Spatiotemporal Trends of Lassa Fever Surveillance in North Easthern States, Nigeria.

*Damashi, M. T., *Babamaaji, R., *Odiji, C. and *Bianka, A. C

**Strategic Space Application, National Space Research and Development Agency (NASRDA) Abuja.*

Email: gend.m.tali@gmail.com

Abstract

Lassa fever is a viral haemorrhagic fever transmitted by rats. Lassa fever is a longstanding public health concern in West Africa with recent molecular studies confirming the fundamental role of the rodent host (*Mastomys natalensis*) in driving human infections, but control and prevention efforts remain hampered by a limited baseline understanding of the disease's true incidence, geographical distribution and underlying drivers. We analyzed confirmed reported data from surveillance records of NCDC dashboard between 2015 to 2020 and primary health facilities from ehealth Africa for spatiotemporal trends of lassa fever and distribution of primary health facilities for upgrade to a diagnostic center. The results shows a spatiotemporal trends increase with hot spot at Bauchi (127), Taraba (117), Gombe (12), Adamawa (5), Borno (4) and Yobe (0) confirmed cases despite a clustered distribution of primary health centers and the population of people in the study area with increment from 2015-2020, there is no LF diagnostic center in the study area. From this report, challenges to control efforts which included poor local laboratory capacity, inadequate/poor quality of protective materials, fear among health workers, and inadequate emergency preparedness should be put in place for proper health planning.

Key words: Lassa fever, Northeastern, Nigeria, Spatiotemporal, Surveillance.

INTRODUCTION

Lassa fever is an acute viral hemorrhagic sickness caused by the Lassa virus, a member of the arenavirus family. This zoonotic illness has a significant morbidity and fatality rate, and it has both economic and health security implications [1]. The ailment was originally documented in 1969 in Lassa, Borno State, Nigeria, when two missionary nurses died of a strange febrile fever. Since then, cases and outbreaks have been reported in Nigeria, and the disease is now widely acknowledged to be endemic in many parts of West Africa [2]. Humans are typically infected with Lassa virus through contact with food or household objects contaminated with the urine or feces of infected Mastomys rats, the virus's host [3]. These rats reproduce frequently and are found throughout West, Central, and East Africa. They are most likely the most common rodent in tropical Africa, and they are found primarily in rural regions, dwelling more often than in surrounding countryside [4]. Rats identified in infected people's homes are seropositive for the

virus ten times more frequently than rats found in control homes. Virus antibodies appear in twice as many people who eat rats as those who do not consume rats following a febrile illness [5]. Lassa fever (LF) is an epidemic-prone disease that requires urgent notification on Nigeria's integrated disease surveillance and response (IDSR) systems. The exact incidence rate in Nigeria is unknown, however case fatality rates range from 3% to 42% (and have remained between 20% and 25% over the last two years) (Ipadeola., 2020). This zoonotic illness has a significant morbidity and fatality rate, and it has both economic and health security implications [1], [6]. The ailment was originally documented in 1969 in Lassa, Borno State, Nigeria, when two missionary nurses died of a strange febrile fever. Since then, cases and outbreaks have been reported in Nigeria, and the disease is now widely acknowledged to be endemic in many parts of West Africa [2]. Between 2018 and 2020, Nigeria recorded its highest annual incidences of Lassa fever (LF) to date (633 confirmed cases in 2018, 810 in 2019 and 1189 in 2020, across 29 states), prompting national and international healthcare mobilisation and raising concerns about an ongoing, systematic emergence of Lassa Fever nationally [2], [7]. Humans are typically infected with Lassa virus through contact with food or household objects contaminated with the urine or feces of infected Mastomys rats, the virus's host [2]. Person-to-person infections and laboratory transmission can also occur in the absence of proper infection prevention and control procedures, particularly in health care settings. Diagnosis and management are important [8]. The overall case fatality rate is 1%. Case mortality is estimated to be around 15% among patients hospitalized with severe clinical manifestations of Lassa fever [9]. Early supportive care, including rehydration and symptom relief, improves survival. Approximately 80% of those who become infected with the Lassa virus show no symptoms. One in every five infections results in severe disease, with the virus affecting multiple organs such as the liver, spleen, and kidneys [10]. There is no vaccine available to protect against Lassa fever at the moment [11]. The partnership of government agencies working with development partners has increased awareness of Lassa Fever and the need for improved infection prevention and control (IPC) measures to be implemented [12].

The present-day incidence and burden, however, remain poorly defined, because LASV surveillance has historically been opportunistic or focused on known endemic districts with preexisting diagnostic capacity [13] and often-cited annual case estimates (of up to 300,000) are consequently extrapolations based on limited serological evidence from a handful of early studies [14], [15]. This, alongside LF's nonspecific presentation, means that many mild or subclinical infections (possibly 80% or more of infections) are thought to go undetected [16], [17]. The patchy understanding of LF's true annual incidence and drivers hinders diagnosis, treatment and disease control [18] and provides a limited contextual understanding of whether the recent surges in reported cases have resulted from improvements in surveillance or a true emergence trend.

Despite the fact that LF is an epidemic in Nigeria and other African nations, the details of the outbreak and subsequent response to contain it have not been properly documented, making it difficult to learn from these experiences in order to better the management of future outbreaks. To address these gaps, in this study we analyse the long-term spatiotemporal epidemiological dataset of reported human LF case data, systematically collected from 2015 to 2020 in north eastern Nigeria. We use this dataset to characterise the epidemiology and spatial trends of Lassa fever and evaluate the drivers that explain the geographical distribution of LF occurrence and incidence.

METHODOLOGY

Study area

North East is one of the geopolitical zones of Nigeria consisting of the following states: Adamawa, Bauchi, Borno, Gombe, Taraba, and Yobe. It is located at longitude 54.9456°N and latitude 1.9480°W. North-eastern state is a former administrative division of Nigeria. It occupies slightly less than one-third of Nigeria's total area and had a projected population of about 23,558,674 (13.5%) of the country's population. The inhabitants are mainly Fulani with only Borno State has kanuri people as majority with more than 100 minority ethnic groups [19].

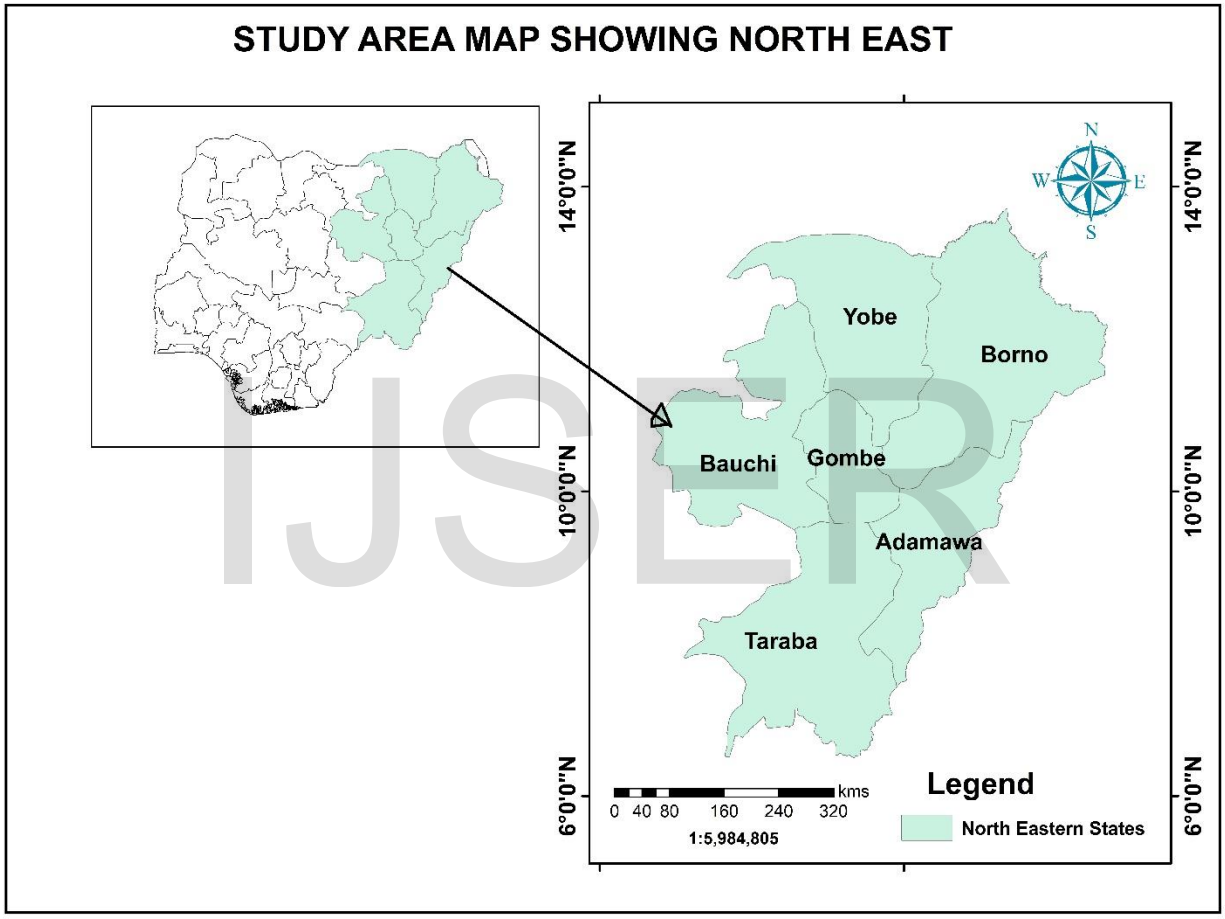
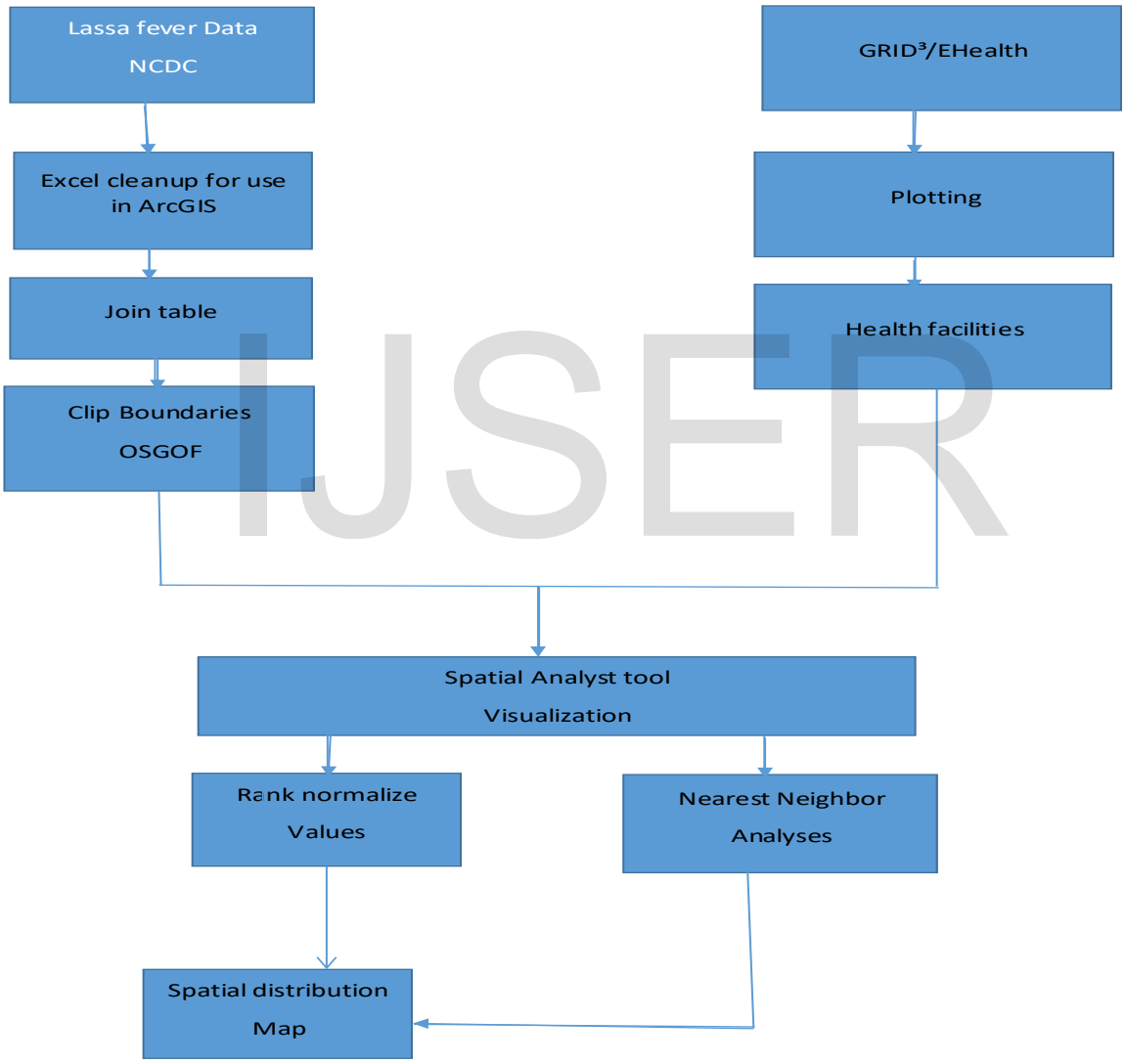


Fig. 1. Study area map showing the six (6) States of North Eastern Nigeria
Source: Author(s) Analysis, 2022.

Flow chart illustrating the Methodology



Data collection

Reported Cases of Lassa fever outbreak in North Eastern Nigeria was gotten from https://ncdc.gov.ng/diseases/sitreps). State and LGA shapefiles used for modelling and mapping were obtained from the Office of the Surveyor General of Federal (OSGOF) and coordinates of the PHCs are obtained from the Geo-Referenced Infrastructure and Demographic Data for

Development (GRID3)/ehealth africa programme website. The inferential statistical tool applied in analyzing the data in this research were the "Nearest Neighbor Analysis" (NNA) and Network Analysis in ArcGIS 10.4.

Trends of Lassa fever surveillance in north eastern Nigeria

We visualized temporal, seasonal trends and annual case accumulation of reported LF cases between 2015 and 2020 to examined spatial changes.

Statistical analysis

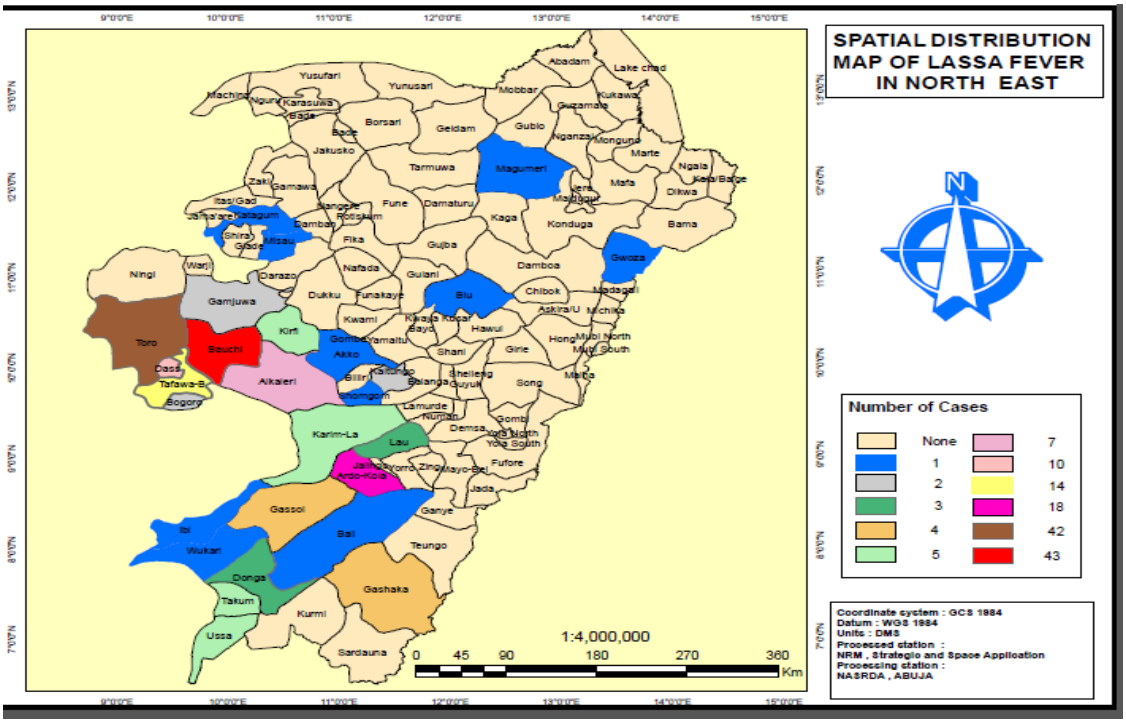
We analyzed the full case time series to characterize the spatiotemporal incidence and drivers of LF in north eastern Nigeria, we firstly analyzed annual LF occurrence and incidence to identify the spatial, climatic and socio-ecological correlates of LF risk in the study area.

Average nearest neighbor

The average nearest neighbor is a measure of the distance between each spatial feature and its nearest neighbor centroids. All these distances are then averaged and compared with a hypothetical random distribution. If the averaged distances of an observed distribution are less than the average of a hypothetical random (expected distribution), the spatial pattern of features being analyzed (the observed) is considered clustered. The value of the average nearest neighbor ratio in this case is less than one. On the other hand, if the average distance is greater than the expected distribution, the spatial pattern is considered dispersed [20].

RESULTS AND DISCUSSION

Between 2018 and 2020, Nigeria recorded its highest annual incidences of Lassa fever (LF) to date (633 confirmed cases in 2018, 810 in 2019 and 1189 in 2020, across 29 states), prompting national and international healthcare mobilisation and raising concerns about an ongoing, systematic emergence of LF nationally[2],[7]. The dataset collated by the Nigeria Centre for Disease Control (NCDC), consists of weekly epidemiological reports (WERs) of acute human LF cases between 2015 and 2020 shows evidence of pronounced spatial and temporal clustering with the majority of cases reported from just 2 of the 6 states (Bauchi and Taraba) in North eastern Nigeria, with lower incidence overall in the remaining 4 states (Gombe, Adamawa, Borno and Yobe) as shown in figure 2 having notably distant from diagnostic centres (Abuja). There is consistent evidence of seasonality in all areas across the reporting period, annual dry season peaks of LF cases typically occur in January, confirming past hospital admissions data from Nigeria[21], [22] and Sierra Leone [23], with some secondary peaks evident in early March and, increasingly, a small number of cases detected throughout the year. Both overall temporal trends and cumulative case curves suggest that 2019 and 2020 appear to be markedly different from previous years, with very high peaks in confirmed cases extending from January into March, and high suspected case reporting (Table 1 and figure 3). Improvements to country-wide surveillance could, however, be driving any apparent increase in both the incidence and geographical extent of LF in Nigeria.



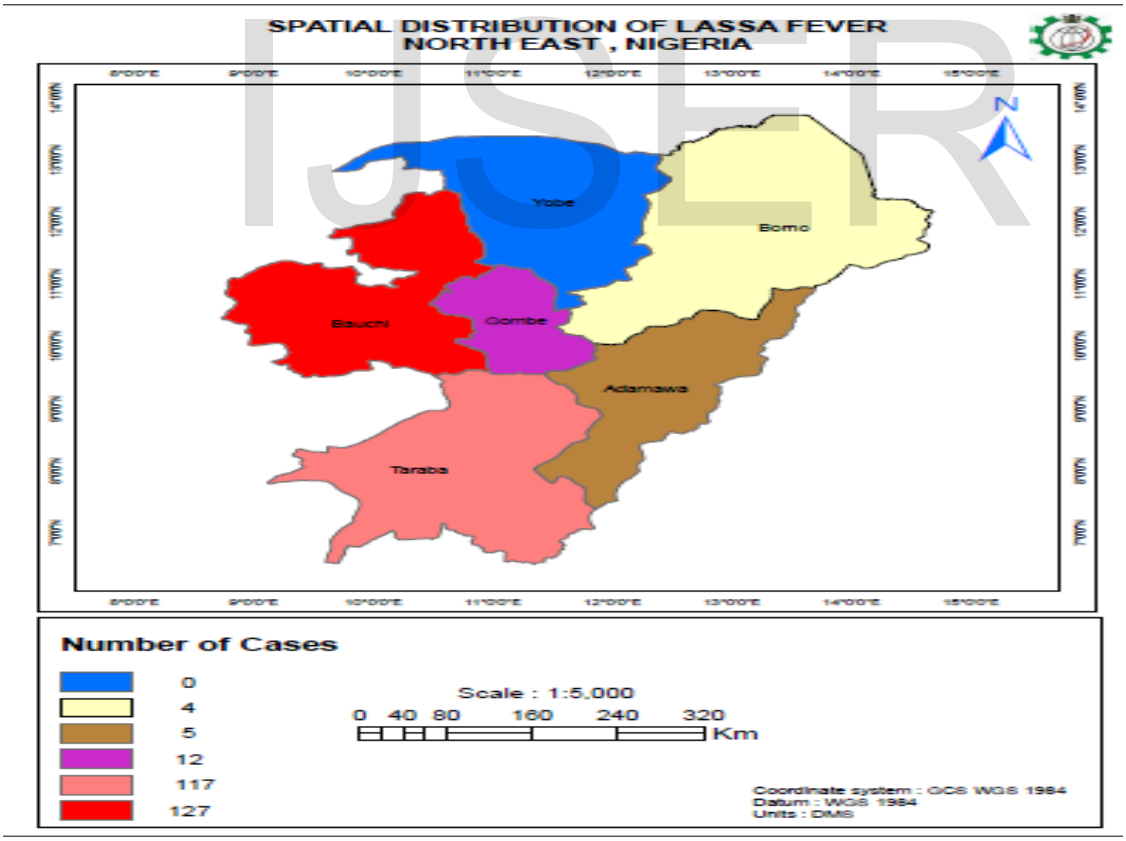


Fig. 2. Spatial distribution of Lassa fever in North Eastern Nigeria at LGAs and States level.

Table 1

Temporal trends in North east Lassa fever case reporting from 2015 to 2020.

	2015	2016	2019	2020	TOTAL
BAUCHI	3	13	57	54	127
TARABA	5	13	42	58	117
GOMBE	0	1	3	8	12
ADAMAWA	0	0	1	4	5
BORNO	0	0	0	4	4
YOBE	0	0	0	0	0
TOTAL	8	27	102	128	

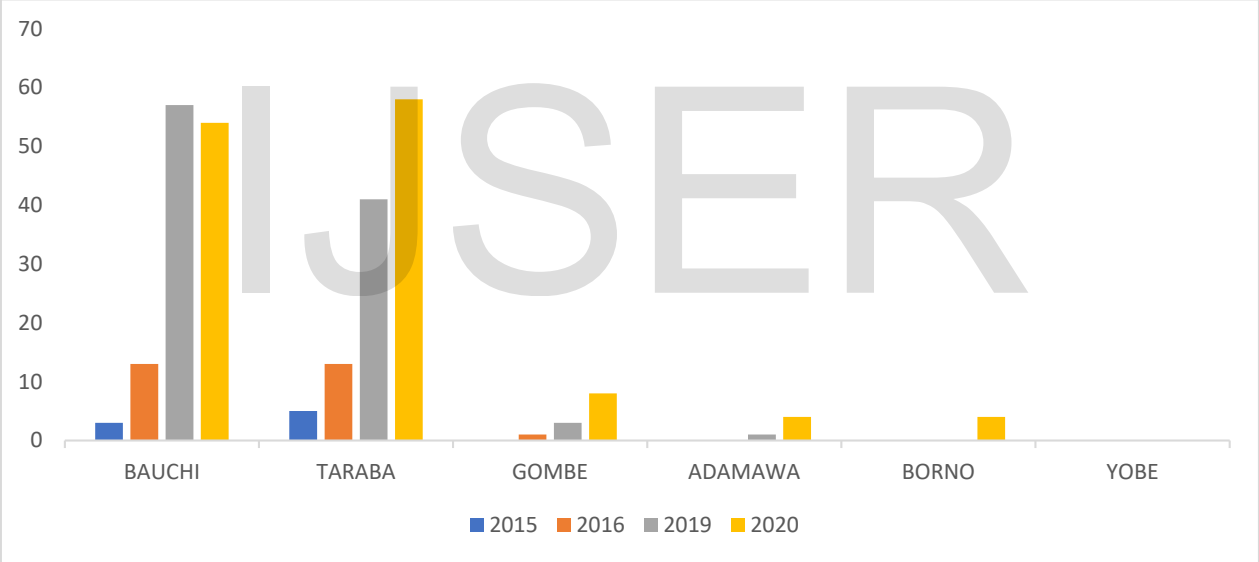
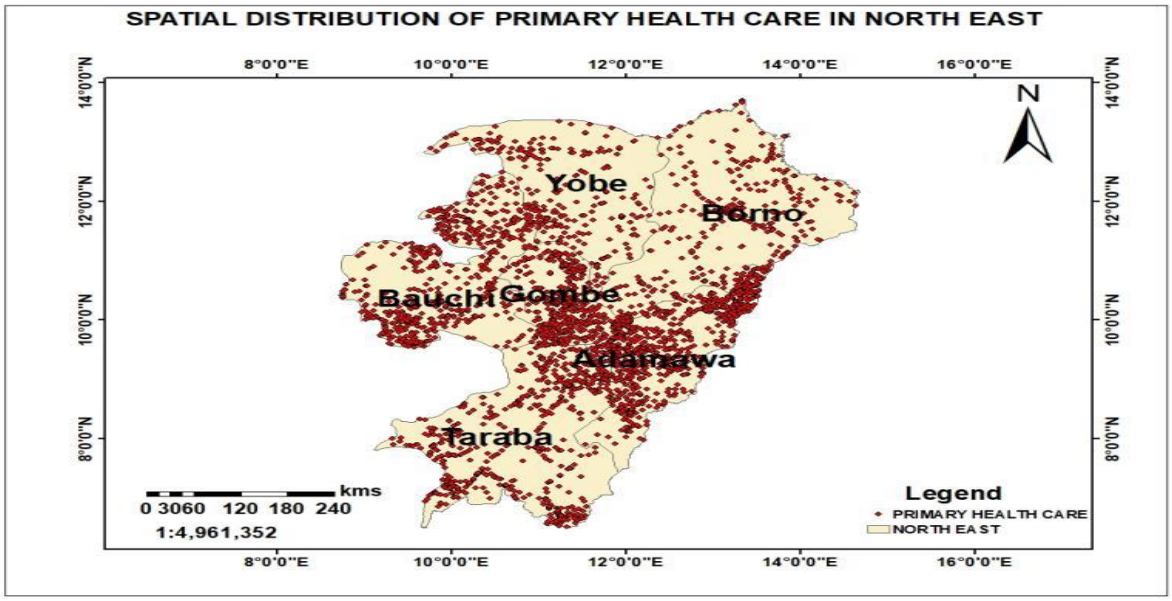


Fig. 3. Temporal trends in North east Lassa fever case reporting from 2015 to 2020.

Spatial distribution of PHCs in North eastern Nigeria

The spatial distribution revealed that PHC across the study area were spatially clustered (Figure 4). The average nearest neighbor ratio was 0.518449 ($p < 0.001$) and the Z-score was −54.7112. Due to the large Z-score, there was less than 1% likelihood that this clustered pattern could be the result of random chance. Overall, the concentrated spatial pattern of PHC tends to be in the center of town with variation in patterns of distribution for individual states as shown in (figure 4). From the aforementioned result, it is clear that the Northern part has dispersed whereas the Southern part showed a random pattern of distribution which can be improved on to get a diagnostic center in the North eastern region of Nigeria.



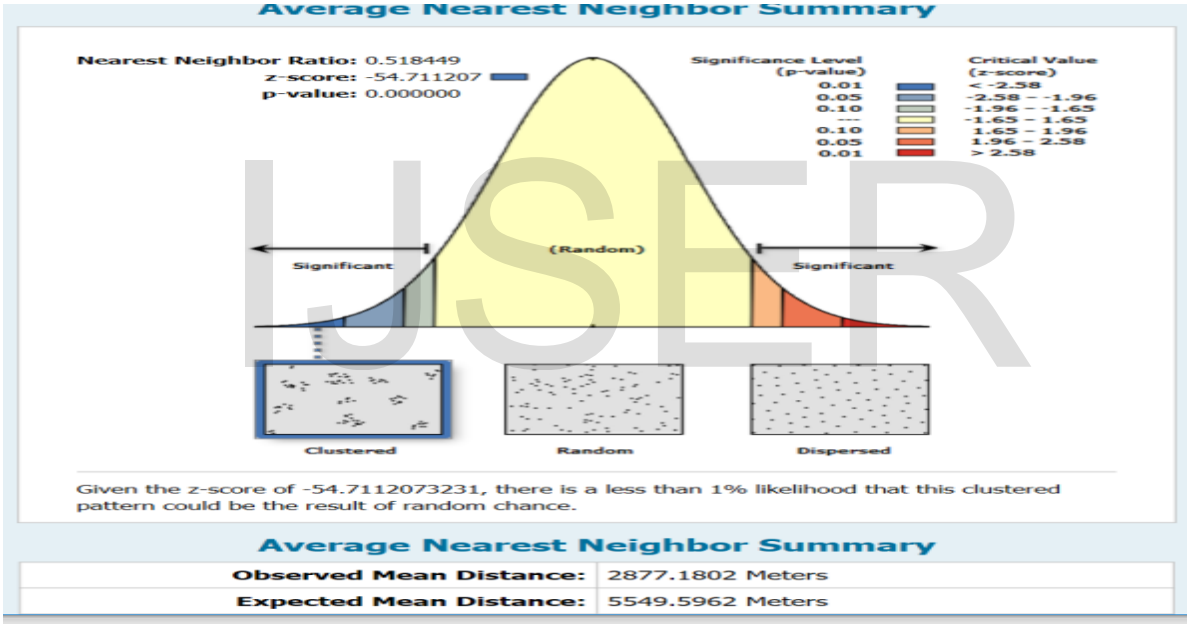


Fig. 4. Spatial distribution and nearest neighbor analysis of PHCs in North Eastern Nigeria.

Climatic factors influencing LF spread

Lassa fever is a climate and land-use sensitive disease of poverty. Much of the environmental mediation of case numbers is likely driven by ecological dependencies of the principal host *M. natalensis*, resulting in a strong association between LF cases and rainfall. Peak LF occurrence appears to be in areas experiencing around 2000-3000 mm of rain annually and moderate temperature which proves the highest trend in Bauchi and Taraba (fig 5 and 3), though incidence increases with rainfall and moderate temperature and wide uncertainty under very high rainfall conditions. While the role of host ecological suitability could be important, it may also be human behaviours that vary in response to climatic conditions, such as crop planting or farming techniques, that could be the principal or additional underlying cause of case variation which

might be the cause of the prevalence in Bauchi and Taraba. The trend of increasing incidence with higher rainfall, but the decreasing probability of disease occurrence, could be reflecting the correlation between rainfall and host habitat suitability in Nigeria. Areas with very high rainfall in the south are principally rainforest, which is unsuitable habitat for *M. natalensis*[14].

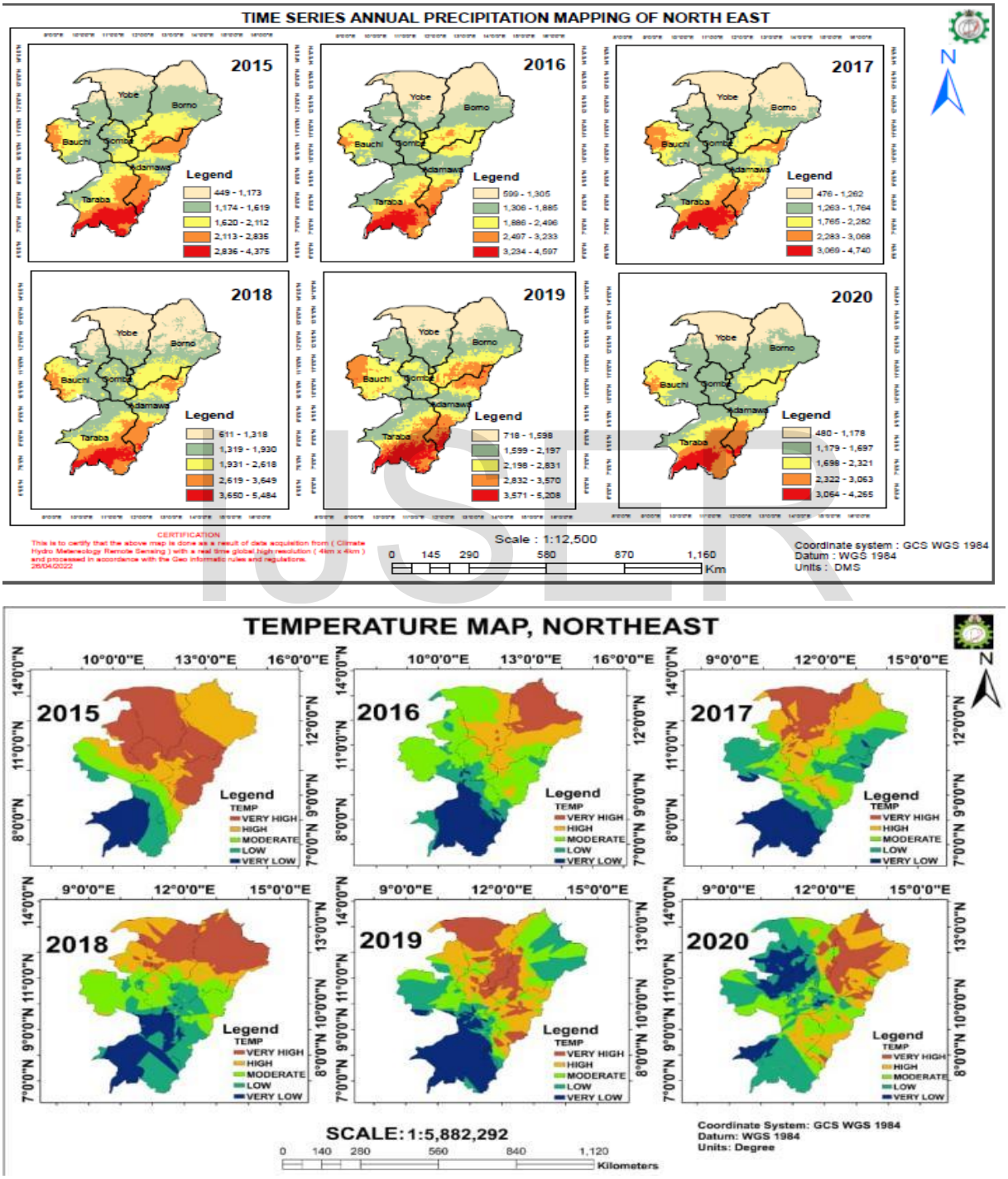


Fig. 5 Annual Rainfall and Temperature of north eastern Nigeria

CONCLUSION

In conclusion, our findings have implications for ongoing disease management and targeting of LASV surveillance in rodents and humans toward environmentally suitable areas where LF is apparently absent, prioritising hotspot areas for future vaccination rollouts, and highlights the critical role of improvements in systematic human case surveillance across Nigeria in helping to explain rising numbers of cases. With LF surveillance continuing to improve in Nigeria, these data and analyses provide a foundation for the future development of userfocused LF risk mapping and forecasting systems, to aid public health responses in this region.

REFERENCES

1. Omilabu, S.A., Badaru, S.O., Okokhere, P., Asogun, D., Drosten, C., Emmerich, P. (2003) Lassa fever, Nigeria, 2003 and 2002 *Emergence of Infectious Diseases*; 11(10):1642–1644.
2. Nigeria Centre for Disease Control. Lassa fever Situation Report, 12 April 2020. (NCDC, 2020)
3. Eze, K.C., Salami, T.A., Eze, I.C., Pogoson ,A.E., Omordia, N., Ugochukwu, M.O., (2010). High Lassa fever activity in Northern part of Edo state, Nigeria: re-analysis of confirmatory test results. *Africa Journal of Health Sciences*;17:52-56.
4. Ilori, E. A. (2018). Epidemiologic and clinical features of Lassa fever outbreak in Nigeria, January *Emergin. Infectious Disease*. 1066–1074.
5. Ter-Meulen, J., Lukashevich, I., Sidibe, K., Inapogui, A., Marx, M., Dorlemann, A. (1996) Hunting of peri domestic rodents and consumption of their meat as possible risk factors for rodent to-human transmission of Lassa virus in the Republic of Guinea. *American Journal of Tropical Medicine and Hygiene.* 55; 661-666.
6. David, W. R, Rory, G., Chioma, C. D., Elsie A. I., Rimamdeyati, U. Y., Saliu, H. O., Michael, O.A., Akanimo, I., Lauren, A. A., Christl, A. D., Ibrahim, A., Kate, E. J. & Chikwe I. (2021). Geographical drivers and climate-linked dynamics of Lassa fever in Nigeria. *Nature Communications* | *Https://Doi.Org/10.1038/S41467-021-25910*.
7. Ipadeola, et al., (2020). Epidemiology and case-control study of Lassa fever outbreak in Nigeria from 2018 to 2019. *Journal of Infectious Diseases;* 80, 578–606.
8. Bausch, D. G. et al. (2001). Lassa fever in Guinea: I. Epidemiology of human disease and clinical observations. *Vector Borne Zoonotic Diseases;* 1, 269–281.
9. Chen, J.P., Cosgriff, T.M.,(2000). Hemorrhagic fever virus-induced changes in haemostasis and vascular biology. *Blood Coagul Fibrinolysis* ;11: 461-83.
10. World Health Organization. Lassa fever in Nigeria (2012) Global alert and response. Available at http://www.who.int/csr/don/2012_04_04/en/. Accessed January 2016. Google Scholar.
11. Nigeria Centre for Disease Control.; Lassa fever factsheet, (2019). https://ncdc.gov.ng/diseases/factsheet/47
12. Nasir, A.I, Sani, M.F. (2015). Outbreak, pathogen containment and laboratory investigation of Lassa fever in Nigeria: How prepared are we ? *International Journal of Tropical Disease and Health*; 10(1):1-10.

13. Gibb, R., Moses, L. M., Redding, D. W. & Jones, K. E. (2017). Understanding the cryptic nature of Lassa fever in West Africa. *Pathogens and Global Health* 111, 276–288.
14. McCormick, J. B., Webb, P. A., Krebs, J. W., Johnson, K. M. & Smith, E. S. A prospective study of the epidemiology and ecology of Lassa fever. *Journal of Infectious Diseases*; 155, 437–444 (1987).
15. Bausch, D.G., Rollin, P.E., Demby, A.H., Coulibaly, M., Kanu, J., Conteh, A.S., (2003). Diagnosis and Clinical virology of Lassa fever as evaluated by enzyme-linked immunosorbent assay, indirect fluorescent-antibody test, and virus isolation. *Journal of Clinical Microbiology* ;38: 2670-7.
16. Wilkinson, A. In One Health: Science, Politics and Zoonotic Disease in Africa (ed. Bardosh, K.) *Ch. 7 (Routledge, 2016).*
17. Sogoba, N. et al. (2016). Lassa Virus seroprevalence in Sibirilia Commune, Bougouni District, Southern Mali. *Emerging Infectious Diseases.* 22, 657–663.
18. Akpede, G. O., Asogun, D. A., Okogbenin, S. A. & Okokhere, P. O. (2018). Lassa fever outbreaks in Nigeria. *Expert Review of Anti-infective Therapy;* 16, 663–666.
19. Abdul-Aziz, M. N., (2011). *Concept note North East Development Commission.*
20. Damashi, M. T., Adedeji, O. I., Mai Bukar A., Babamaaji, R. and Dakul D. A. (2019). Accessibility To Primary Health Center Facilities Using Geospatial Techniques In Southern Plateau, Nigeria. *Nigeria Journal of Parasitology* 41 (2), 33-36.
21. Asogun, D. A. et al. (2012) Molecular diagnostics for Lassa fever at Irrua Specialist Teaching Hospital, Nigeria: lessons learnt from two years of laboratory operation. *PLoS Neglected. Tropical Disease*. 6, e1839.
22. Akpede, G. O. et al. (2019). Caseload and case fatality of Lassa fever in Nigeria, 2001–2018: a specialist center's experience and its implications. *Frontiers in Public Health* 7, 170.
23. Shaffer, J. G. et al. (2014). Lassa fever in post-conflict Sierra Leone. *PLoS Neglected Tropical Disease* 8, e2748.