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TRENDS AND DIFFUSION PATTERN OF MENINGITIS IN KANO STATE, NIGERIA USING INVERSE DISTANCE WEIGHT (IDW) AND LINEAR TREND SURFACE

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Abstract

Cerebrospinal Meningitis (CSM) is an infectious disease that can occur everywhere, but its effect is much in the sahellian Africa called "meningitis belt". The diffusion pattern remains unpredictable due to its nature and the populations it affects. This work examines trend and diffusion pattern of CSM using two most used spatial analytical tools for interpolation (Inverse distance weight (IDW) and Linear Trend Surface (LTS))for documented records of the past outbreaks in Kano State to observe the pattern which can help in understanding and prediction in the future. The addresses and dates of each patient was stored in the CSM record for 2012, 2015-2017, which was used for mapping the diffusion pattern after generating the coordinates of each patient, four stages/phases of diffusion were adopted. The two methods almost predicted similar pattern of CSM diffusion in Kano State, except for 2015 where the IDW indicates the diffusion which originated from the North-western part of the state, while the LTS indicates North-eastern part as the origin. The *possible reason was the impact of the high number of cases that occurred in the second and third phases of the outbreak, which makes LTS change the origin as given based on the first case during the outbreak. The general spatial pattern was observed to be influenced by the number of cases in a particular year. Diffusion originates from North-East or North during the years with less number of cases and from South-West or South when cases are much. In conclusion the application of two methods shows the premise of understanding and predicting the diffusion pattern of CSM in Kano State, which can help in management strategies of CSM control. This paper recommends need for using Geographic Information System technology in all the epidemic response and other activities that need spatial data analysis.*

Keywords: CSM, Diffusion, Interpolation, Pattern.

INTRODUCTION

Cerebrospinal meningitis CSM is an airborne infectious disease spread by droplet (saliva) and throat secretion from infected persons (Sultan *et al.*,2005):It begins with host acquisition of bacterium by nasopharyngeal colonization through large respiratory droplet and spread from person to person(Kamal 2009). Umaru, *et al.,* (2015) urban sprawl, crowdedness, parental smoking, socio-economic disadvantage, and immunity have been identified as valid predisposing factors for CSM. Bassey *et al.*(2016) asserted that, out of 24 most affected states in Nigeria during the outbreak in 2009, Kano State ranked fourth with 6811 cases with 2.4% Case Fatality Rate. Nigerian Best Forum News NBF (2009) reported that over 29 states of the Federation were affected by the Cerebrospinal Meningitis epidemic in 2009, about 19 states in the North and over seven other states in the South (Oyo, Ebonyi, Enugu, Imo, Anambra and Cross River states).

Due to its rapid onset and a short incubation period, CSM requires rapid emergency response to prevent adverse outcome. The later the meningitis is diagnosed and treated, the greater is the possibility of adverse outcome (Faustini 2007). Bassey *et al,* (2016) identifies lack of awareness, nature of terrain and healthcare accessibility as the factors aggravating more spread of disease during epidemic. Obaro & Habib (2016) see the management of the outbreak for prediction and control, case ascertainment, and lack of sound clinical management and surveillance, as some of the factors leading the CSM diffusion in Nigeria. The epidemics of CSM take many by surprise and remain unpredictable in most parts of where it occurs. The need to map these diffusions is important, which can help understand the pattern and allow for predictions.

Geographic Information techniques are widely used in epidemic analysis. The method of analysing changes in relationship to space by correlating the values of geographic units, at sequentially increasing distance for sequentially increasing time can provide a powerful and sensitive tool for analysis of the disease diffusion. Meade & Emch (2010) used interpolation method to predict unknown values for cells in a raster GIS using data from a number of

sample geographic points. The analysis was done on basic assumption that spatially distributed objects are related to their neighbour and the relationship decreases with distance, while the things that are closer tend to have similar values. A lot of interpolation techniques were used for modeling epidemic in space; however, the IDW is the most widely used method (Lai, *et al.,*2009).
IDW is a form moving average, near exact, deterministic, spatial interpolation method that is used to estimate is unknown values from the sample known values. It assumed that the near points are generally more related/have much influence on each other than the far away points. It is useful in displaying infectious diseases like CSM diffusion in space, because the disease normally spread or move outward from a point or beginning place.

Linear Trend Surface Analysis is the mathematical model of spatial variation, deterministic, inexact interpolation method that uses every known point to estimate the unknown values using polynomial regression. The linear trend surface used here create a floating-point raster, useful for fitting a surface to the sample points when the surface varies gradually from region to region over the study area. Regionalization of diffusion is best analysed using trend surface (Chang, 2008).

Even though maps are not without problems when it comes to analysis of health issues but present many advantages in presenting health information and analysis (Rican& Salem, 2010). The use of spatial interpolation in mapping the disease may help in determining and predicting the disease diffusion such as CSM. Richard (2013)uses cluster analysis in GIS of climate variables and CSM cases where he predicted that not all areas with same climatic condition have same CSM cases , while Lawal (2015) uses the Linear Trend Surface and Cubicle Analysis for the diffusion of cholera in Adamawa state Nigeria, and Umaru *et al.,* (2015) use GIS ellipse model for Urban sprawl and CSM incidence. From the forgoing, GIS analysis for disease mapping is becoming possible. Thus CSM as an epidemic can also be mapped. This paper selects Kano State, Nigeria as a state that experiences yearly occurrence of the disease. In addition, the intended diffusion pattern has not been mapped, which can make public health response easy, timely and if continued for more years, it can make prediction of the epidemic possible.

STUDY AREA
Kano state is located in the northern part of Nigeria, it is approximately situated between latitude 10^0 30′N to 12^0N and longitude $7^0$40′Eto $9^0$39′E, at an altitude of about 472.45 meters above sea level. It has 44 local government areas out of which only eight constituted the metropolitan area. It has land mass of about 2000 km^2 (Kano State, 2012), and a population of about 12 million persons (NPC 2006) and nearly over 5 million are living in the metropolis. The State has as at 2010 about 1240 public and private health care facilities with at least one General hospital per Local Government Areas(Figure 1), the ratio of doctor per patients was 1.7 doctors for 100,000 in the government service at all levels (Kano State, 2015). the climate of Kano is typically dry and wet, classified as Aw by Koppen and the monthly annual temperature ranges between 30^0C-33^0C during March-May and as low as 10^0C between

December and January (Olofin and Tanko 2002).The Harmattan winds prevail at this time (dusty condition). Rainfall ranges between 850-870mm with an average of 600mm (Kano State, 2012), and predominant period of maximum rainfall is from June to September, almost 40% of the rainfall comes in August.

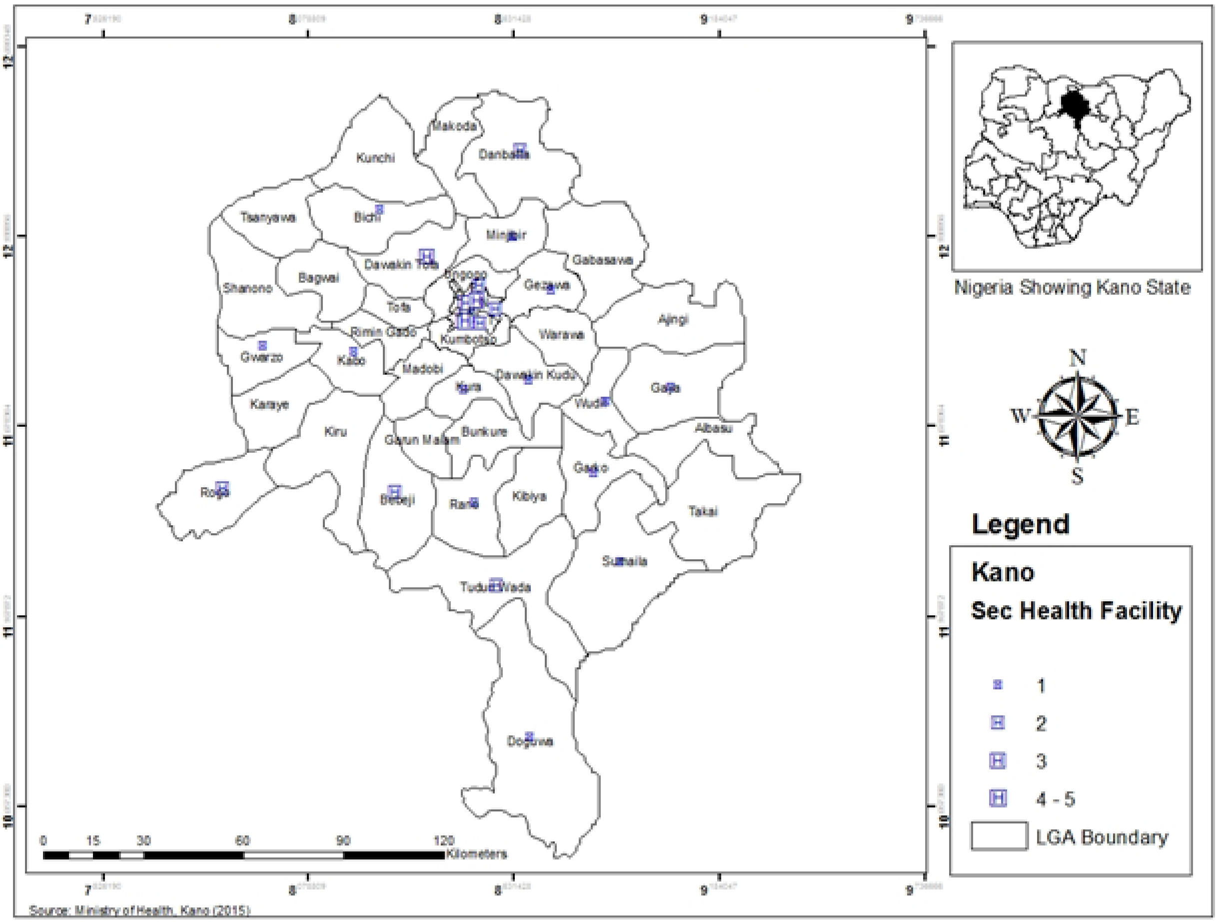

Figure 1:Kano State Secondary Healthcare Facilities

METHOD

An inventory of individual CSM patients in Kano state was collected from Kano State Ministry of Health, Public Health Department, Epidemiology Unit 2017, while the coordinates of patients' settlements for the whole state was collected from Epidemiology unit, Kano State Ministry of Health, the record obtained is technically named as CSM line-list, an excel database sheet The coordinates of all the settlements of the patients were collected from the eHealth settlement mapping project. Other settlements that are not available in the list were collected using Google Earth map by searching the name of the settlement name on Google or by moving the pointer to the position of the settlement to record the coordinate. All the coordinates were converted into decimal degree for this work. The inventory of CSM patients recorded at the different health facility across the state, from 2010 to 2017 (only 2012, 2015, 2016 and 2017 records were available in the record), contains the database that treats each patient as a record. The variables captured are; state epidemic number, local government areas, ward, settlement, name, age, sex, date of birth, date of onset of disease/date seen at the facility, week of onset, Cerebrospinal Fluid (CSF) taken, result, hospital, outcome, comment and remark.

The diffusion analysis is performed in ArcGIS 9.3 software. Variables for the analysis were exported into ArcGIS for analysis. The file contains therein all the corresponding coordinate of all the settlements of the CSM patients for 2012, 2015, 2016 and 2017 record. The exported files were then converted to format shape file format, to allow for the GIS analysis, and together with Kano State shapefile (Kano State local government and state boundary map) same georeference format was given World_WCG_1987. The maps were produced for all the years using the spatial diffusion analysis method of Inverse distance weight (IDW) and Linear Trend Surface) analytical tools for interpolation. The two analyses were run to compare the power of predicting surface trend influence of the CSM diffusion pattern in the State.

For all the years four classes of analysis were adopted as different diffusion stages, that is first, second, third and fourth wave of onset of the CSM in each location, displayed as four divisions from black to white scale, from the time (Month) it started in the state to the time it dissipated. This was based on the first date and last date of the cases recorded in the state for each of the years understudy.

RESULT AND DISCUSSION

Diffusion Analysis of CSM for 2012 Outbreak

The results obtained are presented in Figure 2, the result indicated the origin of the outbreak as Bagwai LG area, which represents the first wave of the diffusion; the impact was visible in the neighbouring areas. The diffusion spread as far as Doguwa LG in the State the farthest distance from the origin.

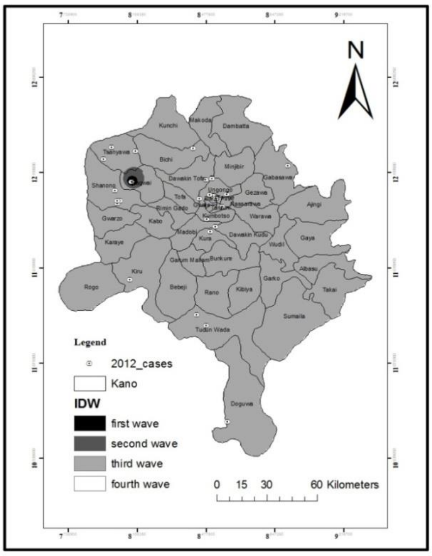

Figure 2a: IDW for CSM outbreak 2012

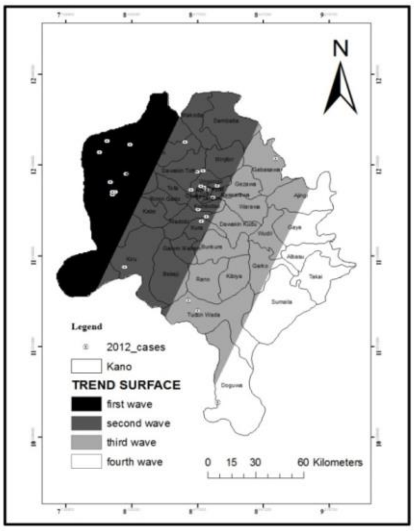

Figure 2b: LTS for CSM outbreak 2012

The linear trend surface (LTS) group cases into regions and the regions are based grouped on dates of the onset of outbreak in a location. The resultant linear trend surface analysis of 2012 CSM outbreak is displayed in Figure 2b. From the analysis of the displayed result, the period for the outbreak was divided into four regions, the black colour region mark the first wave region of the outbreak which shows the gradual movement toward the centre and to the South Eastern part of the state. The second wave shows the intensification of the number of cases and cover parts of the metropolitan areas. It dissipated as it moves to the fourth wave region.

Diffusion Analysis of CSM for 2015 Outbreak

As indicated the first cases were reported around Bagwai LG communities, while the last was reported in the metropolitan areas around the last phase of the outbreak (Figure 3a) to the western part of the state. The IDW analysis for 2015 indicated that the transmission of the disease is translocation from its origin to far distance areas, despite that the first case was found around the age group that are less mobile, so the transmission may not be ascertained as person to person rather a fresh infection in different area at different time since both have same chance of infection of the disease on air. Most parts of the state were at highest risk during the third wave of the diffusion, followed by the dissipating and fourth wave of the diffusion. The general pattern of the diffusion was irregular, and can be attributed to the complex interaction of the people of the state.

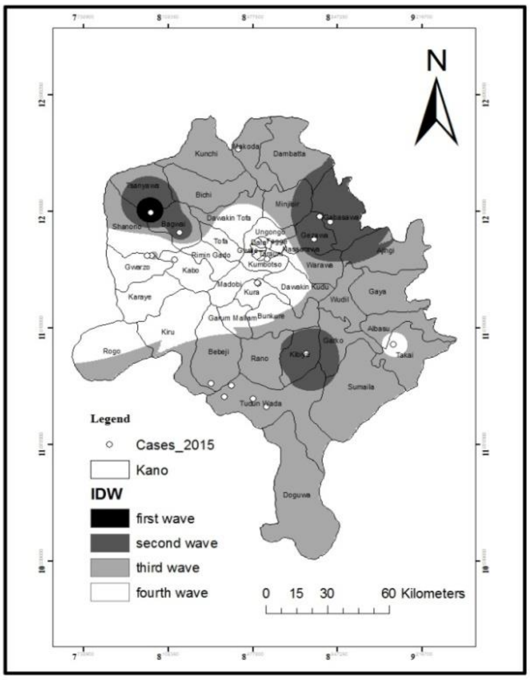

Figure 3a: IDW for CSM outbreak 2015

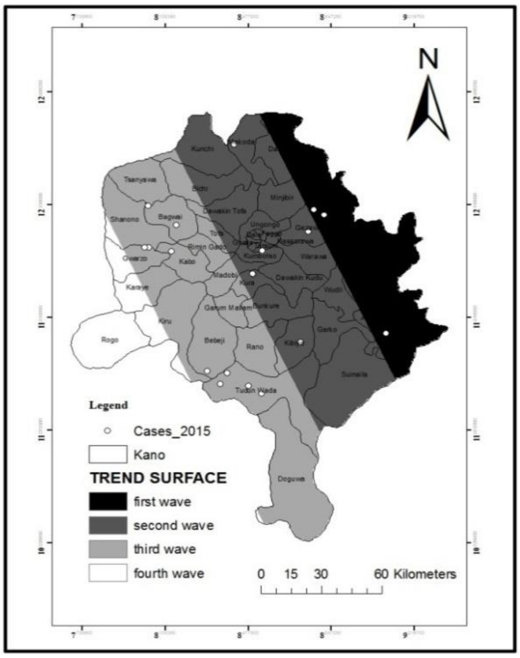

Figure 3b: LTS for CSM outbreak 2015

The linear trend surface for 2015 CSM outbreak indicates that the first region where the outbreak possibly started was from North Eastern part of the state and gradually movedand dissipated to the South Western direction in the state (Figure 3b).By comparing the two analyses IDW and LTS, the IDW result origin was found at NW part of the state, while the LTS indicates NE as its region where the outbreak almost started. In general, it may be ascertained that LTS for 2015 depicted the impact of the many observations (cases) of the same date in shifting the origin of the disease, after the first case, the spread become almost all over and at the same time.

Diffusion Analysis of CSM for 2016 Outbreak

The IDW interpolation result for 2016 indicates the risk in northern part due to the influence of the origins of the diffusion in Bichi, Gezawa and Bagwai, from late February to early March, while the last record in the fourth wave of diffusion was found in Kumbotso around December. This last record might have been the first record for 2017 outbreak, since the period between the last and the second to the last record was about six month, which can be difficult to relate the two events temporally. This might be a fresh wave of new outbreak that is why the location influence was engulfed by the third wave of the interpolated areas (figure 4a).

The result of the LTS interpolation for 2016 also followed same pattern with IDW where the diffusion was interpolated to have been move from NE toward SW part of the state (figure 4b).The influence of the last record of December was totally not displayed in LTS analysis this shows how this diffusion analysis is more critical than IDW. However, they are all exact and deterministic spatial interpolation method.

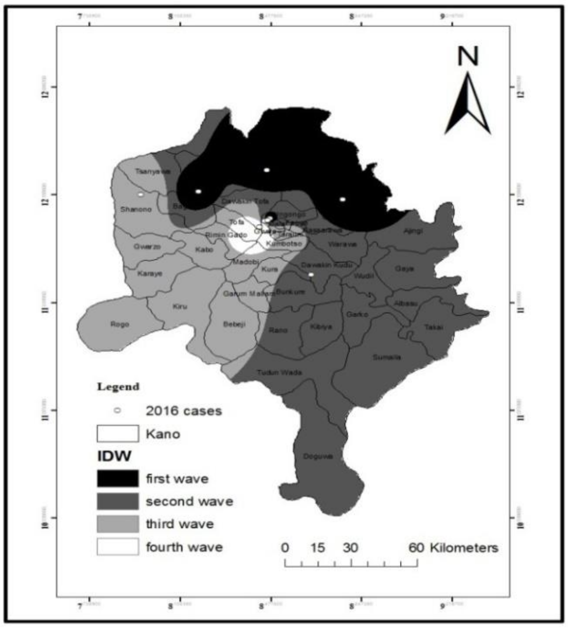

Figure 4a: IDW for CSM outbreak 2016

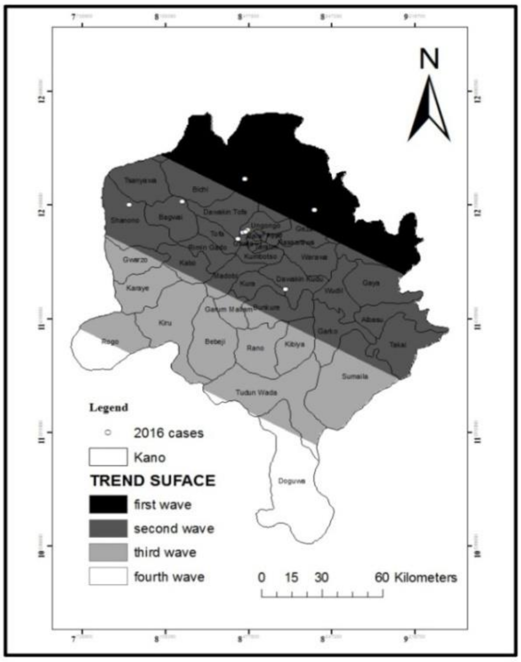

Figure 4b: LTS for CSM outbreak 2016

Diffusion Analysis of CSM for 2017 Outbreak

The spatial diffusion in 2017 started from different location in the metropolitan areas and Tsanyawa, this indicated that the outbreak started virulently in the state or it might have been started unreported elsewhere. The spread of the disease continued to cover the two areas of Gwale and Tsanyawa and beyond, which reaches up to areas in Garko in the east and Tudun Wada in the south, at the same time spreading the wave of influence in-between as displayed on the IDW interpolation map (Figure 5a). The intensity of the outbreak peaked in April, and the result of the IDW analysis indicates that at the onset most of the cases occurred in far different locations in the centre and LGAs at the state boundary, then it spread interpolate back to the centre, where the influence from the onset location met in around April, when risk was at its highest in almost all direction. The spatio-temporal diffusion halts around May-July, in areas of Garko, Makoda, Karaye, Kiru and Bichi in the North. The result also indicated that onset period of the disease occurred in one area and relocated to other places later and gradually continued to diffuse until dissipated.

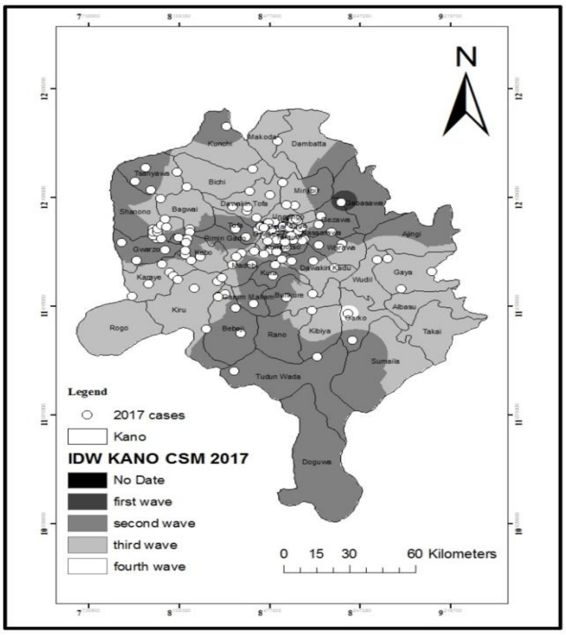

Figure 5a: IDW for CSM outbreak 2017

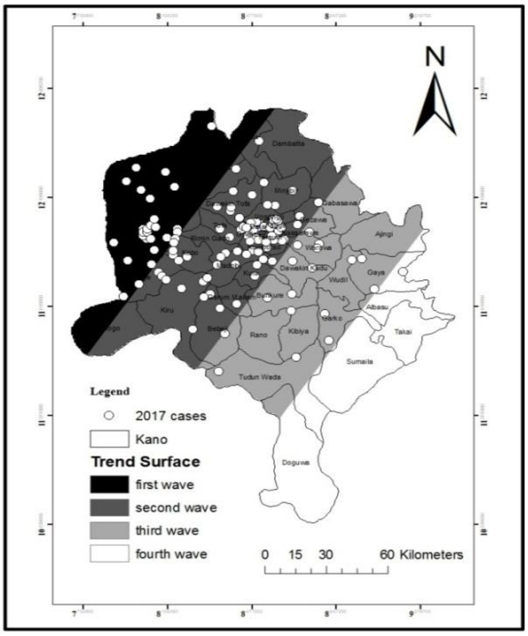

Figure 5b: LTS for CSM outbreak 2017

The linear trend surface of 2017 CSM outbreak shows the temporal region of the diffusion, and the communities in the NW parts of Rogo, Shanono, Tsanyawa, Kunchi and part of Bichi and Makoda areas are grouped as first region of the diffusion. The second wave covered almost all part of the metropolitan region despite that the first case was found in the metropolitan area, but linear trend smoothed it to fall under second wave or region of the diffusion, which display the influence of the concentration of the cases of the second wave of the diffusion that make up the region. The third and the fourth wave covers the entire Kano south and some portion of Central and east, and cases where few. As displayed in Figure 5b, the diffusion region originates from NW toward the SE part of the state at the last part of the outbreak, and the second linear trend surface region constitute the serious time which covers the most densely populated area of the state.

The 2012 diffusion analysis using IDW and LTS indicates that the origin of the outbreak was from a settlement in Bagwai and it continue to spread using a translocation pattern of diffusion till it reaches Doguwa, that is from NW part of the state toward SE part. In 2015 the IDW also indicates the origin from Sare-Sare area of Bagwai from there it spread to other part of the state, but it does not affect metropolitan areas and the southern part of Bagwai until later toward the end of the outbreak period, this affect the LTS for 2015 result which indicate the origin from the NE part unlike the IDW result, and move outward to the Eastern part of the state. The IDW and the LTS for 2016 outbreak show almost similar pattern of diffusion in the state, which originated from Northern part of state and spread south ward, however the diffusion is not gradual. In 2017 many origins where identified on IDW mostly in the metropolitan and the around Rimingado to shanono axis, and the diffusion pattern indicates the influence in all over the state, however, the LTS shows the spatial temporal diffusion which move from NW region as the origin toward SE region.

CONCLUSION

The diffusion pattern is generally translocation and originated mostly from NW during the years with high cases toward SE and from NE or N toward SW or S during the years with few cases. CSM is generally a diseases of hot-dry season, and the fact that northern part of the state start to witness the season first make the trend to always begin there. The spatial concentration of the cases is much in the metropolitan area. The two methods of spatial interpolation that is IDW and LTS have shown reliability for mapping diffusion pattern of CSM. IDW shows something closer to exact pattern which can be used to understand the real nature of the diffusion, while the LTS can help management in an outbreak response activities. It is recommended that for the public health departments to have a very good surveillance system that can be recording necessary information about patients' history and locations. This can help understand the diffusion pattern which can be used in decision on health planning.

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