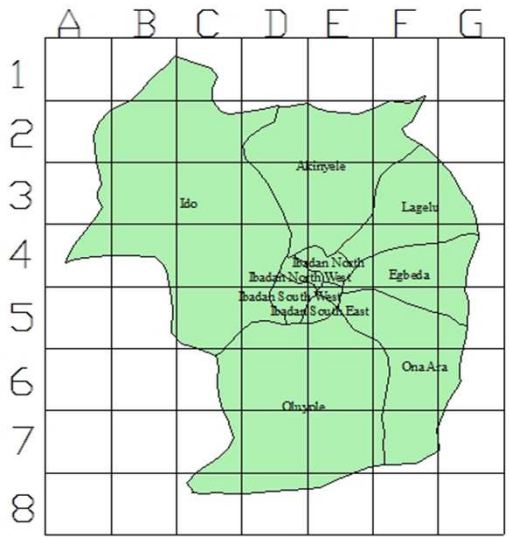
GIS Capabilities



Some GIS Capabilities

- Measurements, retrieval and classification
- Overlay functions
- Neighborhood functions
- Connectivity functions

GRID MAP OF THE STUDY



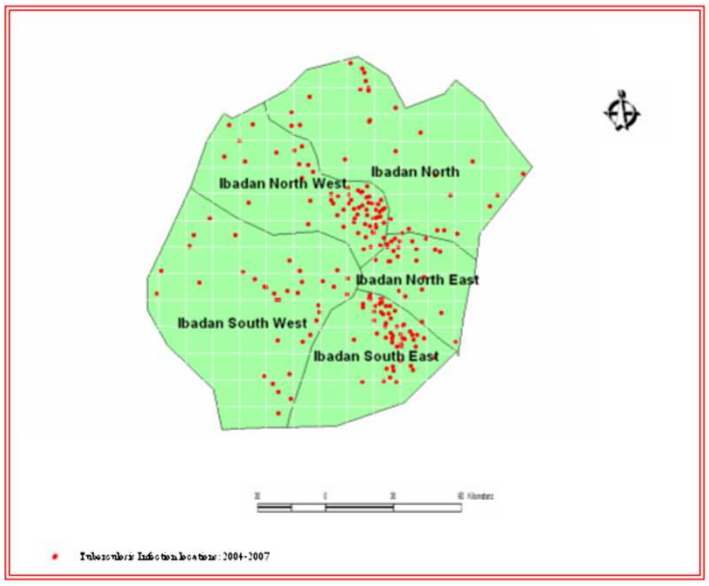
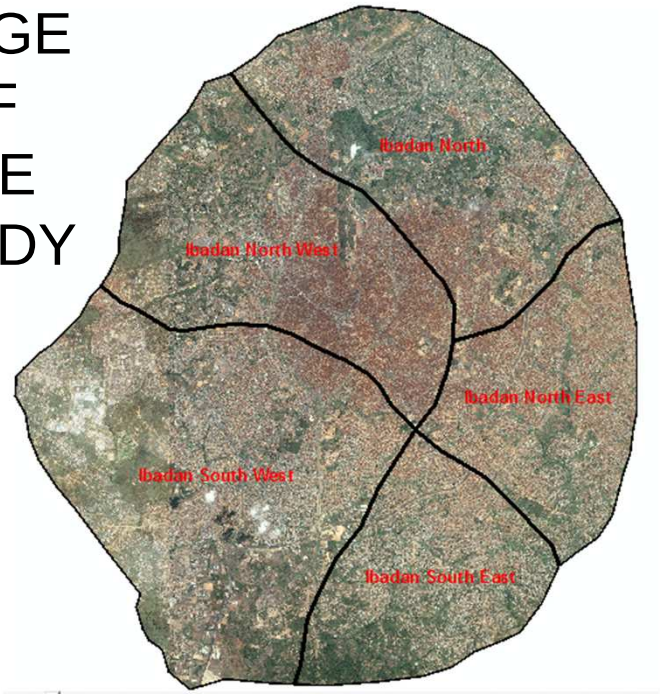


IMAGE OF THE STUDY



MODELLING STRATEGIES

- A GIS analysis using a programme in ArcGIS 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.

Current Spatial TB research in Ibadan

- Geographic disparities in TB spatial trends
- TB testing center locations
- Spatial reach of TB interventions
- GIS aids in faster and better health mapping and analysis than the conventional methods. It gives health professionals quick and easy access to large volumes of data. It provides a variety of dynamic analysis tools and display techniques for monitoring and management of epidemics.GIS has a vital role to play in the future. The possibilities that can be explored are limitless, depending on the skill and imaginative use of the researchers and the willingness of health sector management to resource its implementation. Health administrators, professionals and researchers need training and user support in GIS technology, data and epidemiological methods in order to use GIS properly and effectively.

DATA CONVERSION

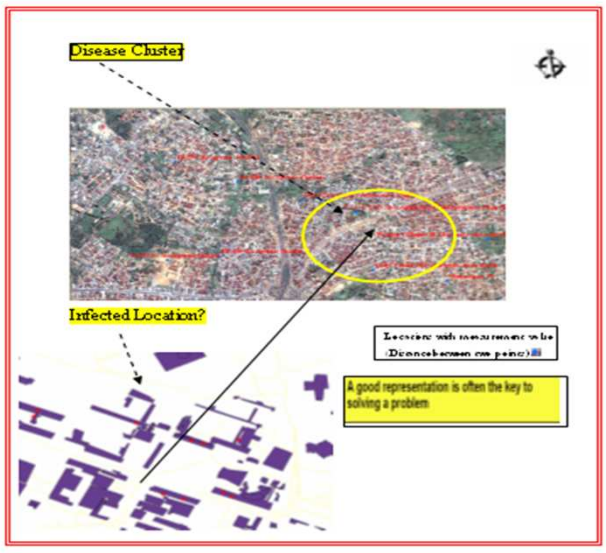


Figure 2: Showing spatial relationship between infected and non infected point, Ibadan (2004-2007).

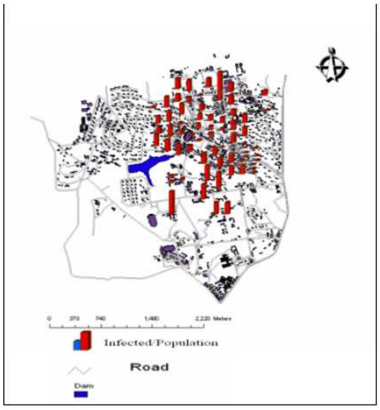
Mapping Geographic Patterns

- Identifying clustered cases within poor housing conditions, low socio-economic status, high unemployment rate and high drug use.
- calculate distances and areas of communities to health centres and to indicate densities of incidence of Tuberculosis with the population in the area covered by the cluster.

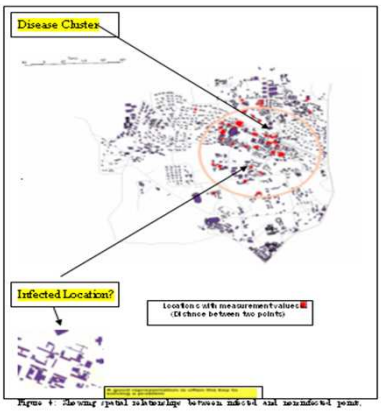
Geographic Patterns of Tuberculosis Transmission in Ibadan

- Map populations at risk and stratify risk factors at level of contact. To evaluate residential addresses of the patients in the study area to determine if there are neighborhoods that are associated with Tuberculosis transmission and also to evaluate the spatial distribution of the patients in thee study which will be assigned a geographic location.
- Statistical analysis using GIS and Satscan to determine cluster in relation with proportion of population and incidence falling within a certain radius of a health centre, and to locate the nearest health facility to the cluster. Also to calculate distances and areas of communities to a health centre to indicate densities of incidence of Tuberculosis with the population in the area covered by the cluster.

QUANTITATIVE CHARTS

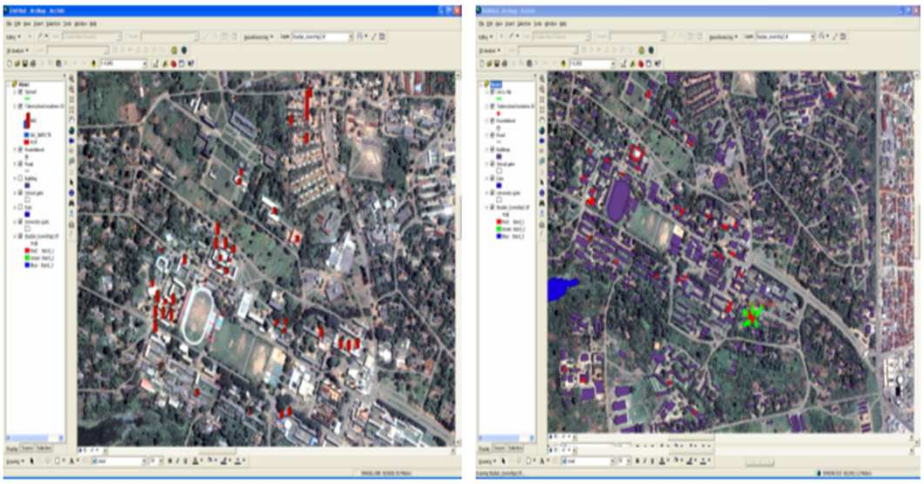


Spatial distribution of tuberculosis infection into low, medium and high



University of Ibadan (2004-2007).

USING SATELLITE IMAGERY



Satellite imagery of Ibadan showing the area of interest

CRITERIA FOR SITING PUBLIC HEALTH CENTERS

- The population of the area should be about 60,000 people
- The area should be accessible (road networking), not farther than 500m from major road
- The site should be located on a terrain with slope less than 20 degrees to prevent erosion
- The hospital should have an area of at least 4 hectares
- The hospital should not be sited at least 300m away from industrial areas, high density population area; this is to ensure maximum silence and avoid unnecessary noise in the hospital
- The site should be at least 100m from high tension power line to ensure safety of lives and property in the hospital
- The hospital should be sited within 5km distance from the centre of the town and should not be closer than 4km to the existing specialist hospital. This is to ensure that the new hospital compliment the existing one by servicing those area that are farther away from the existing hospital.

ANALYZING PATTERNS

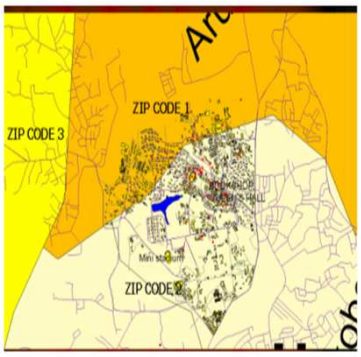
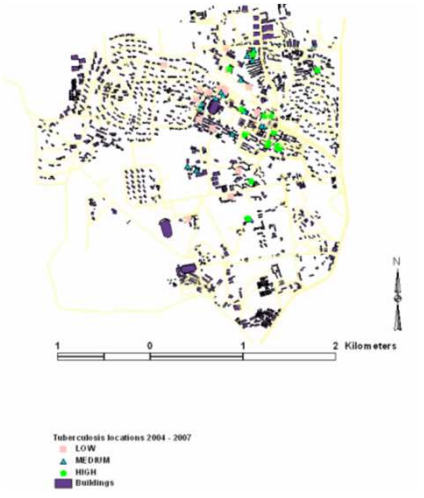


Figure 5: Incidence of Tuberculosis by zip code Nigeria (2004 – 2007).



SPATIAL PATTERNS FROM 2004-2007

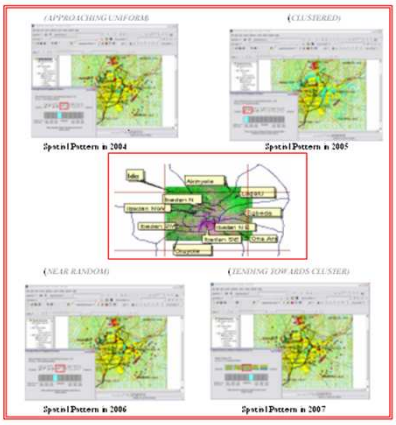


Figure 5: Average Nearest Neighbor Distance showing the distributional pattern of spread of TB in 2004, 2005, 2006 and 2007

Locations of patients infected with tuberculosis (red dots) between 2004 – 2007

Spatial distribution of TB in low, medium and high zones

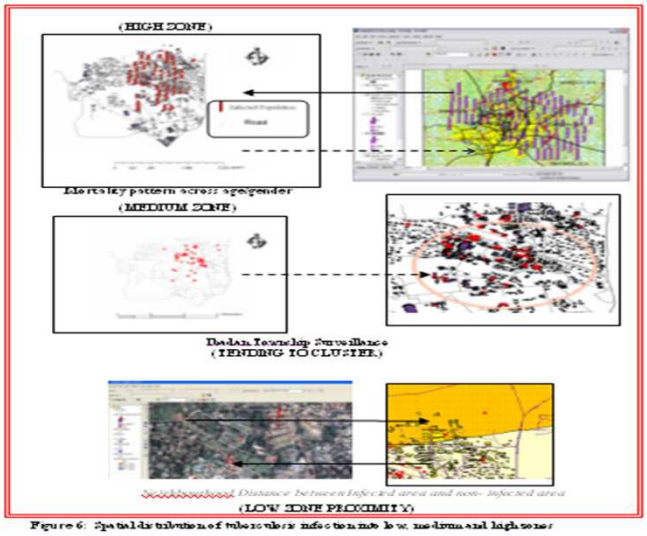


Figure 6: Spatial distribution of tuberculosis infection into low, medium and high zones

Distance analysis

Table 1. Average nearest neighbour index

Year	Population at risk	Nearest neighbour index	Pattern
2004	9,012	0.0703	Clustered
2005	7,582	0.1126	Clustered
2006	11,183	0.110846	Clustered
2007	3, 986	0.7916	Clustered
2004-2007	25, 280	0.7885	Clustered

Table 2:

Distance between TB infected area and non-infected area (m)	Nearest points to the infected areas			Total
	Hostel	Departments	Residential quarters	
100-300	4	16	45	65
300-500	5	17	22	44

Spatial distribution parameters

Table 3: 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 4 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

STATISTICAL AND SPATIAL ANALYSIS

❖ **GIS Data Analysis and Evaluation**

SaTScan™ statistics software would be used to estimate spatial clusters of tb cases identified.

❖ **Identification of associated risk factors of rabies**

Satellite Imagery of Ibadan was was used on Arc GIS to recognize land use areas and activities present at locations of TB clusters.

❖ **Statistical Analysis**

STATA statistical software was used to test for association.

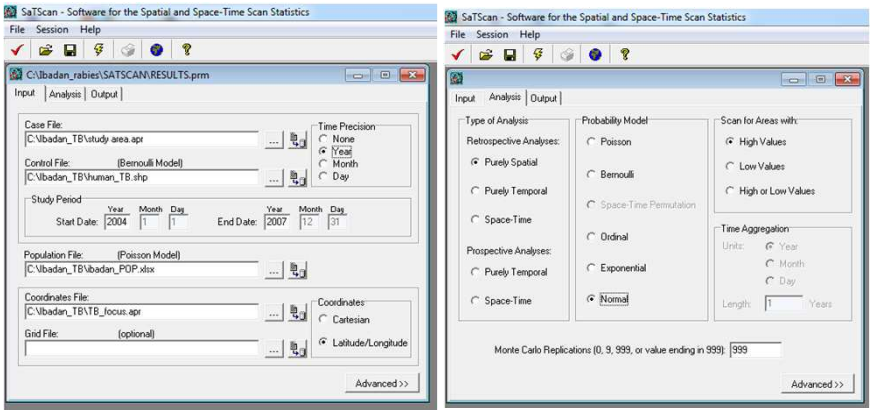
Table 5: Distance between TB infected area and non-infected area (m) in Ibadan South-East Local Government area

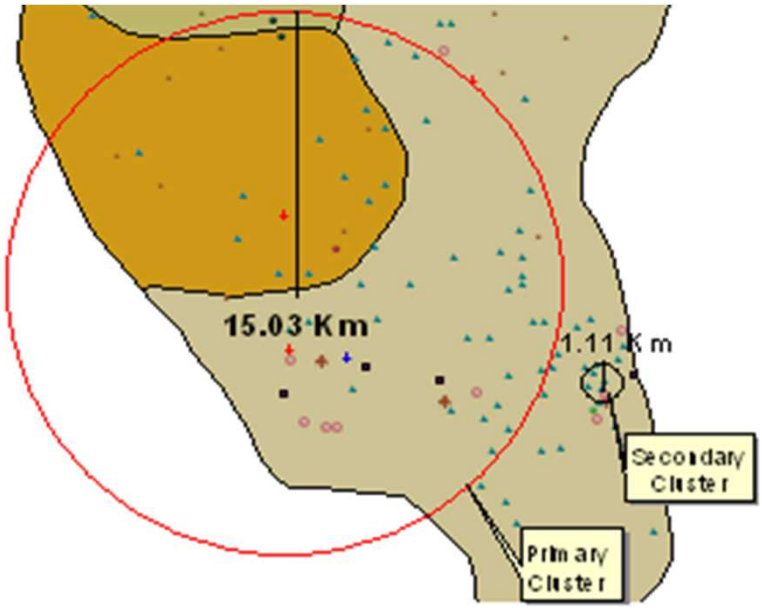
Distance between TB infected area and non-infected area (m)	Nearest points to the infected areas in Ibadan South-East			Total
	Institution/Schools	Commercial centers	Residential quarters	
100-300	13	38	47	98
300-500	18	72	85	175

Table 6: 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

Satscan Software
Cluster -spatial Analysis





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

Table 7: 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 8: 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 9: Average movement of patients to and from Home, market and farm

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

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

Table 10: Ibadan census data (1991 and 2006)

ID	LGA	LGA_HQ	1996_POP	2006_POP
1	Oluyole	Idi Ayunre	91527	263059
2	Ido	Iddo	55382	103261
3	Ona Ara	Akanran	123048	202725
4	Egbeda	Egbeda	129461	281773
5	Akinyele	Moniya	140118	211359
6	Ibadan South West	Oluyole	277047	282385
7	Ibadan North West	Dugbe/Oritaeke	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

POPULATION PERCENT CHANGE

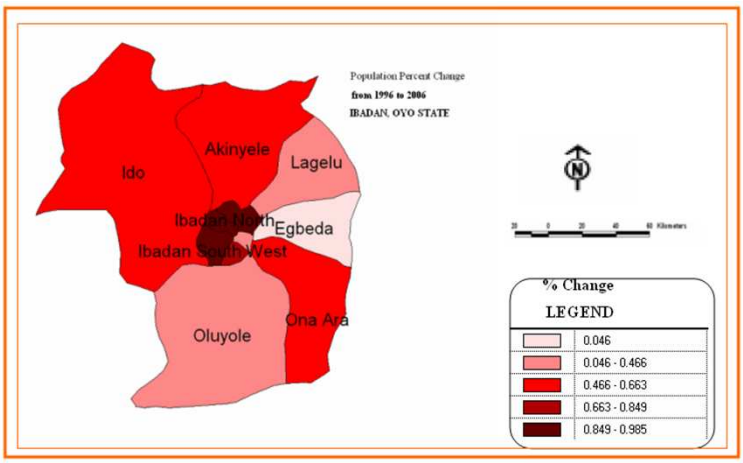


Figure 7: Population Change from 1991 – 2006(% change)

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); 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.

DISCUSSION

- 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).

Conclusion

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.

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.

Questions